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Abbreviations

AGC	Automatic Generation Control
AMI	Advanced metering infrastructure
AMR	Automatic Meter Reading
ATC	Available transmission capacity
CPC	Central Power Corporation
DA	Distribution Automation
DER	Distributed energy resource
DMS	Distribution management system
DR	Demand response
DRMS	Demand response management system
DSA	Dynamic security assessment
DSM	Demand side management
DSO	Distribution system operator
DTCR	Dynamic thermal circuit rating
ERAV	Electricity Regulatory Authority of Vietnam
EV	Electric vehicle
EVN	Vietnam Electricity
FACTS	Flexible AC Transmission System
FLISR	Fault Location, Isolation and Service Restoration
FLS	Fault Locator System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
HCMC	Ho Chi Minh City
HTLS	High temperature low sag
HVDC	High Voltage Direct Current
IEA	International Energy Agency
IED	Intelligent electronic device
IRENA	International Renewable Energy Agency
JRC	European Commission Joint Research Centre
KfW	Kreditanstalt für Wiederaufbau (German Development Bank)
KPI	Key Performance Indicator
LLS	Lightning Location System
MDMS	Meter Data Management System
MOIT	Ministry of Industry and Trade
MWMS	Mobile workforce management system
NLDC	National Load Dispatch Center
NPC	Northern Power Corporation
NPT	National Power Transmission Corporation
OLTC	On-load tap changer
OMS	Outage management system
PDC	Phasor data concentrator
PMU	Phasor measurement unit
RE	Renewable Energy

RTU	Remote Terminal Unit
R&D	Research and Development
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAS	Substation Automation System
SCADA	Supervisory control and data acquisition
SGAM	Smart Grid Architecture Model
SGREEE	Smart Grid Project for Renewable Energy and Energy Efficiency
SPC	Southern Power Corporation
STATCOM	Static synchronous compensator
SVC	Static VAR compensator
TOR	Terms of Reference
ToU	Time-of-Use
TSO	Transmission System Operator
VRE	Variable Renewable Energy
WAMS	Wide area monitoring system

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Executive Summary

About this Report

This report is the final deliverable of the assignment "Technology assessment for promoting state-of-the-art technologies" (Contract Number 81236607, Project Number: 15.2081.6-001.50), delivered by Energynautics GmbH and VietnamMW as part of "Action Area III: Technology Cooperation" of "Smart Grids for Renewable Energy and Energy Efficiency (SGREEE)", a joint cooperation project between ERAV and GIZ on behalf of MOIT and BMZ.

The overall objective of this assignment is to establish a solid and transparent basis for SGREEE's upcoming promotion activities in the field of technology cooperation that facilitates linking discussions between Vietnamese and international experts and promoting the application of state-of-the-art smart grid related technologies.

The assignment is subdivided into four tasks:

Task 1: Review of past and ongoing Smart Grid activities and projects in Vietnam

Task 2: Outlook on upcoming national and international smart energy trends with potential relevance for Viet Nam's energy system in the future

Task 3: Development and introduction of criteria for the analysis of smart energy technology solutions

Task 4: Analysis and pre-selection of suitable smart energy technology solutions

Separate draft reports have been prepared and submitted for the four tasks. The present report merges the revised individual reports into the single final deliverable of the assignment.

Task 1: Past and ongoing Smart Grid activity survey in Vietnam

In chapter 1, the consultants present the smart grid roadmap and development regulations, actual implementation at stakeholders (survey results). This information serves as a basis for the assessment in the next tasks.

Task 2: Identified trends and products in smart energy technology solutions

The trends and products presented in chapter 2 have been selected based on a review of available literature, taking into account the procedures and data sources described in the Terms of Reference and in the Inception Report. This focuses on technologies not yet widely deployed in Vietnam. (Smart Grid technologies that have been applied in Vietnam already are identified in Task 1.)

As the result of task 2, fourteen Smart Grid technologies have been selected for further assessment:

#	Smart Grid technologies	#	Smart Grid technologies
1	Renewable energy forecasting	8	OLTC for Distribution Transformers
2	Wide-area monitoring systems (WAMS)	9	Smart inverters
3	Online Dynamic Security Assessment (online-DSA)	10	Advanced Metering Infrastructure (AMI)
4	High Voltage Direct Current (HVDC) Technology	11	Demand Side Management (DSM)
5	Flexible AC Transmission System (FACTS)	12	Virtual Power Plants (VPPs)
6	Dynamic Thermal Circuit Rating (DTCR)	13	Distributed Energy Storage & Electric Batteries
7	Distribution Automation (DA)	14	Smart Charging of Electric Vehicles

Discussion of the identified trends and products

Each technology is presented in chapter 2 as a two-page section with subsections on

Technology description:	Brief description of the technology
Benefits and impact:	Discussion of the technology's potential impact on VRE integration
Challenges and drawbacks:	Factors potentially impeding wide-spread adoption
International experiences:	Status of application in other countries
Assessment:	Importance and impact of the technology on various indicators, based on an internal expert review

An assessment of some further market metrics such as maturity and availability of the technology is provided in the assessment table in section 2.3 of this document.

Task 3: Criteria for Smart Grid Technology Assessment

The 14 Smart Grid technologies selected in Task 2 are evaluated using the following criteria:

Impact on power system challenges: Does the technology address present or upcoming – especially VRE-related – power system challenges in Vietnam?

Economic viability: Is the technology a cost-efficient measure, likely to provide higher benefit than it costs?

Applicability: Can the technology be currently applied to Vietnam or are there obstacles (in terms of technology development, regulatory framework, etc.)?

Level of existing knowledge: Are there already ongoing pilot projects in Vietnam that can serve as a basis for a roll-out of the respective technology?

As final assessment result, an overall suitability/applicability score is derived from the individual scores on the four criteria. Recommendations directed at Vietnamese stakeholders for technology deployment are compiled based on this evaluation.

Task 4: Smart Grid Technology Assessment for Vietnam

The main assessment method applied to determine the scores of technologies related to the evaluation criteria in this report is evaluation of expert opinions, taking into account extensive literature review and stakeholder surveys and interviews. The results of this assessment are presented in chapter 4. The final overall applicability scores can be summarized as follows:

Smart Grid technologies	Score	Main Rationale
Renewable energy forecasting	High	Economically viable
Wide-area monitoring systems (WAMS)	Medium	Under development, complex integration
Online Dynamic Security Assessment (online-DSA)	Low	Not mature technology yet
High Voltage Direct Current (HVDC) Technology	Medium	No experience yet in Vietnam, application dependent feasibility
Flexible AC Transmission System (FACTS)	Medium	Already in use, but limited applicability
Dynamic Thermal Circuit Rating (DTCR)	Medium	Little experience yet in Vietnam, high uncertainty of applicability
Distribution Automation (DA)	Medium	Good impact on challenges, but expensive
OLTC for Distribution Transformers	Medium	No experience in Vietnam, limited applicability
Smart inverters	High	Economically viable
Advanced Metering Infrastructure (AMI)	Medium	Potentially good applicability, but high regulation/standardization effort and high cost
Demand Side Management (DSM)	High	Good impact on a major system challenge
Virtual Power Plants (VPPs)	Low	Market environment not ready
Distributed Energy Storage & Electric Batteries	Medium	Good impact, but expensive
Smart Charging of Electric Vehicles	Low	No large-scale vehicle deployment planned

The assessment method was selected because it was the only feasible method within the project's constraints. It is not recommended to rely solely on this method for future technology assessment; instead, proper cost-benefit analyses should be conducted.

It is therefore also recommended to validate the assessment results through cost-benefit analyses. This will require significantly more effort than was available for this consulting assignment. References and introduction to published cost-benefit analysis strategies for Smart Grid projects are provided in section 4.3.1.

Recommendations

Time Horizon	Transmission Level (NPT, NLDC)	Distribution Level (NPC, CPC, SPC, Hanoi, HCMC)
Short term (2019-2020)	• EVN NLDC is already implementing **WAMS** and developing capacities for **VRE forecasting**. • **Smart Inverters** are already being deployed for new VRE generation. Distribution transmission companies should coordinate access to functions such as setting active power constraints. • **FACTS** should be included in the system planning processes. • Pilot projects on **Dynamic Thermal Circuit Rating (DTCR)** should be continued and results integrated into system planning processes.	• **Smart Inverters** are already being deployed for new VRE generation capacity. Distribution companies and transmission companies should coordinate access to functions such as setting active power constraints. • **Demand Side Management** mechanisms should be evaluated, and deployed in a standardized manner, as distribution systems are equally affected from demand growth as transmission systems. Distribution PCs should coordinate to share efforts and lessons learned.
Medium term (2021-2023)	• Capacities for **Demand Side Management** and **Demand Response** should be developed with high priority. This also concerns standardisation and regulation. • **Virtual Power Plants (VPP)** cannot be implemented in the short term as they are not only a technical concept, but also a market construct to improve handling flexibility in the system. This depends on suitable market design. • **High-Voltage Direct Current (HVDC)** should be considered for long-distance transmission. • **Online-DSA** becomes relevant for efficient system operation when high instantaneous penetrations of VRE are reached. International trends and products should be tracked and pilot development considered.	• Deployment of **Distribution Automation** increases reliability. Initial pilots should develop into larger-scale applications. • **OLTC for Distribution Transformers** should be incorporated into distribution planning processes. • **Distributed Energy Storage and Batteries** can offer benefits if the costs decrease. • **Smart Charging of Electric Vehicles** will not just be an option, but a necessity when electric vehicles see wide-scale adoption. This is not expected in the short term, but concepts should be developed.
Long term (2024 and later)		• **Short-term VRE Forecasting** will be useful in automated distribution systems. • **Advanced Metering Infrastructure** can provide an efficient interface to Demand Side Management and Decentralized Batteries.

1 Task 1: Review of Past and Ongoing Smart Grid Activities in Vietnam

1.1 Smart Grid Development in Vietnam

1.1.1 The Smart Grid Roadmap

On 08 November 2012, Prime Minister approved Decision No. 1670/QD-TTg on Smart Grid Roadmap. The roadmap of smart grid development will be in three periods, specified as follows:

a) Period 1 (2012-2016):

- *Program on enhancing effectiveness in power system operation:*
  - *To finalize the project SCADA/EMS for the National Power system moderation Center, regional Power system Regulation Centers. To supplement devices in order to assure collection of figures on power system operation in power plants, substations with voltage level of from 110 kV or more; to finalize the automatic recording system of electronic meter for measurement at output of source, deliver and receive electricity to all power plants and stations of 500kV, 220kV, 110kV.*
  - *To develop applications aiming to strengthen the reliability, optimize operation of transmission Power grid, distribution Power grid, reduce power losses; strengthen the system recording fault, system detecting and preventing power failure malfunction on wide-area aiming to assure the safety in transmission on power system 500 kV.*
  - *To examine, supervise implementation of regulations on compulsory system collecting figures in power plants, substations with voltage of 110 kV or more.*
  - *First step, equip system SCADA for some power distribution corporations; equip the software, hardware system, telecommunication system, automatic and remote control system for some stations of 110 kV being selected.*
  - *To train, enhance capability to implement the Smart Grid for the National power transmission corporation, the National power system moderation center, corporations and companies of electricity.*
  - *To complete project on technical support for sub-load research, project on adjusting power sub-load (demand side response) for corporations, companies of electricity.*
  - *To develop and deploy the advanced operation instruments aiming to integrate a big quantity of renewable power sources which cannot control (wind power, solar power, etc) in to system.*
- *Testing programs:*

- *The testing project of AMI - Advanced Metering Infrastructure at some big clients of the Ho Chi Minh City Power Corporation in order to implement program on sub-load management.*
- *The testing project on integrating power sources using new and renewable energy at the Central region Electricity Corporation: To apply for small Hydro-power sources, power sources using new and renewable energy.*

- *To formulate the system of legal documents:*
  - *To finalize processes on researching sub-load of electricity.*
  - *To formulate a promotion mechanism for clients participating in the program on sub-load management in the testing program at the Ho Chi Minh City Power Corporation. + To assess effectiveness from the testing program, to finalize the promotion mechanism for clients participating in the program on sub-load management.*
  - *To formulate system of legal documents allowing to apply technical standards, regulations on moderation – operation for automation of substations and remote controls in power system.*
  - *To propose financial mechanism for development of Smart Grid.*
  - *Based on results of research and assessment on effectiveness of programs in reality, to promulgate newly or amend legal documents creating legal corridor for building infrastructure and deploying applications of Smart Grid.*
- *To formulate technical regulations: To research, promulgate technical standard regulations for Smart Grid, including: System AMI; technical standards of automatic system, remote control system of substation; System SCADA/EMS/DMS; standard to integrate power source using new and renewable energy in dispersal form; structure of the intelligent distribution Power grid and other relevant technical regulations.*
- *The media program for community:*
  - *To build and popularize the Program on development of Smart Grid for state management agencies, units generating power, units distributing power and big clients using power.*
  - *First step, to popularize the Program on development of Smart Grid for clients using civil electricity.*

b) Period 2 (2017-2022):

- *To continue to implement the Program on strengthening effectiveness of power system operation, concentrating on distribution Power grid; equip the information technological and telecommunication infrastructure for distribution Power grid:*
  - *To deploy complete systems SCADA for Power corporations, continue to equip automatic systems for substations of 110 kV.*
  - *To deploy system SCADA/DMS at some electrical station of provinces, cities with big sub-load in the system, connecting with some substations distributing medium voltage being selected.*

- *To continue to train, enhance capability to implement the Smart Grid for corporations and companies of electricity.*
- *To develop tests on optimizing operation of transmission Power grid.*
- *To deploy applications of Smart Grid:*
- *To popularize experiences on system AMI. To deploy expansion of installment of system AMI for big clients at all Corporations of Electricity; deploy the testing project for clients participating in power purchase and sale in competitive electricity market (competitive wholesale market and pilot competitive retail market) at corporations of electricity.*
- *To deploy integrating dispersal power sources, new and renewable energy sources connected into the power system by voltage level of medium and low voltage.*
- *To implement testing projects on Smart Home.*
- *To formulate Smart City tests.*

- *To formulate legal documents:*
  - *To research, propose competent agencies to promulgate mechanisms: encouraging application of Smart Grid in development of new, renewable energy sources; encouraging application of Smart Grid for buildings not using energy from outside (zero energy house); application of Smart Grid in buying, selling, exchanging electricity from side of clients with corporations of electricity.*
  - *To formulate a mechanism to encourage application for civil clients to participate in the program on sub-load management.*
- *To formulate technical regulations: Researching, proposing competent agencies to promulgate technical standards for the energy storage technology, smart appliances at home with ability to adjust energy-consumption rate under the electric supply condition or change of power price table.*
- *The media program for community:*
  - *To update the media program for Smart Grid supplemented changes on new prices and charges.*
  - *To popularize widely – gradually – on program (Smart Grid) to civil clients.*

c) Period 3 (from after 2022):

- *To continue the Program equipping information technological – telecommunication infrastructure for distribution grid:*
  - *To develop system SCADA/DMS for all provincial companies of electricity to a rational quantity of medium voltage distribution stations.*
  - *To deploy tools optimizing the operation from transmission Power grid to distribution Power grid.*
  - *To deploy system AMI for civil clients, facilitate for clients to participate in competitive electricity retail market.*
  - *To continue to encourage the development of dispersal power plants.*

- *The program deploying applications of Smart Grid: To deploy applications of Smart Grid allowing balancing the electricity supply and demand at level of electricity user. To popularize use of new, renewable energy at distribution power grid with mechanism of price buying and selling electricity under each point time combined with operation of the competitive electricity retail market.*
- *To formulate legal documents allowing to deploy applications of Smart Grid on the basis of the existing information technological infrastructure.*

1.1.2 Overall Development of Smart Grid

On 25 November 2016, MOIT issued Decision No. 4602/QD-BCT the approval of overall development of smart grid in Vietnam, specified as follows:

a) *Scheme on research and development of SCADA system in Vietnam Power system:*

-Investing, constructing and upgrading the SCADA/EMS, SCADA/DMS systems in Dispatch Centers of nation, regions, power companies and provincial and municipal power companies with the following objectives:

+ In 2020, striving to invest, equip and complete the SCADA/EMS, SCADA/DMS systems for Dispatch Centers of nation, regions, power companies and provincial and municipal power companies to ensure the maximum utilization of the existing infrastructure, efficient infrastructure and maximizing all investment resources. SCADA/EMS, SCADA/DMS systems must be linked, decentralized and shared data to ensure sufficient information and data serving safe, reliable operation, moderation of national power system; especially when the establishment of Control Centers of power plants, transformer stations, SCADA/EMS, SCADA/DMS systems must be compatible with integration and compatible link.

+ Power plants, substations, Control centers in power systems must be invested and equipped with full RTU/Gateway terminals, telecommunication systems to ensure adequate connection of signals to SCADA/EMS/DMS systems of levels with control rights, Control Centers according to Regulations on power transmission system and Regulations on power distribution system issued by the Ministry of Industry and Trade.

+ Simultaneously implementing solutions on infrastructure investment, technical management, operation management and human resource training to ensure full connection of SCADA signals from power plants, power stations to moderation level has control; ensure the quantity and quality of signals stable, reliable, continuous service for moderation, operation and running of applications of SCADA / EMS, SCADA / DMS systems at control levels with control. Striving in 2020, the rate of power plants and substations having connection and ensure sufficient SCADA signals serving operation as below: i) 100% of power plants have installed capacity of over 30 MW, 500 kV, 220 kV transformer stations have connection and ensure sufficient SCADA signals; ii) 100% 110 kV transformer stations, power plants with installed capacity from 10 MW to 30 MW have SCADA connection, and 90% ensure sufficient SCADA signals for operation.

+ Step by step implement in order to in 2020, can put in operation of EMS system, DMS system in SCADA system in all levels, especially real-time applications serving operation, moderation of power system to ensure the stable, safe, reliable national power system, improve quality of electricity supply such as: capacity flow calculation, error analysis, status assessment, optimize capacity flow, automatically adjust the capacity of machine assembly, forecast the load demand. Continuing to

complete telecommunication system in Vietnam Electricity Corporation to ensure the reliable operation and provide transmission channels for operating production, business, and management of power system. In 2020, striving to achieve the following objectives:

+ Ensuring 100% of 30 MW or higher power plants, 500kV, 220kV substations are connected by two independent optical transmission lines.

+ Ensuring 100% of 110 kV substations are connected by optical cable to Control Center or Moderation Center.

+ Ensuring over 90% of district electricity units are connected by optical cable to the private telecommunication system.

b) *Scheme on studying the organization model of remote switching control centers for electricity grid of National Power Transmission Corporation and Vietnam Electricity Corporation:*

- Taking advantage of the existing infrastructure, step by step research, invest and deploy Control Centers to operate, switch and remote control of electricity equipment in transmission grid and distribution grid, ensuring compliance with the conditions of organization, moderation level, structure of electricity industry and applicable regulations, ensure the safety objectives in operating power system; improve the reliability and quality of electricity supply, increase production efficiency and operation management.

- Model of transmission grid control system: research, select to arrange Control Center in an existing transformer station or transformer station to be built on a transmission station to perform operations away from a group of substations in the area; Operators in Control centers shall operate the equipment under the moderation command of authorized moderation unit.

- Model of distribution grid control Center: Control center will be located in provincial distribution grid Center/Moderation room or in the branch of high voltage grid Electricity Company to perform operations far away from the equipment under moderation command of authorized unit or control devices under control.

- In parallel with the establishment of control centers, researching and applying science and technology in control and automation of substations and equipment of electricity grid to synchronously carry out the transfer the substations with the on-site operators to the substations with in-direct or non-direct operators.

- In 2020, striving to transfer 60% of 220 kV substations and 100% of 110 kV substations under the management of National Power Transmission Corporation and Vietnam Electricity Corporation operating under the criteria of substation with non-direct operators; to control and manipulate safely, reliably and effectively 220kV, 110KV substations in national power system.

c) *Scheme on researching and developing electronic meters and remote collection of measurement data:*

- Applying science and technology, information technology on equipment to complete electricity measurement system and remote collection of measurement data in well head measurement positions, boundary measurement positions between sending and receiving electricity between units, customs using electricity from national power system, serving the operation of power system and competitive electricity market.

- Establishing a specific plan, determining the scope and priority order to step by step modernize

the measurement infrastructure, equip electronic meters and remote collecting system of measurement data for customers using electricity with objectives: (i) Ensuring that cost of electricity is not too high compared with installing mechanical meters, not cause pressure to increase electricity price; (ii) Ensuring the standard, quality of electronic meters and remote collection system of measurement data; (iii) Ensuring reliability, accuracy and security of measurement data; (iv) Ensuring investment efficiency and labor productivity improvement; (v) Improving customs service quality.

- Specific objectives: (i) in the end of 2017, invest and complete the measurement system and remote collection system of measurement data from far positions to serve management, production and business of electricity units (including measurement between units and master meters of 0.4 kV distributor substations); (ii) in end of 2020, striving to install electronic meters and remote collection system of measurement data for about 50% customers.

- Studying the plan of hiring electronic meters to apply for customers using electricity (in which having customers who use electricity for daily life) in order to widely use electricity tariffs over time (Time of Use-ToU).

- Establishing the plan and pathway of equipping advanced/ smart measurement system (advanced metering infrastructure) in accordance with the pathway of Smart Grid Development in Vietnam approved by the Prime Minister at Decision No. 1670/QD-TTg dated 08th November 2012

1.2 Research and Information Collection of Past and Ongoing Pilot Projects

1.2.1 Surveyed Power Sector Entities

To obtain information on past and ongoing pilot projects in the area of Smart Grids, a questionnaire was developed and submitted to the relevant stakeholders in the power sector of Vietnam, kindly asking them for completion of the questionnaire, The data/information was collected at:

- Government entities:
  - Electricity Regulatory Authority of Vietnam (ERAV)
- National Load Dispatch Centre (EVNNLDC)
- National Power Transmission Corporation (EVNNPT)
  - Distribution power corporation:
  - Northern Power Corporation (EVNNPC)
  - Hanoi Power Corporation (EVNHanoi)
  - Central Power Corporation (EVNCPC)
  - Southern Power Corporation (EVNSPC)
  - Ho Chi Minh Power Corporation (HCMPC)

ERAV is a unit assigned by the Ministry of Industry and Trade to preside and be the coordinator for smart grid development in Vietnam. Every year, power sector entities have to report ERAV their situation of projects. International organizations shall collaborate and work on smart grid aspects with ERAV. List of implemented projects in the last 3 years in the Appendix 1 (section 6.2).

The consultant also collaborated with ERAV to work with the power sector entities above to collect detailed information about the projects, the result in Appendix 2 (section 6.3).

1.2.2 Develop an overview in form of project factsheets

The following forms were developed and distributed to the surveyed power sector entities. The questionnaire consists of two parts: In the first part, the power companies were asked to fill out information about past and ongoing Smart Grid projects that have been conducted under their supervision. In the second part, questions relating to specific Smart Grid technologies were used to collect detailed information about the state of implementation.

This section presents the two parts of the questionnaire.

1.2.2.1 Smart Grid Project Form

The following Smart Grid project form was handed out to the surveyed power sector entities to collect information on past and ongoing Smart Grid projects:

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/ Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes

1.2.2.2 Technology Specific Questions

The second part of the questionnaire aims to collect information related to specific Smart Grid technologies:

Technology	Explanation	Questions	Responsibility
SCADA/EMS		Which functionalities does the current SCADA/EMS have? (e.g. situational awareness system, advanced alarm management system, load shedding and restoration system, automatic generation control, short-term load forecasting, network security analysis, dynamic security assessment, voltage and transient stability analysis, operator training simulator)	
		Which projects currently exist to upgrade the SCADA/EMS with additional functionalities? Which functionalities will be added/upgraded?	
		Is the entire transmission grid currently covered in the SCADA/EMS? If not, which parts are currently not included?	
		How many and which solar and wind power plants have been connected to the SCADA system?	
		What are the control capabilities of the solar and wind power plants (e.g. downward control of active power, reactive power control)	
		Are there any forecasting systems in place for solar and wind power production? If not, what are the future plans to implement this?	
		Is there Automatic Generation Control (AGC) currently in place? How many/which power plants are participating in AGC? What are the current plans for expanding AGC to further plants, including solar and wind power plants?	
Substation Automation System (SAS)		How many substations on 500 kV, 220 kV and 110 kV have been upgraded with SAS (as a share of total substations)?	
		How many remote control centers have been established?	
		What are the plans to upgrade substations < 110 kV with SAS?	
		What are the target Key Performance Indicators (KPIs) for SAS?	
		What are the typical hardwares of SAS in Vietnam? Which types of Remote Terminal Unit (RTU), Programmable Logic Controller and Intelligent Electronic Device (IED) are installed? Which technology providers are typically selected?	

Wide area monitoring system (WAMS) / Wide area protection and control (WAPC)	May also be called a Wide Area Surveillance System or Wide area monitoring, protection and control (WAMPAC) system. The objective of a WAMS/WAPC is to estimate the state of system with regard to voltage stability, transient stability, oscillatory stability and other stabilities and to take remedial steps in case stability limits are at risk to be reached.	Has there been any WAMS and/or WAPC projects been carried out?	
		How many 500 kV, 220 kV and 110 kV substations and lines have been connected to the WAMS/WAPC (both in total numbers and as a share of total substations)?	
		How many substations are planned to be connected in upcoming years?	
		Which technology providers are used for the WAMS/WAPC and the different hardware components?	
		Which communication technologies are used for connecting the synchro-phasers / phasor measurement units (PMUs) with the WAMS/WAPC?	
		Which types of faults are recorded with the WAMS?	
		Which types of control signals and remedy actions are sent through the WAPC?	
		What are the target Key Performance Indicators (KPIs) for the project?	
		Which features have already been implemented in the WAMS/WAPC? (detection and remedy of system instabilities: e.g. phase angle monitoring, line thermal monitoring, voltage stability monitoring, power oscillation monitoring, power damping monitoring, event driven data archiving)	
		What are the criteria to identify the location of the PMUs?	
(Online) Dynamic Security Assessment (DSA)	DSA is an evaluation of the ability of a certain power system to withstand a defined set of contingencies and to survive the transition to an acceptable steady-state condition.	How is the dynamic stability assessment (DSA) of the transmission system performed?	
		What hardware and software are currently used to assess the stability?	
		Are there any online DSA implemented in Vietnam? If yes, please specify the name of the project and the details (e.g. year, cost, technology provider, types of stability problems analyzed).	
		How often is offline or online DSA performed?	
Lightning location	Lightning location systems use a	How many sensors have been installed? How many more are planned to be installed? Where are they located?	

system (LLS)	network of lightning detectors to detect and geolocate lightning. This provides vital information for system operators and asset managers, e.g. for the optimization of the use and location of surge arresters, the identification of malfunctions or for safety warnings for personnel.	How many transmission line surge arresters on which respective voltage levels have been installed? What are the plans for upcoming installations?	
		Which technology is used for the LLS?	
		What is the accuracy of the LLS?	
		What are the target Key Performance Indicators (KPIs) for the LLS?	
		How is the LLS currently coupled with the SCADA/EMS and/or Operational Center? Which functionalities are provided?	
		Have analyses/studies been performed between the correlation between lightning events and relay operation? What are the results of these analyses?	
		Is LLS technology used to track thunderstorm activity and provide forecast information on potential problems?	
Fault Locator System (FLS) / fault indicators	A Fault Locator System uses fault indicators to estimate the location of a fault on overhead lines and cables and reduces the time of the team in the field to find the cause of the fault, hence reducing the outage time due to the fault.	How many 500 kV lines/substations have been equipped with FLS (both in numbers and as a share of total lines/substations)? How many lines/substations at other voltage levels (220 kV, 110 kV, <110 kV) have been equipped? What are the future plans for FLS installations?	
		How is a fault located by the team in the field?	
		What are the target Key Performance Indicators (KPIs) for the FLS?	
		Are there any plans for self-healing functionality of SCADA/DMS?	
		What are current SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) numbers? What are targets for the next years?	
		What technologies and methods are used for the FLS?	
		Was the performance of the already installed FLS evaluated? What were the results?	
		Is the FLS integrated in the SCADA system?	
Online Dissolved Gas in Oil analysis	Online DGA is the online monitoring of dissolved gases in	How many transformers at which substation levels have been equipped with online DGA (both in total numbers and as a share of total transformers)? What are the future plans for online DGA installations?	

(DGA)	transformer oil, to identify potential problems with the transformer and use this information for preventive maintenance.	Are new transformers automatically equipped with online DGA? If yes, which transformers/for substation of which voltage levels? What are the current guidelines?	
		What are the target Key Performance Indicators (KPIs) for the online DGA?	
		Which technologies are used for online DGA?	
		Was the performance of the already installed online DGA evaluated? What were the results?	
Flexible AC Transmission System (FACTS)	FACTS increase the reliability of AC grids and reduce power delivery costs. They improve transmission quality and efficiency of power transmission by supplying inductive or reactive power to the grid.	How many FACTS have been installed (including technology (e.g. Static VAR compensator (SVC), static synchronous compensator (STATCOM), Static synchronous series compensator (SSSC), etc.), size and installed voltage level)? What are the targets/plans for FACTS installations?	
		How important are FACTS installations for system security and system efficiency, respectively? What is their main use and purpose in Vietnam?	
		Are there any target Key Performance Indicators (KPIs) for these technologies? If yes, which ones?	
Dynamic Line Rating (DLR) / Dynamic Thermal Circuit Rating (DTCR)	DLR is using measurements and/or simulation models to continuously estimate the thermal capacity of a line by taking into account temperature and wind effects. This increases the thermal capacity compared to the conventional static rating of the line.	How many lines at which voltage level have been installed with DLR? What are the future plans for DLR installations?	
		By how much was the capacity of the respective lines increased compared to the static capacity (on average)?	
		Have any studies been performed about the potential benefits of this technology?	
		What are the target Key Performance Indicators (KPIs) for the DLR?	
		Which technologies are used for DLR?	
		Is the technology based on direct measurements, on algorithms or a combination of both?	
		Are weather forecasts taken into account? Which forecast times are applied?	
		Which effects are taken into account for DLR (e.g. ambient temperature, solar radiation, wind speed and direction)	
		Are there any existing WAMS connected to the DLR?	

SCADA/DMS (including projects on miniSCADA systems)		What functionalities does the DMS have? (e.g. remote switching & restoration, fault locator systems, state estimation, (wide area) voltage control, reactive power (VAR) control, state estimation, short-term load forecasting, short-term solar and wind power output forecasting, etc.)	
		Which power system measurements are collected and processed in the DMS?	
		How much of the distribution grid has been mapped in GIS?	
		Are any Customer Information Systems (CIS), Mobile Workforce Management (MWM) systems, Advanced Metering Infrastructure (AMI), Fault Locator Systems (FLS) or other systems in place? What are their current and planned functionalities?	
		Are there any Key Performance Indicators (KPIs) in place to analyze the performance of the respective systems?	
Outage Management System (OMS)	An outage management system (OMS) is a computer system used by operators of electric distribution systems to assist in restoration of power.	What are the current functionalities of the OMS (e.g. trouble-call handling, outage analysis and prediction, crew management, reliability reporting)? Please provide details about the functionalities.	
		What are the planned functionalities of the OMS?	
		Is the Outage Management System integrated with the SCADA system?	
Advanced Metering Infrastructure (AMI) / Smart Meters	AMI is an integrated system of smart meters, communication networks, and data management systems that enables two-way communication between utilities and customers. The system provides a	How many customers have been equipped with AMI?	
		What are the future plans for the rollout of AMI? How many/which customers are planned to be equipped with AMI and until when?	
		Is there a Meter Data Management System (MDMS) in place? What are its functionalities?	
		Have the customers received or installed any energy displays to track their electricity consumption?	
		Do the customers receive any time-of-use (ToU) tariffs or real-time pricing? What are the specifics of these tariffs?	
		Are the customers, that have been equipped with AMI, also participating in Demand Side Management (DSM) programs?	
		Have any small customers (e.g. households) been equipped with AMI/Smart Meters?	

	number of important functions that were not previously possible or had to be performed manually, such as the ability to automatically and remotely measure electricity use, connect and disconnect service, detect tampering, identify and isolate outages, and monitor voltage.	What are the functionalities of the AMI/Smart Meters (e.g. remote reading, energy display to the customer, ToU tariffs and/or real-time pricing, electricity theft detection, outage detection, voltage monitoring, load control)? How often can readings be made for the power company, how often for the customer (e.g. every 15 minutes)?	
		Is there any cost benefit analysis for smart meter deployment by customer group? If yes, what were the results of this cost benefit analysis?	
Demand Side Management (DSM)	DSM is the change of electricity consumption of a consumer through price signals or direct control of appliances, to increase energy efficiency as well as to reduce peak demand or shift consumption towards times of high renewable generation.	Are there any demand side management (DSM) programs in Vietnam? If yes, please specify the project details and results.	
		How many customers of which respective customer group are participating in the DSM program?	
		Which devices / loads is the power company allowed to control and what are the modalities (e.g. frequency and duration of operation, maximum shiftable load, etc.)?	
		What types of communication and monitoring devices are installed, e.g. smart meters? What are their capabilities and functionalities?	
Demand Response	DR is the change in electricity	Are there any demand response (DR) programs in Vietnam even if it is a voluntary program? If yes, please specify the project details and results.	

(DR)	consumption by customers in response to changes in the price of electricity over time.	How many customers of which respective customer group are participating in the DR program?	
		How does the customer interact with the price signal under the DR program? Are they equipped with a smart meter or any other monitoring device?	
		Are there any price mechanisms under the DR program (e.g. critical peak pricing CPP, Critical Peak Rebate (CPR))?	
		Are there any plans to introduce real time pricing in the future?	
Automatic Meter Reading (AMR)	AMR is the automatic collection of consumption, diagnostic, and status data from electricity and other meters and transferring that data to a central database for billing, troubleshooting, and analyzing.	How many customers of which respective customer group have been equipped with AMR?	
		Which technology and technology provider are used to collect the AMR data?	
		What are the future plans for the rollout of AMR, in particular with respect to household customers?	
Voltage regulated distribution transformers	A distribution transformer that automatically regulates the voltage on the LV side of the transformer by using an on-load tap changer (OLTC)	Are there any voltage regulated distribution transformers installed for MV/LV transformers? If yes, how many transformers have been installed and where?	
Electric Vehicle (EV) Smart Charging	Smart Charging of Electric Vehicles describes the ability of the charging station to control the charging process in	Are there any charging stations/charging infrastructure for electric vehicles that can adapt the charging power of the electric vehicles in order to react to external signals (e.g. due to the need of reducing peak power or to follow price signals)?	
		How many electric vehicles are charging at this charging station?	
		Which types of electric vehicles (e.g. electric car, electric bus, etc.) are charging?	
		What are the constraints / strategies of the charging algorithm (if any)?	

	response to price signals or other external signals, to reduce peak demand or shift charging towards times of high renewable generation.	Are there any public transportation fleets in cities that have been electrified (e.g. electric bus fleet)? How many vehicles does the fleet encompass? How are these electric vehicles charged (e.g. overnight charging, end station charging, opportunity charging)?	
Energy storage system		Are there any energy storage system deployed in the Vietnamese electricity grid (including demonstration projects)? If yes, please specify the details, e.g. type of energy storage, location, capacity, cost, connected voltage level, stand-alone or in combination with renewable energy plant)?	
		What is the purpose and functionality of the energy storage system, e.g. peak demand shaving, renewable energy smoothing, reserve provision, etc.?	
Microgrids		Which generator types and capacities are used in the microgrid?	
		Is the microgrid grid-connected or operated as an island grid?	
		What is the share of renewable energy on the energy production in the microgrid?	
		Is there any energy storage in the microgrid?	
		How many customers are supplied by the microgrid?	
		What is the controllability of the generators and grid assets in the microgrid? Which types of automation systems are applied?	
		What is the reliability of the microgrid regarding outages (e.g. SAIDI/SAIFI)? How many outages occur on average per month/year? Do any other Key Performance Indicators (KPIs) exist for the microgrid?	
High Voltage Direct Current (HVDC)		Are there any plans for HVDC lines within Vietnam or for interconnection to neighbouring countries? If yes, please provide specific detail about these plans.	

1.3 Survey Results Summary

The complete responses from the survey with the power sector entities can be found in Appendix 2 (section 6.3). The table below summarizes the results by showing which power sector entities have implemented the Smart Grid technologies to what extent.

The following subsections 1.3.1 to 1.3.5 present additional information from the survey, also including details of the Smart Grid technologies, their functionality and the manufacturers of products deployed.

Both the summary table below and the additional tables in the following subsections also include information already known to the consultants before the survey. This information can be found in Appendix 1 (section 6.2).

Smart Grid Technology	EVNNLDC	EVNNPT	EVNHanoi	EVNCPC	EVENSPC	EVNHCMC
SCADA/EMS	• The entire transmission grid (500-220kV) is currently covered in the SCADA/EMS • All 152 current power plants in the national power system ensure AGC connection capability including 85 renewable power plants. • SCADA/EMS system does not have a specialized function on renewable energy forecasting • However, the renewable energy plants have SCADA signals for forecasting short-term active power for next 3 hours and resolution for 15 minutes	• Upgrade protection control system for 16 500, 220kV substation				

Smart Grid Technology	EVNNLDC	EVNNPT	EVNHanoi	EVNCPC	EVENSPC	EVNHCMC
Substation Automation System (SAS)		• Not implemented (Currently, EVNNPT is submitting to Electricity and Renewable Energy Authority for approving technical design)				• All 110 kV substations have been equipped with SAS
Wide-area monitoring system (WAMS)	• 10 of the 500 kV substations have been connected to the WAMS					
Online dynamic security assessment (DSA)	• Not yet available					
Lightning Location System (LLS)		• Currently developing an LLS • 09 Sensors installed at regional power transmission • LLS has currently no connection to the SCADA system				
Fault Locator System (FLS) / Fault Location, Isolation and Service Restoration (FLISR)			• FLS / FLISR is available on SCADA / DMS system software. Training and technology transfer are being proposed for implementation		• Pilot is running on the Fault Location System (FLS).	• FLISR technology is available • Regulating the transmission time to isolate faults and re-establish the power supply for fault-free area is ≤ 5 minutes for 22 kV medium voltage lines
Dissolved Gas-in-oil Analysis (DGA)		• All 500 kV transformers and important 220kV transformers. • New 500 kV transformers are also equipped with DGA				

Smart Grid Technology	EVNNLDC	EVNNPT	EVNHanoi	EVNCPC	EVENSPC	EVNHCMC
Flexible AC Transmission System (FACTS)		• Installed 02 sets of SVC at 220kV Viet Tri (on 2007) and Thai Nguyen (on 2009) stations				
Dynamic Thermal Circuit Rating (DTCR)		• Not yet available, only feasibility study/test system of monitoring transmission line limit				
SCADA/DMS			• DMS at the LDC is now being deployed for Northern Red River grid including 05 utilities • DMS has the following capabilities: Volt/Var Control; Fault location, isolation and system restoration (FLISR)	• Deployed SCADA and Control center in several cities • DMS with several functions, including i.a. power grid analysis, FLISR, load forecasting, and outage reporting • MDMS is deployed for specialized transformer stations (100% provided with remote measurement) and public transformer stations (80% provided with remote measurement) • SCADA/DMS system is connected with the CRM and in the future with MDMS	• DMS: The entire 22kV grid has been mapped in GIS	• Update of SCADA System the entire distribution grid (110, 22kV) • 31,25% (5/16 Utilities) have been implementing DAS/DMS • Voltage and Var optimization: control voltage quality • Automation for all 22kV lines in Distribution Grid (RMU, Recloser, LBS) with SCADA)
Outage Management System (OMS)		• Not yet available	• Yes, GIS digital map-based application • Upgrade and integration in process	• Yes, will be upgraded with SCADA and DMS	• OMS is deployed but not integrated with SCADA system	• Yes. Expected to connect between OMS, SCADA and MDMS
Advanced Metering Infrastructure (AMI) / Smart Meters			• AMI pilot with 180 households	• Not yet available	• No current policy for implementation of AMI	• Installed 44 AMI meters of GE for 32 customers • Installed 180 AMI meters and HES System using PLC

Smart Grid Technology	EVNNLDC	EVNNPT	EVNHanoi	EVNCPC	EVENSPC	EVNHCMC
Demand Side Management (DSM)			• Some customers equipped with AMR participate in DSM power demand management programs			• Not yet available
Demand Response (DR)			• Not yet available	• Not yet available	• Not yet available	• 9 Commercial & 5 Industrial Customers participated in Pilot through Curtailable Load Program (CLP) and Voluntary Emergency Demand Response Program (VEDRP) • Pilot operation of DRMS software
Automatic Meter Reading (AMR)			• 900,000 customers equipped with AMR • Target of 100% AMR by 2021	• About 2.700.000 customers equipped with AMR	• About 2.7 million residential and commercial customers equipped with AMR • Targeting 2.8 million AMR by 2020	• 439,507 customers equipped with AMR
Voltage regulated distribution transformer			• Not yet available	• Not yet available	• Not yet available	
Electric Vehicles (EV)			• Not yet available	• A number of pilot electric cars exist to serve internal visitors at some tourist locations such as Da Nang, Hoi An, Hue, ... Vehicles are charged slowly overnight at parking areas • One-way fast charging station with 01 charger has been developed for electric cars	• Not yet available	

Smart Grid Technology	EVNNLDC	EVNNPT	EVNHanoi	EVNCPC	EVENSPC	EVNHCMC
Energy storage			• Not yet available	• There is a battery for a mini-grid with capacity of 9600Ah to supply 80 households	• Not yet available	
Microgrids			• Not yet available	• Microgrids / island grids available on An Binh island, Ly Son island district, Quang Ngai province	• In Phu Quy, 6 MW of wind power and 10 MW of diesel capacity, another 1 MW of solar power expected in 2019	
High Voltage Direct Current (HVDC)			• Not yet available	• Not yet available	• Not yet available	
Other Smart grid projects	• Calculating effects of wind power projects, solar power on operation of the national power system • Building IT infrastructure to run Vietnam Wholesale Electricity Market		• Assessment study on smart grid development, building a roadmap of smart grid implementation for 2018-2026 period			

1.3.1 SCADA/EMS/DMS system

No	Name of program, project, scheme	Stakeholders	Manufacturers	Standards/Applied technology/Functions
1	Regulation: Technical specifications and operation management of SCADA system	ERAV		
2	SCADA/EMS system	EVNNLDC and Regional Load Dispatch Centres	OSI - USA	SCADA functions: Real-time data collection, Historical database, alarm, Man-machine-interface… EMS functions: State estimation, load flow, contingency analysis, automatic generation control… Standard: IEC 60870-5-101/104
3	SCADA/DMS system	EVNHanoi and EVNHCMC	International/Local companies	SCADA functions: Real-time data collection, Historical database, alarm, Man-machine-interface… DMS functions: State estimation, load flow, contingency analysis… Standard: IEC 60870-5-101/104
4	Control Centres	5 Distribution Power Corporations	International/Local companies	Standard: IEC 60870-5-101/104
5	MiniSCADA	Some provincial Power Companies under 5 Distribution Power Corporations	International/Local companies	SCADA functions: Real-time data collection, Historical database, alarm, Man-machine-interface… Standard: IEC 60870-5-101/104
6	Unmanned substation	EVNNPT and 5 Distribution Power Corporations	International/Local companies	Standard: IEC 60870-5-101/104
7	Substation Automation System (SAS system)	EVNNPT and 5 Distribution Power Corporations	International/Local companies	Standard: IEC 60870-5-101/104

1.3.2 Metering system

No	Name of program, project, scheme	Stakeholders	Manufacturers	Standards/Applied technology/Functions
1	Metering code	ERAV		
2	Automatic meter reading (AMR) and Meter Data Management System (MDMS)	5 Distribution Power Corporations	Landis & Gyr/Local companies PCs	a) Information transmission environment • Including PLC, RS485 / RS232, Ethernet, optical cable, xDSL; • Includes RF / RF-Mesh, mobile communication network. b) Information transmission distance • On-site: A solution using handheld indexing devices to collect data directly at the measurement location; • Remote: A solution to use the remote data collection system to collect data of a remote meter or data concentrator (DCU) via a wired or wireless transmission channel.
3	Building the draft Technical Regulation of AMI measuring infrastructure and meter	EVNHCMC	International consultant	IEC standards
4	Test AMI using PLC technology	EVNHCMC		AMI PLC–G3
5	AMI technology pilot project using Trilliant solution	EVNHCMC		AMI RF-Mesh
6	Electronic meter	EVNNPT and 5 Distribution Power Corporations	International/Local companies EVNCPC	IEC standards
7	Smart meter	None	None	

1.3.3 Telecommunication network

No	Name of program, project, scheme	Stakeholders	Manufacturers	Standards/Applied technology/Functions
1	Upgrading and building telecommunication network	EVN and 5 Distribution Power Corporations		

1.3.4 Demand Side Management and Demand Response

No	Name of program, project, scheme	Stakeholders	Manufacturers	Standards/Applied technology/Functions
1	Studying, building, submitting the Demand Side Management (DSM) programs	ERAV		
2	Studying, building, submitting the financial mechanism for the Demand Response (DR) program	ERAV		
3	Proposing the financial mechanism for the Demand Side Management, Demand Response programs, bonus/penalty and electricity tariff mechanisms	ERAV, MOIT		
4	Building and submitting the National Program of Demand Side Management in 2017 – 2020, orienting to 2030 to the competent approving level	ERAV		
5	Building and submitting to Ministry of Industry & Trade for approval: Regulating the performance content, sequence of Demand Response programs; Regulating the study content, method, sequence of Demand Response	ERAV		
6	The pilot project of smart grid solution for ADR-Automated Demand Response sponsored by USTDA and Honeywell Group	EVNHCMC		
7	Load control pilot program	EVNHCMC		

1.3.5 Other systems

No	Name of program, project, scheme	Stakeholders	Manufacturers	Standards/Applied technology/Functions
1	Fault recording system	EVNNLDC	Siemens	
2	Equipping with the online oil monitoring equipment for transformer and 500kV impedance coil (Equipping with 101 online oil dissolved gas monitoring equipment for transformer and 500kV impedance coil)	EVNNPT	International	
3	Equipping with the fault location equipment for the 500/220kV line (69 lines)	EVNNPT	International	
4	Upgrading protection control system	EVNNPT		
5	GIS system	EVNNPT and 5 Distribution Power Corporations		
6	Data warehouse	EVNNPT and 5 Distribution Power Corporations		
7	Wide area monitoring system (WAMS) / Wide area protection and control (WAPC)	EVNNLDC		
8	(Online) Dynamic Security Assessment (DSA)	None		
9	Lightning location system (LLS)	EVNNPT		
10	Online Dissolved Gas in Oil analysis (DGA)	EVNNPT		
11	Flexible AC Transmission System (FACTS)	EVNNPT		
12	Dynamic Line Rating (DLR) / Dynamic Thermal Circuit Rating (DTCR)	EVNNPT		
13	Outage Management System (OMS)	None		
14	Voltage regulated distribution transformers	None		
15	Electric Vehicle (EV) Smart Charging	None		
16	Energy storage system	None		
17	Microgrids	EVNHCMC and EVNSPC		
18	High Voltage Direct Current (HVDC)	None		

1.4 Conclusions

Stakeholders have implemented many projects and programs following Decision No. 1670/QD-TTg on Smart Grid Roadmap and Decision No. 4602/QD-BCT on the approval of overall development of smart grid in Vietnam. Various Smart Grid technologies have been tested or deployed in these projects.

The following technologies have seen wide-scale deployment or high efforts in implementing the technology:

- Recent updates in the **SCADA/EMS** system have extended monitoring and automatic control to most of the transmission grid as well as AGC connection capability to all power plants above 30 MW (152 in total including 85 renewable power plants). Furthermore, protection control systems have been updated for the transmission grid.
- All 500 kV transformers as well as important 220 kV transformers are equipped with **Dissolved Gas-in-oil Analysis (DGA)**.
- Most of the power corporations have installed **SCADA/DMS** systems, functionalities however are varying: Some DMS have achieved a high monitoring and automation capability by monitoring the entire 22 kV distribution grid, implementing Volt/Var control, remote control of RMU, reclosers and LBS, load forecasting and integration with other systems such as Meter Data Management Systems (MDMS), Outage Management System (OMS) and Fault Location, Isolation and System Restoration (FLISR).
- **Outage Management Systems (OMS)** are in place in most power corporations, with the integration with the DMS also currently in progress.
- Most power corporations are successfully deploying **Automatic Meter Reading (AMR)** to most of their customers. Most of them have the target of covering 100% of customers with AMR within the next one to two years.

Further, the following technologies have seen deployment on a smaller scale or some pilot projects:

- In part, 110 kV substations have been equipped with **Substation Automation Systems (SAS)**.
- A **Wide Area Monitoring System (WAMS)** has been established with 10 of the 500 kV substation connected to it.
- A **Lightning Location System (LLS)** has been established with 9 sensors in various regions.
- **Fault Locator Systems (FLS)** or Fault Location, Isolation and System Restoration (FLISR) systems are available at some of the power corporations, however, only a few pilots are running on these new systems.
- **Flexible AC Transmission Systems (FACTS)** are currently not implemented on a wider scale. Only two SVCs are installed at the interconnection to China to improve voltage quality.
- Only some test pilots have been conducted on **Dynamic Thermal Circuit Rating (DTCR)**.
- **Advanced Metering Infrastructure (AMI)** and Smart Meters have only seen very limited deployment with AMI being installed in a few hundred households at some of the power corporations.
- The recent decision 249/2018/QĐ-TTg at 8/3/2018 regulates the national **Demand Side Management (DSM)** program for the 2018-2020 period. So far, only EVNHanoi reported that some

customers are participating in a pilot DSM project.

- EVNHCMC has conducted a pilot on **Demand Response (DR)**, where a few commercial and industrial customers participated through a Curtailable Load Program (CLP) and a Voluntary Emergency Demand Response Program (VEDRP), including the pilot operation of a demand response management system (DRMS) software.
- **Electric Vehicles (EVs)** and EV charging stations are not widely available. Only in some tourist locations some electric cars are available and EVNCPC has further developed one fast-charging EV charging station.
- **Energy storage** has not yet been deployed on a wider scale. There only exists a microgrid with a 9600 Ah battery.
- **Microgrids** are available only on some islands. The island Phu Quy has installed 6 MW of wind power alongside 10 MW of diesel capacity, with another 1 MW of solar power expected in 2019.
- There further exists a current project to build the infrastructure to run and monitor the power transmission for a competitive Vietnamese Wholesale Electricity Market.

Lastly, the following three technologies have not yet been applied in Vietnam:

- **Online Dynamic Security Assessment (DSA)**
- **Voltage regulated distribution transformer**
- **High voltage direct current (HVDC**)

Further Smart Grid technologies known to be not implemented in Vietnam yet have been omitted from the survey. These are discussed in further reports of this assignment beyond the Task 1 report.

2 Task 2: International Smart Grid Trends with Potential Future Relevance for Vietnam

2.1 Challenges with VRE Integration

Smart Grid technologies are seen as a key enabler to increase efficiency in the power system and to facilitate the uptake of variable renewable energy (VRE) into the power system. The fluctuating nature and smaller plant size of VRE generation compared to conventional large-scale generation poses a number of challenges to the future planning and operation of the power grid. This section describes the major challenges that some of the Smart Grid technologies are targeting.

The challenges associated with variable renewable energy (VRE) integration correlate with their target level of penetration and therefore vary in the transition process towards higher shares of VRE generation. While some issues can be expected to arise already at the very beginning of VRE deployment, with limited local impact, other challenges may only arise later with very high penetration levels where VRE contributes to a major share of total power generation.

This gradual transition has been broken down by the IEA into four respective phases of VRE integration [1]. Throughout these four phases, the VRE deployment moves from not-noticeable (phase 1) to noticeable but easily accommodated (phase 2) to significant impact on power system operation and the need for more flexible operation (phase 3) to the final stage, where also system stability becomes a major issue (phase 4).

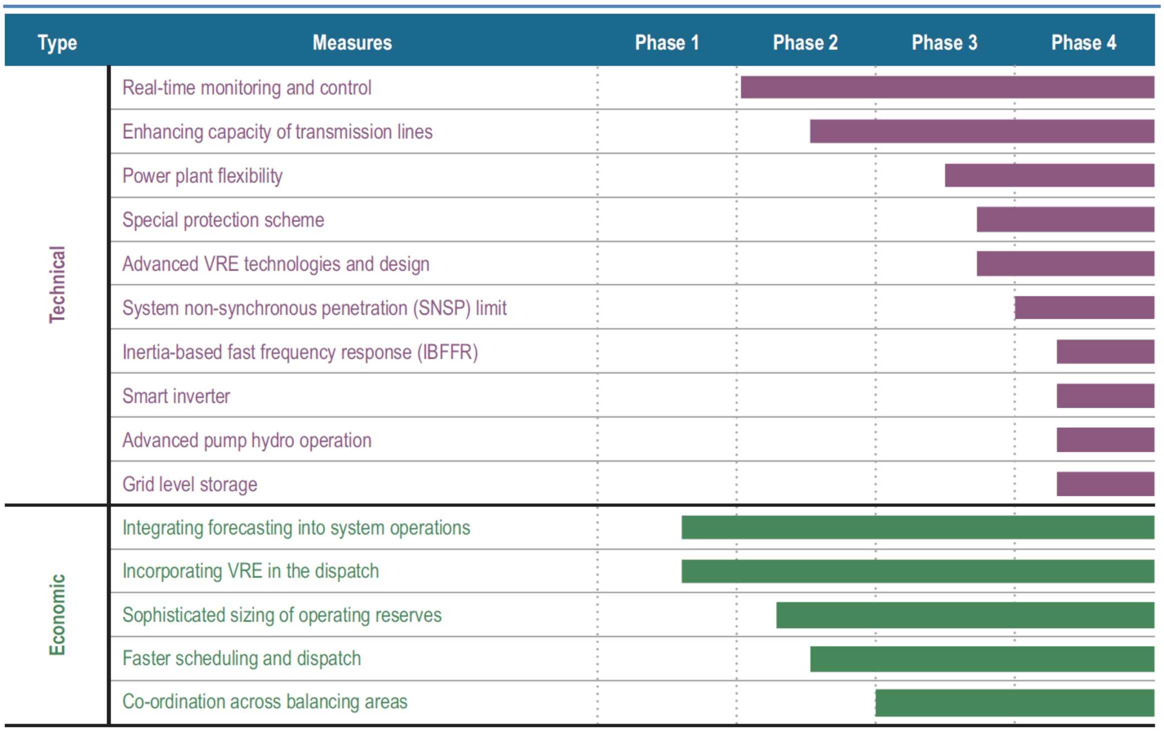
At the start of VRE uptake, particularly local problems may arise as VRE plants are often installed in bulk quantities to single locations, hence locally overloading power system assets and potentially provoking voltage problems. Such problems can be locally resolved by performing grid upgrades in order to properly connect the envisioned VRE power plants.

At the latest when VRE becomes noticeable to system operation, forecasting systems should be set up to accurately estimate the expected solar and wind power infeed for the next few hours and days. At this point, dispatch procedures will have to be updated to accommodate changes in VRE output. Further, reserve calculations should be optimized to include the impact of VRE on imbalance between generation and demand, to reflect potential events such as a fast decline in solar or wind power generation during major storms.

At phase 3, when system flexibility becomes a key enabler, conventional generators should be operated in such a way that their operational flexibility is enhanced. It further becomes important to include major parts of the existing VRE generation park in the dispatch procedures and have the capability to monitor and control the VRE plants from the existing system and control centres. An example application for this is the necessity of reducing VRE production during emergency situations. Due to economic reasons, operational procedures should be optimized as much as possible to apply such curtailment only as a last resort. The grid code should define technical requirements that require the appropriate control capabilities at VRE plants.

In the last phase, VRE penetration will reach levels where stability issues arise on system level, as only little conventional generation is still online and hence a mix of VRE control and new control possibilities (e.g. load control, large-scale storage) are required to ensure security of supply. Only very few countries have reached this level, including Denmark and Ireland. In Ireland, wind power provides up to 60 % of power supply at certain times, which is remarkable because the island's power system is only weakly interconnected with the remaining European power system.

Table 1: Technological options and operation practices for the four phases of VRE deployment [2]



As discussed above, the power system configuration and operation need to be changed and enhanced step-by-step throughout the VRE deployment phases. The major required measures are listed in another IEA report and are depicted in Table 1.

The aim of the present report is to highlight and present the Smart Grid technologies that accompany a successful implementation of these measures, and discuss their applicability in the context of the Vietnamese power system.

In Vietnam, VRE deployment is still at an early stage. However, in recent months significant amounts of VRE have been installed, e.g. with PV capacity reported to be 4 GW in June 2019. More projects have been registered and approved, accumulating to multiple gigawatts and even tens of gigawatts that could potentially be installed within the next few years. Hence, Vietnam may quickly leapfrog phase 1 and 2 of VRE deployment towards phase 3 where VRE has a significant impact, and new VRE generation as well as existing power plants need to be able to adapt to the new system setup and incorporate new operation procedures. At the same time, the coordination and SCADA centres must be enhanced by increased monitoring and control capabilities.

It is therefore of high importance to already test and apply appropriate Smart Grid technologies today, so that the transmission and distribution companies in Vietnam are well prepared for the first three phases of VRE deployment. Such technologies are described in the following chapter and will be subsequently evaluated based on their importance for VRE deployment and their respective effectiveness.

2.2 Categorization of international Smart Grid technologies for better VRE deployment

The following subsections provide information and insights about various Smart Grid technologies currently developed and applied around the world that foster the integration of VRE and are of particular interest to the Vietnamese power system. For each respective technology, the working principles, advantages and disadvantages as well as selected international experiences are listed.

The purpose of Smart Grid technologies is a more efficient operation of the power system, including the processes that revolve around it. It further is seen as a key enabler for the integration of VRE generation, as the challenges mentioned in section 2.1 need a much higher degree of coordination, communication and control for a significantly increased number of power plants.

The following subsections give an overview of technologies that have been applied in other power systems around the world in order to satisfy the new needs with respect to VRE integration as well as the drive to a more efficient and reliable power grid.

The list of Smart Grid technologies draws on various reports that have been compiled by internationally renowned organizations such as the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), the World Bank Group (WBG), the United Nations (UN), the European Joint Research Centre (JRC) and relying on further research of national and international research groups, industry reports and university papers (most importantly [3]–[8]). It does not comprise a full list of Smart Grid technologies but rather represents the authors' point of view of the most relevant ones with respect to the current power system structure and VRE development level in Vietnam.[1] It further disregards technologies that have already been largely deployed in the Vietnamese power system, as these technologies are described in the Task 1 report of this assignment.

The Smart Grid technologies presented below have been classified according to their applied energy sector domain as per the Smart Grid Architecture Model (SGAM). This classification is depicted in Figure 1.

The order in which the technologies are described in their sections follows the order used in the figure, roughly starting with technologies applied mostly in the transmission grid, followed by technologies predominantly enhancing distribution grid operation, and closing with technologies that are applied on the customer level. Each technology description is complemented with information on benefits and challenges for application, and on international experience.

Each section is closed by an assessment of the technology obtained through an internal expert review. Six experts have separately assessed the different technologies in terms of their importance on the following impact domains: RE grid integration, security of supply, reduction of grid reinforcements, decentralized energy production, load flexibility, energy storage, e-mobility, IT security and data protection requirements, ICT architecture requirements, and energy efficiency. The assessment results are depicted

[1] Concerning applicability in Vietnam, no particular filtering or ranking of technologies has been applied at this stage, besides a rough estimation based on the current VRE penetration level. Development of more detailed criteria and their application will be carried out in task 3 and 4 of this assignment.

as radar diagrams.

In section 2.3, a further pre-assessment of all Smart Grid technologies is presented regarding specifically their market aspects (maturity, market penetration, development trend and availability in Vietnam) and their importance for VRE integration.

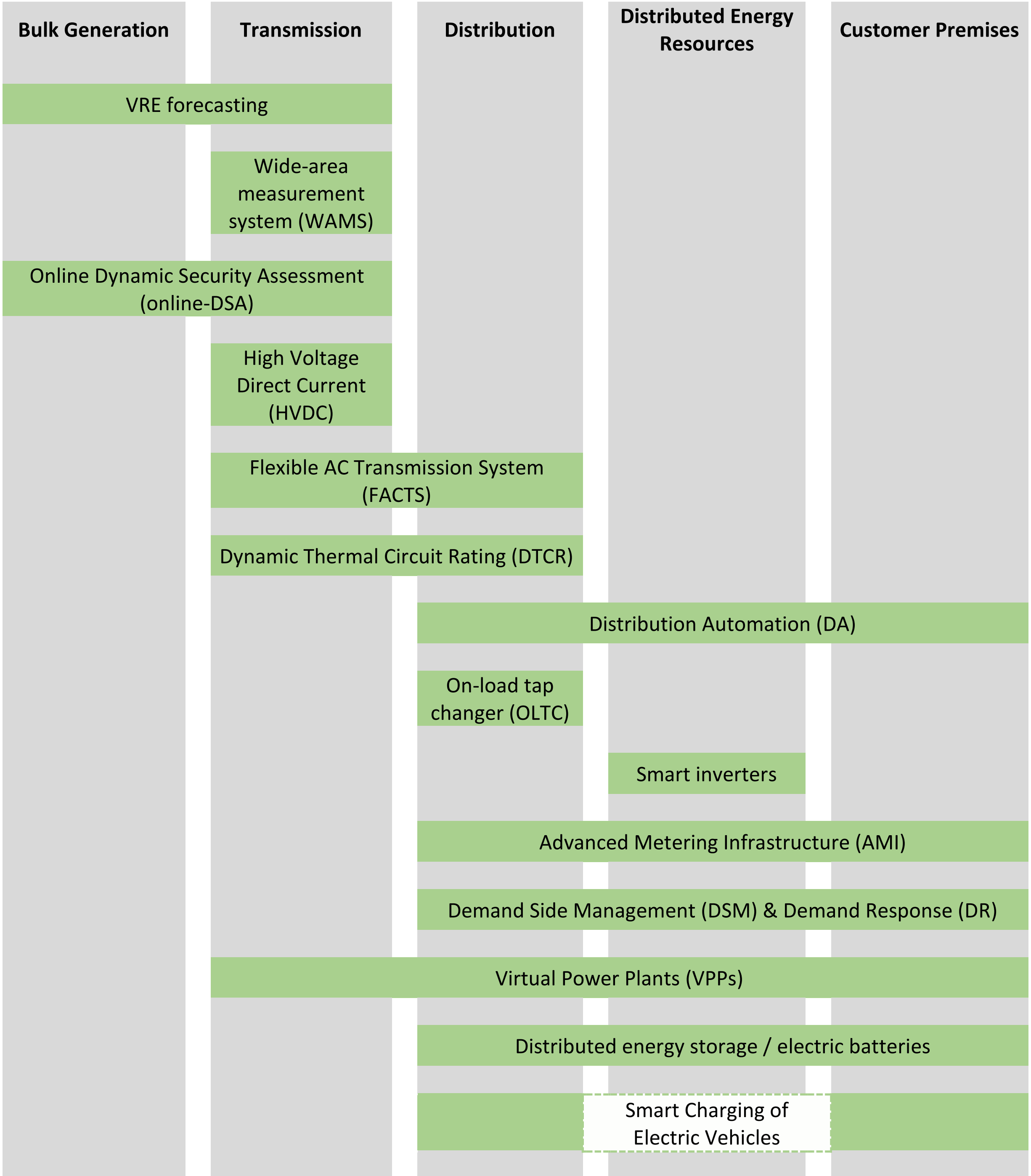


Figure 1: Categorization of Smart Grid technologies according to energy sector domains

2.2.1 Variable renewable energy forecasting

2.2.1.1 Technology description

With VRE penetration levels above about 10 %, forecasting systems for PV and wind power production become important for power system operation. Ahead-of-time knowledge of VRE power injection (including its spatial distribution) facilitates economic dispatch of conventional generation as well as management of grid congestion.

Forecasts typically range from minutes to up to 48 hours and are based on a weighted combination of multiple weather models. These mathematical models make use of current weather data and therefore require extensive sensor networks and sometimes significant computational resources.

Forecast accuracy generally improves with shorter proximity to real-time and, due to smoothing effects, with larger geographical spread. On a country level, the average forecast error (measured as the root mean square error or RMSE) for day-ahead forecasts is usually in the order of 5 %. In Germany for example, the uncertainty of country-wide wind power forecasting is around 2-3 % RMSE of installed capacity, while it ranges from 10 % to 30 % for single wind power plants.

VRE forecasting can be further used in other smart grid technology areas: For dynamic thermal circuit rating (see section 2.2.6), line capacities can be calculated based on forecasted weather situations. For online dynamic security assessment (see section 2.2.3) the expected network state can be estimated to determine security limits. Further, VRE forecasting plays an essential role in scheduling the dispatch of power plants in a Virtual Power Plant (see section 2.2.12).

2.2.1.2 Benefits and impact

Due to the uncertainty in wind and solar power output, good forecasting system are crucial for optimizing power system operation and generator dispatch. Especially in systems with higher VRE contributions, VRE forecasting has been shown to bring substantial economic benefits to the system. Specific events, e.g. storm activity during which many wind power plants may reach their cut-out speed, can be effectively predicted through ramp forecasting and mitigation measures taken beforehand, increasing system security.

2.2.1.3 Challenges and drawbacks

Accurate databases about solar and wind power plants with regards to location, size and technical parameters of turbine/PV panels need to be set up and maintained to ensure forecast accuracy. It is useful to mandate the centralised collection of this information in the grid codes. This registration scheme should be set up early on, so that no retroactive data collection is necessary when there is already significant VRE generation capacity. For the forecast services themselves, these are typically offered to system operators by specialized service providers.

2.2.1.4 International experiences

In Europe, VRE forecasts are used to optimize the generator portfolios of traders for the day-ahead and intraday market. In Germany for example, market participants are penalized for deviating from their offered power output. A larger VRE portfolio reduces these deviations, driving the implementation of Virtual Power Plants (see section 2.2.12). The European system operators use VRE forecasts to calculate the Day-Ahead Congestion Forecast. This forecast calculates expected congestion across trading areas and the TSOs use it to plan redispatch and curtailment measures. Regional forecasts on different scales are also calculated for grid information and security analysis. The German DSO Avacon for example uses regional VRE forecasts in combination with load flow calculations to determine local grid congestions and minimize VRE curtailment.

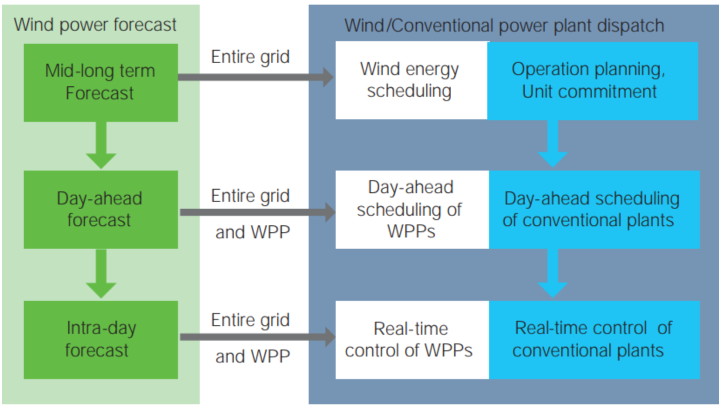
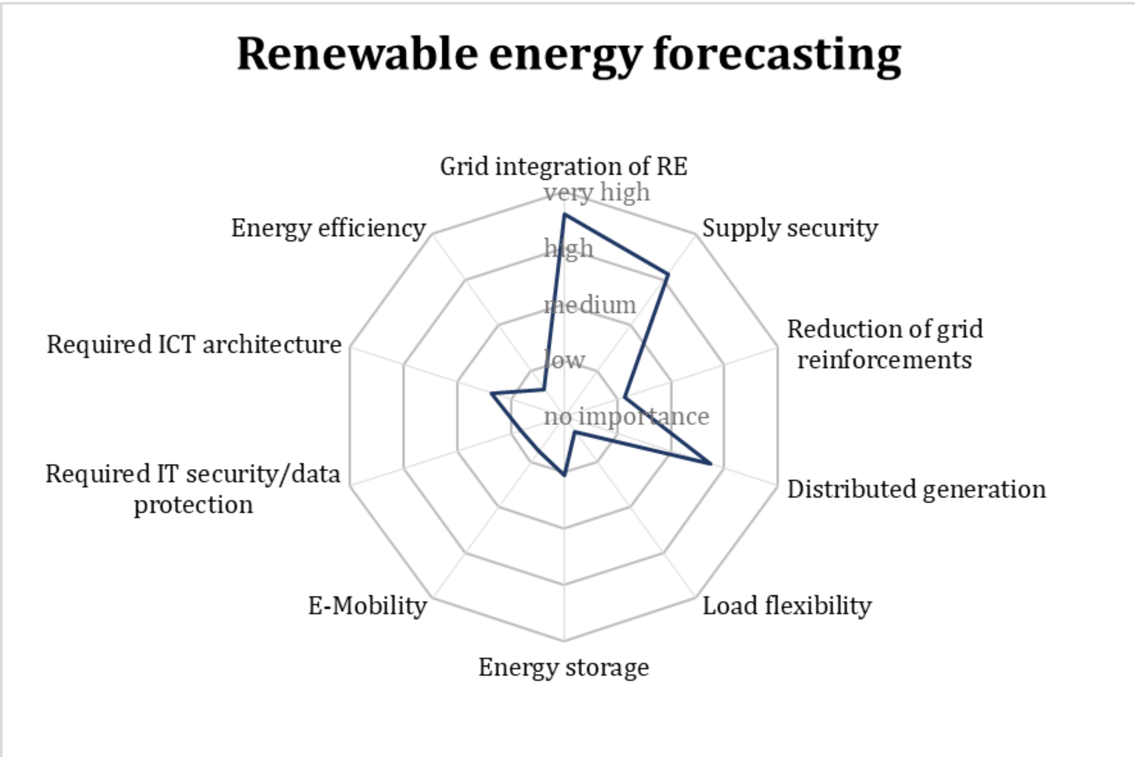


Figure 2: System operation in China taking wind power forecasting into account [9]

2.2.1.5 Assessment



2.2.2 Wide Area Measurement System (WAMS)

2.2.2.1 Technology description

Power system monitoring is essential for the system operator to maintain the reliability and stability of the grid. The 2003 blackout in the USA has shown the need of wide area monitoring system or wide area measurement system (WAMS) for early warning of grid instability and preventing large area disturbances and outages. WAMS offers a state-of-the-art monitoring application by using synchrophasor data to evaluate the grid situation in real time.

Generally, WAMS consists of phasor measurement units (PMUs), phasor data concentrators (PDCs) and software to provide data analysis to the system operator. The PMU is a device to measure magnitude and phase angle of voltages and currents in a given location in a substation. The signals from multiple different substations are sent to the PDC for dynamic power system analysis. The main feature of the PMU system is a high time resolution of 10-60 samples per second that is time-synchronized across all PMUs via GPS, while SCADA can provide only one sample every 2-4 seconds with small time differences between measurements dependent on communication speed. Therefore, PMUs are typically used to offer dynamic measurements for wide area monitoring rather than local monitoring aspects.

WAMS can be used as a stand-alone system or integrated with EMS to enhance situation awareness of the system operator. The data from WAMS can also contribute to protection features such as self-healing and notifications of potential blackouts as part of a Wide Area Protection and Control (WAPC) system.

2.2.2.2 Benefits and impact

WAMS helps the system operator monitor and analyse the system state for large power networks in real-time. The system operator can potentially avoid some blackout events through early detection of critical situations, or can prepare for system restoration. WAMS can enhance distributed energy resource (DER) integration by providing real-time situation monitoring and improve network management performance.

2.2.2.3 Challenges and drawbacks

The communication and visualisation infrastructure is the main challenge for WAMS followed by data quality and cybersecurity. The communication infrastructure must provide effective data transfer between PMUs, PDCs, data centre and applications. The integration of GPS satellite signal ensures the PMU units are synchronized with a high accuracy down to the millisecond. The information needs to be visualised in an appropriate manner to enable proper evaluation by the control centre personnel.

2.2.2.4 International experiences

WAMS has been deployed in various power systems worldwide. For example, the Italian TSO applied WAMS to improve system operation after the Italian blackout in 2003. The Electricity Generating Authority of Thailand (EGAT) aims to implement WAMS to monitor the load of 230 Kilovolt transmission lines between the southern and central region of Thailand. India has an ambitious goal for WAMS deployment for 350 substations of the Northern Grid. The first progress aims to monitor power flow of 110 substations, and the fully commissioned WAMS will consist of 1.184 PMUs and 34 control centres across India for real-time monitoring with geographic display.

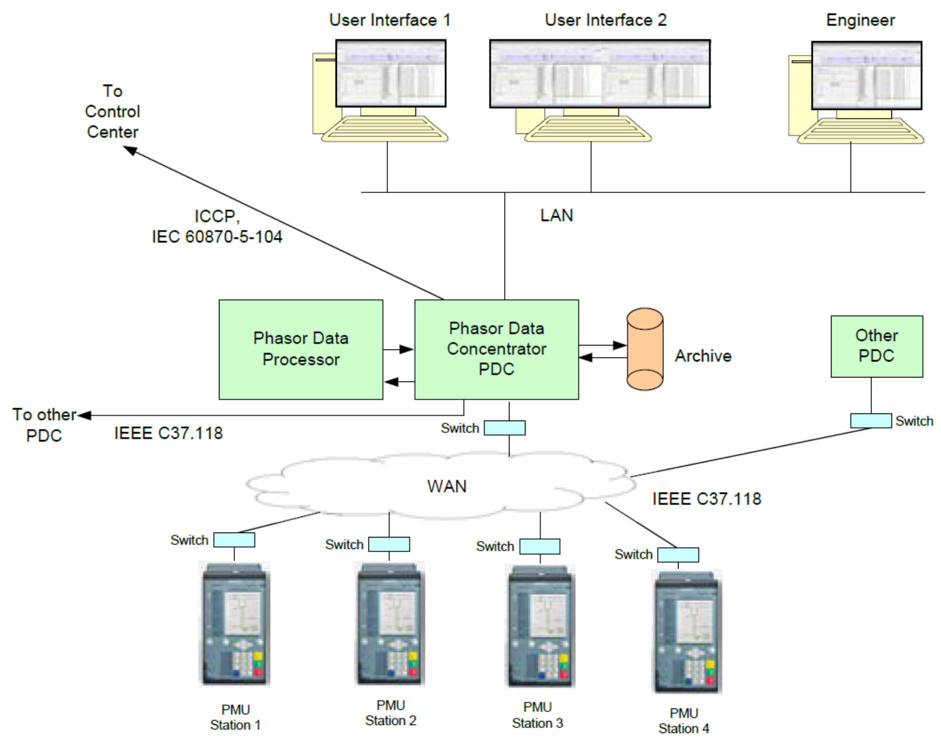
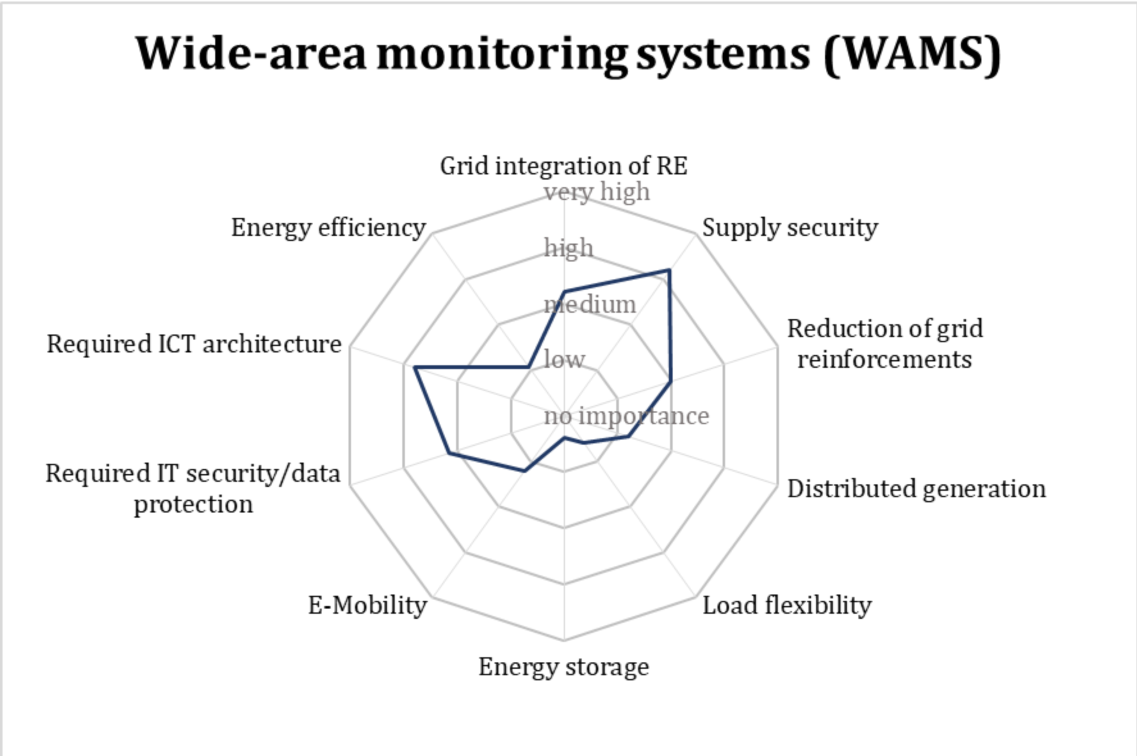


Figure 3: Structure of a WAMS [10]

2.2.2.5 Assessment



2.2.3 Online dynamic security assessment (Online-DSA)

2.2.3.1 Technology description

Still today, system security is often calculated based on steady-state calculations, considering often only the thermal limits of the transmission grid assets. These calculations can be enhanced by a dynamic security assessment (DSA) that evaluates the dynamic stability of the power grid for major contingencies. Traditionally, these calculations are performed offline and provide a valuable tool in particular for power system planning and defining stability limits that can be included in the operation guidelines of the system operator. Since recently, this can been further enhanced by the online calculation of stability, i.e. online-DSA.

Online-DSA can become a helpful assistance tool for system operators of power grids who have to deal with increasingly complex situations in the power system if high VRE levels are reached. This way, the stability limits are continuously recalculated in real time and therefore enable a higher utilization of transmission assets compared to the offline-DSA where always the worst situation would determine the stability limits. The current operating state of the power grid is provided by the SCADA system, often supplemented by phasor measurements from a wide area measurement system (see section 2.2.1).

2.2.3.2 Benefits and impact

Through the constant monitoring of the stability limits the system security is increased and the risk of blackouts reduced. This in turn means that the utilization of transmission assets can be increased until stability limits are approached. The data can be used to specify recommendations for preventive control actions or even to design Special Protection Systems (SPS). Further, it allows for a determination of necessary active and reactive power reserves.

2.2.3.3 Challenges and drawbacks

Detailed information about the dynamic behaviour of conventional and non-conventional generators needs to be available. For new power plants, relevant specifications can be made in the grid codes to enforce that the relevant information and models are validated (e.g. through certification) and are provided to the system operator. The benefits of obtaining such models need to be weighed against the additional cost of creating and providing these models. Further, for old power plants the dynamic parameters may be difficult to be assessed. It also has to be ensured that the data is reliably collected and integrated into the online-DSA tool.

2.2.3.4 International experiences

Most of the system operators in the USA as well as some of the European system operators are using online-DSA to perform the stability assessment with higher accuracy. The Irish national grid company Eirgrid installed a Wind Security Assessment Tool (WSAT) based on Powertech's DSATools in the EirGrid control centre as a real-time application to calculate the maximum allowable wind generation for the real-time condition as well as for the forecasted condition (integrated with wind forecast data). By assessing voltage and transient stability, EirGrid can currently handle up to 65 % VRE penetration on the grid at any time, despite the fact that the Irish power grid is only weakly coupled to the remaining European grid and therefore is more prone to observe stability issues.

Like Ireland, also Spain has a high share of wind power and only few interconnectors to its neighbour countries. The Spanish system operator established already in 2006 the Control Centre for Renewable Energy (CECRE), which monitors and controls all wind power plants above 10 Megawatt. Within CECRE an online-DSA called GEMAS was installed in 2008, evaluating every 20 minutes the maximum penetration level of wind power due to voltage and transient stability. If the stability limit is exceeded, the Spanish system operator is allowed to curtail wind power.

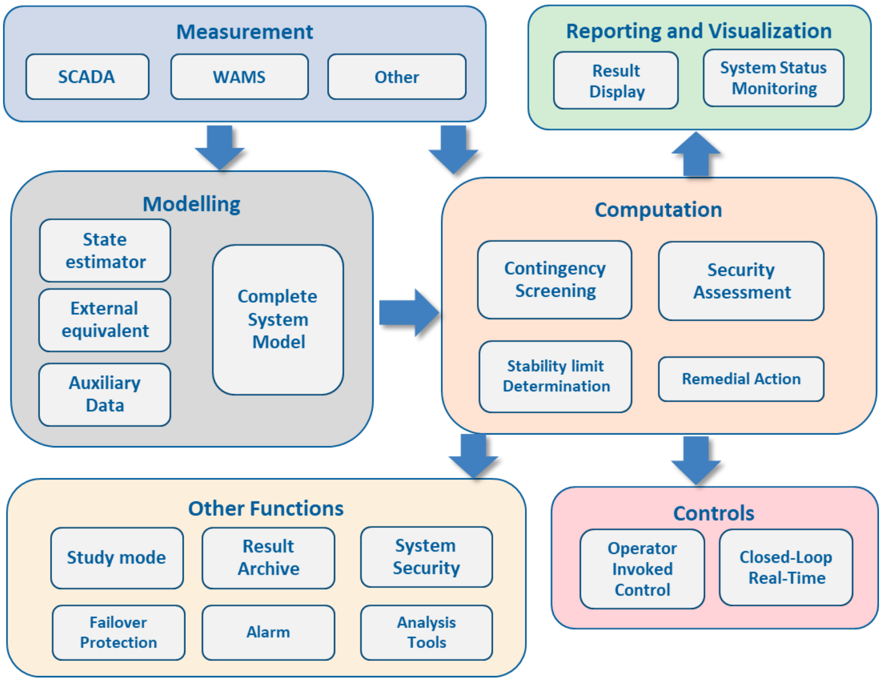
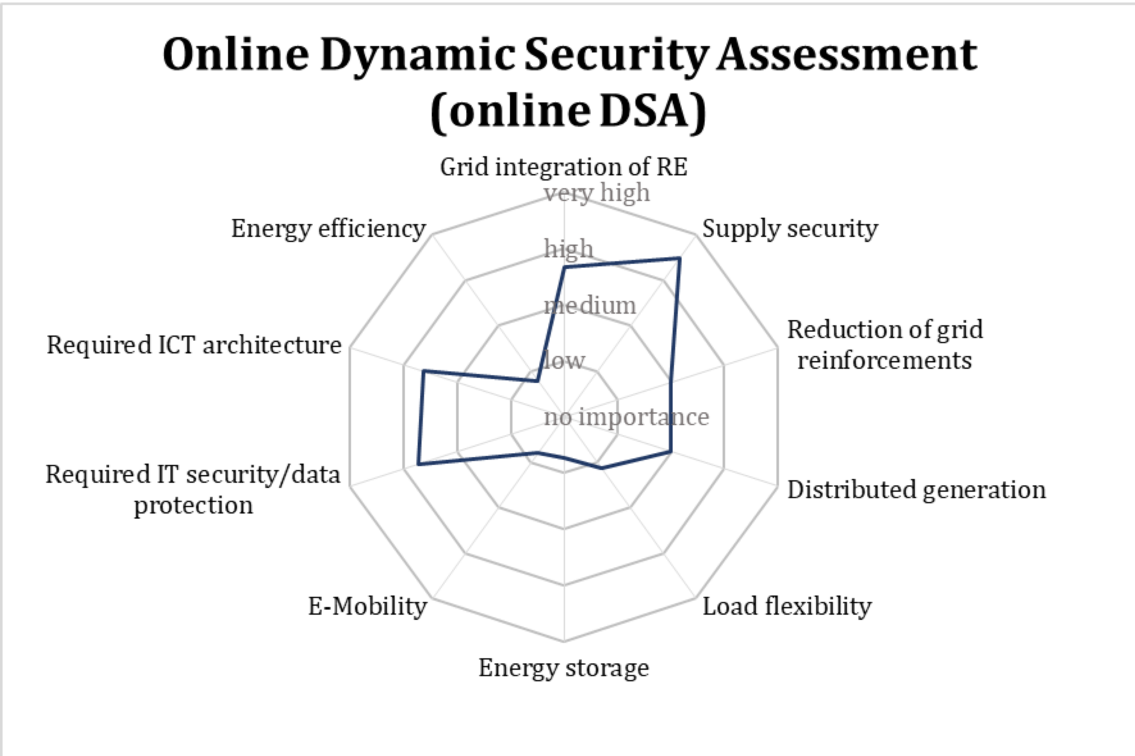


Figure 4: Working principles and functional overview of online-DSA [11]

2.2.3.5 Assessment



2.2.4 High Voltage Direct Current (HVDC)

2.2.4.1 Technology description

High voltage direct current (HVDC) lines are particularly interesting for the transmission of power over long distances. This can be for example interesting for the remote connection of VRE power plants that are installed in regions with high solar or wind resource availability (e.g., offshore wind power plants, or desert solar plants) or for highly congested load centres. Further, their AC/DC converter stations that convert the AC power from transmission lines to DC power and back, are also an instrument to control the power flow in the transmission grid. In AC transmission systems, the power flow is determined through the physical parameters of the AC transmission lines. This can lead to overloading of some lines while others still have free capacity. With HVDC the power flow can be optimized by redistributing the power flow and therefore achieving a more balanced loading of the transmission lines, hence, increasing the overall transmission capacity.

Typically overhead lines are used for HVDC interconnections on land, whereas in particular for offshore wind power plant connections submarine power cables are used.

2.2.4.2 Benefits and impact

The initial investment for an HVDC converter station is much higher than the one for an HVAC substation. However, the investment costs of the overall HVDC transmission system can be lower than those ones of the HVAC transmission system if the cost savings in the transmission line and in the reactive power compensation can make up for the higher HVDC station costs. This is usually achieved if a certain transmission distance is reached (break-even point). Hence, HVDC can offer a cheaper alternative for long-distance transmission lines, e.g. for interconnection with other countries or remote VRE power plants such as offshore wind power. HVDC further enables controlled power flow, optimizing the utilization of the transmission grid, e.g. for the supply of congested areas.

2.2.4.3 Challenges and drawbacks

Apart from the high initial investment costs, also technical challenges need to be overcome related to short-circuit currents, harmonics (which may necessitate expensive filter-compensation units) and complex grounding systems, as well as design and criteria development of appropriate test procedures. Further, the active controllability of HVDC necessitates that continuous and reliable communication need to be set up.

2.2.4.4 International Experiences

HVDC has been deployed worldwide for transferring electricity with long distance.

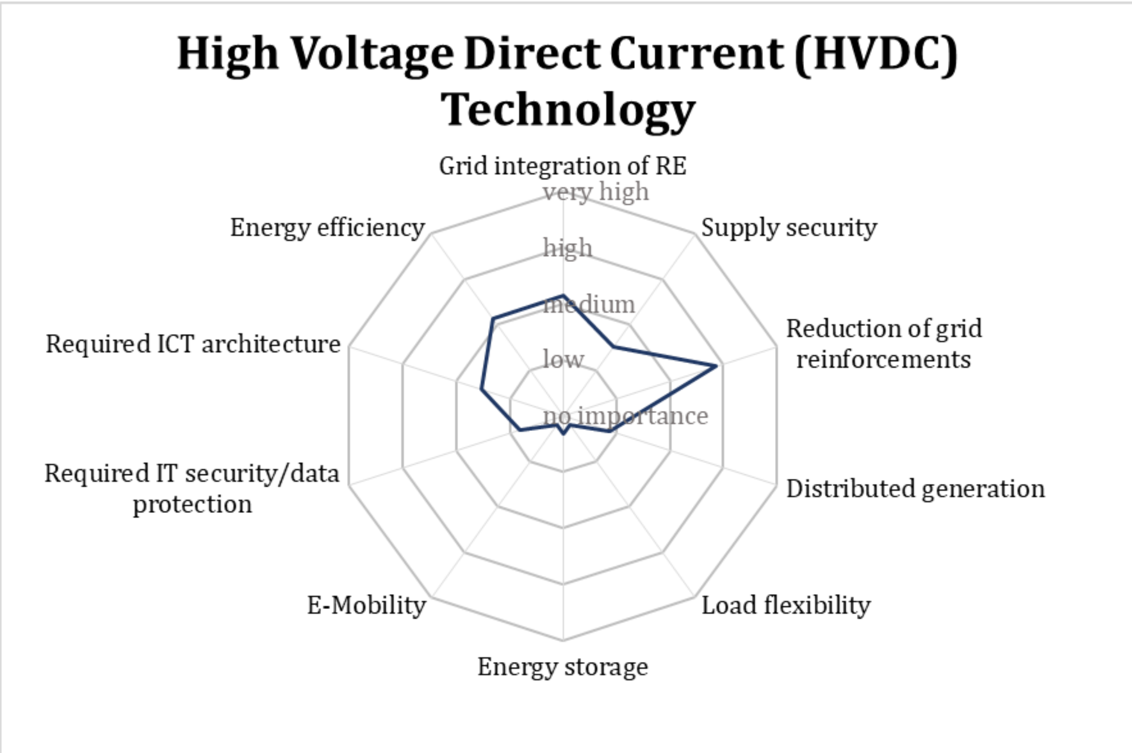
China is the frontrunner in the installation of HVDC transmission lines, with the majority of worldwide capacity installed in the country. Currently, more than 20 HVDC connections with voltages between 500 and 1100 Kilovolt have been installed, transferring mostly power from large-scale generation such as coal and hydro from western China to load centres in eastern China.

In Europe, HVDC technology is mostly used for interconnecting countries and for the connection of offshore wind power plants in the North Sea and the Baltic Sea, with the long-term perspective to expand it towards an HVDC overlay grid on top of the existing European AC transmission system.

In some other countries such as India, also the high growth of electricity demand is driving HVDC deployment. Between Thailand and Malaysia a 300 Megawatt HVDC link is deployed to improve grid reliability and reduce electrical losses.

Figure 5: Proposed and operational HVDC links in the North Sea, connecting offshore wind power plants and interconnecting European countries [12]

2.2.4.5 Assessment



2.2.5 Flexible AC Transmission System (FACTS)

2.2.5.1 Technology description

Reactive power has a direct impact on voltage stability in power systems. High VRE penetrations in power systems raise power stability issue due to the fluctuation of generation. Weak grids with VRE integration often face power oscillation problems that can limit the transmission capability. Flexible AC Transmission Systems (FACTS) enhance the power system stability by providing fast responsive reactive power compensation to the high voltage transmission network.

There exist various technologies for shunt and series compensation, including static VAR compensators (SVC), static synchronous compensators (STATCOM) as well as static synchronous series compensators and thyristor-controlled or -switched series capacitors and series reactors. The choice of compensator and harmonic filtering depends on the different network requirements. Often, compensators such as SVCs are connected in parallel with loads that need to be compensated. The amount of reactive power support can be adjusted dynamically with the compensator.

FACTS are considered as high-performance tools for VRE integration for providing dynamic reactive power support for voltage stability. More VRE can be integrated in the network in the existing transmission line. SVCs are sometimes used as relocatable FACTS for temporary use until stability problems can be resolved by other means such as grid reinforcements.

2.2.5.2 Benefits and impact

FACTS are considered as a powerful equipment to increase power quality with VRE integration, e.g., voltage stability, reactive power compensation, enhancing power transfer capability, power oscillation damping and transient stability improvement. FACTS can enhance network capacity beside network reinforcement at weak nodes where reactive power support is required. Re-locatable SVCs offer the flexibility of relocation after a change of network configuration that resolved the original problem.

2.2.5.3 Challenges and drawbacks

FACTS are expensive devices whose location and size should be carefully planned to make it a cost-effective investment. Especially in the case of VRE integration, the system operator should carry out analyses in advance to check whether FACTS is needed. A relocatable SVC rather than a fixed SVC can be preferable for the TSO if it is expected that the SVC is used only as a temporary solution.

2.2.5.4 International experiences

PLN, the electricity generation and distribution in Indonesia deploys re-locatable SVCs at the 150 Kilovolt substation in Jember by taking the load flow between the power supply and load demand into consideration to identify the location of the SVC.

Power Grid Corporation of India Limited (PGCIL) deployed large-scale SVC systems at 400 Kilovolt in Rajasthan, Punjab, and Kashmir to improve the power quality and stability of the power system.

Another SVC of 50 Mvar inductive to 300 Mvar capacitive is deployed in Bang Saphan city of Thailand in the middle of a 230 Kilovolt long-distance transmission line of 700 km. This can increase power transfer capacity and transient stability.

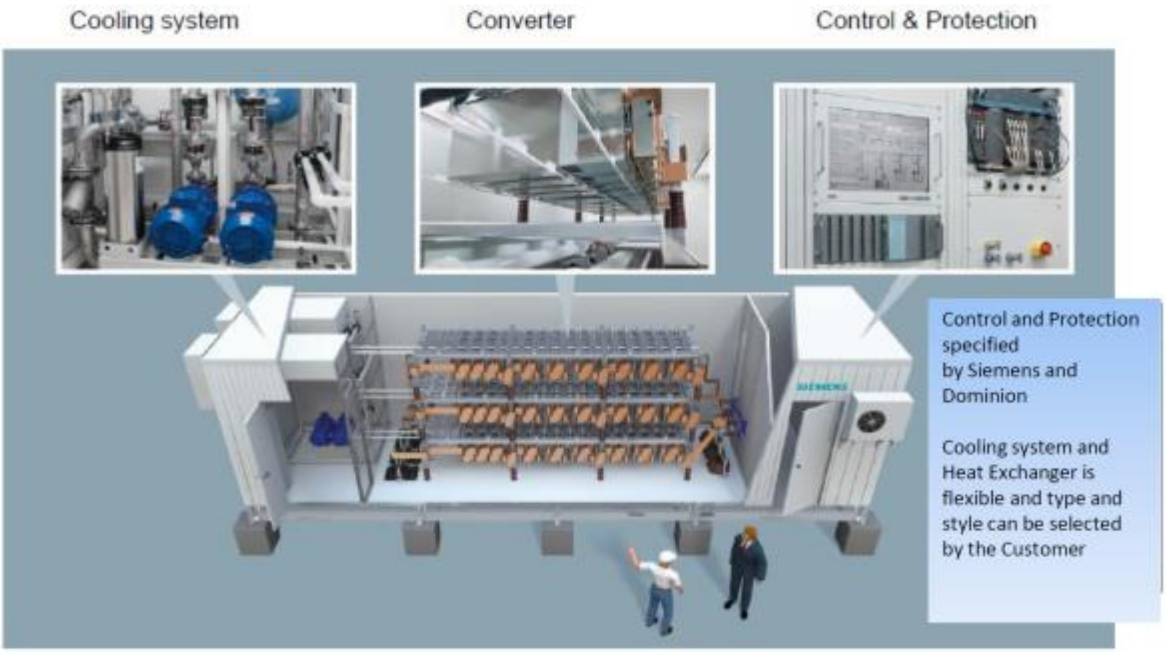
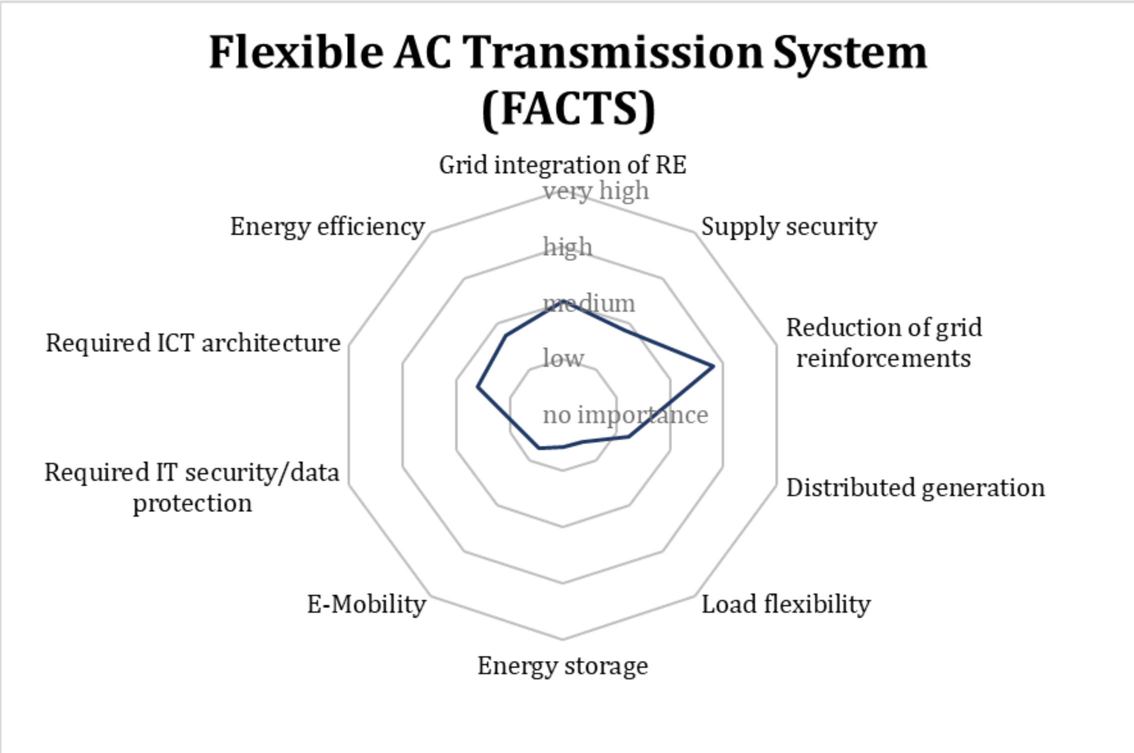


Figure 6: Mobile STATCOM solution offered by Siemens and implemented by Dominion Energy (American power company). The STATCOM is located inside a trailer and can resolve temporary operating issues while long-term solutions are constructed, e.g. due to the growing deployment of VRE [13]

2.2.5.5 Assessment



2.2.6 Dynamic Thermal Circuit Rating (DTCR)

2.2.6.1 Technology description

The available transmission line capacity (ATC) is essential data for the system operator to identify the need of new transmission line infrastructure. Usually, the capacity of a line is evaluated for standard conditions, taking into account conservative assumptions such as high ambient temperature, high solar irradiation and low wind speeds.

Dynamic Thermal Circuit Rating (DTCR), also known as Dynamic Line Rating (DLR), offers dynamic or real-time monitoring of transmission lines to estimate the actual capacity based on real-time conditions. Various parameters can be monitored for this: The line temperature and line sag can be measured, providing insights into actual operation conditions (direct monitoring). Apart from that, also ambient temperature, wind direction and wind speed can be measured or estimated (indirect monitoring).

This weather condition data can be based on direct measurements close to the transmission line, coming from weather models, or following only rough estimations based on seasonal and daily cycles. The more information the system operator has available, the more accurate is the prediction about the actual operating condition of the transmission line. Data is transmitted to the substation and further to the system operator's control centre. Hence, also the available transmission line capacity can be increased. Overall, the optimized use of transmission capacity leads to deterred transmission investments, optimized power flow and improved system reliability.

2.2.6.2 Benefits and impact

The main benefit of DTCR is enhancing the existing transmission network usage and reducing transmission line congestions. The sensors can provide real-time data of the network that are associated with the transmission line parameters and the current load. This defers network reinforcements and can be particularly useful for the VRE integration, as in particular high wind power output is inherently associated with high wind speeds and therefore enhanced cooling of transmission lines.

2.2.6.3 Challenges and drawbacks

Identifying the location and quantity of measurement devices necessary to facilitate a good approximation of actual operating conditions for the DTCR assessment is a challenging task that requires the evaluation of historic data and network situations. The large number of measurement devices that are needed for an accurate assessment, in turn, increases the costs for a wide-scale adoption of this technology. Therefore, DTCR is often applied case-by-case based on a cost-benefit analysis carried out beforehand.

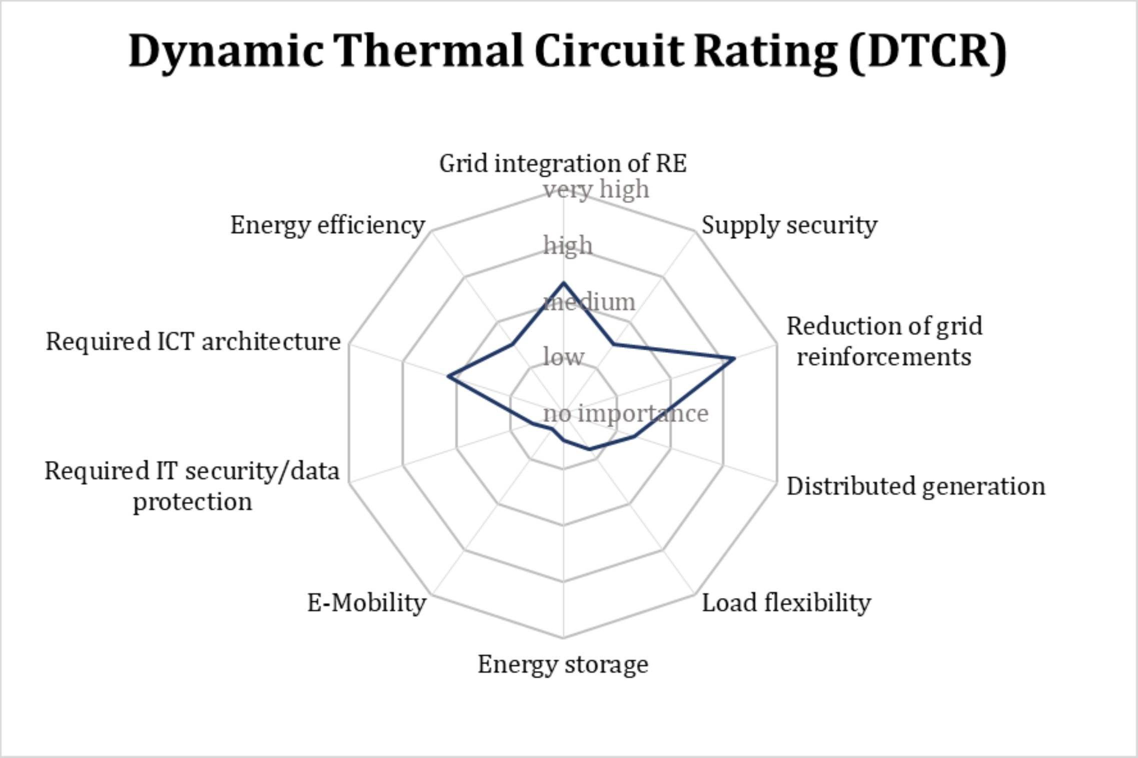
Further, in countries such as Vietnam, which are still experiencing large demand growth, DTCR may only temporarily defer transmission investment that may still become necessary a few years later. Lastly, DTCR cannot enhance the ATC of lines that are limited by dynamic constraints such as voltage instability.

2.2.6.4 International experiences

DTCR have been implemented by system operators to monitor transmission line performance in several countries such as USA, Germany, Sweden, and Australia. Oncor Electricity Delivery Company and New York Power Authority deployed DTCR to enhance existing transmission lines. In Sweden, DTCR is used to monitor wind power integration. In Australia, DTCR is deployed with real-time data to increase transmission capacity for RE integration. For example, in Tasmania the ATC can be increased by up to 40 % during high wind conditions. TenneT, the transmission system operator of the Netherlands and parts of Germany, is applying DTCR for around 40 % of its overhead lines, taking into account actual weather conditions for its calculation.

Figure 7: Line sag measurement modules from Belgian based company Ampacimon, installed at transmission lines of the Belgian TSO elia. The modules allow a continuous calculation of the maximum permanent flow that the line is supporting. [14]

2.2.6.5 Assessment



2.2.7 Distribution Automation (DA)

2.2.7.1 Technology description

Distribution automation (DA) comprises a whole suit of technologies and systems offering a large variety of features and functionalities that enable the DSO to attain increased efficiency and enhanced VRE integration. With large quantities of VRE installed in the distribution grid, such as rooftop solar PV and small wind power plants, there is an increased necessity to monitor VRE generation and effectively manage their integration into the distribution grid. By implementing efficient measures, the ability of the distribution grid to accommodate a large quantity of VRE generator plants can be increased. At the same time, expensive updates to the distribution grid infrastructure are reduced as the equipment can be utilized more efficiently and network overloading and impermissible voltage levels are mitigated.

Specific functionalities of DA with regards to VRE integration are:

- Increased monitoring and remote control of distribution assets for optimized distribution network utilization and detection of overloading and voltage violation situations;
- Automatic tap changer control of power and distribution transformers based on local or remote voltage measurements;
- Access to a GIS database on type, location, size, settings and controllability of VRE generators;
- (Real-time) observability of VRE generators on their active and reactive power output as well as locally measured voltage levels;
- Controllability of VRE infeed in case of emergency situations or for efficient curtailment (peak shaving) to mitigate congestion in the distribution grid;
- Volt/VAR control of VRE generators to decrease voltage rise by means of reactive power consumption;
- State estimation of the distribution grid to identify potential bottlenecks at locations where no measurement devices are installed;
- VRE forecasting to identify potential bottlenecks a priori and initiate mitigation measures;
- Demand response and demand side management to reduce local grid congestions due to high VRE infeed.

Distribution automation encompasses further management systems and technologies to increase efficiency in the distribution grid, such as remote recloser and switches operation, fault locating and isolation systems, outage management systems, mobile workforce management systems. However, as they are mostly unrelated to VRE integration, they are not further examined here.

2.2.7.2 Benefits and impact

If large quantities of VRE plants are to be installed in the distribution grid, DA may be a cost-efficient measure compared to expensive grid extensions to accommodate the desired levels of VRE. Otherwise, overloading of lines and transformers as well as voltage issues may arise and compromise supply security in the distribution grid. By having precise information about VRE generation and power flows in the distribution grid, the distribution system operator is able to utilize his assets more efficiently. Depending on national rules and regulation, he may be allowed to curtail VRE power output for short time periods to reduce the strain on the distribution grid. This eliminates the need to build the distribution grid for the worst-case situation and hence helps preventing costly grid updates.

2.2.7.3 Challenges and drawbacks

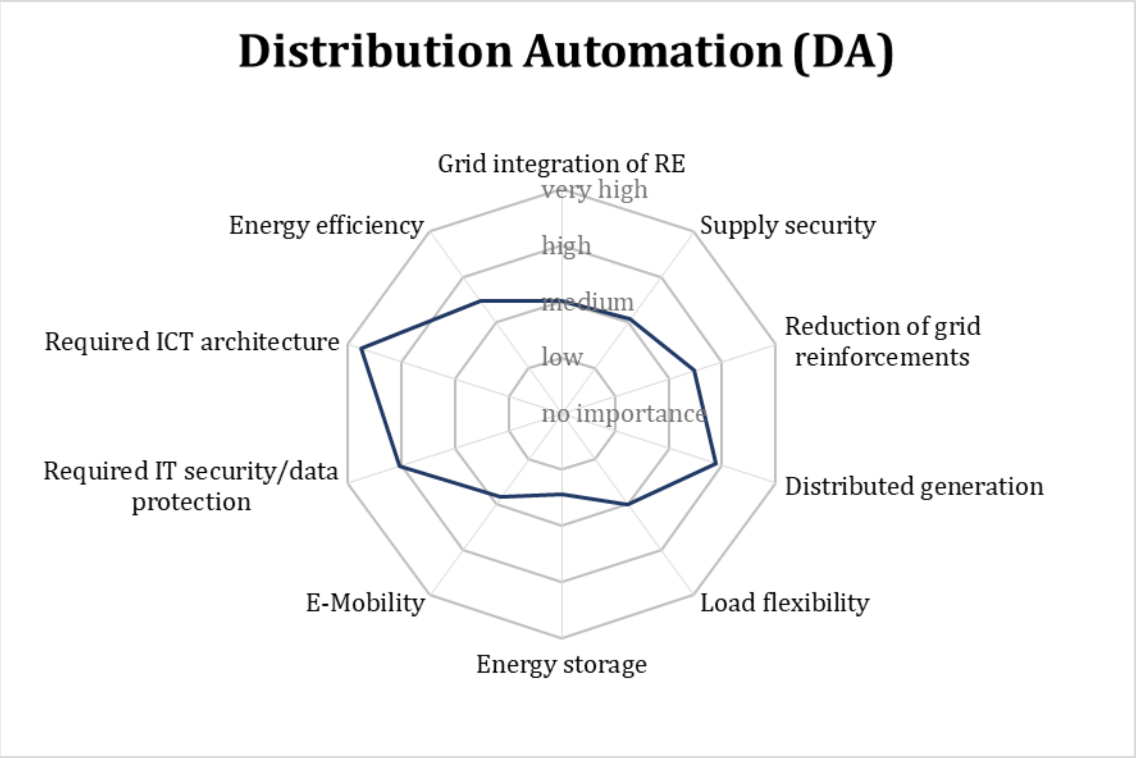
Distribution automation can be implemented and enhanced in steps. To achieve the level of automation described above, however, significant investments in measurement infrastructure and management systems need to be made. Processes need to be in place that guarantee the registration of VRE power plants in the DSO's databases with correct information. Further, the VRE plant needs to be integrated into the DSO's communication system to exchange measurement data and setpoints if certain functionalities such as Volt/VAR control are to be used. A sufficient number of measurement devices need to be installed in the distribution grid to provide the required observability levels for efficient operation. Further measurement and control capabilities need to be foreseen at the VRE power plants, e.g. through the use of smart inverters (see section 2.2.9). Control and management systems need to be in place at the DSO's control room to handle the increased complexity coming from these new functionalities.

2.2.7.4 International experiences

The number of DSOs and utilities that have applied a full-fledged distribution automation system is still limited. Many companies are however implementing the aforementioned functionalities of DA on a step-by-step basis, increasing their degree of automation.

Through the Smart Grid Investment Grant (SGIG) program in the US, utilities deployed volt/VAR optimization technologies on transformer voltage regulators to achieve peak demand reductions of about 1 percent across multiple substations. The utility Consolidated Edison further implemented a distributed energy resources management system (DERMS) to monitor and control multiple supply and demand resources including distributed generation and storage, building management systems and demand response customers.

2.2.7.5 Assessment



2.2.8 On-load tap changer (OLTC) for distribution transformers

2.2.8.1 Technology description

On-load tap-changers (OLTC) have been widely used with power transformer since many years for voltage regulation and phase shifting without interruption of load current. This technology has recently been adopted also for distribution transformers on the medium to low voltage level. The reason is increased rooftop PV power production in some power systems that lead to voltage rise during daytime, and the existing voltage drop during evening peak demand time. This can result in a large voltage spread throughout the day for which the distribution grid is not designed and which may violate the maximum allowable voltage range (typically ± 10 % depending on applicable regulation and standards).

Therefore, DSOs are increasingly looking towards distribution transformers with OLTC technology to mitigate voltage impacts in highly PV penetrated distribution grids. The voltage is locally controlled on the LV side of the transformer but also advanced concepts with remote voltage measurement at critical nodes of the LV grid exist. The OLTC distribution transformer may either be stand-alone or have a communication link to the DSO control centre for remote control.

2.2.8.2 Benefits and impact

In LV grids with high PV penetration, OLTC distribution transformers can offer a cost-efficient alternative compared to distribution line enhancements that may otherwise be necessary to accommodate the desired PV installations. Hence, depending on the local conditions, the maximum PV capacity within an LV grid can sometimes be substantially enhanced. Voltage quality is improved and compliance with regulation ensured.

2.2.8.3 Challenges and drawbacks

OLTC distribution transformers are most useful for highly PV penetrated distribution systems with long feeders and low load density. Therefore, a cost-benefit analysis should be undertaken to examine potential low voltage grids that may benefit from such technology. Rural areas with longer lines than in urban areas may benefit more, as voltage issues are more likely there. In urban areas thermal limits of lines or transformers may appear before any voltage problems arise. In these cases, OLTC technology cannot enhance PV capacity.

2.2.8.4 International experiences

Depending on local regulation, the DSO is responsible for all grid extensions that accommodate any PV power plant requests in LV grids. In Germany for example, feed-in tariffs have led to a sharp increase in rooftop PV. To accommodate these, German DSOs are increasingly relying on OLTC distribution transformers to mitigate voltage rises.

The Dutch DSO Stedin has performed a cost-benefit analysis on his distribution grids and is currently updating OLTC technologies for those where this analysis has been positive.

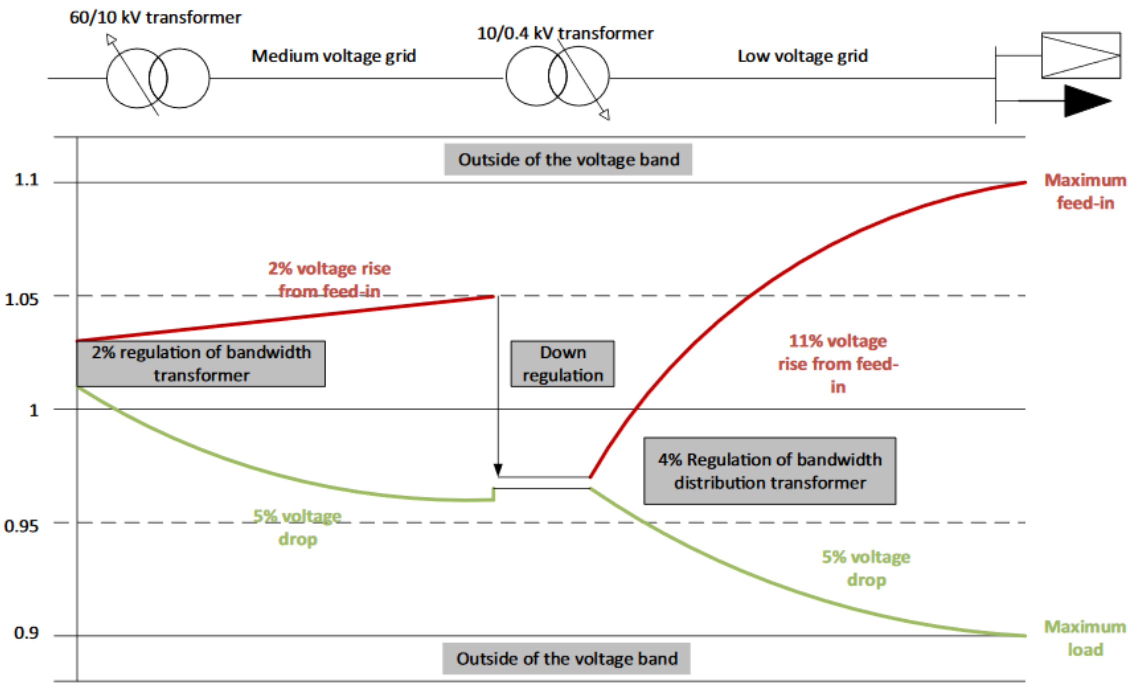
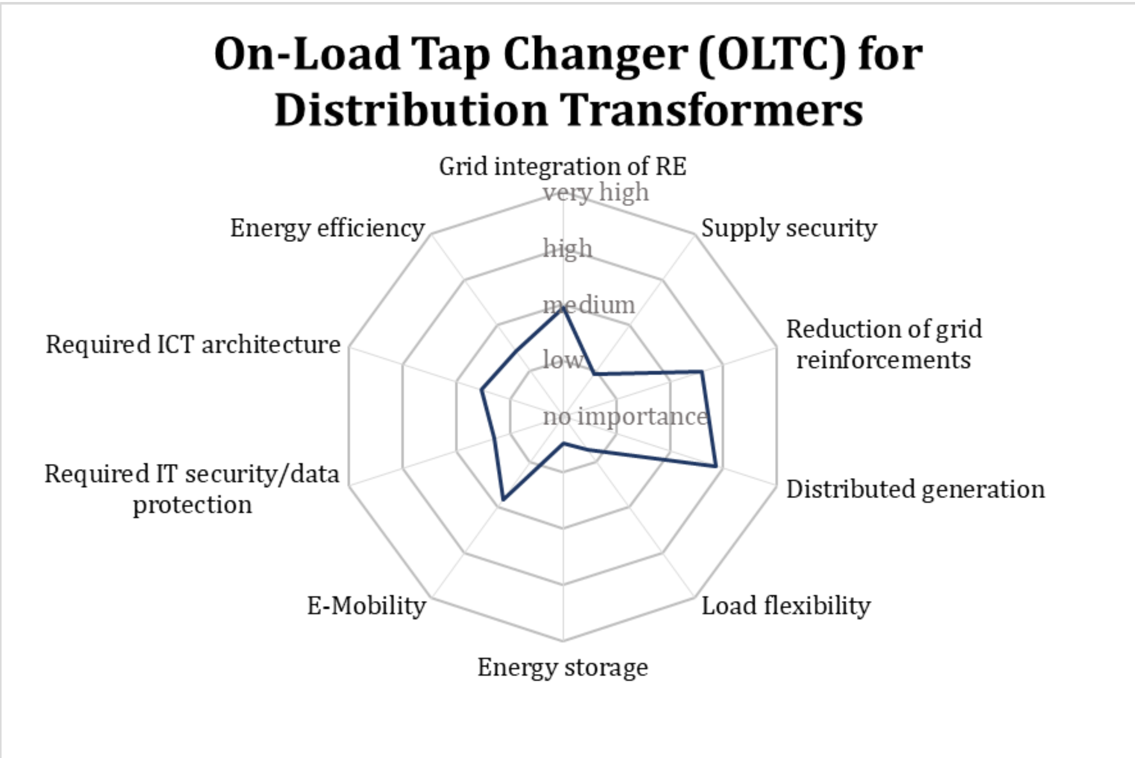


Figure 8: An OLTC for distribution transformers enables downward regulation from MV and LV to increase VRE infeed [15]

2.2.8.5 Assessment



2.2.9 Smart Inverters

2.2.9.1 Technology description

The capabilities of new inverters have been continuously improved over the years. Instead of just feeding power into the grid, smart inverters today are more “grid friendly” than their predecessors. They react to changes and disturbances in the grid in a predefined way and can offer system services to the system operator, controlled through a two-way communication link. As in particular rooftop PV power plants and small wind power plants are connected in large numbers in the distribution grids, it is important that their behaviour is predictable and supporting power system stability. The most important functionalities of smart inverters include:

- Static voltage support: VRE generators in the distribution grid increase the local voltage. By changing the reactive power output of the VRE generator depending on locally measured voltage, the voltage rise can be mitigated to some extent.
- Dynamic grid support: During frequency disturbances, the smart inverter can provide power balancing support by increasing or reducing active power output. During dynamic voltage events such as voltage surges or short-circuits, the inverter is able to stay connected during the grid fault and even provide reactive power support during a short circuit (low voltage ride through, LVRT).
- Active power management: Setpoints for active and reactive power can be sent by the system operator, and feedback signals can be sent via a two-way communication link. This capability can be used for emergency situations as well as for Volt-VAR control and reactive power provision for the transmission grid.

Commonly the use of smart inverter capabilities is mandated by technical requirements in the grid code, which also regulate verification of compliance with the specifications.

2.2.9.2 Benefits and impact

Through appropriate specifications, even very large numbers of distributed VRE power plants can be effectively and reliably handled. This way, the local grid impact of the VRE plant can be mitigated, reducing the necessity for other measures. Moreover, system services that are traditionally provided by conventional generators can also be provided by VRE power plants with smart inverters. Through the two-way communication of the inverter, VRE power plants can be integrated in the power system management of the system operator.

2.2.9.3 Challenges and drawbacks

Technical requirements for VRE generators need to be specified in the respective grid codes; otherwise VRE system owner would choose cheaper options without smart functionalities of the VRE inverter. Compliance with these specifications needs to be enforced by certification bodies or through other means. The required set of technical specifications must be a compromise between desired functionalities and cost: Unnecessarily strict requirements can drive up inverter costs and may not be needed to maintain system security.

2.2.9.4 International experiences

In Germany, PV generators before 2012 were required to disconnect at 50.2 Hz. With large growth of PV power plants in the German system, this posed a threat to system stability, as tens of gigawatts of PV would have disconnected in case of an overfrequency event (see Figure 9). In 2011/12, the requirement was replaced with a gradual frequency-dependent power reduction for new PV units, and older units had to be upgraded through an extensive retrofitting scheme.

A similar situation arose in Spain, where wind power plants were allowed to trip if voltage dipped below 85 %. This could lead to widespread disconnections in case of a fault incident. In 2006, new low voltage ride through specifications were therefore made and incentives introduced to retrofit old wind power plants. Spain further established control centres of renewable energy, through which all VRE plants above 5 MW capacity are monitored and, if necessary, can be controlled.

In the USA, a solar eclipse of 2017 resulted in a temporal reduction of PV output in the morning hours. To mitigate the rapid decrease and then increase in solar generation of up to 100 Megawatts per minute, the Californian system operator CAISO enforced ramp rate limitations on large PV power plants.

CAISO together with NREL and FirstSolar also tested the provision of grid reliability services on a 300 Megawatt PV plant, amongst them the plant following an AGC signal, essentially providing curtailment in direct response to the AGC signal.

The VRE generation installed in Vietnam during 2019 already provides basic Smart Inverter functionality. The Grid Code requirements will need to be revised regularly to ensure all necessary functions are required and compliance is verified.

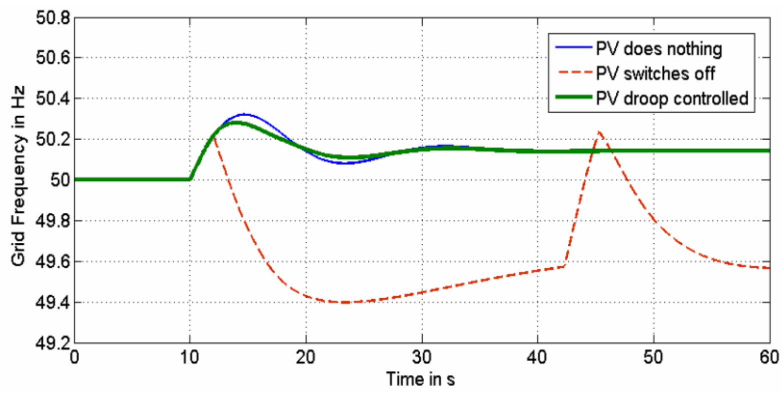
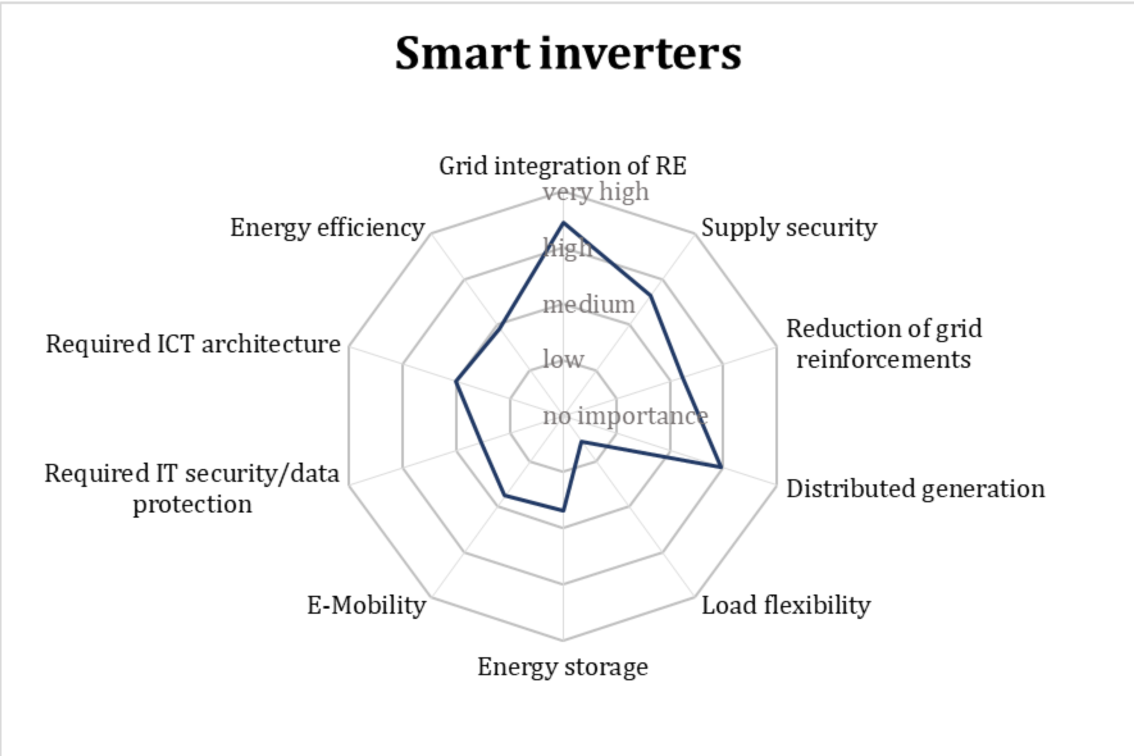


Figure 9: Simulated frequency for the European power system for different inverter settings, amongst them the setting that PV switches off at a frequency above 50.2 Hz according to German regulation [16]

2.2.9.5 Assessment



2.2.10 Advanced Metering Infrastructure (AMI)

2.2.10.1 Technology description

While mechanical electricity meters and automatic meter reading (AMR) offers only one-way communication, Advanced Metering Infrastructure (AMI) based on smart meters enables a two-way communication between the consumer and the DSO. Smart meters can provide real time electricity measurement in short intervals, time-based electricity price scheme support, and identification of outage events. Voltage monitoring can be performed by the smart meter and the data used by the DSO to evaluate system performance and counter-measures. AMI has been deployed worldwide by various DSOs, with varying functionality.

Widespread communication technologies for smart meters are wireless technology, e.g. GPRS, Zigbee, or WiMAX. Meter data management systems (MDMS) must be deployed with smart meters and can often be linked with other systems such as outage management systems (OMS) and distribution automation (DA). In addition, many smart meters can interface with home area networks (HAN) to link with smart home appliances, e.g. in-home display, load control and demand response. For the communication technology of smart meters, several parameters must be considered such as bandwidth, latency, cost, reliability, and cybersecurity.

2.2.10.2 Benefits and impact

AMI provides benefits to many players including the consumer and the DSO. The consumer can monitor his real-time electricity consumption and is able to change behaviour in response to changing electricity prices.

The DSO can benefit from automated and more accurate billing, outage localization for prompt restoration and voltage monitoring to identify grid bottlenecks. This reduces the DSO's workforce cost for manual meter reading and improves reliability through precise outage detection and power quality measurements.

The application of demand response through AMI enables peak demand shaving and incentivizing better demand alignment with VRE production. Further, AMI offers comprehensive electricity consumption data for load projection and power supply planning, enabling better understanding of the current situation and thereby allowing the DSO to enhance RE integration into the power system.

2.2.10.3 Challenges and drawbacks

AMI deployment and smart meters have higher cost than traditional electrical meters. Cost-benefit analyses should be carried out to determine the cost-effectiveness for different customer classes. The AMI must be appropriately integrated with the communication network to ensure reliability and responsiveness. Updates to the smart meter software must be supported, so that new generation functionalities can be included. Sufficient measures need to be set up to ensure data privacy and control third-party access.

2.2.10.4 International experiences

In Germany, smart meters are deployed in consumer groups where the cost-benefit analysis was found positive, while other countries in the EU decided to roll out smart meters to all consumers by 2020. The DSO is responsible for AMI deployment, which must be designed according to EU commission standard to meet technical requirements and commercial interoperability at the large scale.

The Netherlands are one of the countries that have comprehensive data privacy laws for smart meters where the consumer can refuse smart meter installation or request to turn on an administrative mode to avoid data collection, storage and forwarding.

AMI deployment projects in the USA have demonstrated that smart meters can create new business models to the DSO by offering customer data for real-time monitoring and demand response programs.

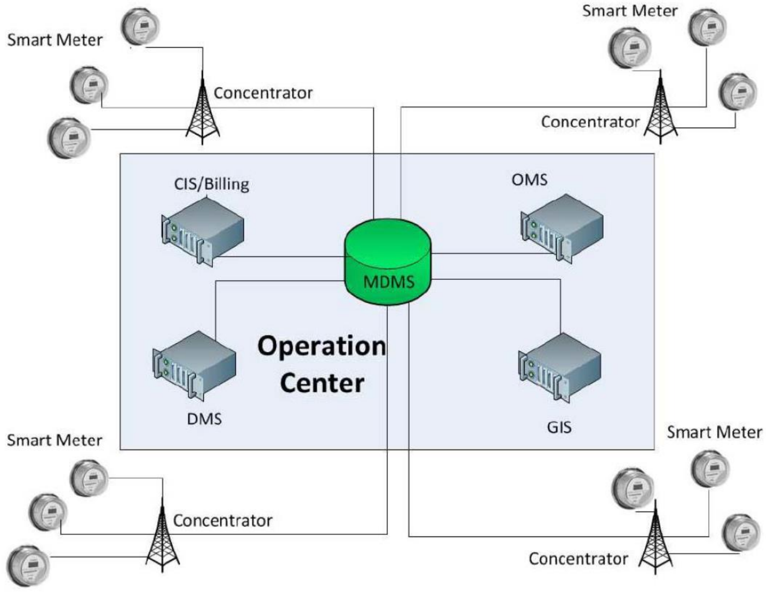
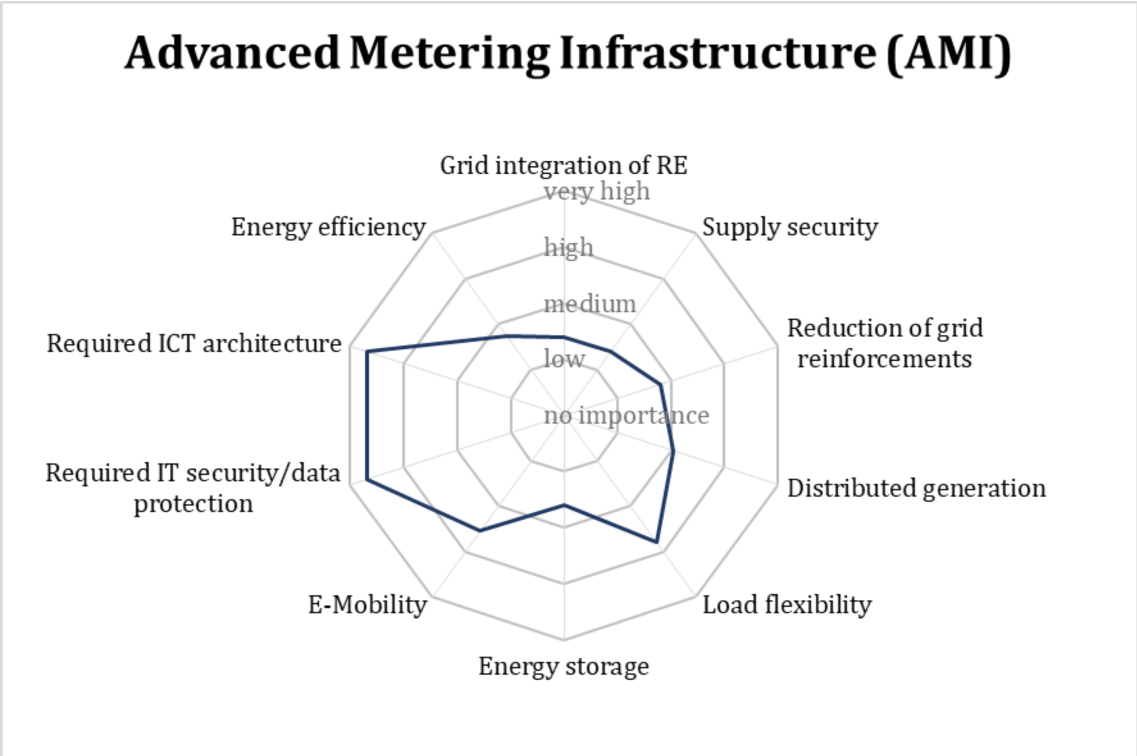


Figure 10: Possible AMI architecture with connection to Customer Information System (CIS), Distribution Management System (DMS), Outage Management System (OMS) and Geographic Information System (GIS) [17]

2.2.10.5 Assessment



2.2.11 Demand Side Management (DSM) and Demand Response (DR)

2.2.11.1 Technology description

Demand Side Management (DSM) and Demand Response (DR) describe the manipulation of loads through direct control or as a response to price signals. Active load control is often applied for larger (industry) consumers where significant potential is available. To shift demand from smaller loads, e.g. in households, the use of dynamic pricing is more suitable. This can stimulate a shift of demand from peak to off-peak periods in order to avoid network congestion, or towards periods of high wind or solar power generation. Possible pricing schemes comprise for example time-of-use (TOU) pricing, critical peak pricing (CPP), peak time rebate (PTR) or real time pricing (RTP).

DSM and DR can be implemented through use of advanced metering infrastructure (AMI) and smart meters (see section 2.2.10) that allow such operation through the load or VRE aggregator centre. The smart meter enables a two-way communication with the customer, and comes with additional functionalities such as remote reading, automatic outage detection, voltage monitoring and even load control. This may also entail a Demand Response Management System (DRMS) capable of facilitating this two-way communication with up to a few millions of endpoints and effectively managing the information flow with these.

2.2.11.2 Benefits and impact

DR programs provide load shifting from on-peak to off-peak periods through the price signal. The customer has the main advantage of lowering his electricity bill if demand is shifted. The electric utility only needs to cover a reduced peak demand. Load and VRE aggregator centres can, in combination with weather forecast systems, achieve further benefit by providing ancillary services and reserves.

2.2.11.3 Challenges and drawbacks

DR programs cannot be implemented without the installation of smart meters with an extensive set of functionalities. Consequently, data security and data privacy must be taken into consideration due to the complex data transfer through the meter. Data integrity must be handled appropriately to automatically detect and correct false data. Pricing mechanism should be defined and experiences gathered on consumer behaviour to meet the maximum demand reduction potential.

2.2.11.4 International experiences

A DR program has been deployed as a pilot project in Thailand by focusing on commercial and industrial sectors where AMI or AMR is available at the site. The demand response signal is sent to the customer in advance by announcement and offering a price rebate e.g. two weeks ahead. However, the demand reduction did not meet the overall potential due to unattractive price signals during the pilot project phase. The load aggregator and DRMS are essential for demand response deployment in action.

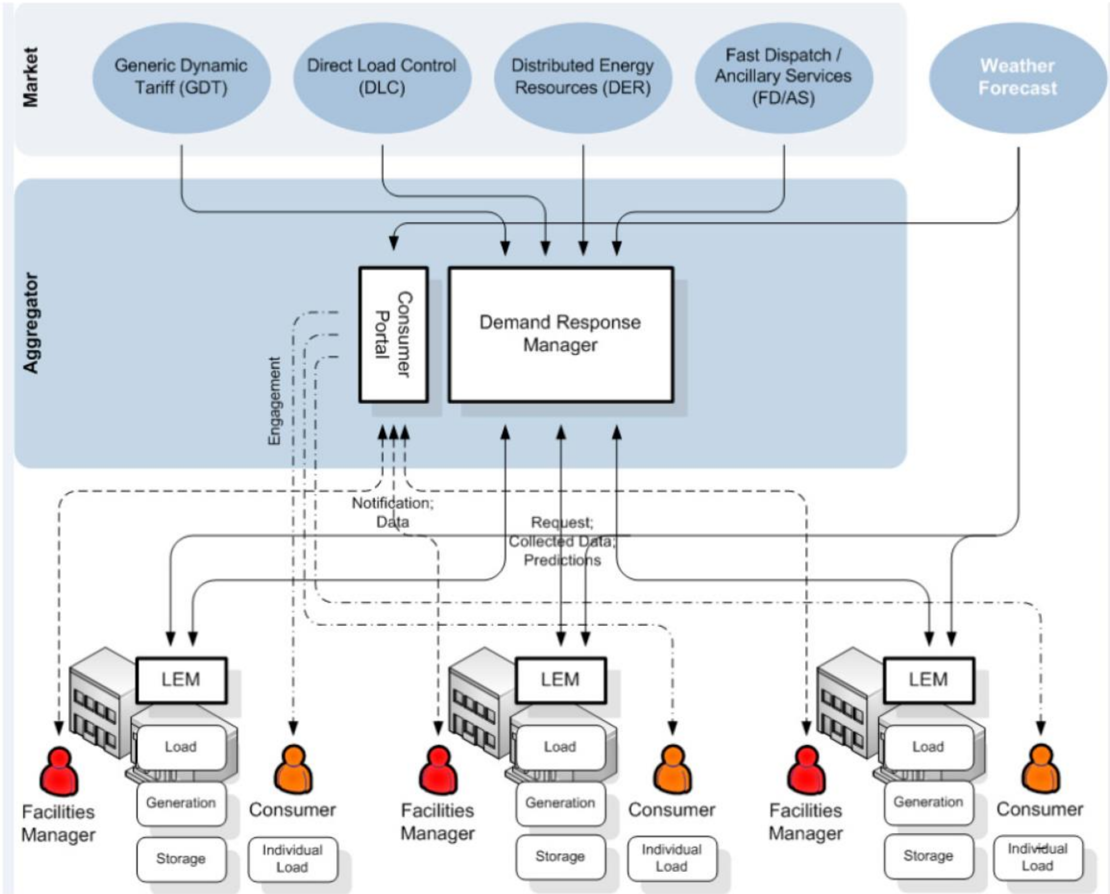
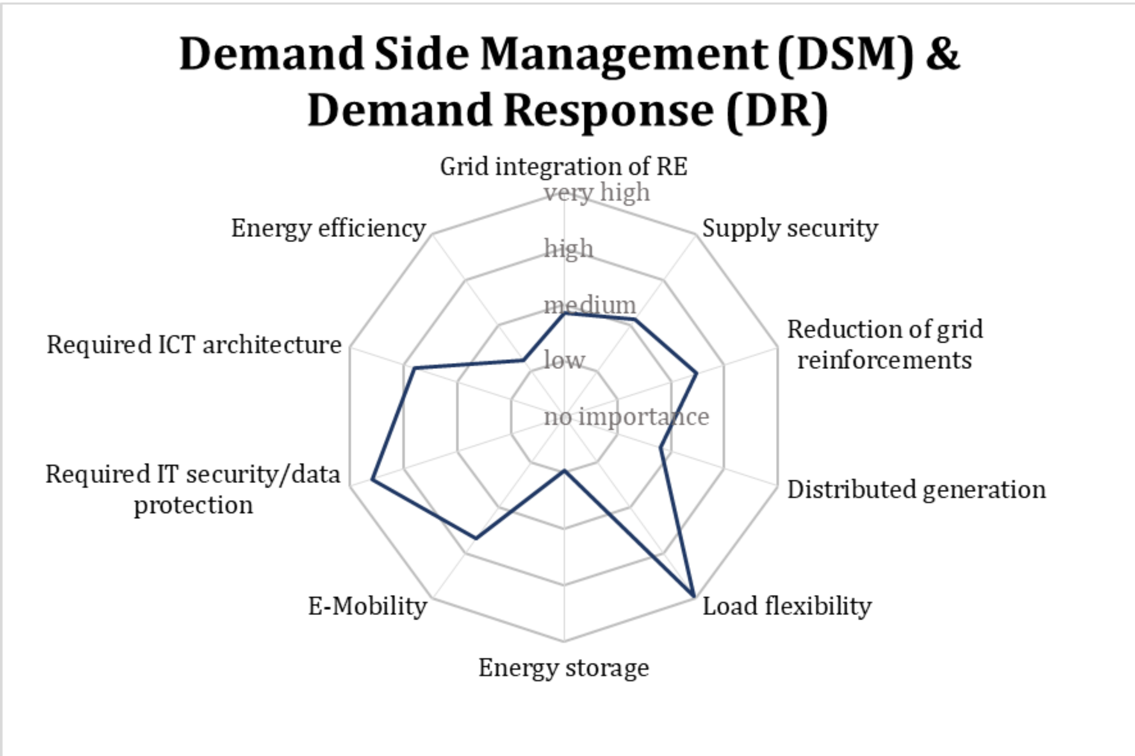


Figure 11: Example of a Demand Response architecture for blocks of buildings [18]

2.2.11.5 Assessment



2.2.12 Virtual Power Plants (VPPs)

2.2.12.1 Technology description

A Virtual Power Plant (VPP) is a network of decentralized, medium-scale power generating units such as wind power plants, solar parks, and Combined Heat and Power (CHP) units, as well as flexible power consumers and storage systems. By aggregating a wide range of distributed energy resources under a central control, the power output can be determined and controlled more accurately, and participation in further kinds of power markets becomes possible.

This is in particular useful if VRE power plants are to be integrated in the VPP, as their stochastic nature and uncertainty makes them otherwise hard to forecast by the system operator. Integrating a significant number of VRE power plants therefore reduces uncertainty due to smoothing effects, and combination with other DER allows further smoothing and increased flexibility. This improves the VPP's operator in his ability to trade or sell power on the electricity market, and allows offering ancillary services, e.g. for providing reserves that are then provided from the combined output of the VPP instead of from a single plant.

In recent years, VPPs have expanded towards smaller and smaller power plants as well as new consumer types such as electric vehicles, due to increasing control and communication capabilities of distributed energy resources.

2.2.12.2 Benefits and impact

For the VPP operator, the aggregation of many VRE and non-VRE power plants into a single power plant improves his operation on the electricity market. He can react more easily to prices on the market and, being able to accurately forecast his generation schedule, he reduces penalty costs for imbalances between traded and actually supplied power. It further enables him to bid into the ancillary service market. Hence, imbalances between generation and demand are not only reduced on the system level, but new market players can also offer system services to the system operator.

2.2.12.3 Challenges and drawbacks

The VPP operator must ensure a high responsiveness and reliability of the communication network for his generation portfolio to avoid communication outages that can impact his trading capability and result in penalties. He further needs to set up accurate VRE forecasting systems (see also section 2.2.1) to improve electricity market operation, for example for making accurate bids on the day-ahead market. Lastly, the high number of power plants also requires a complex billing and management with the different power plant owners.

2.2.12.4 International experience

The company Next Kraftwerke from Germany operated a VPP in seven European countries providing peak-load operation, power trading and grid balancing services with a mix of biogas, solar and wind power plants as well as large power consumers.

The British company Moixa intends to link PV power plants with batteries and electric vehicles to offer various services. There exist many more examples of small to medium scale VPP providers and aggregators that are participating in unbundled power markets.

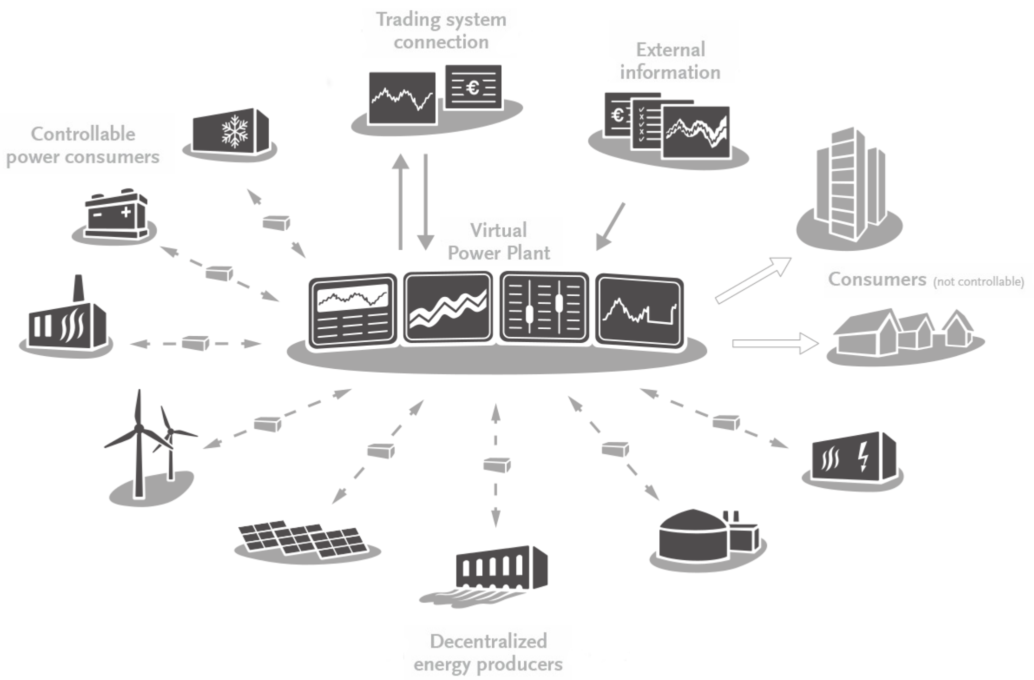
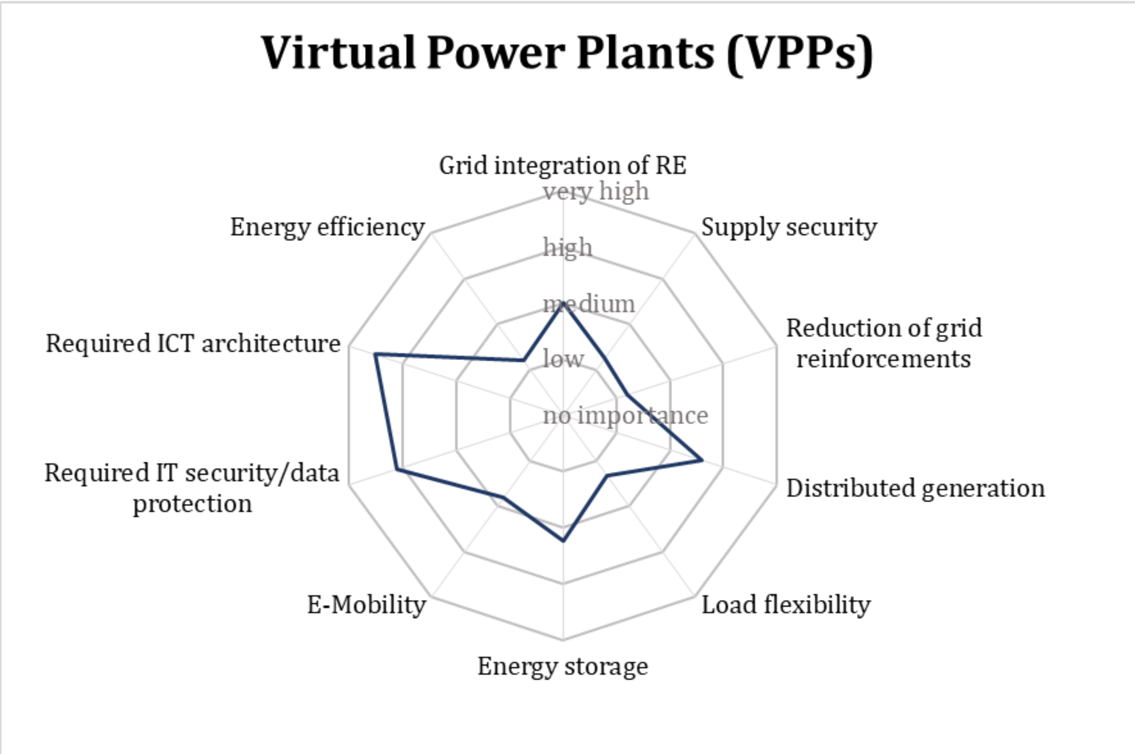


Figure 12: Virtual Power Plant as a central control IT system for distributed energy resources [19]

2.2.12.5 Assessment



2.2.13 Distributed energy storage and electric batteries

2.2.13.1 Technology description

In recent years, not only the cost for PV and wind generation have fallen tremendously, but also distributed energy storage such as batteries have seen drastic cost declines. Distributed energy storage is typically installed at the residential level.

Different technologies can be considered for different applications: For example, for short-term storage in particular lithium-ion and lead-acid batteries are used. Flow batteries provide storage for medium-term storage applications, while various kinds of thermal storage are usually used for long-term storage. In particular lithium-ion batteries have seen sharp cost declines recently and are therefore the predominant choice for residential battery systems in combination with PV and in electric vehicles.

Batteries with advanced power electronics (see smart inverter in section 2.2.9) can be integrated into distribution automation, demand response, or virtual power plant (see section 2.2.12) systems.

2.2.13.2 Benefits and impact

Intelligent control of batteries, enforced or incentivized through regulation and market mechanisms, enables the following applications and advantages:

- Grid frequency and voltage regulation (grid stabilisation and power quality control).
- Smoothing of renewable power variability (ramp rate control).
- Small-scale energy arbitrage (especially with thermal storage).
- Shaving of short-term load peaks.
- Shaving of short-term RE peaks.
- Backup power: short-term islanding of microgrids and supplying loads briefly after islanding before distributed generation comes online.
- Improvement of distribution system asset utilisation and deferral of distribution system upgrades.

Batteries can be deployed quickly and modularly and can be easily relocated if necessary.

2.2.13.3 Challenges and drawbacks

The main inhibitors for wide-scale deployment of distributed energy storage and foremost battery storage are still too high costs (despite rapid declines). Batteries are still a very expensive technology compared to other measures to increase flexibility in the system. Therefore, batteries for the system integration of VRE become only relevant at a late stage of VRE deployment.

2.2.13.4 International experiences

Some countries such as Korea, Germany, the US, China, Japan and Australia are driving battery deployment through larger incentive programs. In Germany there is an incentive program for PV storage systems with a maximum feed-in power limitation of 60 % of the PV system rating. If the PV production increases above 60 %, the feed-in power must be curtailed. By charging the battery during those times, the desired peak shaving effect of PV production is achieved while little energy is curtailed and lost.

Projects that utilize batteries for system services are mostly in pilot phases around the world. For example, the German storage company *sonnen* built up a virtual power plant of home storage units to provide redispatch services to the German TSO *TenneT*. In case of a network congestion in the transmission system, batteries located on one side of the congestion are taking up power by increasing charging, while batteries on the other side of the congestion reduce charging or even discharge. This relieves the power flow across the congested line while the power balance in the entire power system is maintained. Similar projects exist to provide also operating reserves with small-scale battery systems in Belgium, the Netherlands and Germany.

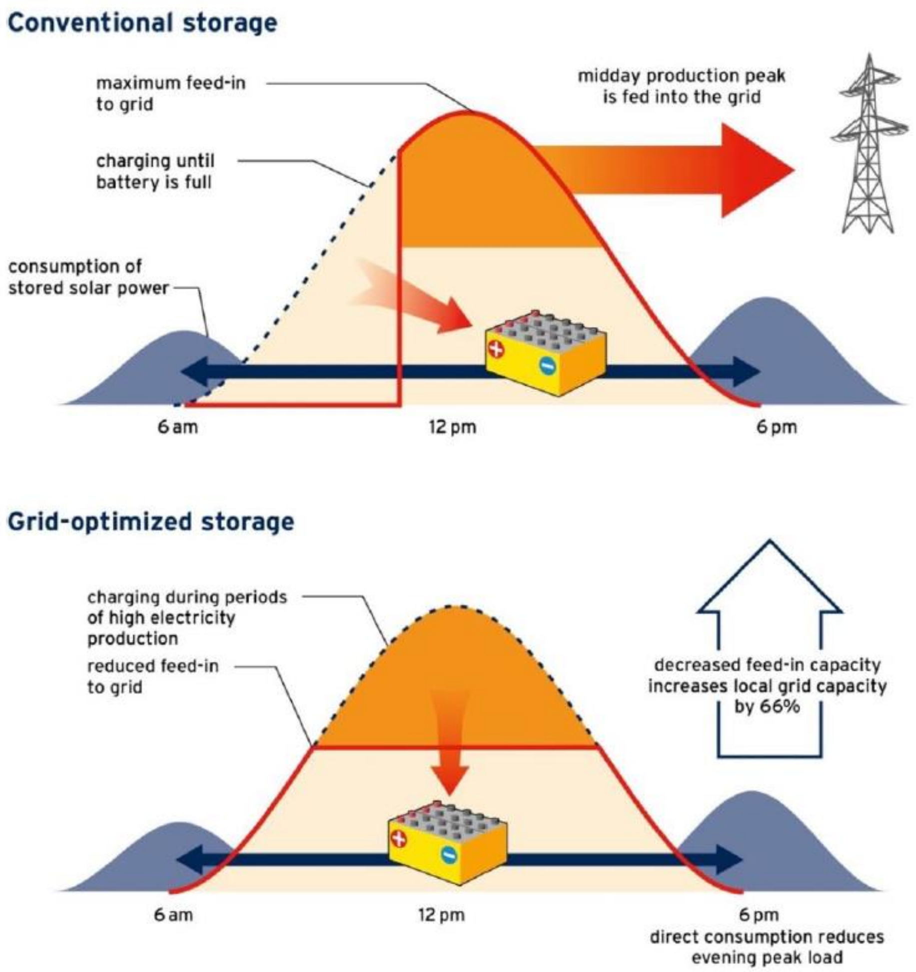
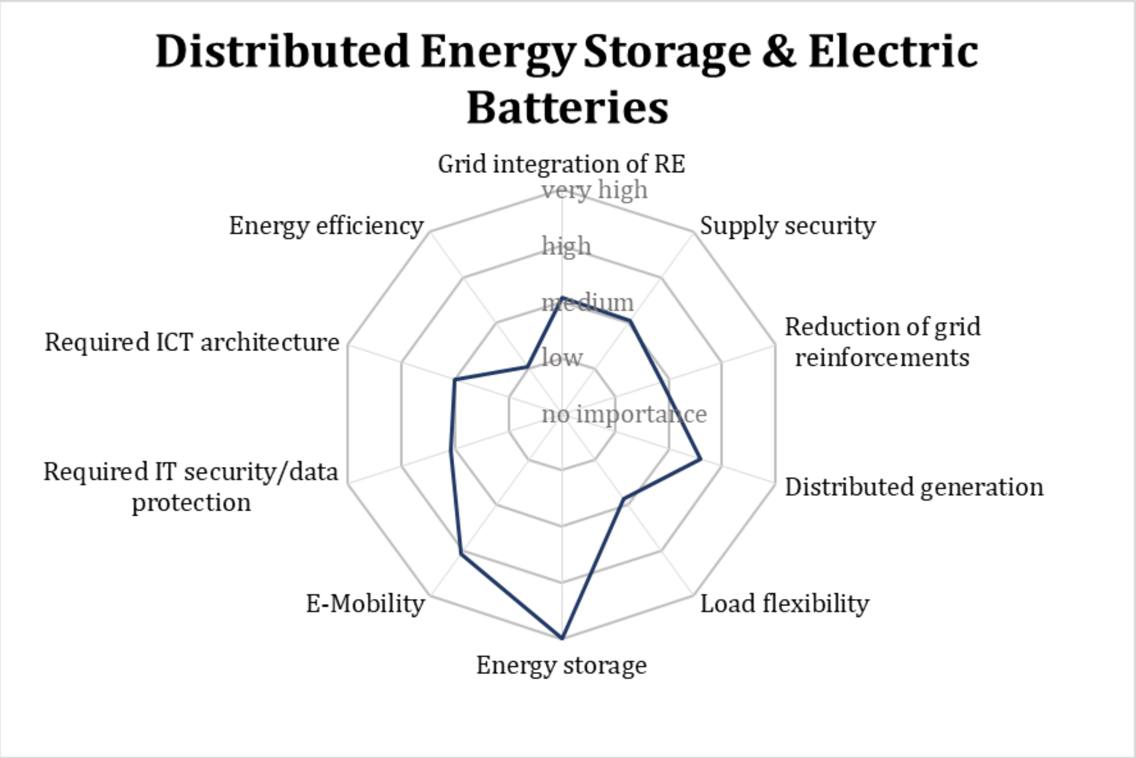


Figure 13: Conventional vs. grid-optimized storage with PV peak shaving capability [20]

2.2.13.5 Assessment



2.2.14 Smart Charging of Electric Vehicles

2.2.14.1 Technology description

Electric vehicles (EVs) are a promising technology to decarbonize the transport sector, and recent technology and cost developments have led to a sharp rise in EV sales in countries such as China, the USA, Norway or the Netherlands. Charging of the EVs increases the demand in distribution grids during certain times. The uncontrolled charging of large EV fleets may locally overload distribution assets or result in voltage problems. On the other hand, coordinated charging of EVs dependent on VRE availability can potentially create significant synergy between the two technologies. Smart charging strategies tap into this potential by sending price signals or direct control signals to EV charging stations.

2.2.14.2 Benefits and impact

A smart charging infrastructure will not only reduce congestion problems resulting from EV charging in the distribution grid, but may also help allowing increased VRE penetration by predominantly charging when solar or wind power is available.

During times of low solar and wind infeed it may even be possible to backfeed power from the EV battery into the grid (vehicle-to-grid or V2G). Investments into distribution grid infrastructure as well as the need for backup generation are reduced, while higher VRE shares can be accomplished. Customers benefit from reduced electricity prices for EV charging if they consent to a limited control of the EV.

2.2.14.3 Challenges and drawbacks

EV smart charging requires a high coordination between the EV chargers and external actors. This requires an extensive communication network as well as measures to ensure security as well as privacy. The roles of market actors and the system operator need to be clarified and specified – in which sense they can control EV charging without restricting the EV user.

2.2.14.4 International experiences

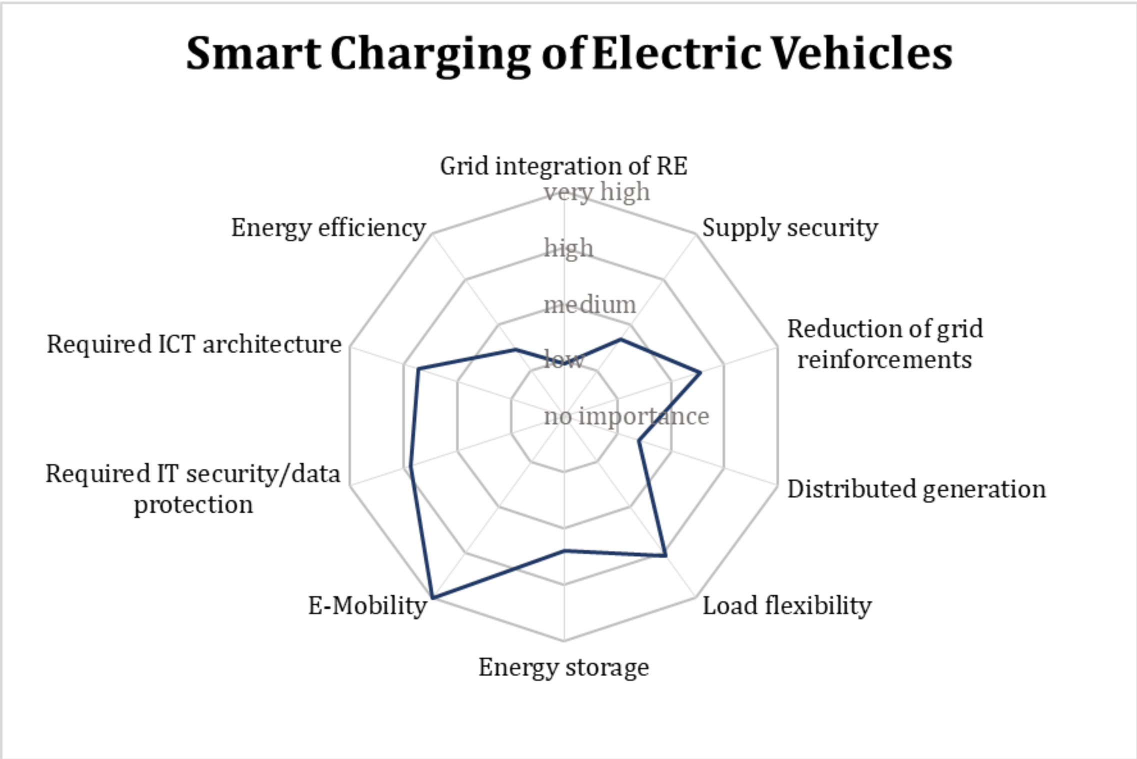
Smart charging strategies have been deployed in research and testing scale in the past 10 years. The Danish “Parker” project was the first smart charging concept with vehicle-to-grid capability represented in commercial scale to provide frequency response with multiple fleets, vehicles, and locations.

Within a project with the Danish TSO Energinet, it was proven that EVs can contribute ancillary services in less than 10 seconds with the duration of up to 30 mins.

Recently, redispatch concepts have been demonstrated in Germany to store excess electricity from VRE in EV batteries to eliminate grid congestion. The project is a collaborative effort between TenneT, Nissan and The Mobility House. An EV can behave as mobile energy storage and provide service support to the TSO in overload or oversupply areas in Germany. The Mobility House developed software to control EV charging and discharging mechanism. The project has produced test result that demonstrated the technology could be applied at commercial scale across Germany in the future.

Figure 14: Electric vehicle with bidirectional charging capability (V2G). In aggregation they are used to offer operating reserves [21]

2.2.14.5 Assessment



2.2.15 Further outlook on upcoming Smart Grid technologies

The following technologies are only briefly described because of their (as of yet) still limited applicability.

2.2.15.1 Microgrids

A Microgrid is a localized group of distributed energy resources with small-scale generators, loads and storage systems that can be operated both in grid-connected and island-mode. The idea behind the concept is a higher resilience and reliability of power supply during transmission system outages, and potentially more efficient consumption of the locally generated power.

Microgrids are typically used on islands and in rural areas where a grid connection to the main grid is not possible, too expensive or not reliable.

2.2.15.2 Power-to-X

Power-to-X describes the conversion of electricity into other usable energy forms. This includes for example the production of hydrogen through electrolysis and possible further processing to methane (power-to-gas), the conversion to heat with heat pumps, resistors or electrode boilers (power-to-heat) and other conversion forms.

The application is particularly useful for the conversion of excess VRE production and usually only relevant for VRE system integration at very high VRE levels. With some technologies, a reconversion is possible, e.g. energy stored in hydrogen can be used to generate electricity with fuel cells.

2.2.15.3 Smart Home

A Smart Home refers to home automation through which intelligent appliances in the house such as water heaters, air conditioning, washing machines, dish washer, refrigerators, and clothes dryers are controlled in a manner to either increase the self-consumption of residential PV or to participate in demand response programs.

In particular heating and cooling systems are considered as high energy consumption loads in the building that can be controlled and managed to lower the electricity bill of the consumer, while providing peak power reduction and increased VRE consumption for the DSO or system operator.

Smart meters are typically a prerequisite to enable these advantages. The benefits need to be weighed against the extra cost for the smart meter and the intelligent devices.

2.3 Pre-Assessment of international Smart Grid technologies

The Smart Grid technologies from section 2.2 are assessed through various metrics below, answering the following questions:

- What is the importance of the technology for VRE integration?
- When should this technology be applied the latest in order to foster VRE integration, i.e. in which VRE phase does it become relevant (see section 2.1)?
- Do any commercial products exist and if yes, how mature are these products?
- How many power systems around the world apply this technology already?
- Is this technology easily available in Vietnam or not?

The maturity level, market penetration and availability in Vietnam have been estimated using a four-level scale (from 0 to 3), explained in Table 2.

Table 3 shows the assessment for all of the Smart Grid technologies. For example, some technologies such as VRE forecasting and smart inverter capability are already important at an early VRE deployment stage and have a large impact on VRE deployment. They should therefore be implemented early.

Other technologies such as online-DSA, however, only become relevant at late stages of VRE deployment, as system security is usually not compromised at low VRE penetration.

HVDC technology can be relevant in all VRE phases if large VRE power plants in remote locations are connected via HVDC line. Similarly, the installation of DTCR can be performed regardless of the VRE phase. DTCR can have a moderate impact on VRE deployment as for example during high wind power output also the available transfer capacity of transmission lines is increased due to wind cooling effects.

Lastly, mature technologies that have been applied already on a wider scale worldwide are also available in Vietnam. Less mature technologies such as smart charging of electric vehicles are much less available; however, their fast development can make them increasingly interesting in the near future.

Table 2: Metrics for the assessment of Smart Grid technologies

	Impact on VRE deployment	Maturity level	Market penetration	Availability in Vietnam
0	No impact	Not tested, just a concept	Not yet commercially applied	Not commercially available
1	Small impact	Tested in pilot projects	Applied in very few power systems	Available in other countries but not in Vietnam
2	Moderate impact	First generation products on the market	Applied in some power systems	Available in Vietnam but expensive
3	High impact	Second or later generation on the market	Applied in many power systems	Available for fair price

Table 3: Assessment of Smart Grid technologies according to various metrics

Smart Grid technology	Relevant in which VRE phase?	Impact on VRE deployment	Maturity level	Market penetration	Development trend	Availability in Vietnam
VRE forecasting	1	3	3	3	Moderate	3
Wide-area measurement system (WAMS)	-	1	3	2	Fast	3
Online Dynamic Security Assessment (online-DSA)	4	2	2	1	Moderate	2
High Voltage Direct Current (HVDC)	1 to 4	1	3	2	Moderate	2
Flexible AC Transmission System (FACTS)	1 to 4	2	3	3	Moderate	3
Dynamic Thermal Circuit Rating (DTCR)	-	2	3	2	Moderate	3
Distribution automation (DA)	3	2	2	1	Fast	1
On-load tap changer (OLTC) for distribution transformers	3	2	3	2	Moderate	2
Smart inverters	1	3	3	3	Moderate	3
Advanced Metering Infrastructure (AMI)	-	1	3	2	Fast	2
Demand Side Management (DSM) & Demand Response (DR)	4	3	2	1	Fast	2
Virtual Power Plants (VPPs)	3	2	2	2	Fast	1
Distributed energy storage and electric batteries	3	3	3	2	Fast	2
Smart Charging of Electric Vehicles	4	2	1	0	Fast	0

3 Task 3: Methodology and Criteria for Smart Grid Technology Assessment

3.1 Methodology and Criteria for the Analysis of Smart Grid Technologies

The identification of Smart Grid trends and products in Task 2 has resulted in a selection of 14 technologies for further evaluation.

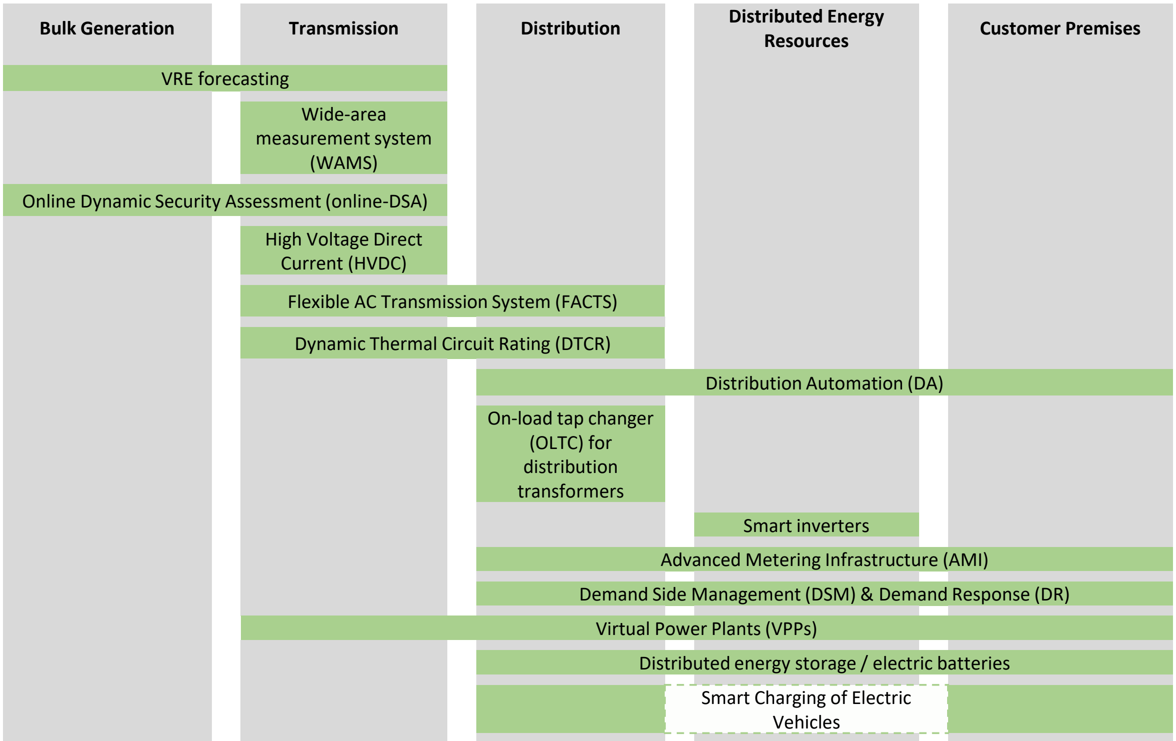


Figure 15: Selected 14 Smart Grid technologies and their application domains

The developed methodology and criteria will be applied on these technologies.

3.1.1 Criteria

The criteria are based on the initial list of criteria from the TOR. The following key criteria are used:

Impact on power system challenges: Does the technology address present or upcoming – especially VRE-related – power system challenges in Vietnam?

Economic viability: Is the technology a cost-efficient measure, likely to provide higher benefit than it costs?

Applicability: Can the technology be currently applied to Vietnam or are there obstacles (in terms of technology development, regulatory framework, etc.)?

Level of existing knowledge: Are there already ongoing pilot projects in Vietnam that can serve as a basis for a roll-out of the respective technology?

3.1.2 Methodology

The basic evaluation approach is to assess each technology along each of the specified criteria. As far as feasible, figures allowing quantitative assessment should be evaluated; otherwise a qualitative assessment is performed. This is supported by surveys, run across the key energy sector stakeholders in Vietnam in order to take the local situation into account wherever possible.

3.1.2.1 Analysing the Relation to Power System Challenges

The following steps and sources are used:

1. Identification of current and expected upcoming challenges in Vietnam
   - Literature review
   - Stakeholder survey in June/July supported by ERAV
   - Stakeholder interviews in Vietnam in August 2019
   - Stakeholder workshop in Hanoi on 15 August 2019
2. Collection of VRE-related challenges known from other countries
   - Literature review and consultants' prior experience
3. Impact Assessment
   - Literature review
   - Impact Estimation by National and International Experts
   - Stakeholder feedback collected in August 2019

Through the stakeholder process, four challenges with high priority and seven challenges with medium priority for the Vietnamese power system have been identified:

Classification	Power System Challenges
High Priority	• Incorporating VRE in the dispatch • System-wide congestion problems in the transmission grid • Lack of generation capacity • Power system reliability and local outages
Medium Priority	• Expected growth of distributed generation • Voltage control in transmission and distribution • Local congestion problems in the distribution grid • Increased long-distance transmission losses • Vulnerability to extreme weather events • Risk of large-scale blackouts • Lack of distribution system monitoring

Low priority challenges do not need to be considered.

3.1.2.2 Analysing Economic Viability

The following assessment sources are used:

- Simplified Cost-Benefit-Analysis (CBA)
  - Definition of Use Case(s)
  - Mapping of Costs and Benefits
  - Data Collection and Evaluation
  - Result: Net Present Value (NPV) and Benefit-Cost-Ratio (BCR)
- International Case Studies
  - Literature review of comparable applications in other countries
- Expert Estimations
  - Consultation of national and international experts

3.1.2.3 Analysing Applicability and Level of Experience

Assessment concerning these two criteria is based on conclusions drawn from:

- Literature review
- Discussions with Vietnamese project team and local consultant
- Stakeholder survey in June/July supported by ERAV
- Stakeholder interviews in Vietnam in August 2019
- Stakeholder workshop in Hanoi on 15 August 2019

4 Task 4: Smart Grid Technology Assessment and Recommendations

4.1 Assessment of Smart Grid Technologies

4.1.1 Impact on Power System Challenges

The impact assessment has been carried out using three distinct levels (low/medium/high). The results are shown in the table below. For the individual power system challenges the "low" impact score is not shown in order to improve the readability of the table.

Technology impacts addressing high-priority challenges are weighted stronger than impacts on medium priority challenges when compiling the overall challenge impact score.

Power System Challenges / Smart Grid technologies	Incorporating VRE in the dispatch	System-wide transmission grid congestion	Lack of generation capacity	Power system reliability and local outages	Expected growth of distributed generation	Voltage control in transmission and distribution	Local distribution grid congestion	Increased long-distance transmission losses	Risk of large-scale blackouts	Lack of distribution system monitoring	Overall score on power system challenges
Renewable energy forecasting	High	Medium	Medium		Medium						High
Wide-area monitoring systems (WAMS)		Medium						Medium	Medium		Medium
Online Dynamic Security Assessment (online-DSA)						Medium			Medium		Low
High Voltage Direct Current (HVDC) Technology		High						High			High
Flexible AC Transmission System (FACTS)		Medium				Medium		Medium			Medium
Dynamic Thermal Circuit Rating (DTCR)		High									High
Distribution Automation (DA)				High	High		Medium			High	High
OLTC for Distribution Transformers				Medium	High	Medium					Medium
Smart inverters	High				High		Medium				High
Advanced Metering Infrastructure (AMI)					Medium					High	Medium
Demand Side Management (DSM)		High	Medium		Medium		Medium				High
Virtual Power Plants (VPPs)	Medium				Medium						Medium
Distributed Energy Storage & Electric Batteries		High	Medium	Medium	Medium		Medium				High
Smart Charging of Electric Vehicles					Medium	Medium	Medium				Medium
	High priority				Medium priority challenges						

Legend:
- High score
- Medium score
- Low score

Online-DSA achieves the lowest overall score due to its medium impact only on medium-priority challenges, and no significant impact on high-priority challenges.

4.1.2 Economic Viability

Estimation of economic viability of selected technology deployment projects has resulted in the following relative scores:

High score:

- **RE forecasting** provides high benefits and is relatively cheap compared to its cost;

- **Smart inverters** are commonly available and raise VRE integration cost only by a small degree, while allowing for much better integration into the power system, e.g. through controllability and monitoring;

Low score:

- A high degree of **Distribution Automation** is considered to be very expensive due to the high number of monitoring and control devices for the distribution system;
- **AMI** has been evaluated by EVN Hanoi and EVN HCMC and is currently still too expensive for a large-scale roll-out in Vietnam;
- **Distributed energy storage**, whilst cost have significantly decreased in the last years and decades, still remains an expensive option compared to other measures.

All other assessed technologies received a medium score.

4.1.3 Applicability in Vietnamese Context

Most of the assessed technologies are applicable to the Vietnamese context and therefore receive a high score on the applicability, with the following exceptions:

- **Online-DSA** has some prerequisites such as extensive data processing needs and a wide-area monitoring system, lowering its applicability score to medium;
- **Virtual Power Plants** require a suitable power market design that is not fully in place yet in Vietnam, leading to low applicability;
- **Electric vehicle** numbers in Vietnam are currently still very low, making **smart charging** unnecessary in the short and medium term in Vietnam and thus leading to low applicability.

4.1.4 Level of existing Knowledge

Estimation of current local experience with the selected technologies has resulted in the following relative scores:

High score:

- NLDC currently has a pilot project to set up a RE forecasting system;
- New VRE plants have been equipped with active and reactive power control and other capabilities, fulfilling most of the Smart Inverter requirements;
- A Demand Side Management program has been established by ERAV.

Medium score:

- Some PMUs have been installed to build up a wide-area monitoring system;
- A few FACTS devices such as SVCs are currently installed in Vietnam;
- Some Advanced Metering Infrastructures pilot projects are carried out at some of the PCs.

For all other assessed technologies the level of experience in Vietnam is considered low.

4.1.5 Assessment Result Overview

The following table presents the assessment overview and adds an overall scoring column, based on the average of the four individual criteria scorings.

Smart Grid technologies / Criteria	Impact on power system challenges	Economic viability	Applicability in Vietnamese context	Level of existing knowledge	Overall scoring
Renewable energy forecasting	High	High	High	High	High
Wide-area monitoring systems (WAMS)	Medium	Medium	High	Medium	Medium
Online Dynamic Security Assessment (online-DSA)	Low	Medium	Medium	Low	Low
High Voltage Direct Current (HVDC) Technology	High	Medium	High	Low	Medium
Flexible AC Transmission System (FACTS)	Medium	Medium	High	Medium	Medium
Dynamic Thermal Circuit Rating (DTCR)	High	Medium	High	Low	Medium
Distribution Automation (DA)	High	Low	High	Low	Medium
OLTC for Distribution Transformers	Medium	Medium	High	Low	Medium
Smart inverters	High	High	High	High	High
Advanced Metering Infrastructure (AMI)	Medium	Low	High	Medium	Medium
Demand Side Management (DSM)	High	Medium	High	High	High
Virtual Power Plants (VPPs)	Medium	Medium	Low	Low	Low
Distributed Energy Storage & Electric Batteries	High	Low	High	Low	Medium
Smart Charging of Electric Vehicles	Medium	Medium	Low	Low	Low

Legend:
- High score (green)
- Medium score (yellow)
- Low score (red)

VRE forecasting, Smart Inverters, and Demand Side Management programs received a high score and are already in the process of being applied or developed in Vietnam.

Most other technologies received a medium score. These are recommended for further evaluation, pilot projects, and eventual deployment in Vietnam. More detailed recommendations are provided in the next section. Technologies with low score are not currently recommended for Vietnam, and should be considered only in the medium or long term.

The rationale for the overall assessment of each technology can be summarized as follows:

Smart Grid technologies	Score	Main Rationale
Renewable energy forecasting	High	Economically viable
Wide-area monitoring systems (WAMS)	Medium	Under development, complex integration
Online Dynamic Security Assessment (online-DSA)	Low	Not mature technology yet
High Voltage Direct Current (HVDC) Technology	Medium	No experience yet in Vietnam, application dependent feasibility
Flexible AC Transmission System (FACTS)	Medium	Already in use, but limited applicability
Dynamic Thermal Circuit Rating (DTCR)	Medium	Little experience yet in Vietnam, high uncertainty of applicability
Distribution Automation (DA)	Medium	Good impact on challenges, but expensive
OLTC for Distribution Transformers	Medium	No experience in Vietnam, limited applicability
Smart inverters	High	Economically viable

Advanced Metering Infrastructure (AMI)	Medium	Potentially good applicability, but high regulation/standardization effort and high cost
Demand Side Management (DSM)	High	Good impact on a major system challenge
Virtual Power Plants (VPPs)	Low	Market environment not ready
Distributed Energy Storage & Electric Batteries	Medium	Good impact, but expensive
Smart Charging of Electric Vehicles	Low	No large-scale vehicle deployment planned

4.2 Recommendations

The recommendations provided below aim to support the stakeholders in the Vietnamese electricity sector in their assessment of Smart Grid technologies. The main objectives of this report include increasing awareness of, and knowledge on, international Smart Grid trends and products and their applicability to Vietnam, thereby facilitating development of the power system with efficient support for rising shares of Variable Renewable Energy (VRE).

4.2.1 Transmission Level

Stakeholders: EVN NPT, EVN NLDC

- Short Term (2019-2020)
    - EVN NLDC is already implementing **WAMS** and developing capacities for **VRE forecasting**.
    - **Smart Inverters** are already being deployed for practically all new VRE generation capacity. Distribution companies and transmission companies should coordinate access to functions such as setting active power constraints.
    - Consideration of **FACTS devices** should be included in the system planning processes where this is not the case yet.
    - Since the level of applicability of **Dynamic Thermal Circuit Rating (DTCR)** is not very clear yet, pilot projects should be further deployed and evaluated. DTCR should then be considered within the system planning processes as appropriate.
- Medium Term (2021-2023)
    - With constant substantial demand growth being a major factor, capacities for **Demand Side Management and Demand Response** should be developed. This is not only a technical issue, but also concerns standardisation and regulation.
    - **High-Voltage Direct Current (HVDC)** transmission technology can be an economic option in multiple applications. Long transmission planning horizons result in a medium term recommendation. Offshore Wind HVDC connections could be implemented faster.
    - **Virtual Power Plants (VPP)** cannot be implemented in the short term as they are not only a technical concept, but also a market construct to improve handling flexibility in the system. This depends on suitable market design.
    - **Online-DSA** becomes relevant for efficient system operation when high instantaneous penetrations of VRE are reached and static security margins become too large and inefficient. This is not expected to happen in the Vietnamese power system in the short and medium term. However, international trends and products should be tracked and pilot development considered.

4.2.2 Distribution Level

Stakeholders: EVN NPC, EVN CPC, EVN SPC, EVN Hanoi, EVN HCMC

- Short Term (2019-2020)
    - **Smart Inverters** are already being deployed for practically all new VRE generation capacity. Distribution companies and transmission companies should coordinate access to functions such as setting active power constraints.
    - **Demand Side Management** mechanisms should be evaluated, and deployed in a standardized manner, as distribution systems are equally affected from demand growth as transmission systems. Distribution PCs should coordinate to share efforts and lessons learned.
- Medium Term (2021-2023)
    - Deployment of **Distribution Automation** is desirable to increase reliability, but expensive and a step-by-step process. Initial pilots should develop into larger-scale applications in the medium term.
    - The concept of **OLTC for Distribution Transformers** should be incorporated into distribution planning processes to allow deployment in the cases where it is more efficient than alternatives.
    - **Distributed Energy Storage and Batteries** can contribute to congestion management in the distribution system. Still very high cost makes this a medium to long term option.
    - **Smart Charging of Electric Vehicles** will not just be an option, but a necessity when electric vehicles see wide-scale adoption. This is not expected in the short term, but concepts should be developed.
- Long Term (2024 and later)
    - Short-term **Renewable Energy Forecasting** will become relevant to distribution systems with increasing monitoring and automation capabilities.
    - **Advanced Metering Infrastructure** can provide a standardized interface to other Smart Grid technologies such as Demand Side Management, Decentralized Batteries, and Smart Charging of Electric Vehicles. High complexity and cyber-security issues make this a long-term development goal.

4.3 Notes on Economic Viability Assessment

While the economic viability assessment results presented in this report are based on a high-level evaluation of international example cases (the case studies presented in chapter 6.4), any desired more accurate economic assessment should be carried out in the form of cost-benefit analyses. However, performing such detailed assessment requires significant data collection and agreement on assumptions beyond what can be done within the scope of this work. This section provides a brief high-level introduction on how cost-benefit analyses for Smart Grid technology projects can be conducted.

4.3.1 Cost-Benefit Analysis (CBA)

Economic viability of technology projects is typically evaluated in cost-benefit analyses (CBA). Guidelines on how to apply such analyses on Smart Grid technology projects have been published:

- The first systematic framework for CBA of Smart Grids was “Methodological Approach for Estimating the Benefits and Costs of Smart Grid Demonstration Projects” by Electric Power Research Institute (EPRI), USA, 2010 [22]
- EPRI has further released “Guidebook for Cost/Benefit Analysis of Smart Grid Demonstration Projects” in 2012 [23], available from: https://www.epri.com/#/pages/product/1025734/
- Based on this, the “Guidelines for conducting a cost-benefit analysis of Smart Grid projects” were published by the European Commission Joint Research Centre (JRC), 2012 [24] https://ses.jrc.ec.europa.eu/sites/ses/files/documents/guidelines_for_conducting_a_cost-benefit_analysis_of_smart_grid_projects.pdf

The JRC guideline is an adaptation and modification of the EPRI approach that has been used in several studies by the World Bank and by IRENA. The approach uses the following outline:

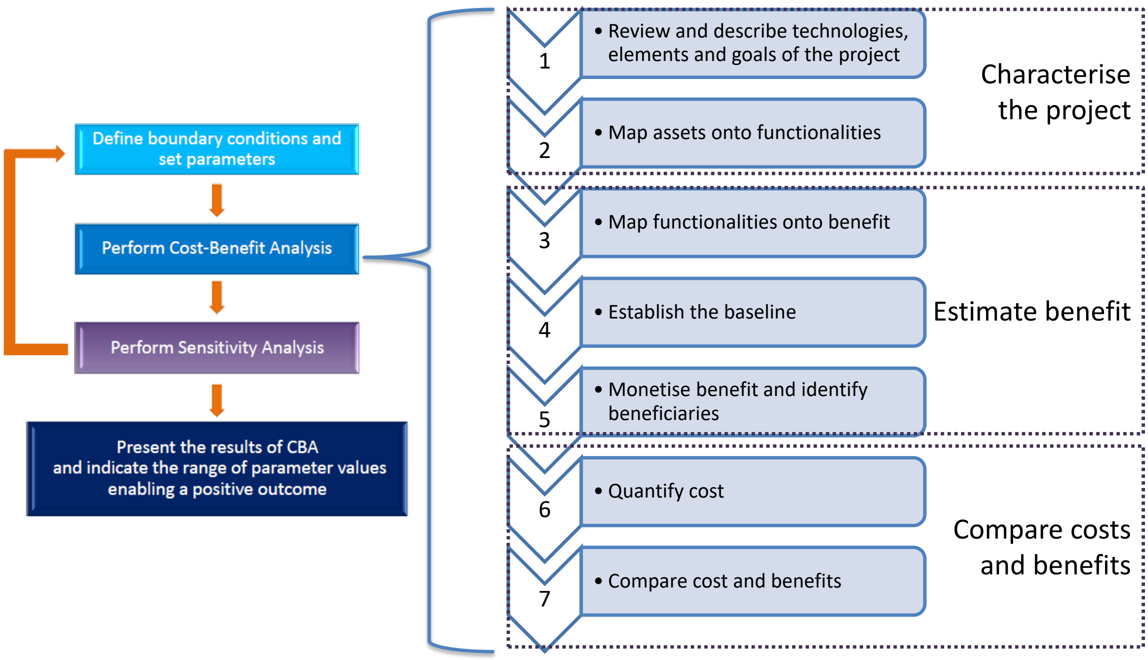


Figure 16: JRC approach for Cost-Benefit Analysis (CBA) of Smart Grid Projects

The CBA requires extensive data and assumptions for specific application and country context. The CBA approach following the JRC guideline as shown in Figure 2 consists of the following steps:

Preparation: Define Boundary Conditions and Set Parameters

Before starting the CBA the input assumptions must be defined: For example discount rate, value of lost load, the value of supply, implementation timeline, hardware and software cost, installation cost, losses at transmission and distribution system.

Step 1: Review and describe the technologies, elements, and goals of the project

It is important to answer the questions following

- What are the purposes of this project?
- What are technology solutions?
- What are the main smart grid technology functionalities?
- Whose are costs and benefit?
- Is it national/project/specific area scale?

The questions above can help to define the project boundary including objective, goal, scale, technology functionalities, relevant stakeholders (whose cost and benefit count).

Step 2: Map assets onto functionalities

Each smart grid technology provides different functionalities. JRC has provided 33 different functionalities (in six different categories) for smart grid technology to be taken into account for the CBA.

Step 3: Map functionalities onto benefit

The purpose of this step is to link benefit and functionality. EPRI and JRC list 22 benefits (across multiple subcategories) for smart grid technologies. Some example benefits are:

- Improving asset utilization
- Enhancing T&D capital and O&M saving
- Reducing electricity theft
- Improving energy efficiency
- Improving electricity cost saving
- Reducing power interruptions
- Improving power quality
- Reducing air emission
- Improving energy security

In the end, it should be determined which smart grid functionalities are related to the above benefits. This mapping can indicate the benefit of smart grid technology.

Step 4: Setting up the baseline

The baseline refers to the current situation (or called Business as Usual: BAU) which is compared and assessed against other scenarios. In this context, the other scenario is the one is integrated with smart grid technology.

Step 5: Monetise the benefits and identify the beneficiaries

Calculating benefit in monetary term should consider the actual benefit from the project and the key beneficiaries. Generally, the CBA is either performed for the actor who implementing smart grid technology or for the consumer.

Step 6: Identify and quantify the cost

The cost of smart grid technology can be easily either estimated by the market price (i.e. manufacturer) or similar project context. The cost consists of capital, operational, and maintenance. The cost of the project can identify the return of investment.

Step 7: Compare costs and benefits

Cost and benefit of the projects are compared to evaluate the cost-effectiveness by using common economic feasibility indicators such as benefit to cost ration (BCR), payback period, internal rate of return (IRR), and/or net present value (NPV)

CBA Result Quality Assessment: Sensitivity Analysis

JRC points out that a sensitivity analysis is a necessary component of a CBA. Any CBA is based on data and assumptions with associated uncertainty, and variation of input variables to the calculation provides an indication of how robust the outcome is against modified parameters. This can also be used to determine under which conditions a project can be economically viable or not.

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6 Annex

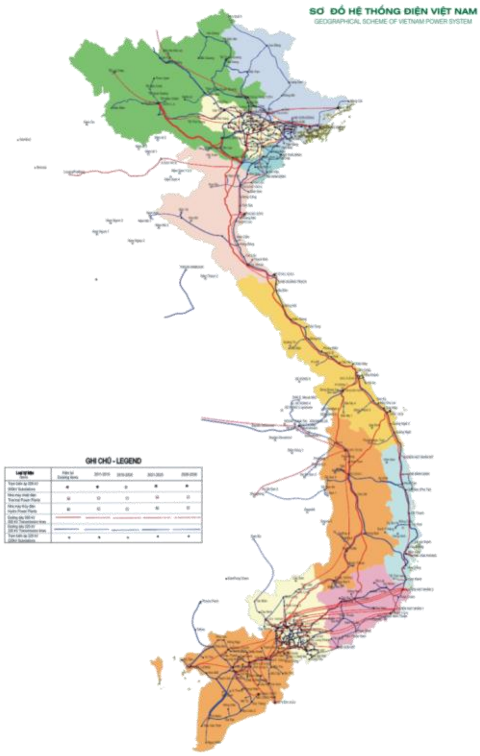
6.1 The Power System of Vietnam

6.1.1 The specific characteristics of Viet Nam's power sector

6.1.1.1 Vietnam power system

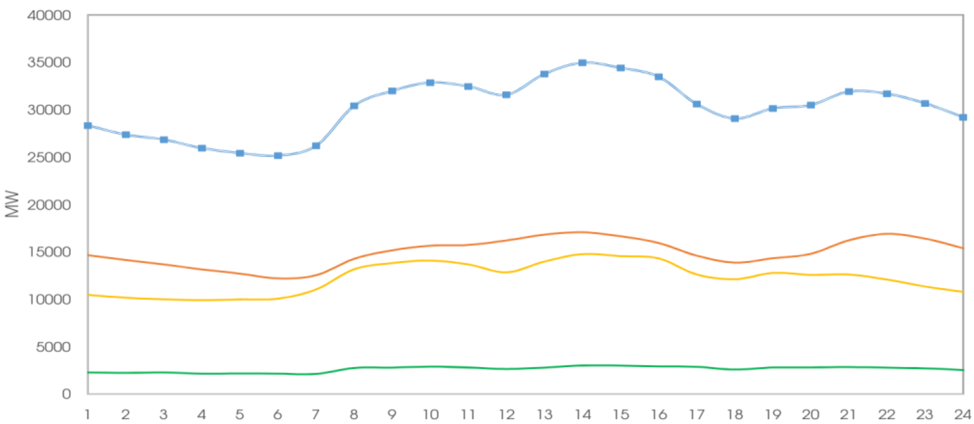
Vietnam power system is a unique system, three sub-systems (Nothern, Central and Southern system) are connected by back-bone 500kV system.

- Transmission network: 500kV, 220 kV owned by NPT
- Distribution network owned by Five Power Corporations (PCs):
  - High voltage: 110kV
  - Medium voltage: 35kV, 22kV
  - Low voltage: 0.4kV, 220V



6.1.1.2 Load

- Sample daily load curve:



(*Source: Vietnam power system operation in the year 2018 - NLDC*)

- Quantity (MWh):

In the year 2018, total generation quantity is 220.31 billion kWh, increasing 11.09% compared with 2017.

Unit: MWh

Month	1	2	3	4	5	6	7	8	9	10	11	12
Quantity	17298	13483	18242	18102	19611	19367	19683	19562	18484	19114	18483	18878

(Source: Vietnam power system operation in the year 2018 - NLDC)

- Peak load (MW):

In the year 2018, the peak load is 35126 MW, increasing 13.6% compared with 2017.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Pmax_Vietnam	29812	28747	29364	30720	32999	34152	35126	31955	32196	31969	32778	32444
Pmax_North	14574	13975	13494	13955	14807	16002	17272	14374	14356	15342	15474	15495
Pmax_Centre	2764	2693	3029	3015	3005	3128	3228	3115	3172	3062	3007	3010
Pmax_South	13706	13402	14877	15295	15274	14824	14758	14789	14621	14904	15040	15161

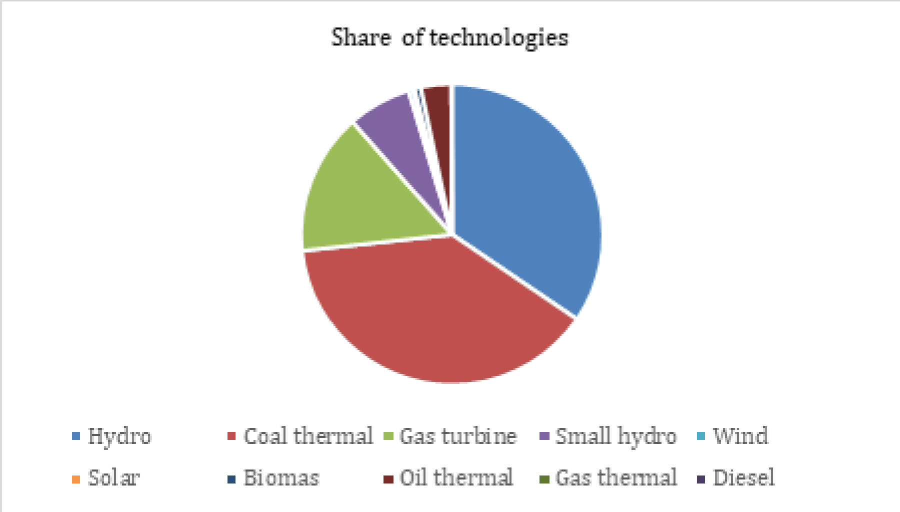
(Source: Vietnam power system operation in the year 2018 - NLDC)

6.1.1.3 Generation

- Installed capacity (MW):

At the end of the year 2018, the total installed capacity is 48838 MW, increasing 7.55% compared with 2017.

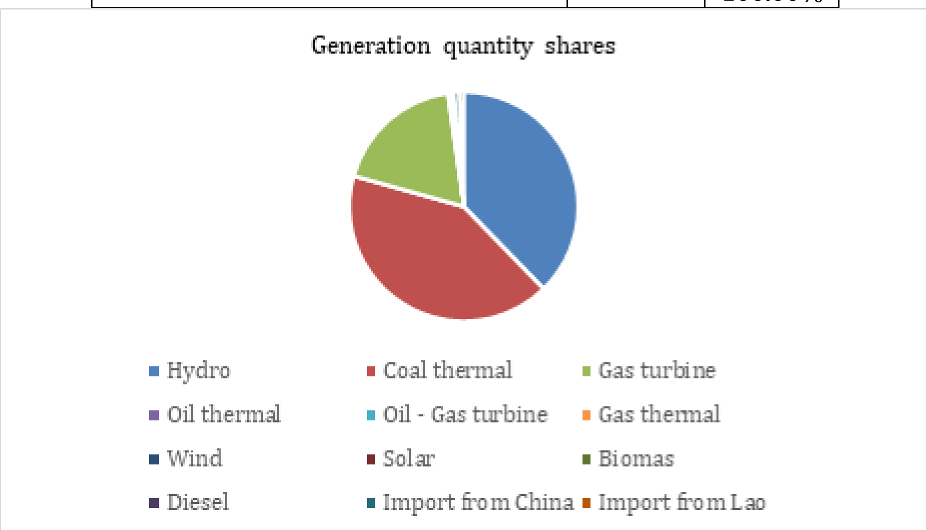
Type	Installed Capacity (MW)	Share (%)
Hydro	16,848	34.50%
Coal thermal	18,945	38.79%
Gas turbine	7,446	15.25%
Small hydro	3,322	6.80%
Wind	243	0.50%
Solar	86	0.18%
Biomass	325	0.67%
Oil thermal	1,579	3.23%
Gas thermal	21	0.04%
Diesel	24	0.05%
Total	**48,838**	**100%**



(Source: Vietnam power system operation in the year 2018 - NLDC)

- Generation quantity (MWh):

Type	Installed Capacity (MW)	Share (%)
Hydro	83081	37.71%
Coal thermal	91654	41.60%
Gas turbine	40562	18.41%
Oil thermal	595	0.27%
Oil - Gas turbine	145	0.07%
Gas thermal	139	0.06%
Wind	487	0.22%
Solar	22	0.01%
Biomas	488	0.22%
Diesel	11	0.00%
Import from China	1697	0.77%
Import from Lao	1427	0.65%
Total	220309	100.00%



(Source: Vietnam power system operation in the year 2018 - NLDC)

6.1.1.4 Transmission and distribution system

In Vietnam, there are four transmission power companies (PTC) under National Transmission Corporation (NPT) which own and operate transmission system (500kV and 220kV). Five distribution power corporations (PC) own and operate distribution system (110kV, medium and low voltage network). The details of the transmission and distribution system as below:

Voltage	Length of lines (km)					
	PTC 1	PTC 2	PTC 3	PTC 4	PC	Total
500 kV	3160	1242	1939	1652	0	7993
220 kV	6974	1527	3570	4934	54	17059
110 kV	0	0	0	0	20041	20041

(*Source: Vietnam power system operation in the year 2018 - NLDC*)

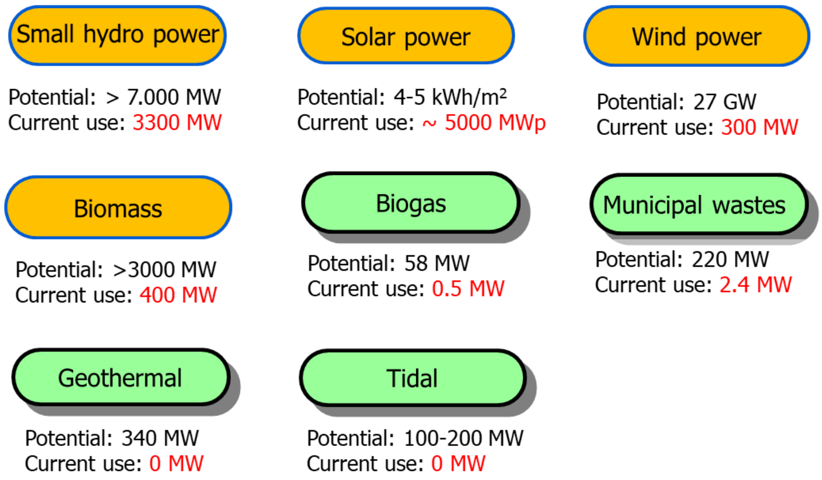
Voltage		North	Centre	South	Total
500 kV	Number of transformer	22	12	19	**53**
	Number of substation	13	6	11	**30**
	Total Capacity (MVA)	15000	5400	12900	**33300**
220 kV	Number of transformer	115	38	123	**276**
	Number of substation	56	21	51	**128**
	Total Capacity (MVA)	25661	5915	25865	**57441**
110 kV	Number of transformer	658	201	606	**1465**
	Number of substation	331	121	320	**772**
	Total Capacity (MVA)	28672	6690	30363.1	**65725.1**

(Source: Vietnam power system operation in the year 2018 - NLDC)

6.1.2 RE development and challenges in Vietnam

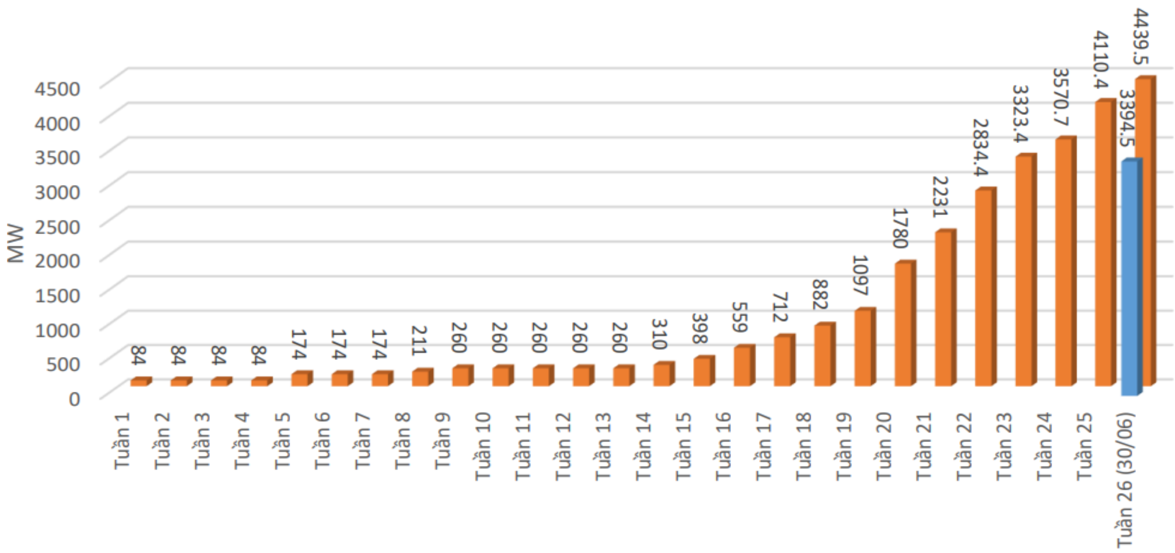
6.1.2.1 RE development

The potential and current use of RE in Vietnam as below:



(*Source: NLDC*)

In the year 2019, it's a boom of solar power development, at the end of June, there were more than 100 new solar power plants with capacity approximately 4430 MW. This capacity is much more than master plan development defined 800 MW in 2020. So Vietnam faces many challenges which are explained in the next section.



(*Source: NLDC*)

6.1.2.2 Challenges

- **Congestion:** There are many congestions at two hot provinces Ninh Thuan and Binh Thuan. The congestions are both in distribution (110kV) and transmission (220kV) network. EVN is requesting their subsidiary companies NPT and Southern Power Corporation (EVNSPC) to build new network very soon but it will take 3-5 years.
- **RES power oscillation:** At present, the capacity of RE is approximate 10% of total system, the RES power oscillation impacts too much on the power system stability.
- **Frequency control**
  - Currently, good operation flexibility thanks to high percentage of hydro power plants
  - In the future, there will be a big problem with frequency control because:
    - Proportion of hydro will gradually be reduced
    - Thermal coal-fired will dominate the generation mix
    - Renewable energy share will be increased
- **Need for reserve capacity:** Before, the share of RE was very small, most of generation was conventional power plant, the reserve capacity was equal the biggest generator but now, the reserve capacity will need much than that because of RES power oscillation.
- **System reliability:** With capacity factor less than or equal to 20%, solar power plants are considered to contribute capacity to the system, not only energy**.**
- **Power quality (Voltage, Harmonic…):** With the high RE penetration, Vietnam will need the smart grid solution to ensure the power quality for system operation.

6.2 Appendix 1: Initial List of Smart Grid Projects in Vietnam

6.2.1 Projects in 2016

No.	Name of program, project, scheme in 2016	Process	Notes
I.	**Electricity Regulatory Authority of Vietnam (ERAV)**		
1.	Studying, building, submitting the Demand Side Management (DSM) project to the competent issuing level.	Completed in 2016	
2.	Studying, building, submitting the financial mechanism for the Demand Response (DR) program to the competent issuing level	Completed in Quarter IV, 2016	
3.	Studying the proper structure of electricity retail price list towards the application of electricity selling price list in time of use for customers who use the household electricity with the electronic meter equipped.	Developed in 2016-2017	
4.	Studying, building the bonus/penalty mechanism in order to improve the electricity supply service quality from Electricity corporations, including: Electricity supply reliability, electricity supply quality; customer care service.	Developed in 2016-2017	
5.	Revising the Regulation of power transmission system; the Regulation of SCADA/EMS/DMS technical requirements and operational management.	Completed in Quarter IV, 2016	
6.	Cooperating with the utilities that study, build the general technical regulations for the SMART GRID.	Developed in 2016	
7.	Chairing the summary, evaluation of performance result in Stage 1 (2012 – 2016) in the SMART GRID development route in Vietnam and building the performance plan in the next stages.	Completed in Quarter IV, 2016	
II.	**Ministry of Finance**		
8.	Cooperating with Ministry of Industry & Trade in proposing: The financial mechanism for the Demand Side Management, Demand Response programs, bonus/penalty and electricity tariff mechanisms mentioned in item II.2 - Assignment Plan in 2016 of the Steering Committee.	Developed in 2016-2017	
III.	**Vietnam Electricity**		
9.	Completing the master scheme of SMART GRID development.	Submitting the Steering Committee in Quarter II, 2016	
10.	Completing the private telecommunication network planning of EVN.	Completed in Quarter II, 2016	
11.	Completing the transmission highway (instead of OPGW Fibre optic Link) in the circuit 1 North-South 500kV line.	Completed in 2017	
IV.	**National Load Dispatch Centre**		
12.	Establishing the technical characteristics and standards to the system configuration of protection relay, automated equipment for the power plant and substation of the power transmission system of Vietnam.	Completed in Quarter II, 2016	
13.	Evaluating, analyzing and giving the solutions in order to enhance the stability and reliability of the power system of Vietnam.	Completed in Quarter IV, 2016	

No.	Name of program, project, scheme in 2016	Process	Notes
14.	The project of terminal improvement in the National Power System: POWER PLANT and SUBSTATION from 110kV voltage level or above	Completed in Quarter IV, 2016	
15.	The Project of Information Technology Infrastructure for operation and supervision and competition improvement of electricity market.	Completed in Quarter IV, 2016	
16.	Equipping with the fault recording system in the National Power System.	Completed in Quarter IV, 2017	
V.	**National Power Transmission Corporation**		
17.	Building the remote control centre: - Summarizing, reporting the Steering Committee of pilot performance result of the remote control centre in Power Transmission Company No.4. - Planning the construction of the remote control centres	Reported to ERAV in Quarter II, 2016 for development.	
18.	Building the Technical Regulation for the remote control centres, SUBSTATIONS.	Submitting the Steering Committee in Quarter II, 2016	
19.	Improving the protection control system for the SUBSTATIONS that are applying to the traditional control technology (05 500kV SUBSTATIONS and 11 220kV SUBSTATIONS).	Developed in 2016–2018	
20.	Equipping with the online oil monitoring equipment for TRANSFORMER and 500kV impedance coil (Equipping with 101 online oil dissolved gas monitoring equipment for TRANSFORMER and 500kV impedance coil).	Completed in Quarter II, 2016	
21.	Equipping with the fault location equipment for the 500/220kV line (69 lines).	Completed in Quarter IV, 2016	
22.	Building the geographical information system GIS	Completed in Quarter IV, 2016	
VI.	**Hanoi Power Corporation**		
23.	Improving and enhancing the SCADA system.	Completed in Quarter II, 2016	
24.	Building the substation control centre in the Hanoi Load Dispatch Centre.	Developed in 2016-2017	
25.	Building the private telecommunication system of Hanoi Power Corporation.	Completed in Quarter IV, 2016	
26.	Building the 110kV tele-control substation and Unmanned substation.	Reported to ERAV in Quarter IV, 2016	
27.	Equipping with the remote measuring data collection & control system.	Completed in Quarter IV, 2016	
28.	Taking the remote monitoring to the distribution substations	Executed from 2016	
VII.	**HCM Power Corporation**		
29.	Improving and enhancing the SCADA/DMS system in EVNHCMC Load Dispatch Centre.	Completed in Quarter II, 2016	

No.	Name of program, project, scheme in 2016	Process	Notes
30.	- Proceeding the test of AMI advanced measuring infrastructure system. - Building the draft Technical Regulation of AMI measuring infrastructure and meter.	- Reported to ERAV of the detailed content and test result in Quarter II, 2016. - Submitted the STEERING COMMITTEE of "the Regulation of AMI measuring infrastructure and meter" in Quarter III, 2016.	
31.	Summarizing, evaluating the test; building and operating the substation control centre which located in EVNHCMC Load Dispatch Centre.	Reported to the Steering Committee in Quarter II, 2016	
32.	The draft Technical Procedure of 110kV Unmanned substation.	Reported to, submitted the Steering Committee in Quarter II, 2016	
33.	Completing the miniSCADA/DAS system for the power grid in the scope of control of Tan Thuan and Thu Thiem Power Companies.	Completed in Quarter IV, 2016	
34.	The pilot project of smart grid solution for ADR-Automated Demand Response sponsored by USTDA and Honeywell Group.	Cooperated with ERAV in the performance on 2016	
VIII. Northern Power Corporation			
35.	Completing the remote measuring system of 110kV SUBSTATIONS in the scope of control.	Completed in Quarter IV, 2016	
36.	Building the remote control centres of 110kV SUBSTATIONS in 11 Provincial Power Company: Hai Phong, Hai Duong, Ninh Binh, Bac Ninh, Vinh Phuc, Ha Nam, Hoa Binh, Ha Tinh, Son La, Thai Nguyen, Hung Yen.	Completed in 2016	
37.	The power grid operation management software in the GIS map	Developed in 2016	
38.	The projects of internal provincial, inter-provincial cable completion and connection of 110kV substations.	Completed in 2016	
IX. Central Power Corporation			
39.	Expand and upgrade SCADA systems in Kon Tum and Dak Lak into the control centres.	Completed in Quarter II, 2016	
40.	The control centre construction investment project in Binh Dinh and Da Nang.	Completed in Quarter I, 2016	
41.	The control centre construction investment project in Quang Binh, Phu Yen, Dak Nong.	Completed in Quarter IV, 2016	
42.	The SCADA/DMS projects in Quang Nam, Gia Lai, Quang Tri, Quang Ngai.	Developed in 2016–2017	

No.	Name of program, project, scheme in 2016	Process	Notes
43.	The GIS project in Thua Thien Hue Power Company.	Completed in Quarter III, 2016	
44.	The transmission network system for production and business - stage 1.	Completed in Quarter IV, 2016	
45.	Building the Data Warehouse and smart analysis tool for reporting.	Completed in Quarter IV, 2016	
46.	Developing the 3G transmission line model using Private APN to establish the cutout transmission lines in the grid, standby transmission lines for 110kV SUBSTATIONS.	Completed in Quarter II, 2016	
X.	**Southern Power Corporation**		
47.	Completing the SCADA system.	Completed in Quarter IV, 2016	
48.	Summarizing, evaluating the pilot result; building the plan of official operation of two remote control centres in Dong Nai and Tay Ninh.	Reported to ERAV in Quarter I, 2016	
49.	Putting into operation of 18 control centres in Power Companies and High Voltage Branches: Dong Thap, Kien Giang, Tien Giang, Ben Tre, Hau Giang, Lam Dong, Binh Phuoc, Tra Vinh and Vinh Long.	Completed in Quarter II, 2016	
50.	Putting into operation of 20 control centres in Power Companies and High Voltage Branches: An Giang, Bac Lieu, Ba Ria Vung Tau, Binh Duong, Binh Thuan, Ninh Thuan, Ca Mau, Can Tho, Long An and Soc Trang.	Completed in Quarter IV, 2016	
51.	Building the plan of establishing control centres and unmanned SUBSTATIONS.	Reported to ERAV in Quarter II, 2016	
52.	Completing the scheme of building automated standards and route, remote equipment control in medium voltage grid.	Completed and reported to ERAV in Quarter II, 2016	
53.	Developing the projects of Solar Energy connection to the Con Dao grid and automated distribution grid in island districts: Phu Quy, Phu Quoc, Con Dao.	Developed in 2016	

6.2.2 Projects in 2017

No.	Name of program, project, scheme in 2017	Plan	
I.	**Electricity Regulatory Authority of Vietnam**		
	Building and submitting the National Program of Demand Side Management in 2017 – 2020, orienting to 2030 to the competent approving level	Completed in Quarter II, 2017	
	Building and submitting to Ministry of Industry & Trade for approval: Regulating the performance content, sequence of Demand Response programs; Regulating the study content, method, sequence of Demand Response.	Completed in Quarter IV, 2017	
	completing and issuing the Regulation of SCADA/EMS/DMS technical requirements and operation management.	Completed in Quarter II, 2017	

No.	Name of program, project, scheme in 2017	Plan	
	Technical regulation of protection relay, automated equipment for power plants and substations; Regulation of measuring data collection, processing and control.	Completed in 2017	
	Studying the proper structure of electricity retail price list towards the application of electricity selling price list in time of use for customers who use the household electricity with the electronic meter equipped.	Proceeded the development in 2017	
	Studying, building the bonus/penalty mechanism in order to improve the electricity supply service quality from Electricity corporations, including: Electricity supply reliability, electricity supply quality; customer care service.	Proceeded the development in 2017	
	Cooperating with the units that study, build the general technical regulations/processes for SMART GRID.	Developed in 2017	
II.	**Ministry of Science & Technology**		
	- Checking, cooperating in providing the information to Ministry of Industry & Trade and the Steering Committee of the result of relative scientific subjects for the SMART GRID development. - Cooperate, propose proper scientific research subjects, support the SMART GRID development	Developed in 2017	
III.	**Ministry of Finance**		
	Cooperating with Ministry of Industry & Trade in proposing: the financial mechanism for the Demand Side Management, Demand Response programs, bonus/penalty and electricity price mechanisms mentioned in item III.3 - Assignment Plan in 2017 of the Steering Committee.	Developed in 2017	
IV.	**Vietnam Electricity**		
	Completing the transmission highway (instead of OPGW Fibre optic Link) in the circuit 1 North-South 500kV line.	Completed in 2017	
	Submitting ERAV of the draft Regulation of requirements for protection relay, automated equipment for POWER PLANTS/SUBSTATIONS	Completed in Quarter II, 2017	
V.	**National Load Dispatch Centre**		
	Exploiting the functions of new SCADA/EMS system.	Developed in 2017	
	Completing the draft Regulation of requirements for protection relay, automated equipment for power plants and substations.	Completed in Quarter II, 2017	
	The Project of Information Technology Infrastructure for operation and monitor and competition improvement of POWER MARKET.	Completed in 2018	
	carrying out the work of equipping with information technology infrastructure for pilot power wholesale market	Developed in 2017	
	Equipping with the fault recording system in the National Power System.	Completed in 2018	
VI.	**National Power Transmission Corporation**		

No.	Name of program, project, scheme in 2017	Plan	
	Completing the SCADA signal connection, the remote data measuring and collecting system of 500kV, 220kV SUBSTATIONS in the scope of control, strive the SCADA signal response ratio of 90%; Completing the remote measurement of all 110kV feeders and medium voltage master feeders (meters are controlled by EVNNPT).	Completed in 2017	
	Planning the construction, gradually putting into operation for 220kV unmanned SUBSTATIONS in order to achieve the goal of 60% unmanned SUBSTATIONS until 2020	Developed in 2017	
	Building the Technical Regulation for unmanned SUBSTATIONS.	Completed in 2017	
	Improving the protection control system for SUBSTATIONS (05 500KV SUBSTATIONS AND 11 220kV SUBSTATIONS).	Developed in 2017 – 2018	
	Equipping with the fault location equipment for the 500/220kV line.	Completed in 2017	
	Building the geographic information system GIS.	Completed in 2017	
	Building the information collection, monitoring, lightning alarm systems.	Completed in 2017	
	Testing the 220kV dynamic transmission limitation monitoring system.	Developed in 2017 – 2018	
VII.	**Hanoi Power Corporation**		
	Improving and enhancing the SCADA system.	Completed in Quarter II, 2017	
	Building the control centre in the Hanoi Load Dispatch Centre.	Completed in Quarter II, 2017	
	Putting into the 26 Recloser remote control in medium voltage grid (under the control of Long Bien Power Company).	Completed in 2017	
	Building the private telecommunication system of EVNHANOI.	Completed in 2017	
	Proceeding to build and put 110kV SUBSTATIONS with no watchman into operation (Operating 27 110kV SUBSTATIONS on the basis of no watchman in 2017).	Developed in 2017	
VIII.	**HCMC Power Corporation**		
	Gradually studying, consider the exploitation of new functions in the improved, upgraded SCADA/DMS system.	Developed in 2017	
	Proceeding the test of AMI advanced measuring infrastructure system.	Reported to ERAV of the detailed content and test result in 2017	
	Approving the scheme of establishing the control centre in EVNHCMC Load Dispatch Centre to put into official operation.	Reported to the Steering Committee in Quarter II, 2017	

No.	Name of program, project, scheme in 2017	Plan	
	Proceeding to put into official operation for 10 additional 110kV SUBSTATIONS with no watchman (Total 41 110kV SUBSTATIONS with no watchman).	Completed in 2017	
	Developing the miniSCADA system in the whole suspended medium voltage grid (including the 1077 Recloser remote control).	Developed in 2017	
	Studying, developing the construction of typical SMART GRID model (unmanned SUBSTATIONS, automation of medium voltage outgoing feeders, remote control of all loads, reliable information technology infrastructure).	Developed in 2017	
	Studying, developing the construction of Micro Grid model in Quang Trung software park.	Developed in 2017	
IX.	**Northern Power Corporation**		
	Completing the SCADA system and the remote measuring system of 110kV SUBSTATIONS in the scope of control.	Completed in 2017	
	Building 11 the control centres and 88 110kV unmanned SUBSTATIONS in 11 provincial power companies: Hai Phong, Hai Duong, Ninh Binh, Bac Ninh, Vinh Phuc, Ha Nam, Hoa Binh, Ha Tinh, Son La, Thai Nguyen, Hung Yen.	Completed in 2017	
	The projects of inter-provincial, internal provincial cable completion and connection of 110kV SUBSTATIONS.	Proceeded the development in 2017	
X.	**Central Power Corporation**		
	The projects of SCADA/DMS system construction in Quang Nam, Gia Lai, Quang Tri, Quang Ngai and the control centres in Quang Tri and Quang Ngai.	Completed in Quarter IV, 2017	
	Putting into operation for 25 additional 110kV unmanned SUBSTATIONS.	Completed in Quarter IV, 2017	
	Putting into remote control for 563 cutout equipment in the medium voltage grid (Recloser and LBS).	Completed in 2017	
	The GIS project in Thua Thien Hue Power Company.	Developed in 2017-2018	
	Building the Data Warehouse and smart analysis tool for reporting.	Developed in 2017-2018	
	Developing the 3G transmission line model using Private APN to establish the cutout transmission lines in the grid, standby transmission lines for 110kV SUBSTATIONS.	Completed in Quarter IV, 2017	
XI.	**Southern Power Corporation**		
	Completing the pilot operation and putting into official operation for the SCADA system	Completed in Quarter II, 2017	
	Putting into remote control for 1300 cutout equipment in the medium voltage grid (970Recloser and 330 LBS)	Completed in 2017	
	Putting into operation for 91 additional SUBSTATIONS with no watchman.	Completed in 2017	

No.	Name of program, project, scheme in 2017	Plan	
	Developing the power supply project by solar energy in Con Dao and Phu Quy island districts in 2016-2020: - Con Dao: Installing 1.5MW - Phu Quy: Installing 1 MW	Developed in 2017 (After the project is approved)	
	The integrated system of non-grid connection power supplies in Con Dao and Phu Quy island districts.	Developed in 2017 (After the project is approved)	

6.3 Appendix 2: Smart Grid Activity Survey Responses

6.3.1 Smart Grid Projects

6.3.1.1 National Load Dispatch Centre (EVNNLDC)

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer / Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
1	Project for new National Load Dispatch Centre (new SCADA/EMS system)	2012	2016	EVNNLDC, RLDCs		World Bank	OSI (USA)	Purchasing, installing, and providing warranty for SCADA / EMS system with decentralization at EVNNLDC, RLDCs		Completed		
2	IT infrastructure project for operating and monitoring Vietnam Competitive Generation Market	2016	2019	Vietnam power system		WB - EVN		Constructing infrastructure for operating and monitoring Vietnam Competitive Generation Market		Final settlement procedure in progress		
3	Project for "Equipping breakdown recording system in the national power system"	2016	2019	EVNNLDC, RLDCs, National Power Transmission Corporation, Some big Power Plants under EVN		EVN	Siemens	Equipping breakdown recording system in the national power system		In progress		

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer / Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
4	Project for "Setting up technical specifications and standards for the configuration of protective relay systems, automation equipment for power plants and transformer station of Vietnam's power transmission system"	2015	2016	EVNNLDC		EVN	EDF	Setting up technical specifications and standards for the configuration of protective relay systems, automation equipment for power plants and transformer station of Vietnam's power transmission system		Completed		
5	Project for "Evaluating, analyzing and proposing solutions to enhance the stability and reliability of Vietnam's power system"	2014	2016	EVNNLDC		EVN	Siemens	Evaluating, analyzing and proposing solutions to enhance the stability and reliability of Vietnam's power system		Completed		
6	Project for "Calculating stability of Vietnam's power system"	2018	2018	EVNNLDC		EVN	EGI	Calculating stability of Vietnam's power system for 2018 – 2030 period		Completed		

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer / Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
7	Project for "Calculating effects of wind power projects, solar power on operation of the national power system"	2018	2018	EVNNLDC		EVN	EGI	Calculating effects of wind power projects, solar power on operation of the national power system		Completed		
8	Building IT infrastructure to run Vietnam Wholesale Electricity Market	2018	2019	EVNNLDC		EVN	Infonet-ES Joint venture	Building infrastructure to run and monitor power transmission in competitive power wholesale		In progress		

6.3.1.2 National Power Transmission Corporation (EVNNPT)

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
1	**Complete SCADA signal at 500/220KV substations**	2013		500/220KV substations	Transmission Company	Significant investment and repair projects		Supplement and complete missing SCADA signals and move to Ax	Complete missing SCADA signals	There are currently 07 substation including SCADA signal		
2	**Remote measurement system at 500/220kV substations.**	2013	2015	500, 220kV substations	Transmission Company	Investment projects	ICT	Develop software, provide computer to collect meter data from substations	Collect meter data for electricity market operation	Completed the connection of all meters managed by EVNNPT		

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
3	**Unmanaged substations**	2017	2020	220kV substation	Transmission Company	Production costs			Transfer 220kV substations to operation from Ax and implement unmanaged substation	Transferred 55 220kV substations to unmanaged operation		
4	**Upgrade protection control system for 16 500, 220kV substation**	2015	2021	Sixteen 500, 220kV substation	Board of Project Management	TEP		Upgrade the conventional control system at TBA to DKMT system	Upgrade the conventional control system at TBA to DKMT system	Ongoing implementation		
5	**Provide fault locator equipment for transmission line 500/220kV**	2016	2018	500, 220kV lines	Transmission Company	Investment project		Provide fault location system for sixty-nine 500, 220kV lines	Accurately determine fault location	Installation for 69 lines of 500, 220kV	Travelling wave fault location	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
6	**Provide online oil monitoring equipment for transformers and 500kV electric resistance**	2015	2016	Transformer and 500kV electric resistance	Transmission Company	Investment project		Provide online oil monitoring equipment for transformers and 500kV electric resistance	Monitor coal gasification in transformer's oil and 500kV electric resistance, timely detect defective equipment to prevent faults	Installing 101 devices for transformers and 500kV electric resistance	PAS	
7	**Develop geographic information system**	2017	2020	Transmission grid	Transmission Company No. 4	Investment project		Develop transmission grid management software system based on GIS geographic information map	Apply to technically manage transmission grid on GIS technology. Connect with Asset Management System AMS, Outage Management System OMS and real-time monitoring devices.	Hiring consultants to prepare technical research reports		

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
8	**Develop a system of collecting monitoring data and warning lightning**	2017	2019	Northern Region and North of Central Region	Transmission Company No.1	Investment project	Vaisala	Provide lightning measuring stations, computer systems and software for collecting information, observing and warning of lightning	- Collect information, observe and warn of lightning. - Locate and determine the parameters of the lightning strike. Make statistics on the density of lightning striking on the ground in areas with transmission lines and substations;	Under installation	TOA/MDF	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
9	**Test system of monitoring transmission line limit**	2018	2020	Test for 01 line	Northern Project Management Board	Investment project		- Equip sensors to collect information on the status of line operation: conductor temperature, load current, wind speed, deflection ... - Calculate, forecast dynamic load capacity of the line, and calculate short-term overload capacity and deflection.	- Determine the dynamic load capacity of the line (usually higher than the rated load capacity), accordingly increase the efficiency of line operation. - Warn of the risk of line breakdown due to increased deflection.	Hiring consultants to prepare technical research reports		

6.3.1.3 Hanoi Power Corporation (EVNHanoi)

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
1	Program to support construction and development of a smart grid for EVN HANOI	2018	2026		Mr. Mai Thanh Duc mai-thanh.duc@siemens.com Mobile: 0903461633	German Development Bank (KfW)	Siemens Consultant	-Detailed assessment of appropriateness and activities / status of current Smart Grid and potential of Smart Grid on EVN HANOI grid. -Build a roadmap of smart grid implementation for 2018-2026 period, such as (i) in compliance with Vietnam's smart grid roadmap (effective evaluation matrix) And (ii) in correlation with the developed business roadmap and (iii) in consideration of costs, effort, costs and benefits.	- Idea development of the smart grid in EVN HANOI. - Identification of sub0projects of the smart grid for Effective energy project in urban area in phase 2.	-- Kick-off report - Smart grid roadmap - Report on identifying scale of subprojects under effective energy project in the urban area in phase 2		

6.3.1.4 Central Power Corporation (EVNCPC)

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
1	Building a control center in Binh Dinh province	Feb-2016	Jul-2016	Binh Dinh province	Control center in Binh Dinh province (0256 382 2713)	EVNCPC's basic construction capital	ATS CO., LTD	Building control center and transferring 110kV transformer stations to unmanaged operation	Automate the grid, reduce troubleshooting time, improve power supply reliability, reduce power consumption, improve labor productivity	- Building a control center in Binh Dinh province - Transferring 05 transformer stations to unmanaged operation	Application of SCADA technology for remote control	
2	Building a control center in Thua Thien Hue province	Sep-2015	Dec-2015	Thua Thien Hue province	Control center in Thua Thien Hue province (0234 399 8666)	EVNCPC's basic construction capital	Self-extension based on current SCADA software	Building control center and transferring 110kV transformer stations to unmanaged operation	Automate the grid, reduce troubleshooting time, improve power supply reliability, reduce power consumption, improve labor productivity	- Building a control center in Thua Thien Hue province - Transferring 05 transformer stations to semi-managed operation	Application of SCADA technology for remote control	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
3	Investing in SCADA system and control center in Quang Binh, Phu Yen, Dak Nong Provinces	Jun-2016	Dec-2016	Quang Binh, Phu Yen, Dak Nong Provinces	- Control center in Quang Binh Province (0232 383 5668) - Control center in Phu Yen Province (0257 383 5188) - Control center in Dak Nong Province (0261 2246567)	EVNCPC's basic construction capital	- Self-performed by EVNCPC - SCADA software provided by My Phuong	Investing in SCADA system to monitor and control stations on medium voltage electrical network, TTG, 110kV transformer stations. Transferring 110kV transformer stations to unmanaged operation.	Automate the grid, reduce troubleshooting time, improve power supply reliability, reduce power consumption, improve labor productivity	- Building control center in Quang Binh, Phu Yen, Dak Nong Provinces - Transferring 13 transformer stations to unmanaged operation (Quang Binh: 5; Phu Yen: 4; Dak Nong:4)	Application of SCADA technology for remote control	
4	Building a control center in Kon Tum, Dak Lak provinces	Jun-2016	Dec-2016	Kon Tum, Dak Lak provinces	- Control center in Kon Tum Province (0260 2220242) - Control center in Dak Lak Province (0262 3947799)	EVNCPC's basic construction capital	Self-extension based on current SCADA software	Transferring 110kV transformer stations to unmanaged operation	Automate the grid, reduce troubleshooting time, improve power supply reliability, reduce power consumption, improve labor productivity	- Building a control center in Kon Tum, Dak Lak provinces - Transferring 11 transformer stations to unmanaged operation (Dak Lak: 7, Kon Tum: 4)	Application of SCADA technology for remote control	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
5	Building a control center in Quang Tri, Quang Ngai provinces	Sep-2016	Dec-2016	Quang Tri, Quang Ngai provinces	- Control center in Quang Tri Province (0233 222 0214) - Control center in Quang Ngai Province (0255 371 0635)	High-tech capital source	ATS CO., LTD	Transferring 110kV transformer stations to unmanaged operation	Automate the grid, reduce troubleshooting time, improve power supply reliability, reduce power consumption, improve labor productivity	- Building a control center in Quang Tri, Quang Ngai provinces - Transferring 15 transformer stations to unmanaged operation (Quang Tri: 7, Quang Ngai: 8) - Connecting 7 TTG, partitioning 22kV at 01 220kV transformer stations to control center (Quang Tri: 6, Quang Ngai: 1) - Connecting 125 Recloser to the control center (Quang Tri: 88, Quang Ngai: 37)	Application of SCADA technology for remote control	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
6	Building a control center in Quang Nam, Gia Lai provinces	Mar-2018	Jun-2018	Quang Nam, Gia Lai provinces	- Control center in Quang Nam Province (0235 222 0307) - Control center in Gia Lai Province (0269 3868688)	EVNCPC's basic construction capital	Power Technical Solutions Joint Stock Company	Transferring 110kV transformer stations to unmanaged operation	Automate the grid, reduce troubleshooting time, improve power supply reliability, reduce power consumption, improve labor productivity	- Building a control center in Quang Nam, Gia Lai provinces - Transferring 13 transformer stations to unmanaged operation (Quang Nam: 6, Gia Lai: 7)	Application of SCADA technology for remote control	
7	Researching, manufacturing and designing SRFI	Jun-17	Aug-18	PC Khanh Hoa, EMEC	Central power electronic measurement equipment manufacturing center (EMEC) Sđt: (0236)2 246 555 Email: emec@cpc.vn	EMEC's production and business capital	Seft-done	Researching and manufacturing fault indicator equipment on medium voltage grid	Quicky identify fault areas	Successfully applied at 5 PC: Hue, Dak Lak, Kon Tum, Gia Lai, Dak Nong and being deployed in the remaining PCs		

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
8	Automation of distribution automatic system (DAS) in Da Nang City Grid	Jan-17	Jan-18	Da Nang City	Control center of Da Nang City (0236 322 1111)	Da Nang PC's investment and construction capital	MY PHUONG TRADING COMPANY	Research, configure database and software at control center, DAS application for 02 routes and 05 cutting machines.	Improve power supply reliability	Application of DAS for exporting route 471 / Ngu Hanh Son 220 and 472 / Ngu Hanh Son 220,	DAS	
9	DMS 4 provinces: Quang Binh, Phu Yen, Kon Tum, Dak Nong	Jun-18	Dec-20	4 provinces: Quang Binh, Phu Yen, Kon Tum, Dak Nong		KfW 3.2 loans	Undefined	Providing basic DMS functions to serve the operation of the power system	Monitoring and operating the grid	Pending competent authority (EVN, Ministry of Finance)'s approval for the project	DMS	
10	DMS in Binh Dinh province	Mar-19	Dec-19	Binh Dinh	Contro center in Binh Dinh province (0256 382 2713)	EVNCPC's construction investment capital in 2019	Undefined	Providing basic DMS functions to serve the operation of the power system	Monitoring and operating the grid	Preparing an investment project	DMS	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
11	Manufacturing electronic meters	2003	2018 (27 electronic meters were successfully studied and produced from 2003 to 2018 in total)	- 13 provinces and cities in the central region - Central Highlands (managed by EVNCPC). - EVNNPC: Lang Son, Phu Tho, Hung Yen, Thai Nguyen, Ha Giang and Bac Can - EVNSPC: Duyen Hai	Central power electronic measurement equipment manufacturing center (EMEC) Sđt: (0236)2 246 555 Email: emec@cpc.vn	EMEC's production and business capital	Self-perform	Researching and manufacturing electronic meters	Monitoring power at distance, improving meter accuracy, preventing fraud and power thief	Successfully produced 1-phase, 3-phase, multi-function electronic meters and meters with the same tariff	Built-in remote meter indicating function with RF radio	
12	Manufacturing electric vehicle charging station	Jun-18	Dec-18	Da Nang City	Central power electronic measurement equipment manufacturing center (EMEC) Sđt: (0236)2 246 555 Email: emec@cpc.vn	KHCB of EVNCPC	Self-perform	Researching, applying, testing and developing electric charging stations for electric energy vehicles	Enhancement of the promotion of clean energy application	Installed charging station for electric cars at Central Power Corporation (charging station studied and produced by EMEC).	Development of CHAdeMO-based charging station	

6.3.1.5 Southern Power Corporation (EVNSPC)

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
1	Integration of off-grid power supply in Phu Quy island district	Apr-18	2020	Phu Quy, Binh Thuan Province		Commercial loans	Joint venture of STD & T ENGINEERING – SERVICES COMPANY LTD and CMP ENGINEERING JOINT STOCK COMPANY	- Additionally installing solar energy - Integrating and controlling sources of diesel mixtures and wind power turbines. The solar power will be connected with control system of energy storage in the future.	Increasing reliability of electricity supply and electricity quality on the island, automatic synchronous control of renewable energy sources, maximizing the potential of renewable energy sources or increasing the operation rate of energy sources renewable, contributing to ensure national security and socio-economic development for island districts	- Complete automatically combined control system of 02 windy and diesel powers. - Quarter III / 2019 and 2020: EVNSPC will continue to develop solar power, complete the off-grid power supply integration system on Phu Quy island district after considering and evaluating the actual operation.	Visual + Phoenix.	

6.3.1.6 Ho Chi Minh Power Corporation (EVNHCMC)

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
1	Improvement, update of SCADA System in EVNHCMC Load Dispatch Center	2014	2016	EVNHCMC Load Dispatch Center	Bui Quang Minh (0963.699.094)	DEP Project, World Bank Loan	Alstom (GE)	- Improve construction architecture; - Install hardware, software system; - Technology transfer training.	Building new SCADA System to replace existing SCADA System in operation to monitor and control the entire distribution grid (110, 22kV) in EVNHCMC	Complete	Monitor, control and operation of the grid	
2	Building Remote Control Centers	2016	2017	EVNHCMC Load Dispatch Center	Bui Quang Minh (0963.699.094)	Investment Capital of EVNHCMC	Based on foundation of SCADA/DMS system	Establish model of center based on foundation of SCADA/DMS system to monitor, control 110, 22kV grid in EVNHCMC	Improve grid management and operational capacity.	Complete	Monitor, control and operation of the grid	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
3	Implement 110kV Substation Automation System	2014	2018	110 kV Substations in EVNHCMC	Nguyen Vinh Phan (0966.630.366)	Investment Capital of EVNHCMC	Providers	- Set up regulations of 110 kV Substation; - Invest, complete SCADA System, firefighting and fire protection system, security surveillance camera, etc. meeting the building criteria to operate 110 kV Substation Automation System.	Improve power supply reliability; labor productivity.	Complete 54/54 110 kV Substation Automation System	Monitor, control and operation of the grid	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
4	Automation of 22kV Distribution Grid	2014	2019	All 22 kV lines in EVNHCMC	Nguyen Viet Dung (0961.816.718)	Investment Capital of EVNHCMC	Providers	- Equip medium voltage switchgear (RMU, Recloser, LBS) with SCADA functions to install in the grid; - Build database on DMS software for remote monitor, control and automatic operation.	Improve power supply reliability.	80% Remote control of 22 kV grid (in which automatic operation is 20%). It's expected that by the end of 2019, it will remote control 100% of 22 kV grid (in which automatic operation is 30%).	Monitor, control and operation of the grid	
5	Set up technical regulations for AMI System	2013	2014		Nguyen Van Khoa (0968.020.809)	DEP Project, World Bank Loan	Mercados	HCM EVN coordinates with EVN Distribution Corporations to hire consultants to set up technical regulations for AMI System	Serving investment, equipment for AMI System in EVN.	Complete	Remote collection of meter data	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
6	AMI technology pilot project using Trilliant solution	2014	2016	Customers in High-Tech Zone of District 9	Nguyen Nhat Minh (0966.768.779)	Investment Capital of EVNHCMC and one part of Trilliant sponsor	Trilliant	Install 44 AMI meters of GE for 32 customers in HCMC High-Tech Zone; Use 2,4/5,8 GHz RF-Mesh communication technology	Pilot AMI RF Mesh technology for evaluation and expand implementation with suitable objects.	Complete	AMI RF-Mesh	
7	Test AMI using PLC technology	Jul-15	Apr-16	2 distribution transformer substations in Gia Dinh Electricity Company	Nguyen Nhat Minh (0966.768.779)	Science and Technology Capital of EVNHCMC	VES - Tatung	Install 180 AMI meters and HES System; using PLC transmission technology to test AMI System (remote switching, remote rate changing)	Piloting AMI PLC technology for evaluation and expand implementation with suitable objects.	Complete	AMI PLC–G3	
8	Remote meter data collection and management system	2014	2019	EVNHCMC	Nguyen Van Khoa	DEP Project, World Bank Loan	Posco-Nuri	- Equip remote meter data management system (MDMS);	Improve labor productivity	Complete	AMR	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
					(0968.020.809)			- Equip 95,300 remote electronic meters to install in distribution transformers and important customers.				
9	Load control pilot program	2015	2015	14 customers of Thu Thiem PC and Sai Gon PC	Phan Quang Vinh (0903.386.497)	Science and Technology Capital of EVNHCMC	Diamond Energy	- Mobilize customers to participate in the project; - Pilot operation of DRMS software to conduct load adjustment events.	Contribute to reducing capacity in peak hour; evaluate efficiency of the incentive mechanism to extend the later stages	Finish 4 load adjustment events: 2 load reducing events (24h notice) and 2 voluntary emergency load adjustment events (2h notice)	Power load adjustment	

No.	Name of the project	Start Date	End Date	Location (if applicable)	Contact person(s)	Actors and sponsors (if applicable)	Manufacturer/Provider	Contents	Objectives	Findings and results	Applied Technologies	Notes
10	Installation of grid-connected solar power system	2017	Continue	Headquarters of units belonging to EVNHCMC; 110 kV substations under scope of management and customers in EVNHCMC	Vo Bich Ngoc (0975.403.650)	Business capital of EVNHCMC	Providers	- Install grid-connected solar power systems in headquarters of units belonging to EVNHCMC and 110 kV substations under scope of management; - Mobilize customers in EVNHCMC to install grid-connected solar power system.	Contribute to economical and efficient use of electricity.	It has been and continues to be implemented. Up to now, there have been 2,647 customers installing MTAM electricity with total capacity of 32.19 MWp.	Grid-connected solar power system	

6.3.2 Technology Specific Questions

6.3.2.1 National Load Dispatch Centre (EVNNLDC)

Technology	Questions	Response
SCADA/EMS	Which functionalities does the current SCADA/EMS have? (e.g. situational awareness system, advanced alarm management system, load shedding and restoration system, automatic generation control, short-term load forecasting, network security analysis, dynamic security assessment, voltage and transient stability analysis, operator training simulator)	All functions of SCADA system under Load Dispatch Center EMS applications such as AGC, grid computing
	Which projects currently exist to upgrade the SCADA/EMS with additional functionalities? Which functionalities will be added/upgraded?	Project for upgrading the service contract of supporting after warranty of software
	Is the entire transmission grid currently covered in the SCADA/EMS? If not, which parts are currently not included?	The entire transmission grid (500-220kV) is currently covered in the SCADA/EMS
	How many and which solar and wind power plants have been connected to the SCADA system?	85 renewable energy plants including 83 solar power plants and 2 wind power plants
	What are the control capabilities of the solar and wind power plants (e.g. downward control of active power, reactive power control)	Inverter technology of renewable energy plants has a speed of increase / decrease of capacity, fast-relatively reactive Power, up to 20MW / min.
	Are there any forecasting systems in place for solar and wind power production? If not, what are the future plans to implement this?	SCADA / EMS system does not have a specialized function on renewable energy forecasting The renewable energy plants have SCADA signals for forecasting short-term active power for next 3 hours and resolution for 15 minutes. However, most of plants haven't completed this item yet.
	Is there Automatic Generation Control (AGC) currently in place? How many/which power plants are participating in AGC? What are the current plans for expanding AGC to further plants, including solar and wind power plants?	The AGC system is included in the SCADA / EMS system. All 152 current power plants in the national power system ensure AGC connection capability including 85 renewable power plants. The current regulations have required power plants to connect to the national power system to ensure AGC connection.
Wide area monitoring system (WAMS) /	Has there been any WAMS and/or WAPC projects been carried out?	Currently, the WAM system under the project scope has been tested and equipped with a system to record faults on the national power system.
	How many 500 kV, 220 kV and 110 kV substations and lines have been connected	10 500 kV Substations have been connected to the WAM system

Technology	Questions	Response
Wide area protection and control (WAPC)	to the WAMS/WAPC (both in total numbers and as a share of total substations)?	
	How many substations are planned to be connected in upcoming years?	10 500 kV Substations
	Which technology providers are used for the WAMS/WAPC and the different hardware components?	Siemens
	Which communication technologies are used for connecting the synchro-phasers / phasor measurement units (PMUs) with the WAMS/WAPC?	IEEE C37.118
	Which types of faults are recorded with the WAMS?	Fault causing power fluctuations on the power system, line or machine breakdowns leading to intermittent firing circuit ...
	Which types of control signals and remedy actions are sent through the WAPC?	Not yet
	What are the target Key Performance Indicators (KPIs) for the project?	No specific KPI yet
	Which features have already been implemented in the WAMS/WAPC? (detection and remedy of system instabilities: e.g. phase angle monitoring, line thermal monitoring, voltage stability monitoring, power oscillation monitoring, power damping monitoring, event driven data archiving)	Monitoring phase angle, voltage stability, electrical oscillator, island detection,
	What are the criteria to identify the location of the PMUs?	Current locations of existing PMUs are important positions on the system, stations for connecting lines, serving the needs of monitoring 500 kV transmission lines. In addition, it is also necessary to place PMUs to monitor large power plants, important customers ... and locations to ensure the system's visibility.
(Online) Dynamic Security Assessment (DSA)	How is the dynamic stability assessment (DSA) of the transmission system performed?	National Load Dispatch Centre (EVNNLDC) has not yet been equipped with Dynamic Stability Assessment (DSA).
	What hardware and software are currently used to assess stability?	
	Is there any online DSA implemented in Vietnam? If yes, please specify the name of the project and the details (e.g. year, cost, technology provider, types of stability problems analyzed).	
	How often is offline or online DSA performed?	
Fault Locator System (FLS) / fault indicators	How many 500 kV lines/substations have been equipped with FLS (both in numbers and as a share of total lines/substations)? How many lines/substations at other voltage levels (220 kV, 110 kV, <110 kV) have been equipped? What are the future plans for FLS installations?	EVNNLDC is not assigned to manage and exploit the Fault Locator System (FLS)
	How is a fault located by the team in the field?	
	What are the target Key Performance Indicators (KPIs) for the FLS?	

Technology	Questions	Response
	Are there any plans for self-healing functionality of SCADA/DMS?	
	What are current SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) numbers? What are targets for the next years?	
	What technologies and methods are used for the FLS?	
	Was the performance of the already installed FLS evaluated? What were the results?	
	Is the FLS integrated into the SCADA system?	

6.3.2.2 National Power Transmission Corporation (EVNNPT)

Technology	Questions	Response
Substation Automation System (SAS)	How many substations on 500 kV, 220 kV and 110 kV have been upgraded with SAS (as a share of total substations)?	Not implemented (Currently, EVNNPT is submitting to Electricity and Renewable Energy Authority for approving technical design)
	How many remote control centers have been established?	
	What are the plans to upgrade substations < 110 kV with SAS?	
	What are the target Key Performance Indicators (KPIs) for SAS?	
	What are the typical hardware of SAS in Vietnam? Which types of Remote Terminal Unit (RTU), Programmable Logic Controller and Intelligent Electronic Device (IED) are installed? Which technology providers are typically selected?	Major suppliers include ATS, SIEMENS, ABB, AREVA, NARI, TOSHIBA,
Lightning location system (LLS)	How many sensors have been installed? How many more are planned to be installed? Where are they located?	09 Sensors installed at regional power transmission
	How many transmission lines surge arresters on which respective voltage levels have been installed? What are the plans for upcoming installations?	500kV grid: All lines 220kV grid: 60 lines Plan: Installation at locations including lots of faults caused by lightning strikes.
	Which technology is used for the LLS?	TOA/MDF
	What is the accuracy of the LLS?	150 – 200 m
	What are the target Key Performance Indicators (KPIs) for the LLS?	N/A

Technology	Questions	Response
	How is the LLS currently coupled with the SCADA/EMS and/or Operational Center? Which functionalities are provided?	LLS are being installed without connecting with the SCADA system. Data shared with operation centers include information on the location of the lightning, the intensity of the lightning, movement direction of lightning cloud, statistics on the density of lightning strikes to the ground (number of times / km2.year) in the areas with transmission lines and transformer stations;
	Have analyses/studies been performed between the correlation between lightning events and relay operation? What are the results of these analyses?	The system has not been put into operation, so there is no analysis.
	Is LLS technology used to track thunderstorm activity and provide forecast information on potential problems?	Early warning of the formation and occurrence of potential lightning storms as a danger to the transmission grid.
Online Dissolved Gas in Oil analysis (DGA)	How many transformers at which substation levels have been equipped with online DGA (both in total numbers and as a share of total transformers)? What are the future plans for online DGA installations?	All transformers, 500kV electrical resistance (101 sets for transformers and electric resistance) will be researched and equipped for important 220kV transformers.
	Are new transformers automatically equipped with online DGA? If yes, which transformers/for substation of which voltage levels? What are the current guidelines?	New transformers, 500kV electric resistance are equipped with DGA.
	What are the target Key Performance Indicators (KPIs) for the online DGA?	N/A
	Which technologies are used for online DGA?	PAS, GC
	Was the performance of the already installed online DGA evaluated? What were the results?	Online monitor content of gas dissolved in transformer oil and electric resistance, give a warning when the gas content is increased that helps to early detect impairment of the device and then prevent the risk of a fault.
Flexible AC Transmission System (FACTS)	How many FACTS have been installed (including technology (e.g. Static VAR compensator (SVC), static synchronous compensator (STATCOM), Static synchronous series compensator (SSSC), etc.), size and installed voltage level)? What are the targets/plans for FACTS installations?	Installed 02 sets of SVC at 220kV Viet Tri (on 2007) and Thai Nguyen (on 2009) stations
	How important are FACTS installations for system security and system efficiency, respectively? What is their main use and purpose in Vietnam?	Flexibly adjust the regional voltage of the grid which imports electricity from China
	Are there any target Key Performance Indicators (KPIs) for these technologies? If yes, which ones?	N/A
Dynamic Line Rating (DLR) /	How many lines at which voltage level have been installed with DLR? What are the future plans for DLR installations?	Hiring consultants to prepare reports. It is expected to install 01 220kV line

Technology	Questions	Response
Dynamic Thermal Circuit Rating (DTCR)	By how much was the capacity of the respective lines increased compared to the static capacity (on average)?	
	Have any studies been performed about the potential benefits of this technology?	
	What are the target Key Performance Indicators (KPIs) for the DLR?	
	Which technologies are used for DLR?	
	Is the technology based on direct measurements, on algorithms or a combination of both?	
	Are weather forecasts taken into account? Which forecast times are applied?	
	Which effects are taken into account for DLR (e.g. ambient temperature, solar radiation, wind speed and direction)	
	Are there any existing WAMS connected to the DLR?	
Outage Management System (OMS)	What are the current functionalities of the OMS (e.g. trouble-call handling, outage analysis and prediction, crew management, reliability reporting)? Please provide details about the functionalities.	Not implemented yet
	What are the planned functionalities of the OMS?	
	Is the Outage Management System integrated with the SCADA system?	

6.3.2.3 Hanoi Power Corporation (EVNHanoi)

Technology	Questions	Response
SCADA/DMS (including projects on miniSCADA systems)	What functionalities does the DMS have? (e.g. remote switching & restoration, fault locator systems, state estimation, (wide area) voltage control, reactive power (VAR) control, state estimation, short-term load forecasting, short-term solar and wind power output forecasting, etc.)	Power flow calculation function: Load flow. Short circuit calculation function: Short Circuit. Grid reactive power control function: Volt / Var Control. Fault location, isolation and service restoration (FLISR): Training for use is not done

Technology	Questions	Response
	Which power system measurements are collected and processed in the DMS?	Static data: line and Substation parameters, ... Load Dispatch Centre (LDC) under EVNHANOI is now collecting data directly from utilities (sent via Excel file, * .doc), then engineers of EVNHANOI LDC will manually make data entry into the system. Dynamic data: U, I, P, Q, f ...: For node locations (distribution substation, intermediate substation, cutting station ...) with SCADA connection, data will be collected automatically to run DMS problem; For the button positions without SCADA connection: the engineers of Center currently have use manual data entry.
	How much of the distribution grid has been mapped in GIS?	DMS at the LDC is now being deployed for Northern Red River grid including 05 utilities.
	Are any Customer Information Systems (CIS), Mobile Workforce Management (MWM) systems, Advanced Metering Infrastructure (AMI), Fault Locator Systems (FLS) or other systems in place? What are their current and planned functionalities?	For CIS, MWM functions: These functions are being applied in some units under EVNHANOI. For AMI function: At present, the Corporation has developed distance measurement data. EVNHANOI LDC is also exploiting for moderation. For FLS (FLISR) system: This function is available on SCADA / DMS system software. Training and technology transfer are being proposed for implementation.
	Are there any Key Performance Indicators (KPIs) in place to analyze the performance of the respective systems?	Improve power supply reliability (Voltage deviation, ...); System Average Interruption Duration Index (SAIDI); System Average Interruption Frequency Index (SAIFI);
Outage Management System (OMS)	What are the current functionalities of the OMS (e.g. trouble-call handling, outage analysis and prediction, crew management, reliability reporting)? Please provide details about the functionalities.	Manage power cut schedule, breakdown statistics; calculate power supply reliability, calculate range, number of customers losing power (power switching on the diagram) l; report data of customers losing power; information of customers losing power through CRM system.
	What are the planned functionalities of the OMS?	GIS digital map-based application, calculation of reliability of power supply through the distance meter system
	Is the Outage Management System integrated with the SCADA system?	Upgrade and integration in process.
Advanced Metering Infrastructure	How many customers have been equipped with AMI?	N/A
	What are the future plans for the rollout of AMI? How many/which customers are planned to be equipped with AMI and until when?	EVNHANOI hasn't planned to implement AMI, instead EVNHANOI has implemented 100% AMR.

Technology	Questions	Response
(AMI) / Smart Meters	Is there a Meter Data Management System (MDMS) in place? What are its functionalities?	MDMS system is available. Functions: manage measurement data from different types of meters, different collection systems on a consistent database within the cycle of 1 day / time or 30 minutes / time, may manage a lot metering data (measurement points, indicators, output, warnings, load diagrams, operating parameters ...), may display chart-form data, auto-check f-estimate - data editing function, provision of controlled data for other related applications such as CMIS, customer service applications, load research, CRM, OMS ...
	Have the customers received or installed any energy displays to track their electricity consumption?	Customers can monitor their electricity consumption through EVN HANOI's customer service applications such as EVNHANOI CUSTOMER SERVICE, website cskh.evnhanoi.com.vn. In addition, customers can also look up information via Chatbot, Zalo, MT and MO SMS.
	Do the customers receive any time-of-use (ToU) tariffs or real-time pricing? What are the specifics of these tariffs?	EVNHANOI publishes TOU price list on customer service information channels, accordingly customers can easily look up. Currently no customers are equipped with AMI but only some customers equipped with AMR participate in DSM power demand management programs.
	Are the customers, that have been equipped with AMI, also participating in Demand Side Management (DSM) programs?	Not equipped yet
	Have any small customers (e.g. households) been equipped with AMI/Smart Meters?	AMI Pilot Project provided by Tatung installs 180 smart AMI meters for household customers.
	What are the functionalities of the AMI/Smart Meters (e.g. remote reading, energy display to the customer, ToU tariffs and/or real-time pricing, electricity theft detection, outage detection, voltage monitoring, load control)? How often can readings be made for the power company, how often for the customer (e.g. every 15 minutes)?	Not used yet by EVNHANOI
	Is there any cost benefit analysis for smart meter deployment by customer group? If yes, what were the results of this cost benefit analysis?	Not used yet by EVNHANOI
Demand Side Management	Are there any demand side management (DSM) programs in Vietnam? If yes, please specify the project details and results.	Decision 2447/QĐ-BCN at 17/7/2007 for the national program of DSM for 2007-2015.

Technology	Questions	Response
(DSM)	How many customers of which respective customer group is participating in the DSM program?	Decision 249/2018/QĐ-TTg at 8/3/2018 regulated the national DSM program of 2018-2020 with the vision to 2030
	Which devices / loads are the power company allowed to control and what are the modalities (e.g. frequency and duration of operation, maximum shiftable load, etc.)?	
	What types of communication and monitoring devices are installed, e.g. smart meters? What are their capabilities and functionalities?	
Demand Response (DR)	Are there any demand response (DR) programs in Vietnam even if it is a voluntary program? If yes, please specify the project details and results.	N/A
	How many customers of which respective customer group is participating in the DR program?	N/A
	How does the customer interact with the price signal under the DR program? Are they equipped with a smart meter or any other monitoring device?	N/A
	Are there any price mechanisms under the DR program (e.g. critical peak pricing CPP, Critical Peak Rebate (CPR))?	N/A
	Are there any plans to introduce real-time pricing in the future?	N/A
Automatic Meter Reading (AMR)	How many customers of which respective customer group has been equipped with AMR?	There are currently 900,000 customers equipped with AMR together with load components of .1.4 million customers for daily activities will be equipped with 100% AMR in the near future (expected before 2021).
	Which technology and technology provider is used to collect the AMR data?	AMR data is collected by RS-485, PLC, RF, 3G/GPRS technologies provided by Gelex, Huu Hong, Vinasino, OMNI manufacturers.
	What are the future plans for the rollout of AMR, in particular with respect to household customers?	EVNHANOI will install 100% electronic meters and automatically collect AMR remote data in 2020.
Voltage regulated distribution transformers	Is there any voltage regulated distribution transformers installed for MV/LV transformers? If yes, how many transformers have been installed and where?	In medium voltage and low voltage grid transformers are not equipped with load-under pressurizer
Electric Vehicle (EV) Smart Charging	Are there any charging stations/charging infrastructure for electric vehicles that can adapt the charging power of the electric vehicles in order to react to external signals (e.g. due to the need of reducing peak power or to follow price signals)?	Not implemented yet
	How many electric vehicles are charging at this charging station?	

Technology	Questions	Response
	Which types of electric vehicles (e.g. electric car, electric bus, etc.) are charging?	
	What are the constraints / strategies of the charging algorithm (if any)?	
	Are there any public transportation fleets in cities that have been electrified (e.g. electric bus fleet)? How many vehicles does the fleet encompass? How are these electric vehicles charged (e.g. overnight charging, end station charging, opportunity charging)?	
Energy storage system	Are there any energy storage system deployed in the Vietnamese electricity grid (including demonstration projects)? If yes, please specify the details, e.g. type of energy storage, location, capacity, cost, connected voltage level, stand-alone or in combination with renewable energy plant)?	Not implemented yet
	What is the purpose and functionality of the energy storage system, e.g. peak demand shaving, renewable energy smoothing, reserve provision, etc.?	
Microgrids	Which generator types and capacities are used in the microgrid?	Not implemented yet
	Is the microgrid grid-connected or operated as an island grid?	
	What is the share of renewable energy on energy production in the microgrid?	
	Is there any energy storage in the microgrid?	
	How many customers are supplied by the microgrid?	
	What is the controllability of the generators and grid assets in the microgrid? Which types of automation systems are applied?	
	What is the reliability of the microgrid regarding outages (e.g. SAIDI/SAIFI)? How many outages occur on average per month/year? Do any other Key Performance Indicators (KPIs) exist for the microgrid?	
High Voltage Direct Current (HVDC)	Are there any plans for HVDC lines within Vietnam or for interconnection to neighboring countries? If yes, please provide specific detail about these plans.	N/A

6.3.2.4 Central Power Corporation (EVNCPC)

Technology	Questions	Response
SCADA/DMS (including projects on miniSCADA systems)	What functionalities does the DMS have? (e.g. remote switching & restoration, fault locator systems, state estimation, (wide area) voltage control, reactive power (VAR) control, state estimation, short-term load forecasting, short-term solar and wind power output forecasting, etc.)	DMS software includes lots of functions, but they may be grouped into 5 main functional groups as follows: 1. Functions related to Grid construction and display including: Network Model, Topology, Extended Data Management; 2. Functions related to Power grid analysis including: State Estimation, Load Flow, Short Circuit, Optimal Power Flow; 3. Functions related to grid operation including: Contingencies Analysis, Optimal Compensate Capacitor, Tie Open Point Optimization (TOPO), volt-amperes reactive control (VAR), Fault positioning, isolation and automatic power supply recovery (DAS) 4. Functions related to Load including: Load Modelling, Load Forecast; 5. Reporting-related functions: Outage Reporting and Statistics, Power and Loss Report
	Which power system measurements are collected and processed in the DMS?	There are currently 02 data sources to provide data for DMS including: 1. SCADA system: provide P, Q, U, I at equipment connected with SCADA for real-time DMS, including: input cutting machine (2kV, 35kV MC cabinet) at 10kV, 220kV transformer stations, MC or Recloser at TTG, power plants, segment devices on the grid (Recloser, LBS, RMU) (successfully connected); 2. Meter data management system (MDMS): provide P, E, cosphi at specialized transformer stations (100% provided with remote measurement) and public transformer stations (80% provided with remote measurement at general ATM) additional charging transformer stations in DMS (connection is being studied).
	How much of the distribution grid has been mapped in GIS?	At the present, EVNEVNCPC has basically finished grid map in DMS based on real grid map, is studying DMS's functions to accurately identify input data aimed at continuing to supplement grid parameters to DMS's elements for operating DMS

Technology	Questions	Response
	Are any Customer Information Systems (CIS), Mobile Workforce Management (MWM) systems, Advanced Metering Infrastructure (AMI), Fault Locator Systems (FLS) or other systems in place? What are their current and planned functionalities?	Currently, EVNCPC is only implementing connection of SCADA / DMS system with the CRM (Customer Relationship Management) program to provide power failure information to customers, staff of the Customer Service Center of Central electricity and automatically calculate power supply reliability. In the coming time, EVNCPC will implement connection of SCADA / DMS system with Meter Data Management System (MDMS) to provide meter data for additional charging transformer stations in DMS.
	Are there any Key Performance Indicators (KPIs) in place to analyze the performance of the respective systems?	Currently, DMS system is only in progress of study and pilot application of some routes, so KPI hasn't been applied to DMS. For SCADA system, EVNCPC is focusing its forces to complete the Grid Monitoring Center for EVNCPC and changing transformer stations into unmanaged ones, so KPI hasn't been applied to analyze efficiency of SCADA system in EVNCPC.
Outage Management System (OMS)	What are the current functionalities of the OMS (e.g. trouble-call handling, outage analysis and prediction, crew management, reliability reporting)? Please provide details about the functionalities.	Current functions of OMS system: - Handling the call for power loss notice from customers: Record the information of power loss from customers (customer code associated with transformer station code to preliminary determine the scope and causes of power failure); - Fault analysis: The program includes a list of the causes of faults, elements affected by faults, damages found by faults and general reports to support users to collect data and analyze cause of the fault; - Task team management: The program does not have this function (monitoring troubleshooting process of the working team); - Management of power cut plans: The program includes the function allowing users to make working plans to estimate the time and scope of the impact of power cuts; Report on power supply reliability: The program includes the function of calculating power supply reliability index based on IEEE 1366 formula
	What are the planned functionalities of the OMS?	Functions expected to be upgraded with OMS system: - Manage working team (upgrading existing functions); - Automatically update the time of power outages from SCADA and Smart Meter; - Complete the link to power outage data from SCADA to OMS

Technology	Questions	Response
	Is the Outage Management System integrated with the SCADA system?	OMS is currently a separate system from SCADA system. It is expectedly integrated with SCADA/DMS system when implementing DMS.
Advanced Metering Infrastructure (AMI) / Smart Meters	How many customers have been equipped with AMI?	EVNCPC has not implemented AMI system and Smart meter.
	What are the future plans for the rollout of AMI? How many/which customers are planned to be equipped with AMI and until when?	EVNCPC has no plan to deploy AMI because it is too expensive and beyond demand.
	Is there a Meter Data Management System (MDMS) in place? What are its functionalities?	EVNCPC has equipped the MDMS system built by FIS & Landis + Gyr joint venture, completed and put into use from 2018 with the following functions: Concentrate, manage and store measurement data provided by collection system (HES); VEE (data validation and correction); provide management interface, exploit measuring data; data source for software / applications for metering data.
	Have the customers received or installed any energy displays to track their electricity consumption?	Customers can view past and current electricity consumption on the EVNCPC website or Customer Service application.
	Do the customers receive any time-of-use (ToU) tariffs or real-time pricing? What are the specifics of these tariffs?	Price is different among rush hour, normal hour and low-load hour for each customer and publicized on the mass media.
	Are the customers, that have been equipped with AMI, also participating in Demand Side Management (DSM) programs?	EVNCPC has not implemented AMI system and Smart meter.
	Have any small customers (e.g. households) been equipped with AMI/Smart Meters?	
	What are the functionalities of the AMI/Smart Meters (e.g. remote reading, energy display to the customer, ToU tariffs and/or real-time pricing, electricity theft detection, outage detection, voltage monitoring, load control)? How often can readings be made for the power company, how often for the customer (e.g. every 15 minutes)?	
	Is there any cost benefit analysis for smart meter deployment by customer group? If yes, what were the results of this cost benefit analysis?	
Demand Side Management (DSM)	Are there any demand side management (DSM) programs in Vietnam? If yes, please specify the project details and results.	Decision 2447/QĐ-BCN at 17/7/2007 for the national program of DSM for 2007-2015. Decision 249/2018/QĐ-TTg at 8/3/2018 regulated the national DSM program of 2018-2020 with the vision to 2030
	How many customers of which respective customer group is participating in the DSM program?	

Technology	Questions	Response
	Which devices / loads are the power company allowed to control and what are the modalities (e.g. frequency and duration of operation, maximum shiftable load, etc.)?	
	What types of communication and monitoring devices are installed, e.g. smart meters? What are their capabilities and functionalities?	
Demand Response (DR)	Are there any demand response (DR) programs in Vietnam even if it is a voluntary program? If yes, please specify the project details and results.	N/A
	How many customers of which respective customer group is participating in the DR program?	
	How does the customer interact with the price signal under the DR program? Are they equipped with a smart meter or any other monitoring device?	
	Are there any price mechanisms under the DR program (e.g. critical peak pricing CPP, Critical Peak Rebate (CPR))?	
	Are there any plans to introduce real time pricing in the future?	
Automatic Meter Reading (AMR)	How many customers of which respective customer group has been equipped with AMR?	About 2.700.000 customers.
	Which technology and technology provider is used to collect the AMR data?	- Radio Frequency (RF) provided by EVNCPC EMEC; - GPRS / 3G provided by IFC Company.
	What are the future plans for the rollout of AMR, in particular with respect to household customers?	100% of customers in cities, towns and islands and 50% of rural customers will be finished remote measurement;
Voltage regulated distribution transformers	Is there any voltage regulated distribution transformers installed for MV/LV transformers? If yes, how many transformers have been installed and where?	N/A
Electric Vehicle (EV) Smart Charging	Are there any charging stations/charging infrastructure for electric vehicles that can adapt the charging power of the electric vehicles in order to react to external signals (e.g. due to the need of reducing peak power or to follow price signals)?	The infrastructure of one-way fast charging station for electric cars developed by Central Power Corporation can meet. In case of adjustment, the charging station will minimize charging current during exchanging between the charging station and electric vehicle.
	How many electric vehicles are charging at this charging station?	01 position of electric vehicle
	Which types of electric vehicles (e.g. electric car, electric bus, etc.) are charging?	Currently, the Central region has 3 types of electric vehicles: electric cars, hybrid cars and electric cars for tourists.

Technology	Questions	Response
	What are the constraints / strategies of the charging algorithm (if any)?	The one-way fast charging algorithm for electric cars has strict charging and safety requirements
	Are there any public transportation fleets in cities that have been electrified (e.g. electric bus fleet)? How many vehicles does the fleet encompass? How are these electric vehicles charged (e.g. overnight charging, end station charging, opportunity charging)?	Currently, the Central region only has a number of pilot electric cars to serve internal visitors at some tourist locations such as Da Nang, Hoi An, Hue, ... This vehicle uses batteries and charges slowly overnight at parking areas.
Energy storage system	Are there any energy storage system deployed in the Vietnamese electricity grid (including demonstration projects)? If yes, please specify the details, e.g. type of energy storage, location, capacity, cost, connected voltage level, stand-alone or in combination with renewable energy plant)?	N/A
	What is the purpose and functionality of the energy storage system, e.g. peak demand shaving, renewable energy smoothing, reserve provision, etc.?	
Microgrids	Which generator types and capacities are used in the microgrid?	Solar power and Diesel
	Is the microgrid grid-connected or operated as an island grid?	The grid operates independently in An Binh island, Ly Son island district, Quang Ngai province.
	What is the share of renewable energy on energy production in the microgrid?	Renewable energy source: 96kWp. Diesel: 402kW.
	Is there any energy storage in the microgrid?	There is power storage battery for mini-grid with capacity of 9600Ah.
	How many customers are supplied by the microgrid?	About more than 80 households
	What is the controllability of the generators and grid assets in the microgrid? Which types of automation systems are applied?	Automatic operation combination system between solar power, battery and diesel.
	What is the reliability of the microgrid regarding outages (e.g. SAIDI/SAIFI)? How many outages occur on average per month/year? Do any other Key Performance Indicators (KPIs) exist for the microgrid?	Uninterrupted power supply to customers on the island
High Voltage Direct Current (HVDC)	Are there any plans for HVDC lines within Vietnam or for interconnection to neighboring countries? If yes, please provide specific detail about these plans.	N/A

6.3.2.5 Southern Power Corporation (EVNSPC)

Technology	Questions	Response
SCADA/DMS (including projects on miniSCADA systems)	What functionalities does the DMS have? (e.g. remote switching & restoration, fault locator systems, state estimation, (wide area) voltage control, reactive power (VAR) control, state estimation, short-term load forecasting, short-term solar and wind power output forecasting, etc.)	EVNSPC plans to expand and upgrade SCADA / DMS in 2019.
	Which power system measurements are collected and processed in the DMS?	No quantitative data has been collected and processed in DMS now
	How much of the distribution grid has been mapped in GIS?	The entire 22kV grid has been mapped in DMS
	Are any Customer Information Systems (CIS), Mobile Workforce Management (MWM) systems, Advanced Metering Infrastructure (AMI), Fault Locator Systems (FLS) or other systems in place? What are their current and planned functionalities?	CIS, MWM and AMI systems have not been equipped currently. However, EVNSPC has implemented and is using a number of systems such as Customer Information Management System (CMIS), Human Resource Management system (HRM), Meter Data Acquisition System (MDAS). - Piloting the Fault Location System (FLS).
	Are there any Key Performance Indicators (KPIs) in place to analyze the performance of the respective systems?	KPI has not been applied

Technology	Questions	Response
Outage Management System (OMS)	What are the current functionalities of the OMS (e.g. trouble-call handling, outage analysis and prediction, crew management, reliability reporting)? Please provide details about the functionalities.	a. Operation - Electricity loss update - Operation log b. Power cut schedule - Making Power cut schedule - List of power cut schedule c. Grid control - Review design grid - Review grid operation - Update the single line grid - Grid update log - List of Grid element - List of low voltage - Update station information - OMS station comparison - CMIS - Power grid faults d. Report - Electricity loss log - Extension log - Cause-based Reliability - Set the cause group - PMIS Reliability - Propose review of power outages - Daily power outages e. System - User administration - Notification settings - Support settings
	What are the planned functionalities of the OMS?	N/A
	Is the Outage Management System integrated with the SCADA system?	OMS system has not currently been integrated with SCADA system
Advanced	How many customers have been equipped with AMI?	No customer is equipped with AMI

Technology	Questions	Response
Metering Infrastructure (AMI) / Smart Meters	What are the future plans for the rollout of AMI? How many/which customers are planned to be equipped with AMI and until when?	AMR and AMI implementation plan are made and done as per EVN's direction. EVN has now policy of implementing AMR, which has been implemented since 2011 and has not had any policy to implement AMI.
	Is there a Meter Data Management System (MDMS) in place? What are its functionalities?	EVNSPC has implemented the MDMS system according to the general model of EVN. MDMS system includes the following basic functions: 1. Manage metering system data; 2. Manage data collected from EVNSPC's HES systems, from the metering system, customer power sale system; 3. Implement VEE function during date management; 4. Connect data to the back-end Application of EVNSPC.
	Have the customers received or installed any energy displays to track their electricity consumption?	Customers can monitor electricity consumption directly from the electricity meter, through customer service site of power company and customer service center. Customers are not equipped with separate equipment to monitor electricity consumption.
	Do the customers receive any time-of-use (ToU) tariffs or real-time pricing? What are the specifics of these tariffs?	Customers get information about TOU tariffs or electricity prices through mass media, at transaction offices, customer service center. When there is a change in the electricity price, the electricity supplier can inform and communicate via SMS, email, ... Electricity prices issued by the government are not changes by day, by hour, so there is no need for real-time information.
	Are the customers, that have been equipped with AMI, also participating in Demand Side Management (DSM) programs?	No customer is equipped with AMI
	Have any small customers (e.g. households) been equipped with AMI/Smart Meters?	No customer is equipped with AMI
	What are the functionalities of the AMI/Smart Meters (e.g. remote reading, energy display to the customer, ToU tariffs and/or real-time pricing, electricity theft detection, outage detection, voltage monitoring, load control)? How often can readings be made for the power company, how often for the customer (e.g. every 15 minutes)?	No customer is equipped with AMI
	Is there any cost benefit analysis for smart meter deployment by customer group? If yes, what were the results of this cost benefit analysis?	No customer is equipped with AMI

Technology	Questions	Response
Demand Side Management (DSM)	Are there any demand side management (DSM) programs in Vietnam? If yes, please specify the project details and results.	Decision 2447/QĐ-BCN at 17/7/2007 for the national program of DSM for 2007-2015. Decision 249/2018/QĐ-TTg at 8/3/2018 regulated the national DSM program of 2018-2020 with the vision to 2030
	How many customers of which respective customer group are participating in the DSM program?	
	Which devices / loads is the power company allowed to control and what are the modalities (e.g. frequency and duration of operation, maximum shiftable load, etc.)?	
	What types of communication and monitoring devices are installed, e.g. smart meters? What are their capabilities and functionalities?	
Demand Response (DR)	Are there any demand response (DR) programs in Vietnam even if it is a voluntary program? If yes, please specify the project details and results.	N/A
	How many customers of which respective customer group are participating in the DR program?	N/A
	How does the customer interact with the price signal under the DR program? Are they equipped with a smart meter or any other monitoring device?	N/A
	Are there any price mechanisms under the DR program (e.g. critical peak pricing CPP, Critical Peak Rebate (CPR))?	N/A
	Are there any plans to introduce real time pricing in the future?	N/A
Automatic Meter Reading (AMR)	How many customers of which respective customer group has been equipped with AMR?	Group of customers equipped with AMR: 1. Customers who buy electricity through their own transformer stations: 20,653 customers, belonging to industrial, construction, commercial and service sectors 2. Customers after public stations: 2,676,000 customers, mainly living customers

Technology	Questions	Response
	Which technology and technology provider are used to collect the AMR data?	Data collection technology: 1. Customers who buy electricity through separate transformer stations: GPRS / 3G technology. Equipment supplier: Telecommunication infrastructure development investment consultancy joint stock company. Software provider: EVN Information and Communication Technology Company (EVNICT). 2. Customers after public stations: PLC and RF technology. The supplier includes Gelex Electrical Equipment Co., Ltd., Smart Energy Management Joint Stock Company, Vinasino Electrical Equipment Joint Stock Company, Huu Hong Industrial Equipment Joint Stock Company
	What are the future plans for the rollout of AMR, in particular with respect to household customers?	AMR implementation plan under the direction of EVN for 2016-2020 periods reaches 2.8 million electronic meters with distance measurement equipment
Voltage regulated distribution transformers	Are there any voltage regulated distribution transformers installed for MV/LV transformers? If yes, how many transformers have been installed and where?	In medium voltage and low voltage grid transformers are not equipped with load-under pressurizer
Electric Vehicle (EV) Smart Charging	Are there any charging stations/charging infrastructure for electric vehicles that can adapt the charging power of the electric vehicles in order to react to external signals (e.g. due to the need of reducing peak power or to follow price signals)?	N/A
	How many electric vehicles are charging at this charging station?	N/A
	Which types of electric vehicles (e.g. electric car, electric bus, etc.) are charging?	N/A
	What are the constraints / strategies of the charging algorithm (if any)?	N/A
	Are there any public transportation fleets in cities that have been electrified (e.g. electric bus fleet)? How many vehicles does the fleet encompass? How are these electric vehicles charged (e.g. overnight charging, end station charging, opportunity charging)?	N/A
Energy storage system	Are there any energy storage system deployed in the Vietnamese electricity grid (including demonstration projects)? If yes, please specify the details, e.g. type of energy storage, location, capacity, cost, connected voltage level, stand-alone or in combination with renewable energy plant)?	N/A

Technology	Questions	Response
	What is the purpose and functionality of the energy storage system, e.g. peak demand shaving, renewable energy smoothing, reserve provision, etc.?	N/A
Microgrids	Which generator types and capacities are used in the microgrid?	Phu Quy has currently wind power and diesel power connection. In 2019 it is expected to install 1MW solar power.
	Is the microgrid grid-connected or operated as an island grid?	Phu Quy grid is an independent grid on the island.
	What is the share of renewable energy on energy production in the microgrid?	Proportion of renewable energy sources connected to the grid is extremely small: 6/10 (6MW wind power, 10MW diesel power source)
	Is there any energy storage in the microgrid?	At present, Phu Quy does not have a system to store electricity.
	How many customers are supplied by the microgrid?	At present, Phu Quy is having 7251 customers
	What is the controllability of the generators and grid assets in the microgrid? Which types of automation systems are applied?	DCS distributed control system which controls the diesel-wind mixture and can automatically adjust capacity of diesel engines and wind turbine, automatically up and down diesel engines and balance the power between diesel engines and wind turbines in preset proportion.
	What is the reliability of the microgrid regarding outages (e.g. SAIDI/SAIFI)? How many outages occur on average per month/year? Do any other Key Performance Indicators (KPIs) exist for the microgrid?	Phu Quy power grid applies the power supply reliability index as the national grid (SAIDI / SAIFI / MAIFI). The average number of power outages in 2018 (SAIDI) was 413.27 minutes; the average number of power outages in 2018 (SAIFI) was 2,124 times / year; There are no transient power outages No other key performance indicators (KPIs) are applied to micro grid.
High Voltage Direct Current (HVDC)	Are there any plans for HVDC lines within Vietnam or for interconnection to neighboring countries? If yes, please provide specific detail about these plans.	N/A

6.3.2.6 Ho Chi Minh Power Corporation (HCMPC)

Technology	Questions	Response
SCADA/DMS (including projects on miniSCADA systems)	What functionalities does the DMS have? (e.g. remote switching & restoration, fault locator systems, state estimation, (wide area) voltage control, reactive power (VAR) control, state estimation, short-term load forecasting, short-term solar and wind power output forecasting, etc.)	- Dynamic Coloring and Circuit tracking: showing wire line or power failure area according to color - Bus load Allocated: evaluating load distribution serving DPE (power distribution) - distribution power Flow: calculating capacity Flow - FLISR – Fault Location, Isolation and Service Restoration: locating faults, isolating and restoring The grid. - automatic Feeder Reconfiguration: analyzing The grid structure and solve The grid optimization issues - Planned Outage Study: planning power outages - distribution Contingency Analysis: analyzing grid backup - voltage and Var optimization: control voltage quality - Short Circuit Analysis: calculating Short Circuit - protection Validation: calculating The protection coordination
	Which power system measurements are collected and processed in the DMS?	- From SCADA system: medium voltage transmission, Recloser, LBS, RMU - Load of Substation: From remote measuring system (if any) of periodic measurement. - Grid parameters (line, Substation) From GIS system (geographic information system)
	How much of the distribution grid has been mapped in GIS?	31,25% (5/16 Utilities) have been implementing DAS/DMS
	Are any Customer Information Systems (CIS), Mobile Workforce Management (MWM) systems, Advanced Metering Infrastructure (AMI), Fault Locator Systems (FLS) or other systems in place? What are their current and planned functionalities?	EVNHCMC currently uses the following systems: - CMIS 3.0 (CIS): system to manage all information of customers using electricity in the city, used to follow contract, invoice, etc. - MWM: now, EVNHCMC uses GIS pair repairing management application, allow customers and electricity industry to follow the process of electricity repair from customer's request. - AMI: has implemented 2 pilot projects (details in Part I) - FDIR (FLS): is currently a function of DMS software being used by EVNHCMC as mentioned above.

Technology	Questions	Response
	Are there any Key Performance Indicators (KPIs) in place to analyze the performance of the respective systems?	EVNHCMC has applied KPI to evaluate the effectiveness of using the above systems: - CMIS: evaluation criteria have not been set up. - MWM: evaluated by the percentage of completed electrical repair request and within specific time (not more than 2 hours). - AMI: Regulated by a successful remote data collection of ≥ 99%. - FDIR: Regulating the transmission time to isolate faults and re-establish the power supply for fault-free area is ≤ 5 minutes for 22 kV medium voltage lines deployed SCADA/DAS/DMS (troubleshooting time depends on the nature of the fault and re-establishment of the following power supply).
Outage Management System (OMS)	What are the current functionalities of the OMS (e.g. trouble-call handling, outage analysis and prediction, crew management, reliability reporting)? Please provide details about the functionalities.	- Management of grid operation on single line diagrams; - Update power outage information for customers; - Calculate the grid reliability factors (MAIFI, SAIFI, SAIDI).
	What are the planned functionalities of the OMS?	Add automatic connection between OMS and SCADA and MDMS
	Is the Outage Management System integrated with the SCADA system?	Implementing SCADA and OMS connection
Advanced Metering Infrastructure (AMI) / Smart Meters	How many customers have been equipped with AMI?	- 180 customers in AMI pilot project using PLC technology of Tatung; - 32 customers in AMI pilot project using RF Mesh technology of Trilliant. The AMI Meters in these two projects are connected with official measuring meters to control and test, not using measuring date of AMI meters to issue invoice for customers.
	What are the future plans for the rollout of AMI? How many/which customers are planned to be equipped with AMI and until when?	HCM EVN implements when directed by Electricity of Vietnam (EVN).
	Is there a Meter Data Management System (MDMS) in place? What are its functionalities?	Due to small number of customers, testing is only implemented on data collecting system (HES), not implemented on MDMS.
	Have the customers received or installed any energy displays to track their electricity consumption?	Not yet available
	Do the customers receive any time-of-use (ToU) tariffs or real-time pricing? What are the specifics of these tariffs?	Not yet available
	Are the customers, that have been equipped with AMI, also participating in Demand Side Management (DSM) programs?	Not yet available

Technology	Questions	Response
	Have any small customers (e.g. households) been equipped with AMI/Smart Meters?	AMI Pilot Project provided by Tatung installs 180 smart AMI meters for household customers.
	What are the functionalities of the AMI/Smart Meters (e.g. remote reading, energy display to the customer, ToU tariffs and/or real-time pricing, electricity theft detection, outage detection, voltage monitoring, load control)? How often can readings be made for the power company, how often for the customer (e.g. every 15 minutes)?	- Warning of instantaneous power outage; - Configuring Remote tariffs; - Controlling remote switch; - Allowing flexibility to control the collection cycle for 15 minutes or more
	Is there any cost benefit analysis for smart meter deployment by customer group? If yes, what were the results of this cost benefit analysis?	Not yet available
Demand Side Management (DSM)	Are there any demand side management (DSM) programs in Vietnam? If yes, please specify the project details and results.	Decision 2447/QĐ-BCN at 17/7/2007 for the national program of DSM for 2007-2015. Decision 249/2018/QĐ-TTg at 8/3/2018 regulated the national DSM program of 2018-2020 with the vision to 2030
	How many customers of which respective customer group are participating in the DSM program?	
	Which devices / loads is the power company allowed to control and what are the modalities (e.g. frequency and duration of operation, maximum shiftable load, etc.)?	
	What types of communication and monitoring devices are installed, e.g. smart meters? What are their capabilities and functionalities?	
Demand Response (DR)	Are there any demand response (DR) programs in Vietnam even if it is a voluntary program? If yes, please specify the project details and results.	Pilot Demand Side Response (DSR) programs implementation in HCMPC. Proposed DR Pilot for EVNHCMC: - Curtailable Load Program (CLP) - Voluntary Emergency Demand Response Program (VEDRP)
	How many customers of which respective customer group are participating in the DR program?	9 Commercial & 5 Industrial Customers participated in Pilot
	How does the customer interact with the price signal under the DR program? Are they equipped with a smart meter or any other monitoring device?	Communication is limited, some time the notifications of DR events are not received. The customers are equipped interval meter.
	Are there any price mechanisms under the DR program (e.g. critical peak pricing CPP, Critical Peak Rebate (CPR))?	No. Used the Science and Technology Fund of EVNHCMC. Incentive Rate: The prevailing tariff for the corresponding period when the event is scheduled with a multiplier of 3 for Peak, 2 for Shoulder, and 1 for Off Peak. The prevailing tariff for the corresponding period when the event is scheduled with a multiplier of 3 for Peak, 2 for Shoulder, and 1 for Off Peak.

Technology	Questions	Response
	Are there any plans to introduce real time pricing in the future?	Development and issuance of DR Incentive Mechanism
Automatic Meter Reading (AMR)	How many customers of which respective customer group has been equipped with AMR?	439,507 customers.
	Which technology and technology provider are used to collect the AMR data?	RF technology provided by: GELEX, EMEC – EVNCPC, Posco – Nuri.
	What are the future plans for the rollout of AMR, in particular with respect to household customers?	Up to June 2020, will complete remote measuring for all customers
Voltage regulated distribution transformers	Are there any voltage regulated distribution transformers installed for MV/LV transformers? If yes, how many transformers have been installed and where?	In medium voltage and low voltage grid transformers are not equipped with load-under pressurizer
Electric Vehicle (EV) Smart Charging	Are there any charging stations/charging infrastructure for electric vehicles that can adapt the charging power of the electric vehicles in order to react to external signals (e.g. due to the need of reducing peak power or to follow price signals)?	Not implemented yet
	How many electric vehicles are charging at this charging station?	
	Which types of electric vehicles (e.g. electric car, electric bus, etc.) are charging?	
	What are the constraints / strategies of the charging algorithm (if any)?	
	Are there any public transportation fleets in cities that have been electrified (e.g. electric bus fleet)? How many vehicles does the fleet encompass? How are these electric vehicles charged (e.g. overnight charging, end station charging, opportunity charging)?	
Energy storage system	Are there any energy storage system deployed in the Vietnamese electricity grid (including demonstration projects)? If yes, please specify the details, e.g. type of energy storage, location, capacity, cost, connected voltage level, stand-alone or in combination with renewable energy plant)?	Not implemented yet
	What is the purpose and functionality of the energy storage system, e.g. peak demand shaving, renewable energy smoothing, reserve provision, etc.?	
Microgrids	Which generator types and capacities are used in the microgrid?	Not implemented yet
	Is the microgrid grid-connected or operated as an island grid?	
	What is the share of renewable energy on energy production in the microgrid?	
	Is there any energy storage in the microgrid?	
	How many customers are supplied by the microgrid?	

Technology	Questions	Response
	What is the controllability of the generators and grid assets in the microgrid? Which types of automation systems are applied?	
	What is the reliability of the microgrid regarding outages (e.g. SAIDI/SAIFI)? How many outages occur on average per month/year? Do any other Key Performance Indicators (KPIs) exist for the microgrid?	
High Voltage Direct Current (HVDC)	Are there any plans for HVDC lines within Vietnam or for interconnection to neighboring countries? If yes, please provide specific detail about these plans.	N/A

6.4 Case studies

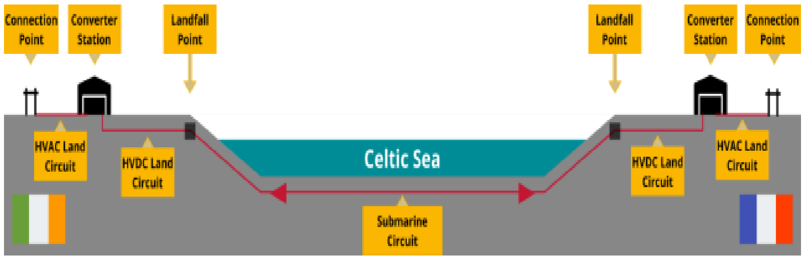
6.4.1 HVDC

6.4.1.1 HVDC with 2.5 GW offshore windfarm in South Korea

<table>
<tr><th>Element</th><th>Detail</th></tr>
<tr><td>Project summary</td><td>This project evaluates the economic analysis of HVDC and HVAC for 2 GW offshore wind farm</td></tr>
<tr><td>Location</td><td>South Korea

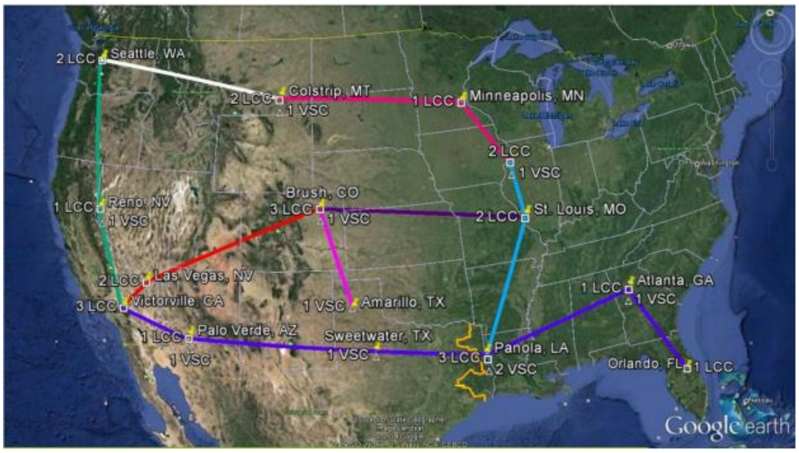
</td></tr>
<tr><td>Project scale</td><td>2 GW offshore wind farm, 80 km form shore</td></tr>
<tr><td>Smart grid technology</td><td>HVDC versus HVAC</td></tr>
<tr><td>Cost parameter</td><td>Investment cost (unit: billion KRW) 1000 KRW = 0.76 EUR
<table>
<tr><th>Component</th><th>CSC HVDC</th><th>VSC HVDC</th><th>HVAC</th></tr>
<tr><td>Substation</td><td>420.00</td><td>630.00</td><td>50.00</td></tr>
<tr><td>Cable</td><td>180.00</td><td>240.00</td><td>720.00</td></tr>
<tr><td>Cable installation</td><td>96.00</td><td>192.00</td><td>288.00</td></tr>
<tr><td>Offshore substation rig</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Onshore land use</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>STATCOM</td><td>-</td><td>-</td><td>32.87</td></tr>
<tr><td>Inductive compensator</td><td>-</td><td>-</td><td>42.08</td></tr>
<tr><td>Total</td><td>696.00</td><td>1,062.00</td><td>1,132.95</td></tr>
</table></td></tr>
<tr><td>Benefit parameter</td><td>Does not indicate in the study due to evaluate only for cost parameter</td></tr>
<tr><td>Key findings</td><td>The CSC VHDC is the cheapest solution for a 2 GW wind farm with an 80 km cable length. Although the VSC substation cost decreases, the CSC HVDC still remain the most favourable option.
Net Present Value (unit: billion KRW)
<table>
<tr><th>Component</th><th>CSC HVDC</th><th>VSC HVDC</th><th>HVAC</th></tr>
<tr><td>Net investment</td><td>696.00</td><td>1,062.00</td><td>1,132.95</td></tr>
<tr><td>Losses</td><td>14.13</td><td>38.70</td><td>46.43</td></tr>
<tr><td>Maintenance cost</td><td>2.58</td><td>4.11</td><td>2.06</td></tr>
<tr><td>Net present value</td><td>794.39</td><td>1,379.73</td><td>1,499.28</td></tr>
</table></td></tr>
<tr><td>Sensitivity analysis criteria</td><td>The decreasing cost of VSC substation</td></tr>
<tr><td>References</td><td>https://pdfs.semanticscholar.org/1d50/b4379a7cdc0441a03d56203eff131c0802d3.pdf</td></tr>
</table>

6.4.1.2 Celtic Interconnector Project

Element	Detail
Project summary	This project evaluate the CBA of 700 MW HVDC
Location/Context	Between Ireland and France 
Project scale	700 MW power rating, 75 km length
Smart grid technology	VSC HVDC versus HVAC
Cost parameter	- The project cost (initial desktop analysis of environmental, technical, third-party and economic factors, subsequent in-depth studies) is estimated at 930 M€ with uncertainty range of -110 + 140 M€ - O&M cost of 8.4 M€ per annum - Network and operation system cost of 15.7 M€
Benefit parameter	Does not indicate value in the study. The benefit parameters including - Socio economic welfare (RE fuel saving, emission cost saving) - RE integration - CO2 variation - Societal well-being - Grid losses - System adequacy - System security
Key findings	Four scenarios are considered. The description of each scenario can be found in the publication page 81. If the costs are shared equally between Ireland and France, the NPV results in positive value to both countries. Net Present Value (unit: billion KRW)
Sensitivity analysis criteria	The delay in Celtic, commissioning, CAPEX assumption, O&M assumption, Security of Supply generation adequacy benefit
References	https://www.cru.ie/wp-content/uploads/2018/12/CRU18265a-Celtic-Investment-Request.pdf

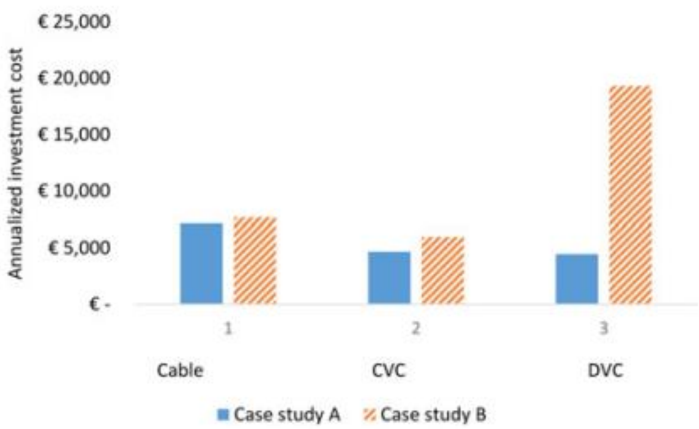
NPV (M€)	Sustainable Transition	Distributed Generation	EUCO	Slowest Progress	Mean Value
France	70	15	-235	-180	-83
Ireland	420	260	215	145	260

6.4.1.3 Continental Transmission across USA

Element	Detail
Project summary	This project evaluates the BCR for HVDC system across USA.
Location/Context	MISO area, USA 
Project scale	LCC (5400 MW) and VSC (2200 MW), transmission capacity of 15 GW, 12,318 km length 22 LCC terminals, 10 VSC terminals
Smart grid technology	LCC and VSC HVDC
Cost parameter	- HVDC 1.74 M€ per km - LCC terminal 431 M€ per terminal - VSC terminal 260 M€ per terminal
Benefit parameter	- Load diversity 19.8 M€ - Frequency response 9 M€ - Wind diversity 2.01 M€ - Other benefit 11.14 M€
Key findings	Benefit to cost ration is 1.25. The HVDC helps to smoothening and dispatching vRE output in the host region to supply the load in the client region.
Sensitivity analysis criteria	Not available
References	https://www.eia.gov/analysis/studies/electricity/hvdctransmission/pdf/transmission.pdf

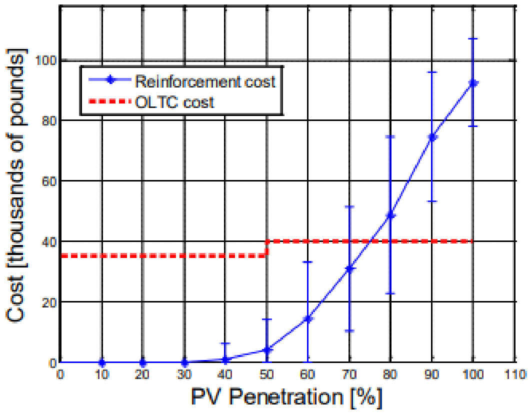
6.4.2 On-Load Tap Changer for Distribution Transformers

6.4.2.1 Distribution grid planning considering smart grid technologies

<table>
<tr><th>Element</th><th>Detail</th></tr>
<tr><td>Project summary</td><td>This paper evaluates economic analysis between centralized (CVC) and decentralized voltage control (DVC)</td></tr>
<tr><td>Location/Context</td><td>Germany</td></tr>
<tr><td>Project scale</td><td>LV residential distribution grid</td></tr>
<tr><td>Smart grid technology</td><td>OLTC for distribution transformer</td></tr>
<tr><td>Cost parameter</td><td>
<table>
<tr><th>Options</th><th>Costs</th></tr>
<tr><td>MV/LV – OLTC transformer</td><td>30,000€</td></tr>
<tr><td>LV cable</td><td>100 €/m</td></tr>
<tr><td>network losses (C_{losses}) [1]</td><td>0.079 €/kWh</td></tr>
<tr><td>reactive power compensation [1]</td><td>0.0087 €/kVarh</td></tr>
<tr><td>curtailment cost (C_c) [1]</td><td>0.2874 €/kWh</td></tr>
<tr><td>communication and control</td><td>10,000€/feeder for DSO</td></tr>
</table>
</td></tr>
<tr><td>Benefit parameter</td><td>Not available</td></tr>
<tr><td>Key findings</td><td>Both CVC and DVC approach can solve a voltage problem at LV grid. The DVC is the most economical option if the annual curtailment is not imposed by the regulator. In contrast, the CVC option is cheaper when annual curtailment is enforced. Case study A indicates low PV penetration while case study B represents 50% higher PV penetration.


</td></tr>
<tr><td>Sensitivity analysis criteria</td><td>Not available</td></tr>
<tr><td>References</td><td>https://shop.tarjomeplus.com/UploadFileEn/TPLUS_EN_2258.pdf</td></tr>
</table>

6.4.2.2 Increasing the PV hosting capacity of LV networks

Element	Detail
Project summary	This project investigate the techno-economic benefit from using OLTC to cope with high penetration rate of PV
Location/Context	UK
Project scale	Low voltage network (6 feeders, 9.2 km total length)
Smart grid technology	OLTC for distribution transformer
Cost parameter	- Main cable 158 €/m - Service cable 90 €/m - OLTC transformer 40,587 EUR (3-4 times higher than traditional transformer)
Benefit parameter	Not available
Key findings	Network reinforcement is the cheapest for PV penetration up to 60% The OLTC option is cheaper than network reinforcement when PV penetration reaches 70%. Tue OLTC can improve PV hosting capacity. 
Sensitivity analysis criteria	Not available
References	https://www.researchgate.net/publication/282949395_Increasing_the_PV_hosting_capacity_of_LV_networks_OLTC-fitted_transformers_vs_reinforcements

6.4.3 Dynamic Thermal Circuit Rating (DTCR)

6.4.3.1 Dynamic thermal rating for increasing network capacity and delaying network reinforcements

<table>
<tr><th>Element</th><th>Detail</th></tr>
<tr><td>Project summary</td><td>This paper investigate technical challenges and potential benefit for DTCR</td></tr>
<tr><td>Location/Context</td><td>Scottish</td></tr>
<tr><td>Project scale</td><td>132 kV, distance between two towns is 7 km</td></tr>
<tr><td>Smart grid technology</td><td>OLTC for distribution transformer</td></tr>
<tr><td>Cost parameter</td><td>Rating, maximum transmission capacity and cost
<table>
<tr><th></th><th>Rating [A]</th><th>Capability [GWh/year]</th><th>Cost [M£]</th></tr>
<tr><td>Static rating</td><td>390</td><td>762</td><td>0</td></tr>
<tr><td>Re-tensioned</td><td>520</td><td>1034</td><td>0.16</td></tr>
<tr><td>DTR</td><td>Variable</td><td>1696</td><td>0.1</td></tr>
<tr><td>New line</td><td>770</td><td>1542</td><td>2</td></tr>
</table>
</td></tr>
<tr><td>Benefit parameter</td><td>Not available</td></tr>
<tr><td>Key findings</td><td>The DTCR offers the greatest potential benefit with lowest cost. The DTCR enables twice of transfer capacity compared to the static rating.</td></tr>
<tr><td>Sensitivity analysis criteria</td><td>Not available</td></tr>
<tr><td>References</td><td>https://hal.archives-ouvertes.fr/hal-01848959/document</td></tr>
</table>

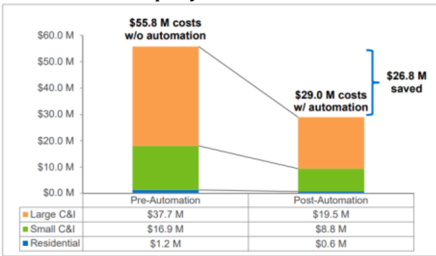
6.4.3.2 Implementation of dynamic line rating in a sub-transmission system for wind power integration

<table>
<tr><th>Element</th><th>Detail</th></tr>
<tr><td>Project summary</td><td>This paper investigates the technical and economic aspects of DTCR across an overhead conduction in 130 kV after integrating 60 MW wind farm.</td></tr>
<tr><td>Location/Context</td><td>Sweden</td></tr>
<tr><td>Project scale</td><td>130 kV, 60 MW of wind farm integration</td></tr>
<tr><td>Smart grid technology</td><td>OLTC for distribution transformer</td></tr>
<tr><td>Cost parameter</td><td>Rating, maximum transmission capacity and cost
- Real-time communication and computer tools 182,570 €
- Capital cost of upgrading the line 3 M€ 30 km, 593 mm, 593 mm²)
- Capital cost for building new line 3.68 M€ (30 km, 593 mm, 593 mm²)</td></tr>
<tr><td>Benefit parameter</td><td>Annual benefit from ampacity upgrading solutions
- Dynamic line rating 0.027 M€
- Conductor upgrading 0.013 M€
- New line construction 0.0084 M€</td></tr>
<tr><td>Key findings</td><td>The DTCR can improve the capacity of overhead conductor and facilitate wind power output. The DTC is cheaper than upgrading the conductor and new line construction.</td></tr>
<tr><td>Sensitivity analysis criteria</td><td>Not available</td></tr>
<tr><td>References</td><td>https://www.scirp.org/pdf/SGRE_2015081413582695.pdf</td></tr>
</table>

6.4.4 Distribution Automation (DA)

6.4.4.1 EPB Chattanooga distribution automation

Element	Detail
Project summary	This paper estimates the interruption cost by deploying DA
Location/Context	USA
Project scale	174,000 customers
Smart grid technology	Automatic switches, system circuits, installation, and software (exclude the fiber optic communications infrastrucuture)
Cost parameter	- Investment costs 5.1 M€ per year (total 44.1 M€)
Benefit parameter	- Benefit 24.5 M€ per year

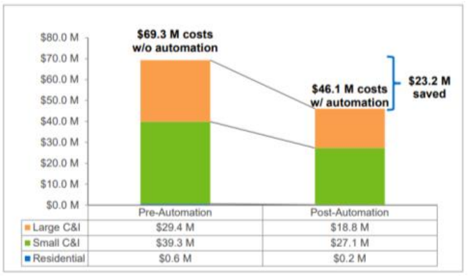


Element	Detail
Key findings	The DA can reduce SAIDI by 45% and SAIFI by 51%. The avoided cost of interruption cost is approx. 21 M€ during severe storm in July 2012.

EPB reliability metrics before and after DA investment

Metric		Value Before Automation	Value After Automation	% Change
SAIDI	Minutes per year	112	61.8	↓45%
SAIFI	Interruption per year	1.42	0.69	↓51%
CAIDI	Minutes per interruption	78.9	89.6	↑14%

Customer outage costs with and without DA in July 2012



Element	Detail
Sensitivity analysis criteria	Not available
References	https://emp.lbl.gov/sites/all/files/nexant-ice-calculator-epb-dis-automation-dec-2015.pdf

6.4.4.2 Consolidated Edison

Element	Detail
Project summary	This paper evaluates the DA technologies for performance, cost and benefit in real-world applications
Location/Context	USA
Project scale	810 distribution circuits, 3 million customers
Smart grid technology	Automated feeder switches, automated capacitors, automated regulators, feeder monitors, remote battery monitor, remote fault indicators, transformer monitors, smart relays, recloser controls
Cost parameter	Not available
Benefit parameter	- Interruption cost reduction for 14 feeders 1.1 M€ - Average customer saving 593 €/large customer and 210 €/small customer - Reducing peak 2.8%, resulting in a net saving of 14.3 M€ - Reducing system losses 310,000 €
Key findings	DA can reduce the customer cost from fewer and shorter outages, improve voltage management and substation capacity under peak conditions, and control of demand resources
Sensitivity analysis criteria	Not available
References	https://www.energy.gov/sites/prod/files/2016/11/f34/Distribution%20Automation%20Summary%20Report_09-29-16.pdf

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