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

Francisco Gafaro

The transformation of the power system

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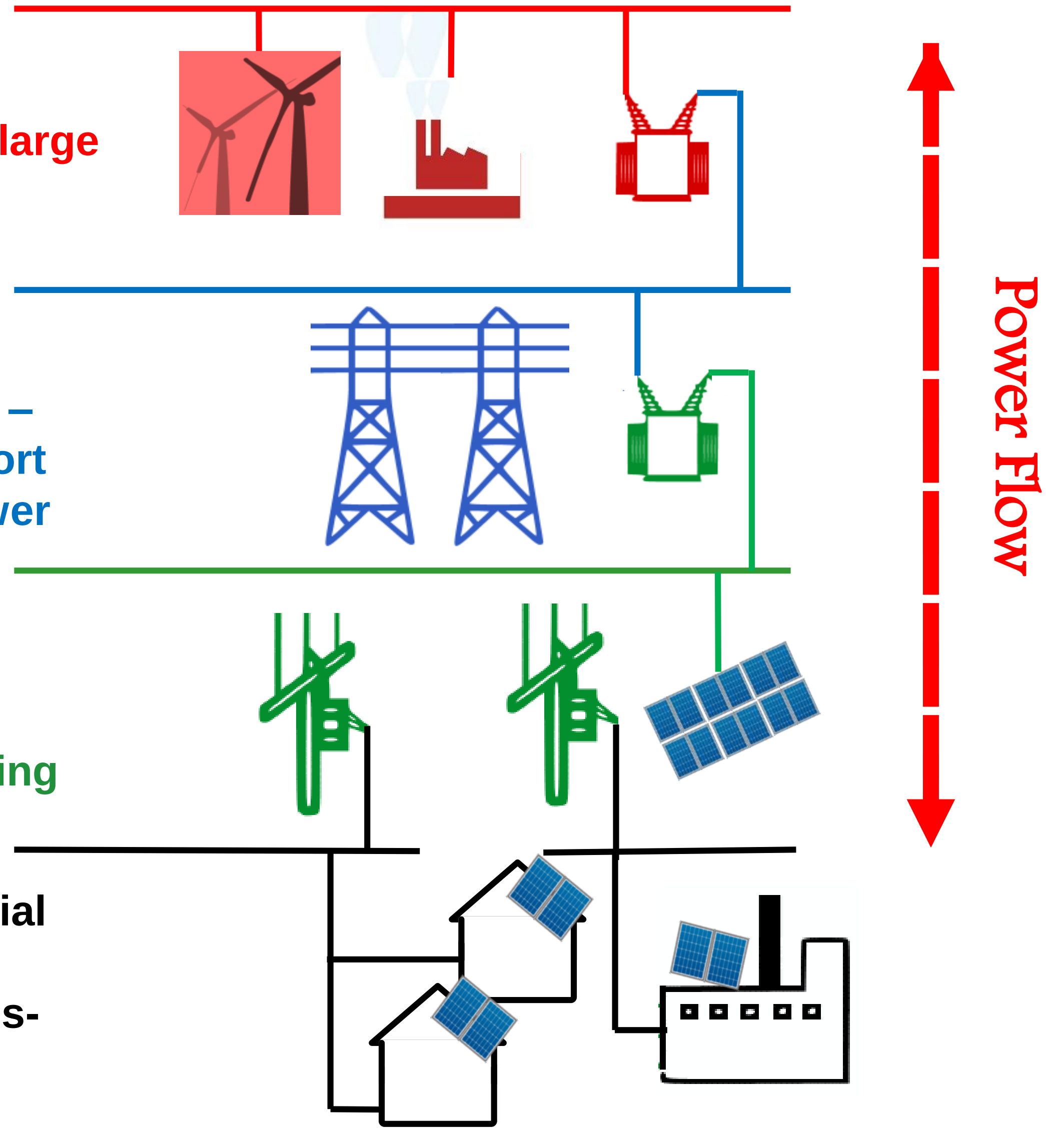
Centralised Power Generation including large scale VRE

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

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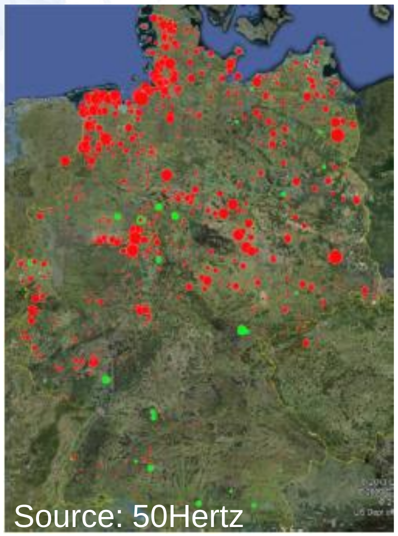

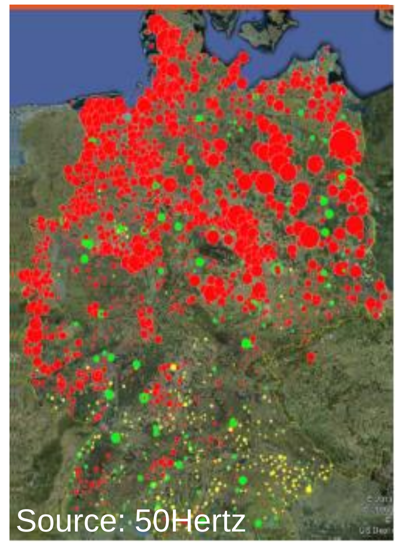

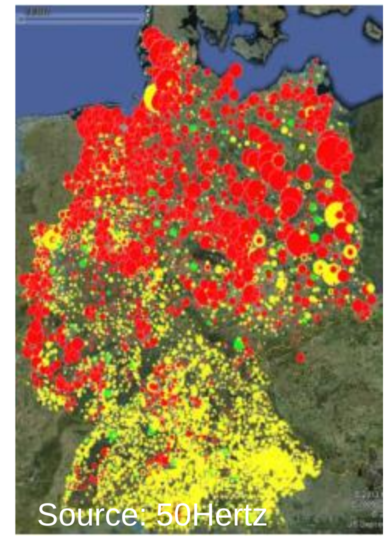

around 30.000 plants | around 220.000 plants | around 1.500.000 plants

2000 | 2006 | 2014

Wind | Photovoltaics | Biomass

Example in Germany
Source: 50Hertz

The transformation is happening everywhere regardless of its size

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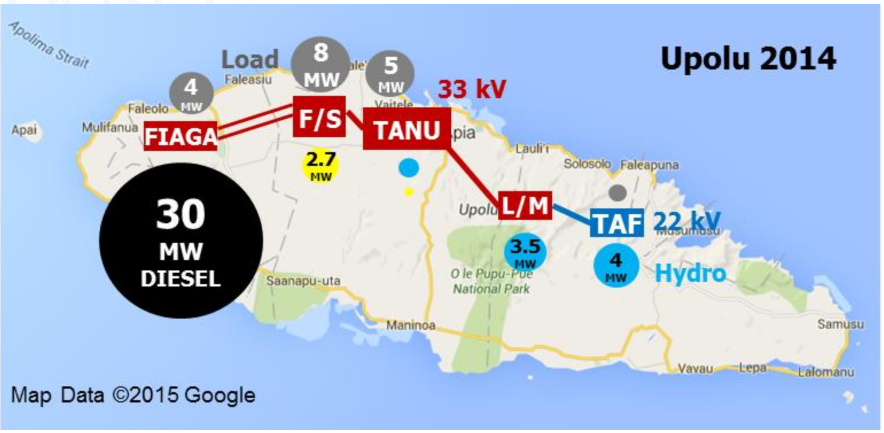
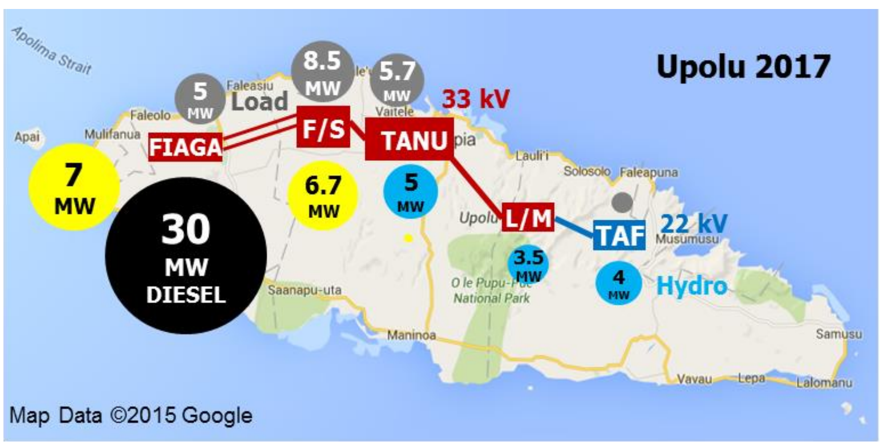
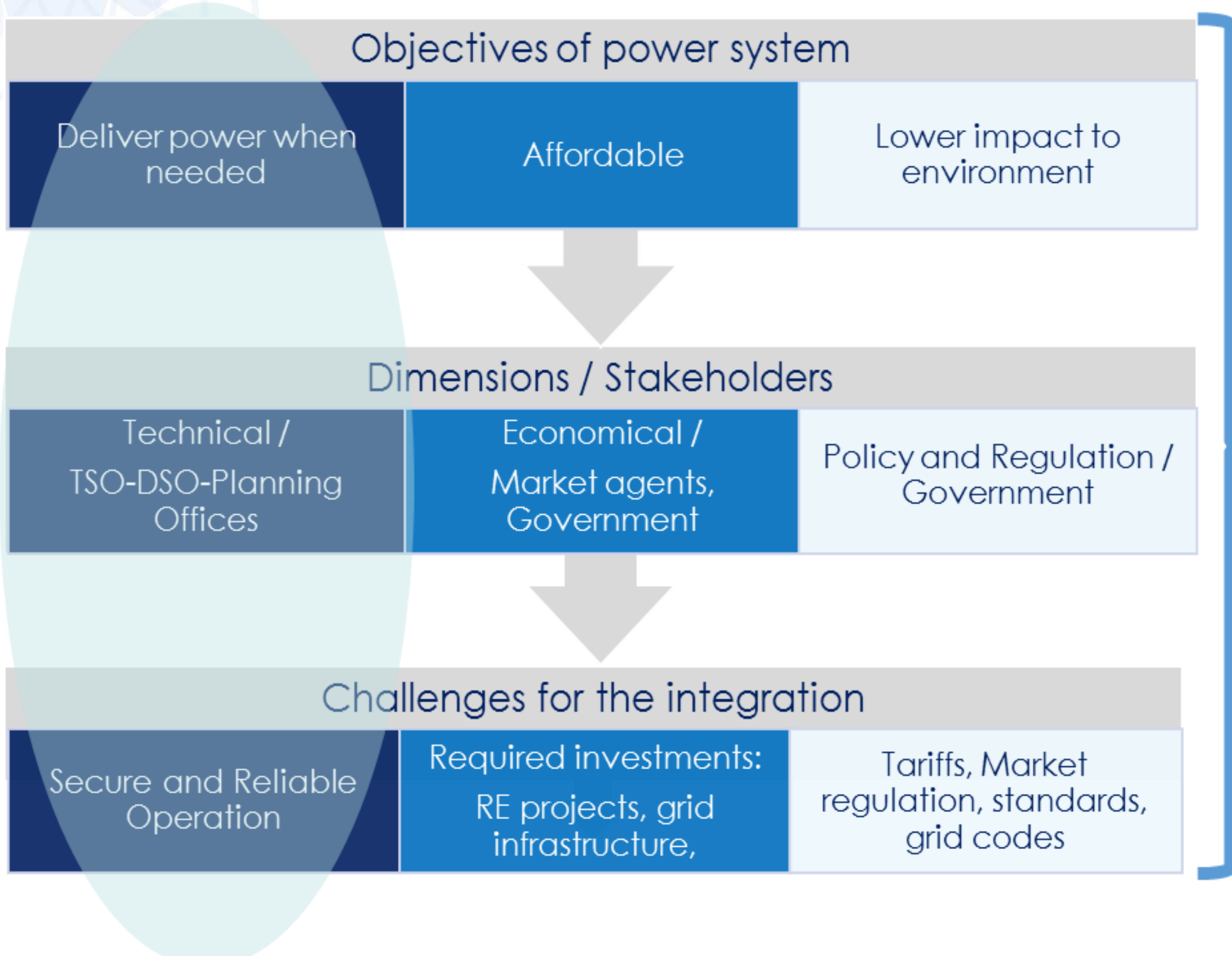




Challenges at different levels



Successful transformation requires:

- ✓ **Political commitment - stable regulatory framework**
- ✓ **Planning for coherent energy systems**
- ✓ **Innovative solutions**

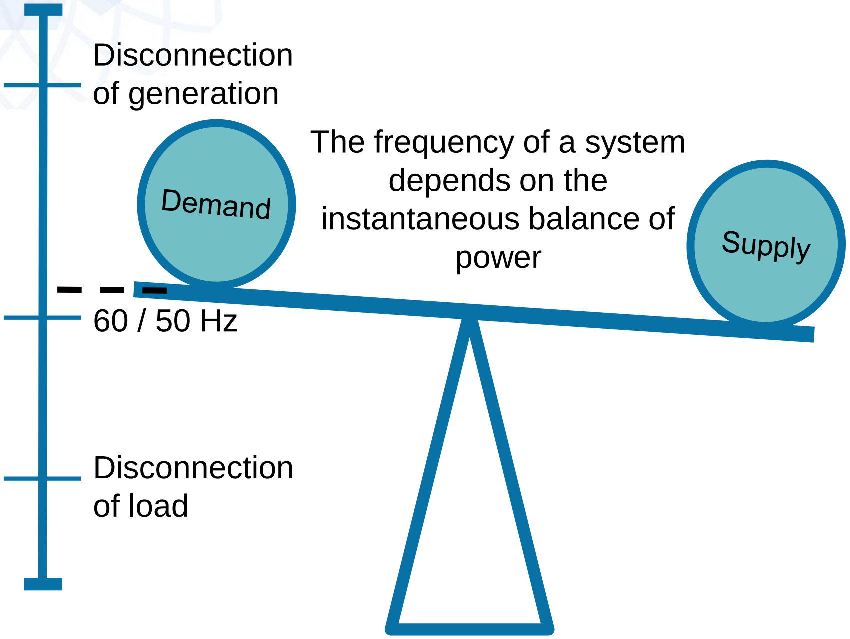
The technical Challenge

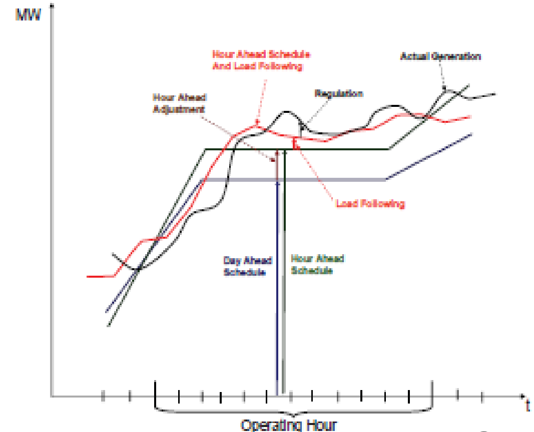
How to develop the system to maximize the value of VRE generation as it comes - and still ensure the security of supply?

Preconditions for secure system operation:

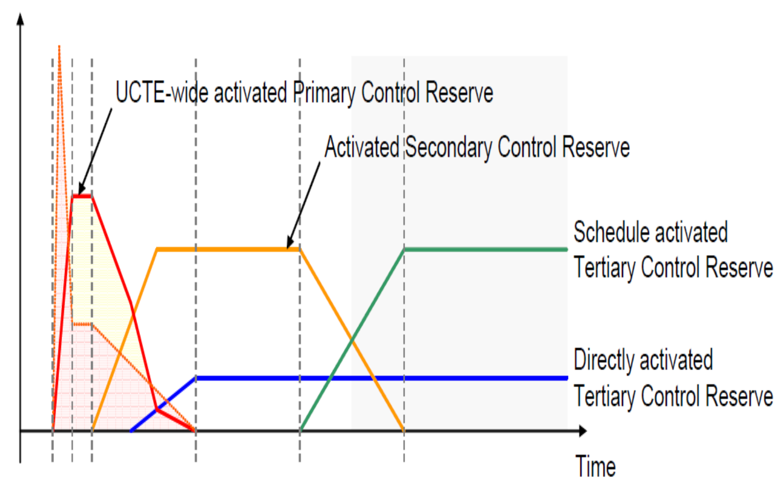
- ✓ Availability of power to cover demand (adequate generation fleet)
- ✓ Adequate network and associated infrastructure
- ✓ Availability of ressources to cover system imbalances in the operational hour
- ✓ System stability

Frequency Control





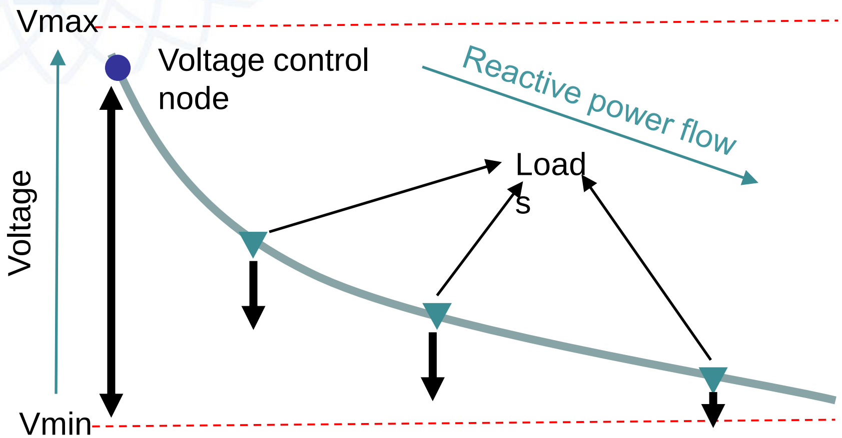
Source: CAISO



Source: ENTSOE

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

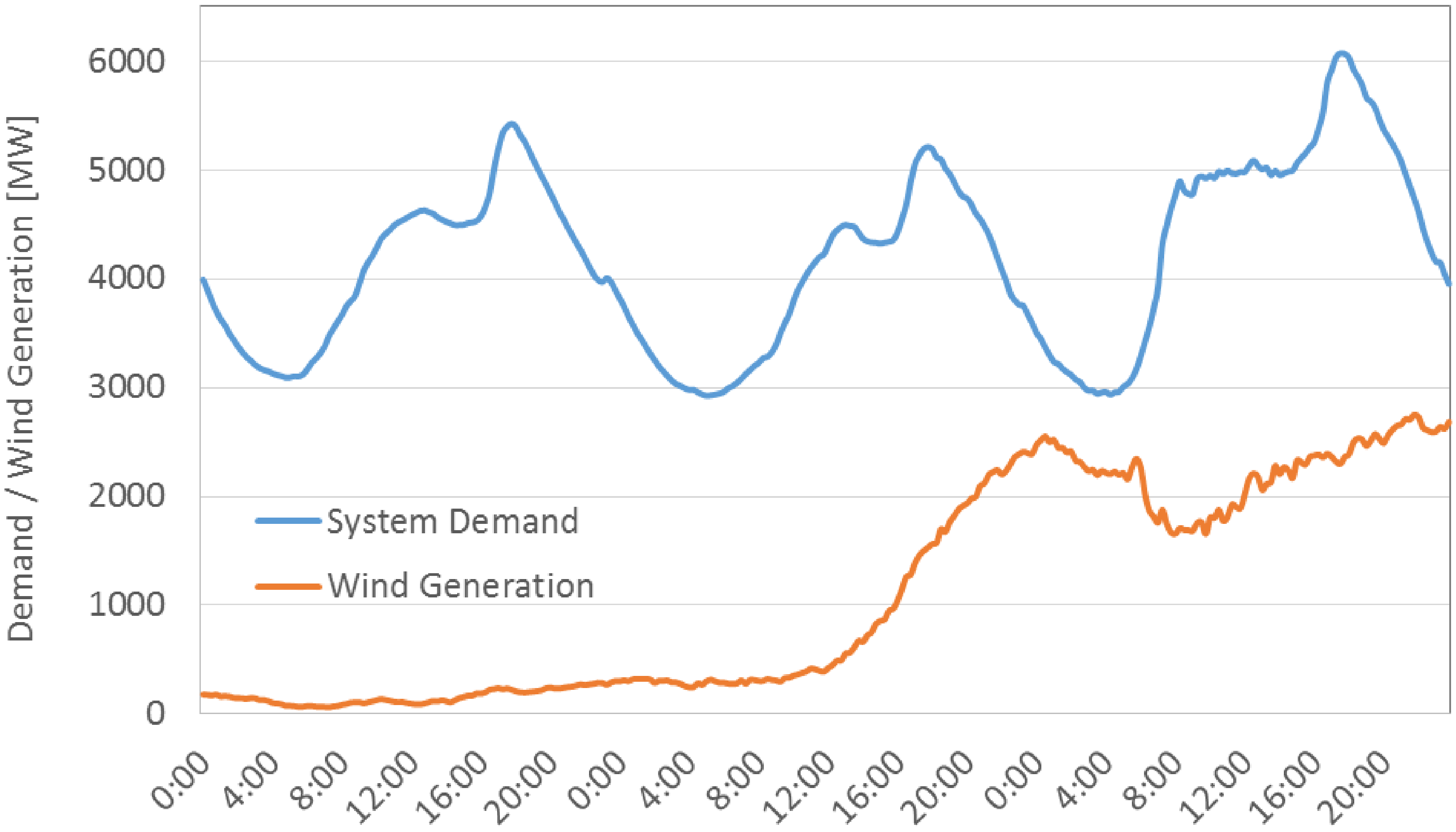
Voltage Control



Injection of active power also affects voltage → higher influence in distribution networks (i.e. PV in distribution feeders affect voltage)

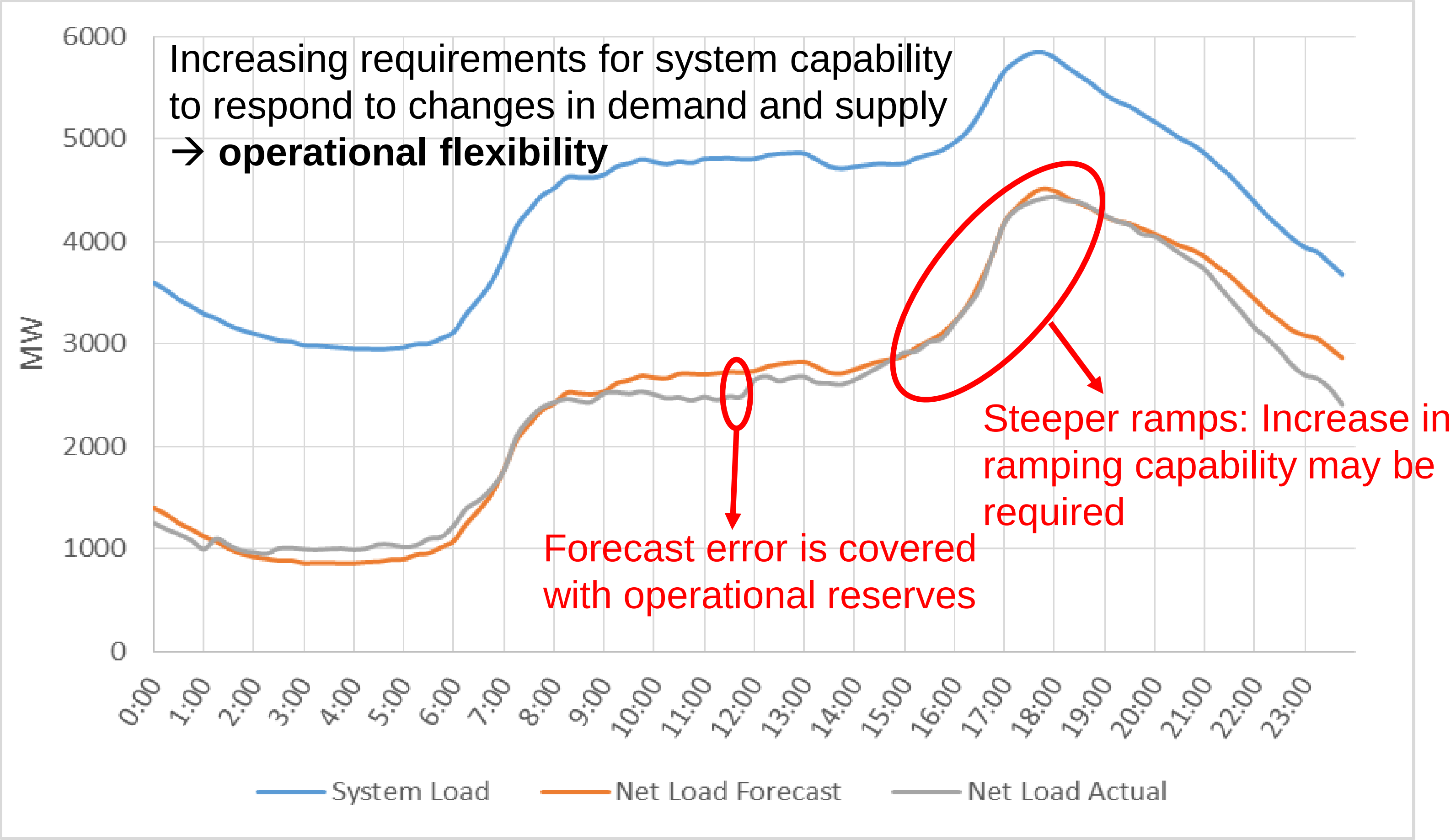
- Voltage at terminals of connection of equipment must be within acceptable limits (i.e. +/- 10% of nominal voltage)
- Voltage control is achieved by production and absorption of reactive power
- Reactive power sources:
  - Generators, capacitor banks, underground cables
- Reactive power sinks:
  - Generators, 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)

Generation does not coincide with consumption



Data from: http://www.eirgridgroup.com

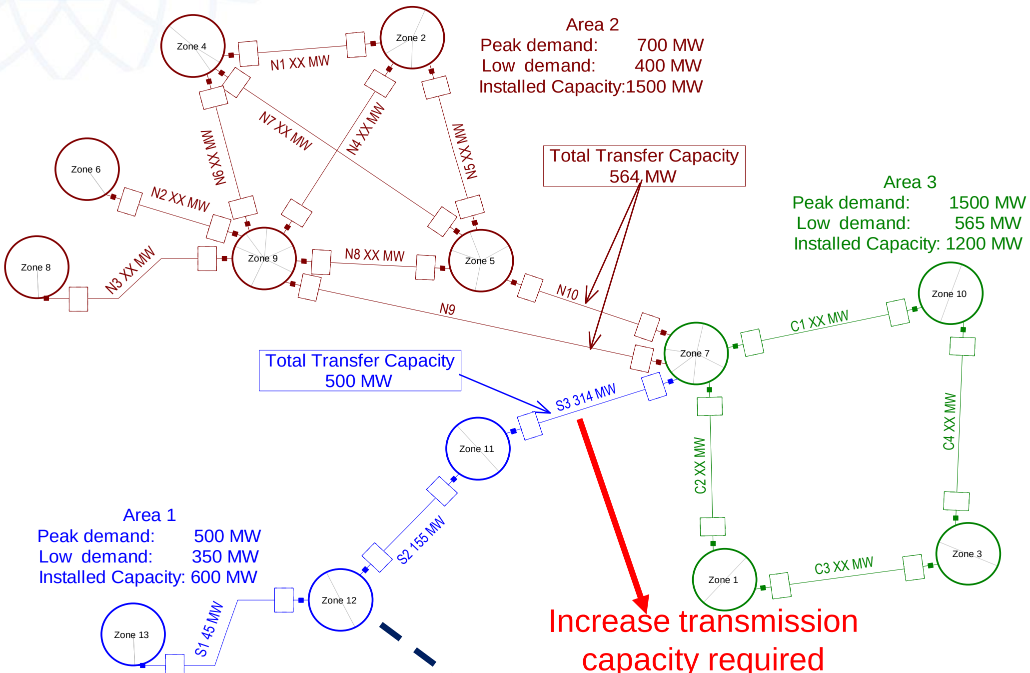
Variability and limited predictability

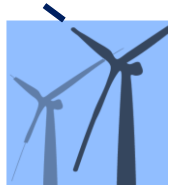


Data from: http://www.eirgridgroup.com

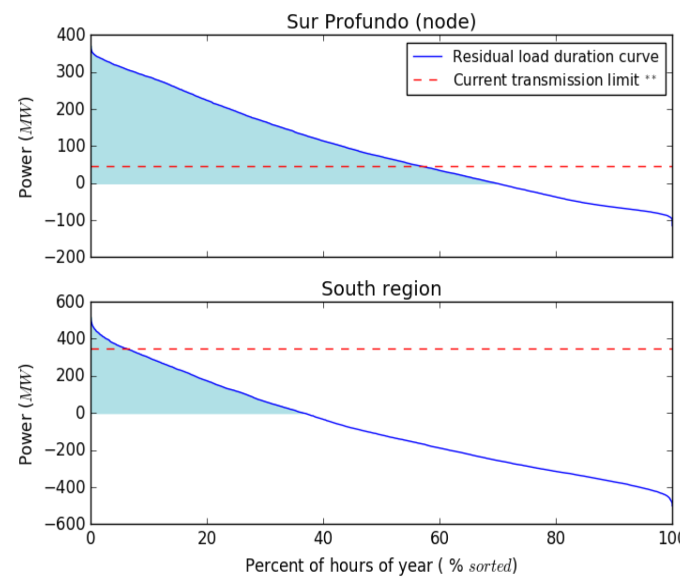
Transmission system adequacy

TRANSMISION SYSTEM OVERVIEW 2016



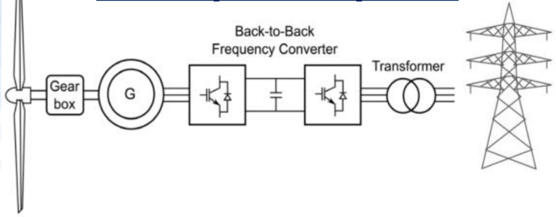


High Wind Resources Zone identified for future development



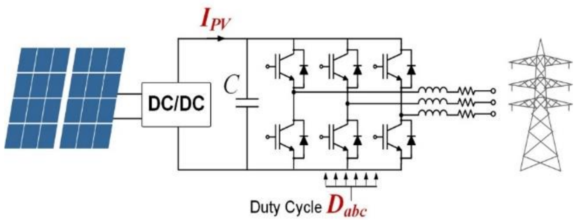
Different interaction with the grid

Wind power plant

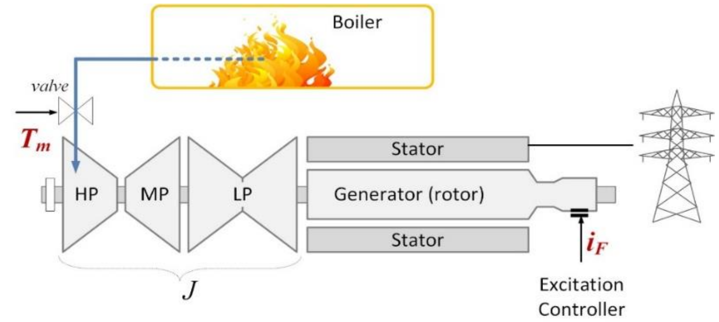


VS

Solar power plant



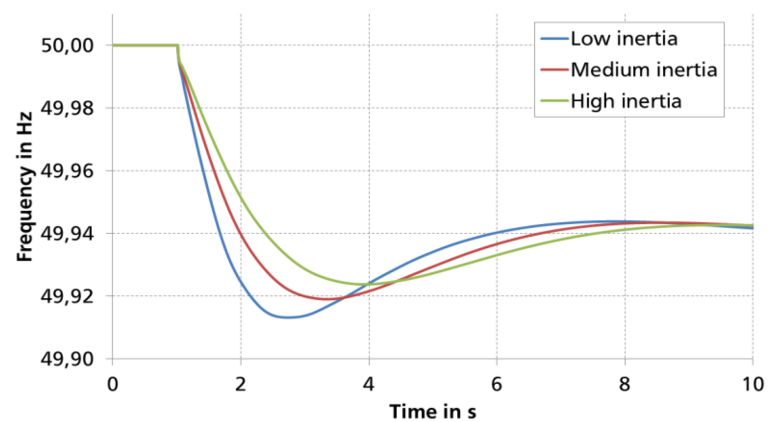
Conventional power pant



Source: CPES Virginia Tech

- 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.**

Inertia



The technical challenges

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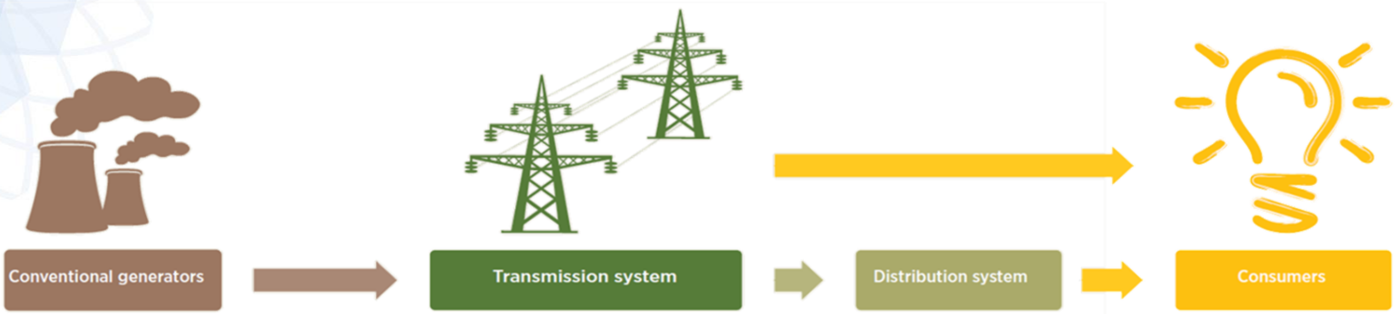


Load-generation balance

- **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

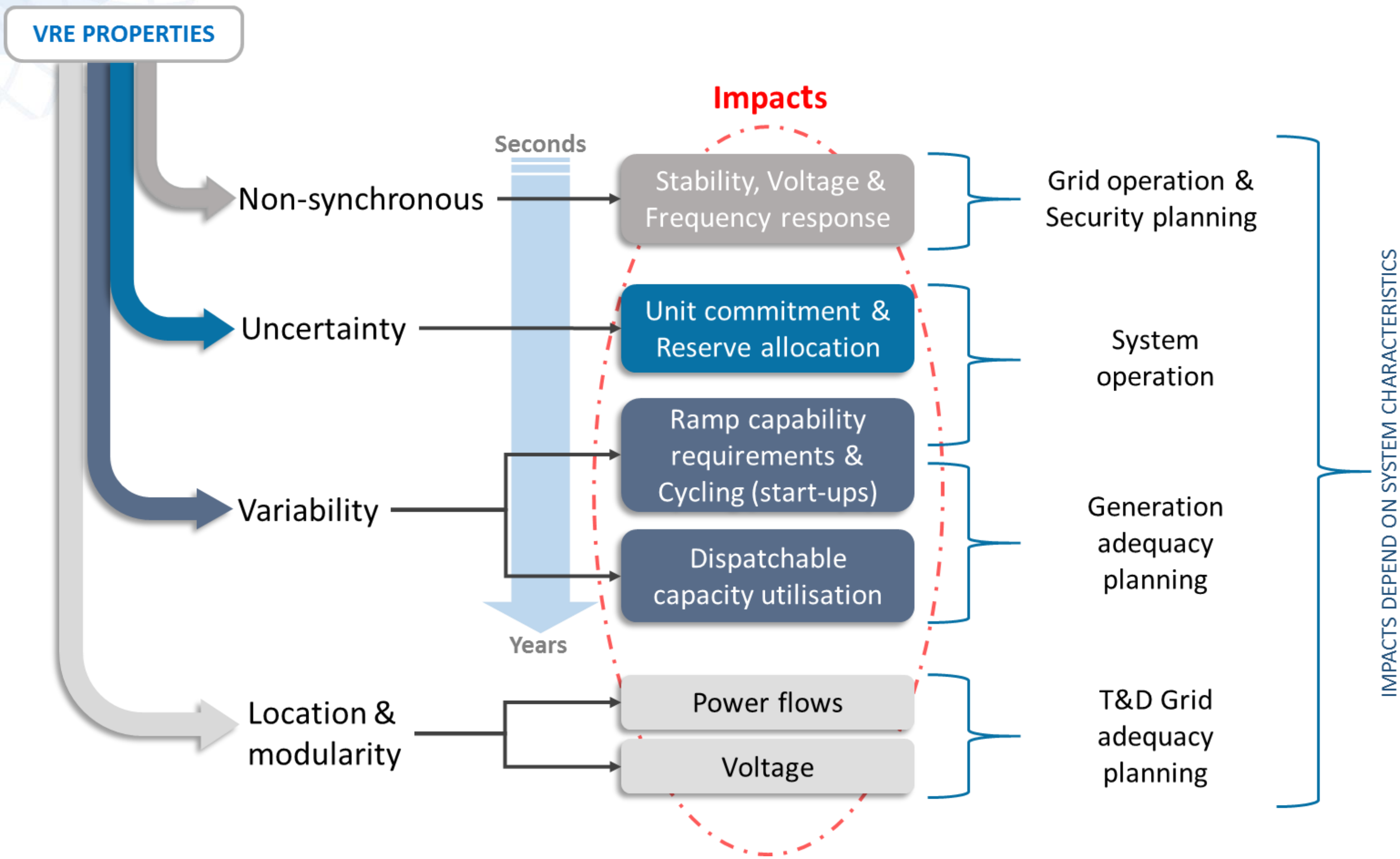
- Reversed **short circuit currents** in case of **fault**
- **Unwanted islanding**: decentralized RE injecting power after a fault leading to **safety issues** during maintenance operation

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



Solutions for the recognised issues are already in place

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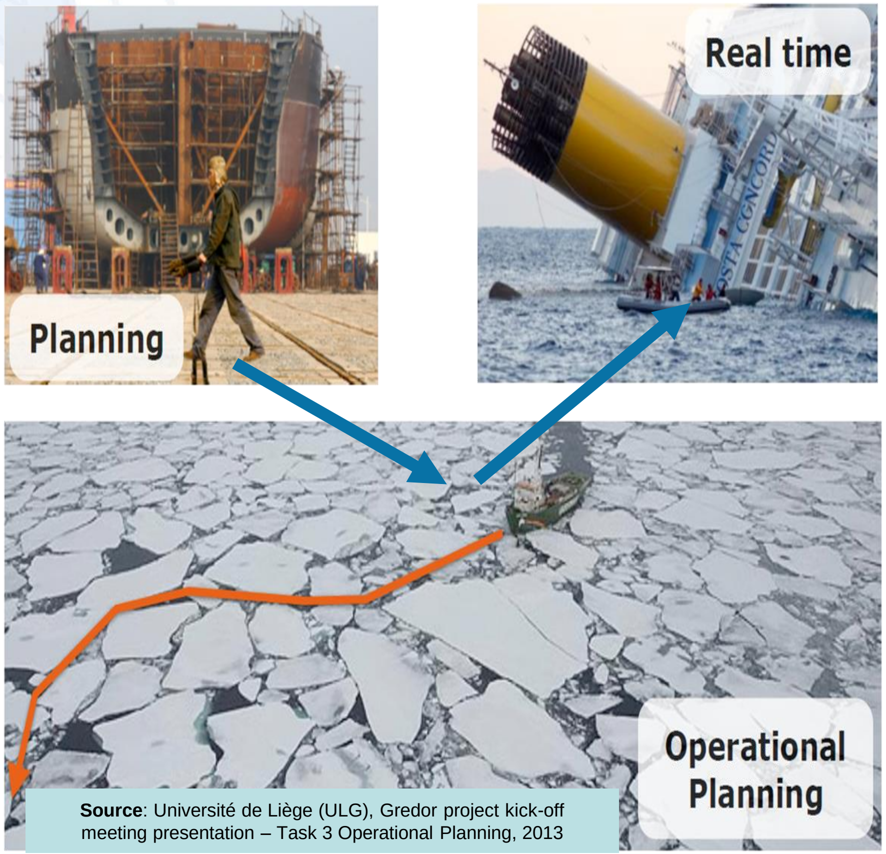
- Provision of grid services from VRE
- Strong transmission grids.
- Interconnection with neighbour systems.
- Flexible conventional generation.
- Storage/ demand side management.
- Specialised forecasting and operational planning tools
- SmartGrids to SmartEnergy to optimize RES utilization across energy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

Looking forward for new innovative solutions

Planning the secure operation of the power system



Source: Université de Liège (ULG), Gredor project kick-off meeting presentation – Task 3 Operational Planning, 2013

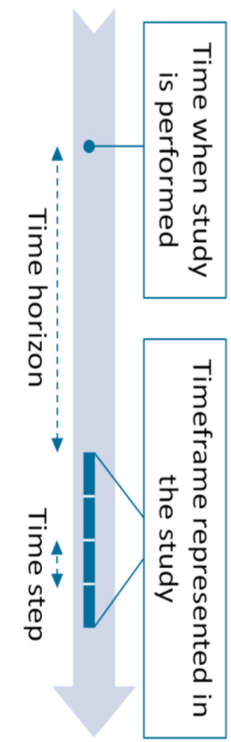
Long term generation adequacy planning

Long term grid adequacy planning

Update of operational constraints / reserve requirements

Outage planning and programming

Day ahead generation scheduling & Security Checks



Real time operation

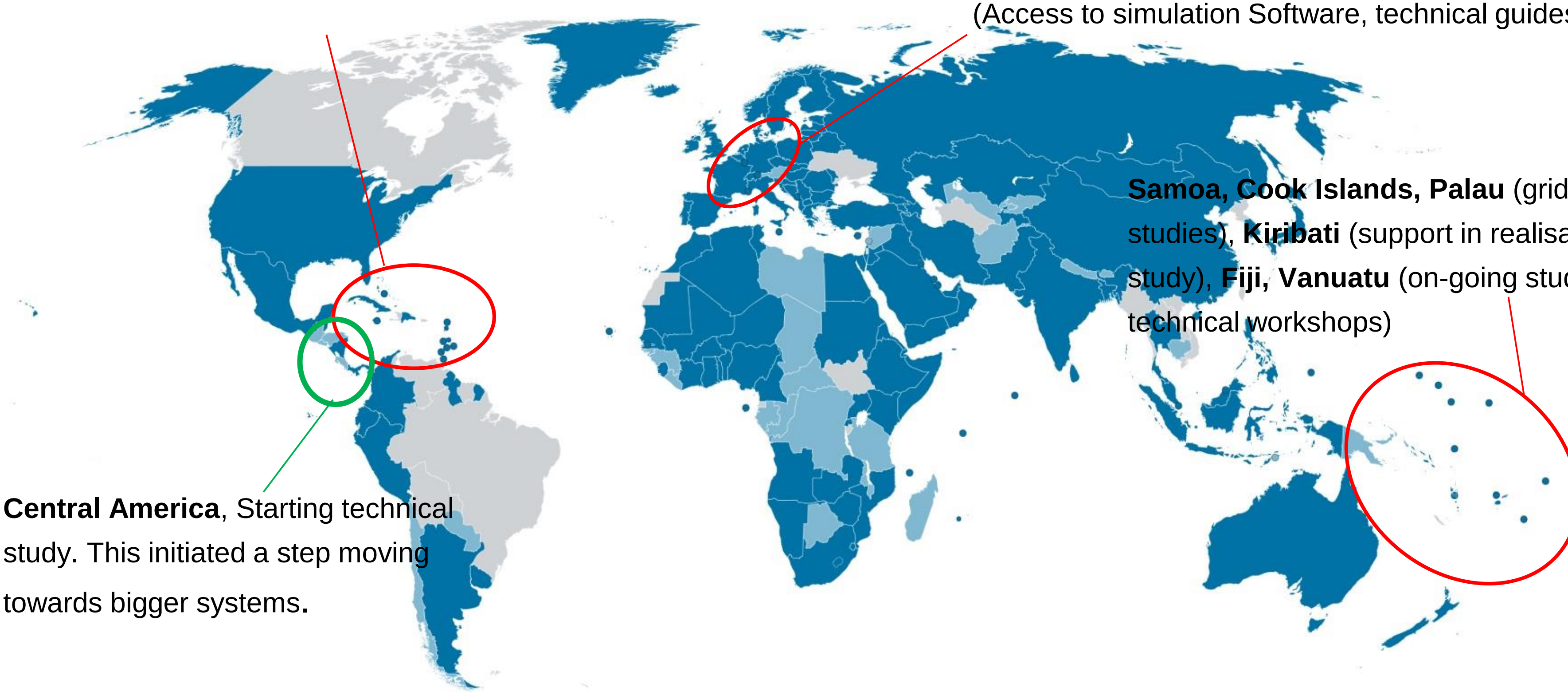
- Power system operation and planning aims to provide a **reliable** and **efficient** supply of electricity at any time.
- Operation of the power system is a very **complicated and critical task** that must be supported by a **strong planning process.**

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)



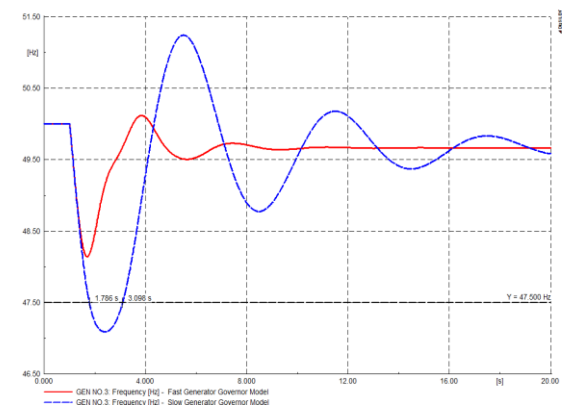
Samoa, Cook Islands, Palau (grid studies), **Kiribati** (support in realisation of study), **Fiji, Vanuatu** (on-going studies, technical workshops)

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

VRE Grid integration studies

RE Roadmaps → **Grid Integration studies**

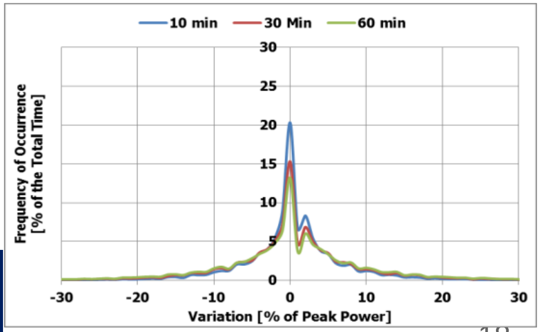
- Identification of technical constraints
- Recommendations on grid infrastructure investments
- Recommendations on Grid support functions to be provided by VRE / Planning & Operational procedures



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

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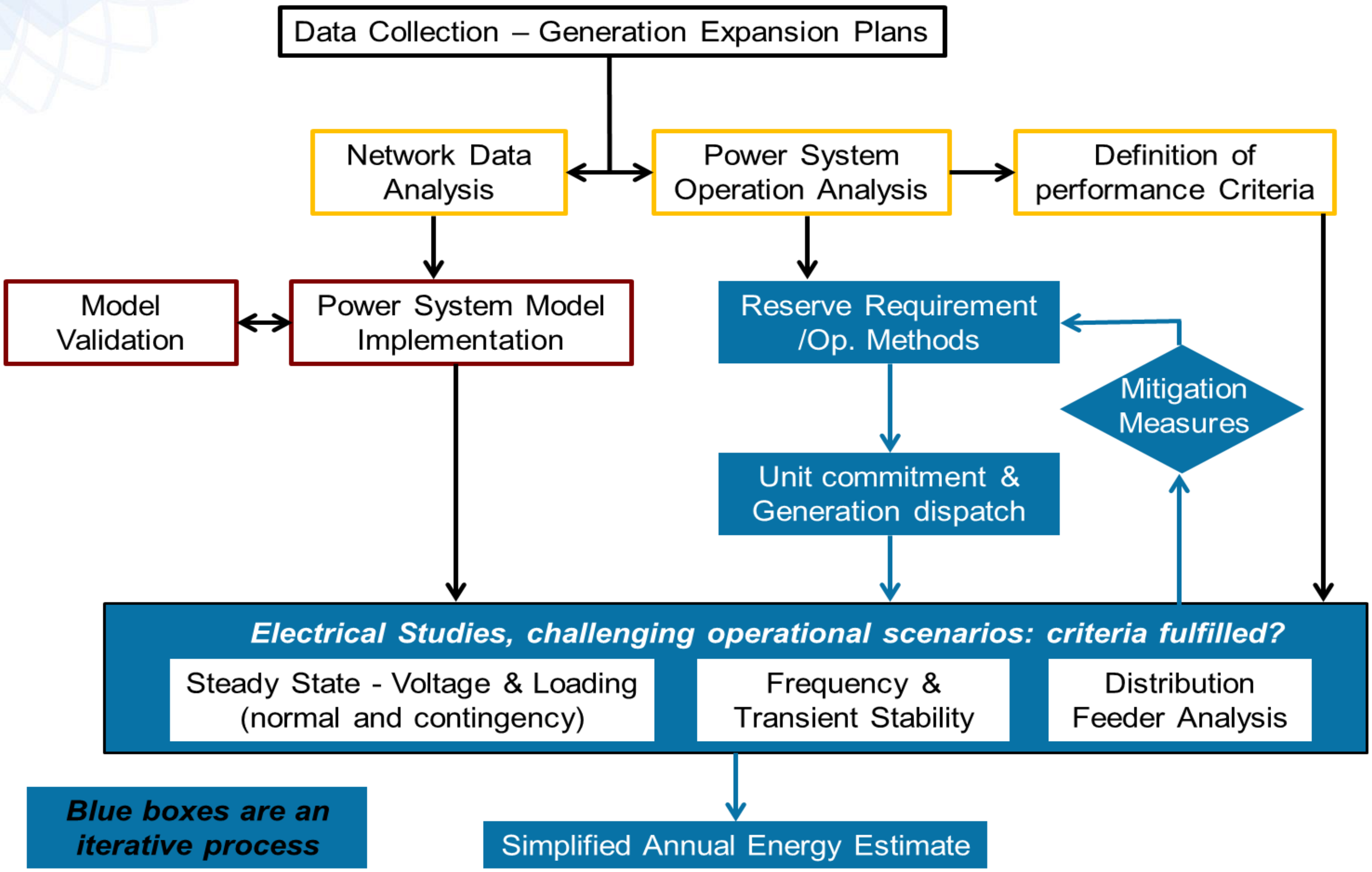
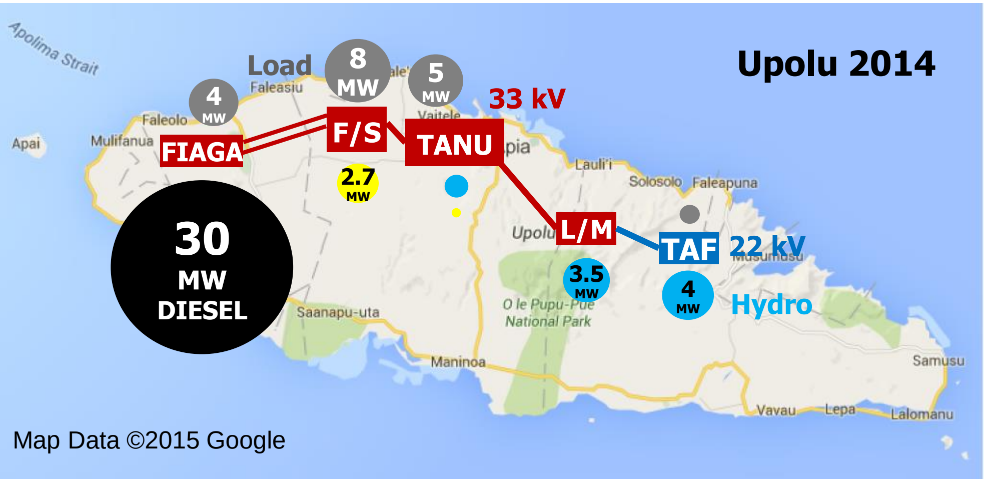
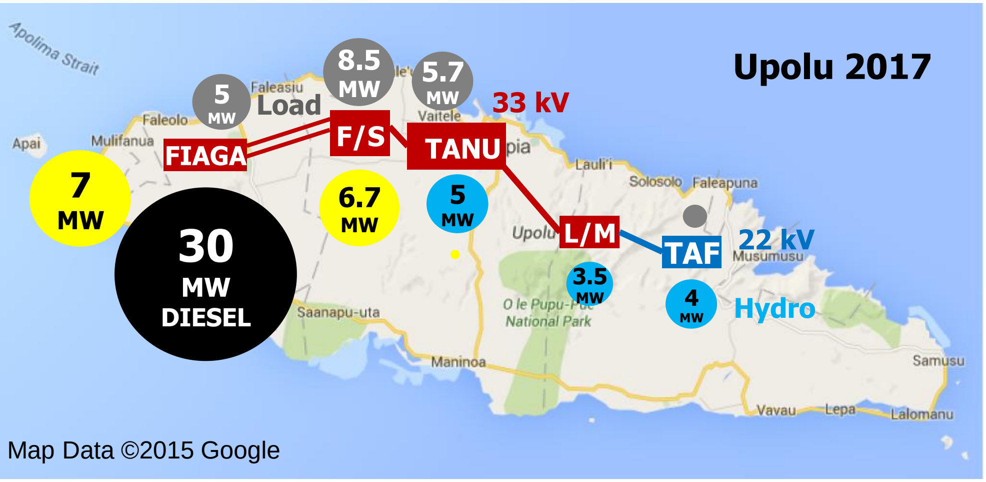


CASE SAMOA - UPOLU

- 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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		Time horizons at which assessment is generally performed			Parts of the power system to be represented		
		Mid- and long-term planning (month to years ahead)	Operational planning (day to week ahead)	Real time dispatch (second to minutes ahead)	Load & generation	Transmission	Distribution
	Generation adequacy						
	Sizing of operating reserves						
	Generation scheduling						
Static	Load flow & static security assessment						
Static	Voltage & reactive power control						
Static	Short-circuit currents						
Dynamic	System stability						
Special	Protection coordination						
Special	Power quality						
Special	Defence plans						(UFLS & UVLS)

Guide : Stability in small and isolated power systems with high share of VRE

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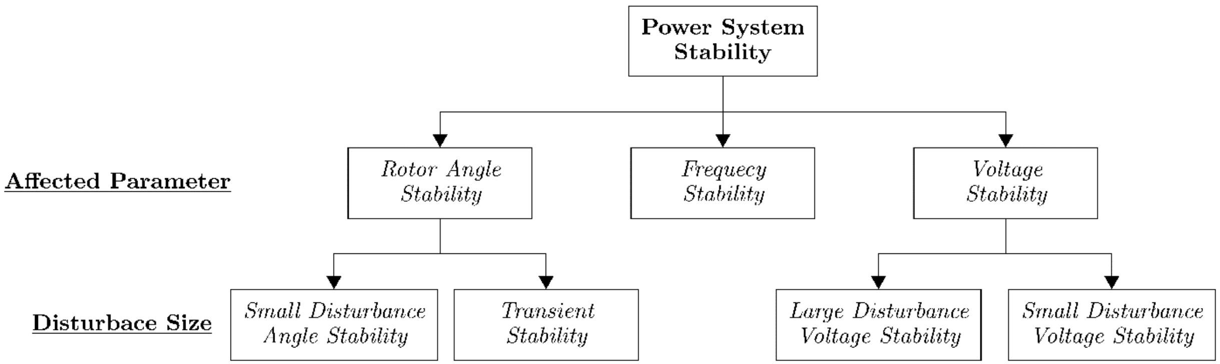

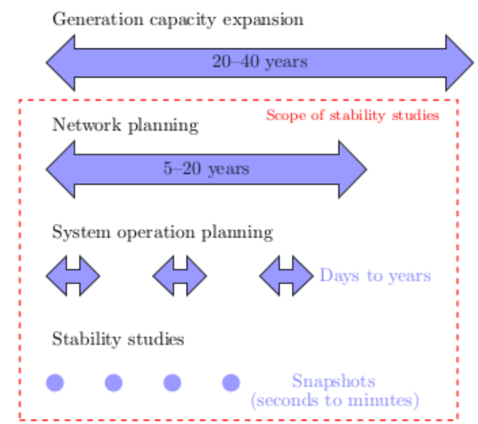

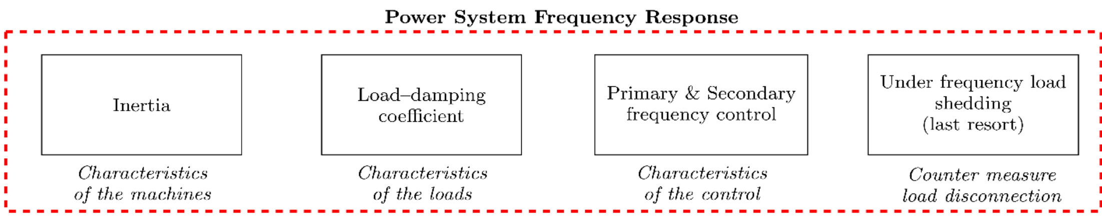

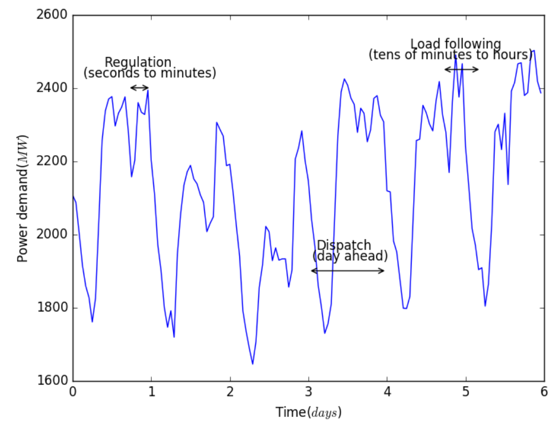

Aims to:

- 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

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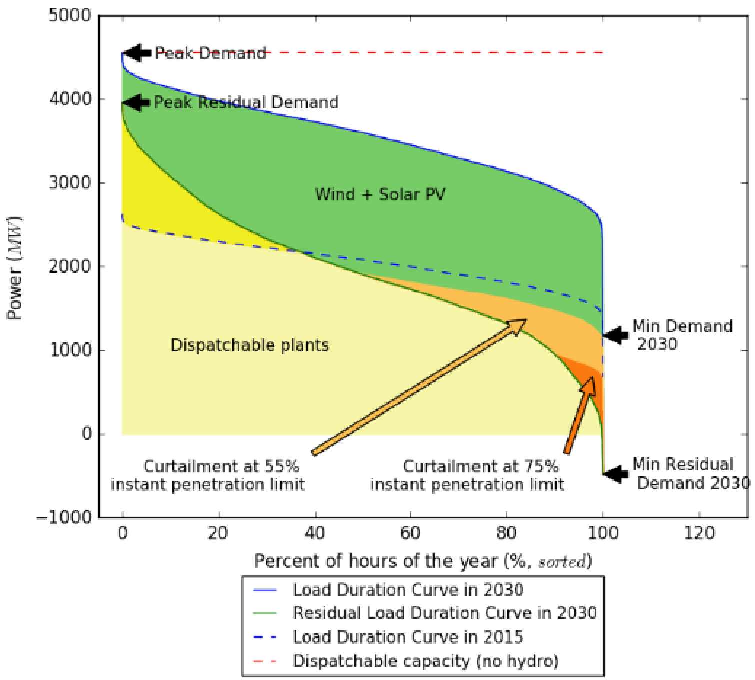
- ✓ Webinars and technical workshops in partnerships with local stakeholders and regional organizations
- ✓ Global access and support in use of stability analysis software DigSilent PowerFactory
- ✓ Guides on grid stability and technical assessments for grid integration planning

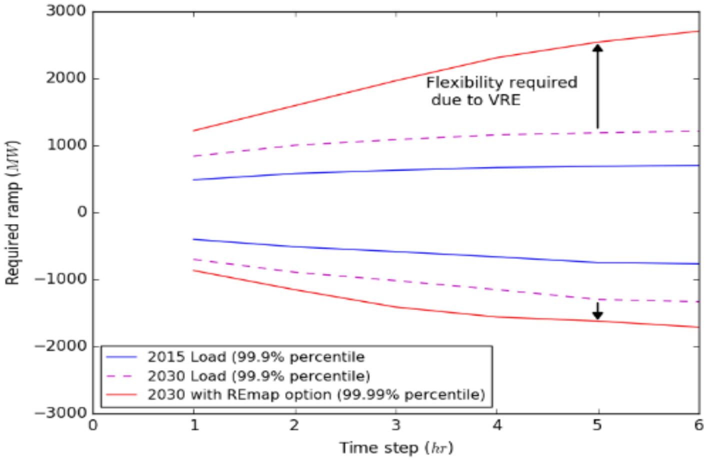
Support in planning the operability of larger isolated systems – Dominican Republic

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

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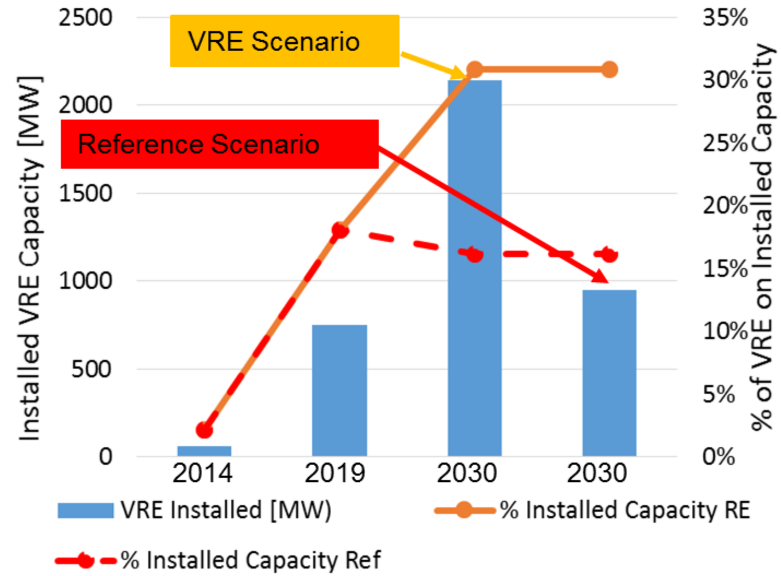
- High shares of VRE expected in the mid term.
- Associated technical challenges must be addressed.
- TSO has a very well stablished planning process already including impact of VRE.
- **Project plan is currently under development with national stakeholders. Based on exchange of knowledge considered 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



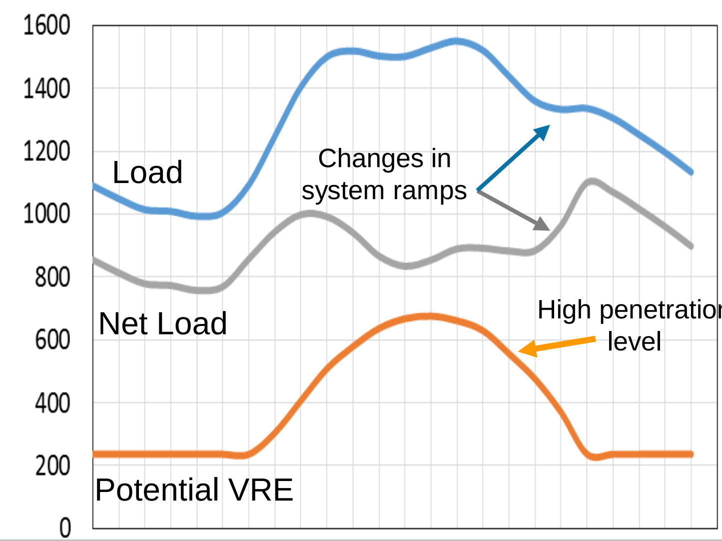


Illustration of potential VRE and impact on daily operation (wind assumed constant, using data from CND)

CONCLUSIONS

- 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 a lot of work to do

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