Planning the operability of power systems – Overcoming technical and operational bottlenecks

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The transformation of the power system

Centralised Power Generation including large scale VRE

Power Transmission: High Voltage Network – Long distance transport of large blocks of power

Power Distribution Medium/Low Voltage power delivery including VRE

Residential, commercial industrial customers Different voltage levels - Distributed VRE
The transformation of the power system

Example in Germany

Source: 50Hertz
The transformation is happening everywhere regardless of its size
Challenges at different levels

<table>
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<th>Objectives of power system</th>
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<td>Deliver power when needed</td>
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<th>Dimensions / Stakeholders</th>
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<td>Technical / TSO-DSO-Planning Offices</td>
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<th>Challenges for the integration</th>
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<td>Secure and Reliable Operation</td>
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Successful transformation requires:
- Political commitment - stable regulatory framework
- Planning for coherent energy systems
- Innovative solutions
The technical Challenge

How to develop the system to maximize the value of VRE generation as it comes - and still ensure the security of supply?

**Preconditions for secure system operation:**

- Availability of power to cover demand (adequate generation fleet)
- Adequate network and associated infrastructure
- Availability of resources to cover system imbalances in the operational hour
- System stability
Frequency Control

The frequency of a system depends on the instantaneous balance of power. The frequency is typically 60 Hz in the United States and 50 Hz in Europe.

System operators schedule generation resources to meet demand, however 100% accuracy is not possible. **Flexibility** to rapidly adapt schedules to changing conditions and **regulating reserves** to cover unavoidable deviations are necessary.

Source: ENTSOE

Source: CAISO

Source: ENTSOE
Voltage Control

- Voltage at terminals of connection of equipment must be within acceptable limits (i.e. +/- 10% of nominal voltage)
- Voltage control is achieved by production and absorption of reactive power
- Reactive power sources:
  - Generators, capacitor banks, underground cables
- Reactive power sinks:
  - Generators, reactors, motors, transformers
- Methods of Voltage control:
  - Generators
  - Controllable sources or sinks of reactive power (i.e. capacitor banks, SVC, STATCOM, etc)
  - Regulating transformers (i.e. tap changing transformers)

Injection of active power also affects voltage → higher influence in distribution networks (i.e. PV in distribution feeders affect voltage)
Generation does not coincide with consumption

Data from: http://www.eirgridgroup.com
Variability and limited predictability

Increasing requirements for system capability to respond to changes in demand and supply → operational flexibility

Steeper ramps: Increase in ramping capability may be required
Forecast error is covered with operational reserves

Data from: http://www.eirgridgroup.com
Transmission system adequacy

Total Transfer Capacity
500 MW

Total Transfer Capacity
564 MW

Area 3
Peak demand: 1500 MW
Low demand: 565 MW
Installed Capacity: 1200 MW

Increase transmission capacity required

High Wind Resources Zone identified for future development

Transmission system restrictions study for 2016-2019, OC-SENI 2015
Different interaction with the grid

Wind power plant

Solar power plant

Conventional power pant

• Physical principle, and included interface between the grid and the source of energy is different.
  • Robustness of the system and capability to control frequency and voltage may be affected (stability).

• Minimum grid performance requirements and technical assessment to identify security threads are required.
The technical challenges

Load-generation balance

- **Long term (year):**
  - Lower (than conventional) firm capacity to ensure adequacy with peak load

- **Mid term (day/month):**
  - Lack of energy/capacity in case of prolonged RE unavailability

- **Short term (real-time/minutes):**
  - Increased need for ramping/balancing/reserve due to variability
  - Decreased number of units able to provide ramping/balancing/reserve

- **After black-out:**
  - Decreased number of units able to restore the system after a black out

Grid equipment overloads

- **Uncontrollable (reverse) flows** can provoke overloading/congestions on some lines and transformers

Over/under voltage

- **Decreased number of units** able to perform voltage control
- **Voltage outside acceptable ranges** due to RE

Protections dysfunction

- **Reversed short circuit currents** in case of fault
- **Unwanted islanding:** decentralized RE injecting power after a fault leading to safety issues during maintenance operation

Decrease of power quality

- **Deviations from ideal sine wave** (V,I) due to decentralized RE characteristics (harmonics,…)

Different dynamic response of the system to disturbances
The technical challenges - Summary

Non-synchronous
Uncertainty
Variability
Location & modularity

Seconds
Years

VRE PROPERTIES

Impacts
Stability, Voltage & Frequency response
Unit commitment & Reserve allocation
Ramp capability requirements & Cycling (start-ups)
Dispatchable capacity utilisation
Power flows
Voltage

Grid operation & Security planning
System operation
Generation adequacy planning
T&D Grid adequacy planning

IMPACTS DEPEND ON SYSTEM CHARACTERISTICS
Solutions for the recognised issues are already in place

• Provision of grid services from VRE
• Strong transmission grids.
• Interconnection with neighbour systems.
• Flexible conventional generation.
• Storage/ demand side management.
• Specialised forecasting and operational planning tools
• SmartGrids to SmartEnergy to optimize RES utilization across energy sectors and support price flexibility
• ...

Looking forward for new innovative solutions
Power system operation and planning aims to provide a **reliable** and **efficient** supply of electricity at any time.

Operation of the power system is a very **complicated and critical task** that must be supported by a **strong planning process**.
Engagement with Member Countries

Cooperation with decision makers, network operators and technical experts at a global level supporting exchange of experiences on grid operation & expansion – Until now focus on small islands but moving towards larger interconnected systems.

**Dominican Republic** (grid study), **Antigua & Barbuda** (grid study), **Barbados** (revision of studies), **CARILEC** (technical workshops), **CUBA** Workshop Planning and Operating the Electricity System

DIgSILENT, TU Darmstadt, TRACTEBEL-ENGIE (Access to simulation Software, technical guides)

**Samoa, Cook Islands, Palau** (grid studies), **Kiribati** (support in realisation of study), **Fiji, Vanuatu** (on-going studies, technical workshops)

**Central America**, Starting technical study. This initiated a step moving towards bigger systems.
VRE Grid integration studies

Aim: Facilitate coordination between long-term, policy-driven RE targets and their actual deployment in the grid

General Approach: Assessment of reliability and security of the system with planned penetration levels of VRE through statistical analysis and electricity grid modelling & simulation
- Mid term time horizon (2 – 5 years)
- Cooperation with relevant stakeholders, Flexible and adapted to the country needs

Facilitation of exchange of experiences with network of top technical experts.
Grid Study – Methodology for Small Isolated Systems

Data Collection – Generation Expansion Plans

Network Data Analysis

Power System Operation Analysis

Definition of performance Criteria

Model Validation

Power System Model Implementation

Reserve Requirement /Op. Methods

Unit commitment & Generation dispatch

Mitigation Measures

Electrical Studies, challenging operational scenarios: criteria fulfilled?

Steady State - Voltage & Loading (normal and contingency)

Frequency & Transient Stability

Distribution Feeder Analysis

Blue boxes are an iterative process

Simplified Annual Energy Estimate
CASE SAMOA - UPOLU

- Technical constraints associated with the implementation of the PV and wind generation projects planned by the utility (EPC) to achieve the national target of 100% renewable energy were identified.

- The power utility is implementing the recommendations of the study to achieve stable operation with 14 MW of solar PV:
  - Through a development partner funding the utility is currently procuring an energy storage system.
  - The technical assessment and the models prepared by IRENA are being used as technical references in the procurement process.

- More aggressive scenarios with further projects to achieve 100% RE target were also assessed.
Guide: Planning of electricity grids in Small Island Developing States with VRE – A methodological guide

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<th>Time horizons at which assessment is generally performed</th>
<th>Parts of the power system to be represented</th>
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<td>Mid- and long-term planning (month to years ahead)</td>
<td>Load &amp; generation</td>
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<td>Operational planning (day to week ahead)</td>
<td>Transmission</td>
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<td>Real time dispatch (second to minutes ahead)</td>
<td>Distribution</td>
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| Generation adequacy  |                                          |                                            |
| Sizing of operating reserves |                                          |                                            |
| Generation scheduling |                                          |                                            |

| Static               |                                          |                                            |
| Load flow & static security assessment |                                          |                                            |
| Voltage & reactive power control       |                                          |                                            |
| Short-circuit currents               |                                          |                                            |

| Dynamic              |                                          |                                            |
| System stability      |                                          |                                            |

| Special              |                                          |                                            |
| Protection coordination |                                         |                                            |
| Power quality         |                                          |                                            |
| Defence plans         |                                          |                                            |

(UFLS & UVLS)
Guide: Stability in small and isolated power systems with high share of VRE

Aims to:

- Explain the stability issues to non-technical persons.
- Give practical recommendations to people interested on doing stability studies themselves, or communicate with people in charge of performing the studies.
Exchange of knowledge

- Webinars and technical workshops in partnerships with local stakeholders and regional organizations
- Global access and support in use of stability analysis software DigSilent PowerFactory
- Guides on grid stability and technical assessments for grid integration planning
Support in planning the operability of larger isolated systems – Dominican Republic

IRENA Remap report for Dominican Republic included a characterization of the technical challenges to overcome in 2030 if options including 2.3 GW of wind and 1.9 GW of solar PV are implemented

- At least 4 GW of dispatchable generation would be required to cover demand peaks in periods with low availability of renewable resources.
- Around 10% of the energy generation from VRE would have to be curtailed to guarantee reliable system operation in 2030
- State-of-the-art technologies and operational practices could allow higher instantaneous penetration limits and lower energy curtailment
- Increase requirements for flexibility in the future
- Potential congestions in the transmission system identified

Detailed techno-economic studies to identify solutions are planned for 2017 together with government and TSO
Support in planning the operability in the Central America Clean Energy Corridor-Panama

- High shares of VRE expected in the mid term.
- Associated technical challenges must be addressed.
- TSO has a very well established planning process already including impact of VRE.
- Project plan is currently under development with national stakeholders. Based on exchange of knowledge considered options include:
  - Improvement of simulation models
  - Assessment of current operational practices and system flexibility
  - Identification of additional constraints in the mid term
  - Facilitate exchange of knowledge
The transformation of the power system is rapidly happening in developing and emerging countries quick action is required to support operability of systems in the mid term

Challenges for the integration are at different levels, usually are addressed separately but can not be isolated. Holistic approach is required to support planning

There is an enormous variety. Each power system is a unique case. Particularities define approach required for support / technical assessments

The transformation of the power system is a journey with stop and review stages

RE integration is a new field nothing is possible without people with the proper skills. There is knowledge and awareness in emerging countries but still a lot of work to do