IRENA

International Renewable Energy Agency

South East Europe Workshop on Grid Integration of Variable Renewable Energy Sources

Challenges And Solutions For Interconnected Power Systems

Vienna. 7th November 2018

Grid Integration Team

IRENA Innovation and Technological Center. Bonn

International Renewable Energy Agency

- Power sector transformation
- Grid integration assessment team
- Challenges to integration of variable renewable energy (VRE)
- Mitigation measures
- Case studies

Power sector transformation

Power sector planning and transformation

International Renewable Energy Agency

Planning scopes for techno-economic analysis

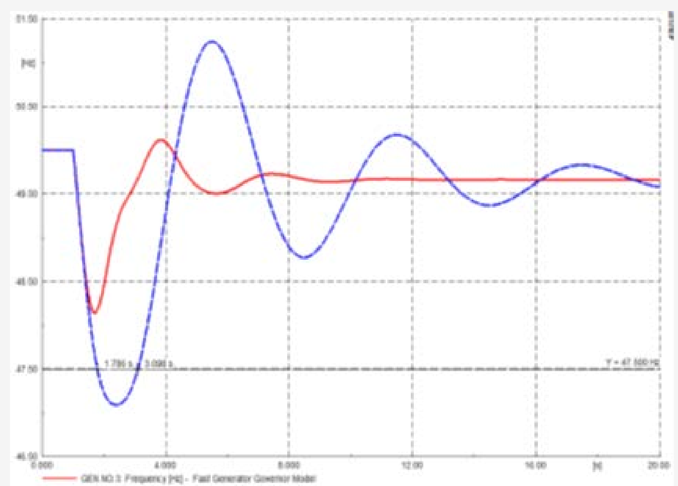
Generation expansion planning

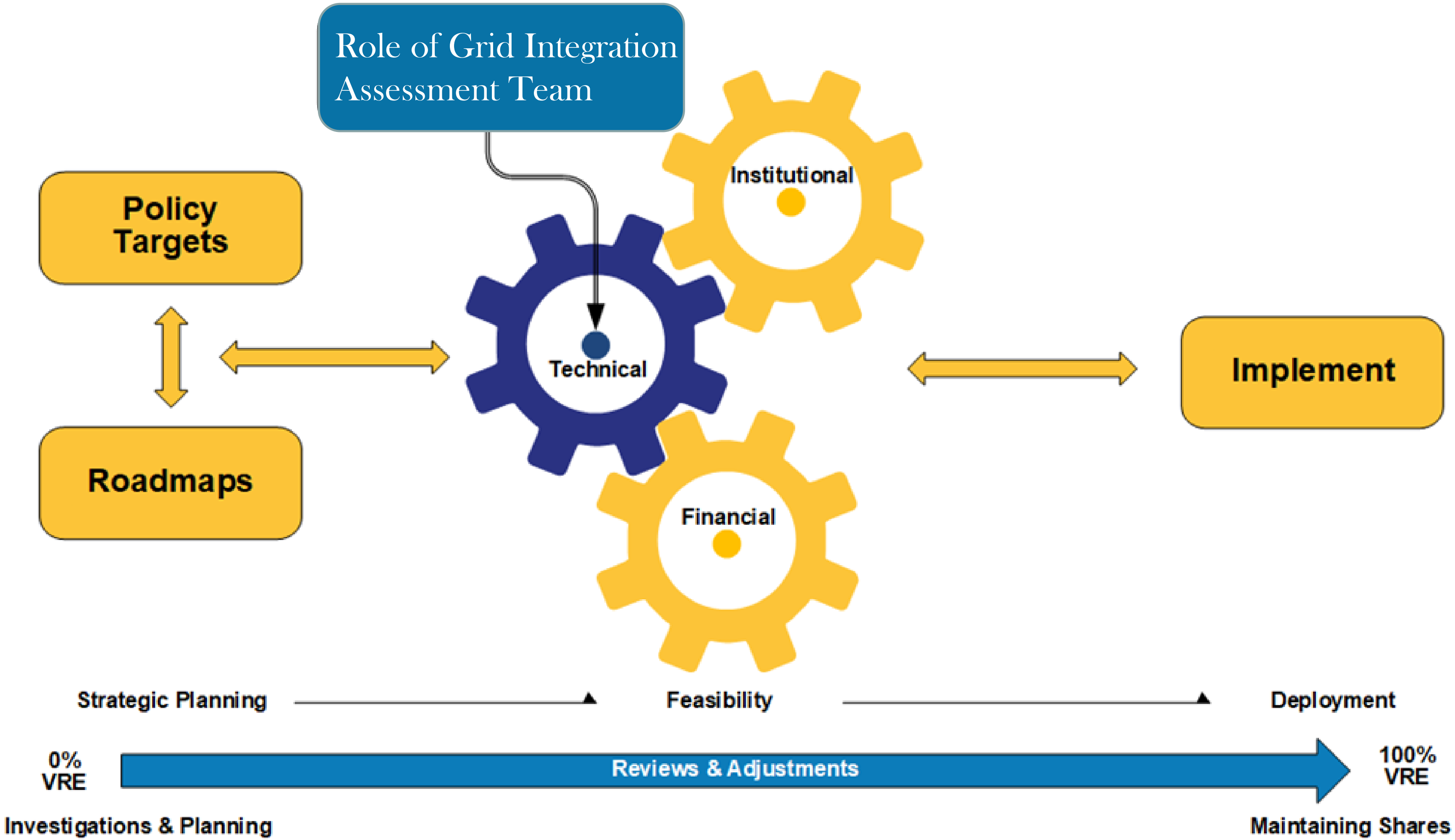
Geo-spatial planning

Dispatch simulation

Technical network studies

- TSO
- Regulator
- Project developer





Based on : IRENA 2018(unpublished)- "Transforming small-island power systems- Technical planning studies for the integration of variable renewables"

What we do

International Renewable Energy Agency

Technical assistance for grid assessment studies

- Based on the system specifications and priorities of each country
- Modelling of the existing system and any proposed growth in system in an Industry friendly power system software
- Assess by means of technical studies
  - ✓ how much VRE can be included- without major investment-hosting capacity
  - ✓ feasibility and impact of increasing the penetration of RE in the system
  - ✓ the optimum level of integration of RE and the measure required to achieve them.
- Give recommendations to mitigate technical challenges that are evident from the study
- Capacity building

What we require

- Accurate and sufficient information regarding the system
- Cooperation and engagement from stakeholders

Projects Completed

- Antigua and Barbuda
- Cook Islands-Aitutaki
- Palau
- Samoa
- Vanuatu
- Fiji

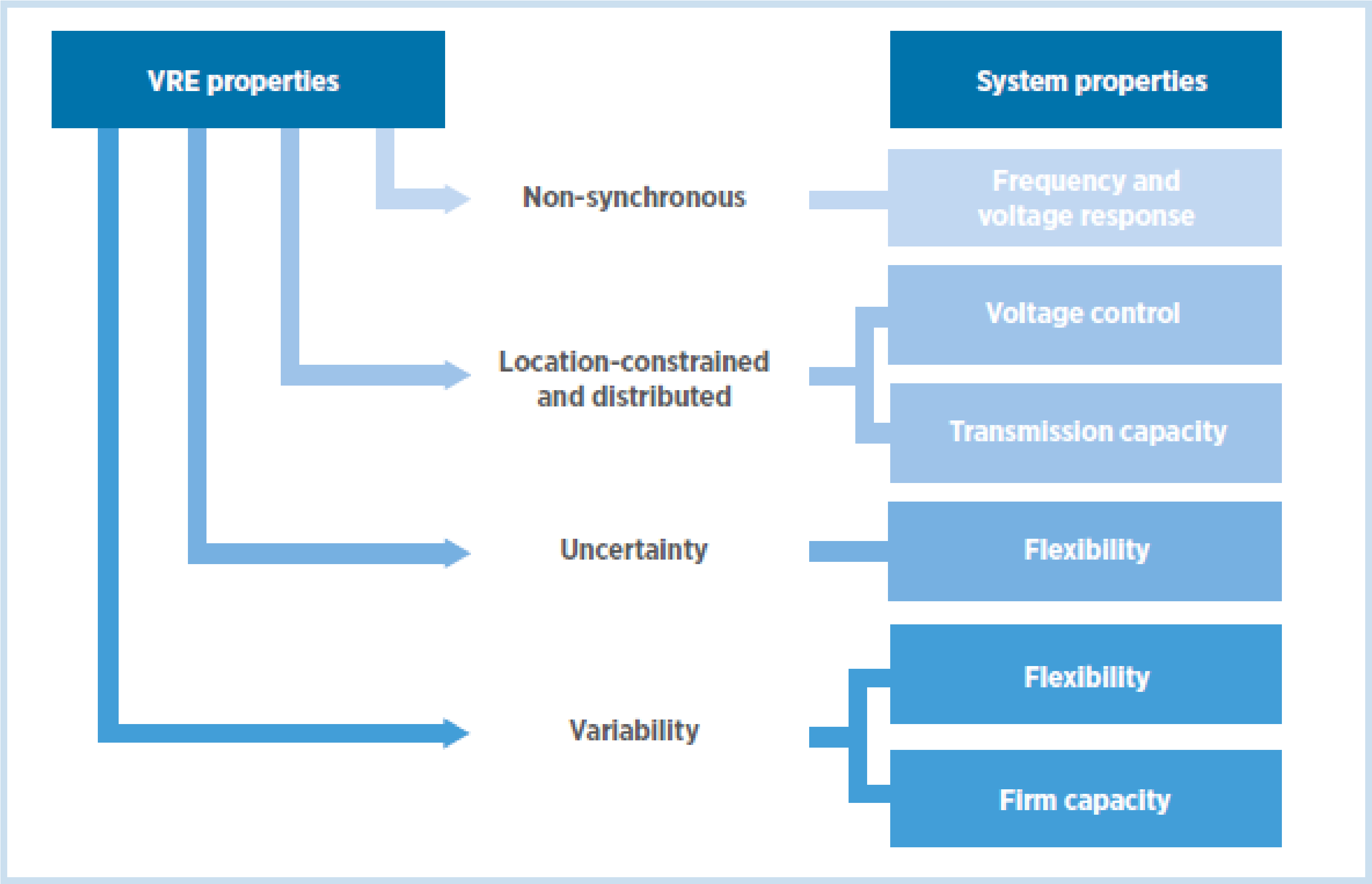
In progress

- Dominican Republic
- Mozambique

Challenges To VRE Integration in Interconnected Power Systems.

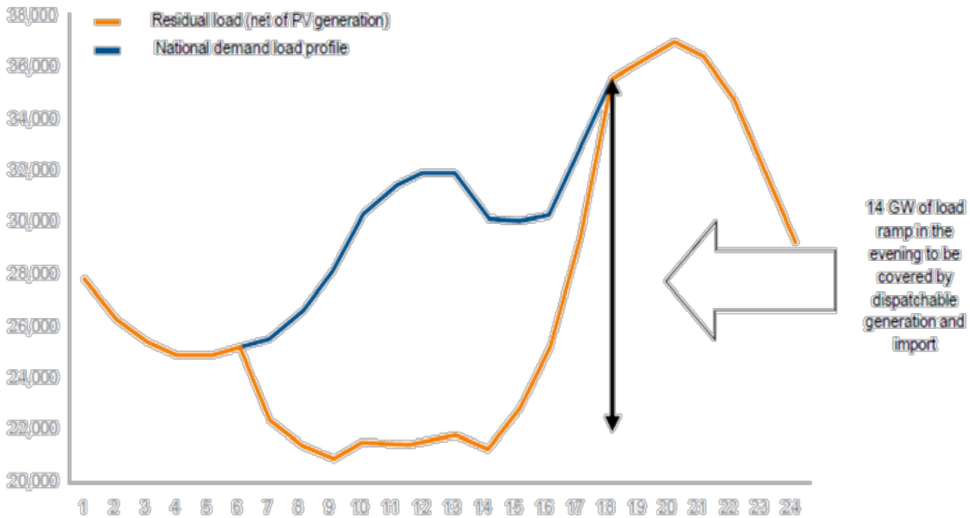
Key links between variable renewable energy and power system properties.

International Renewable Energy Agency

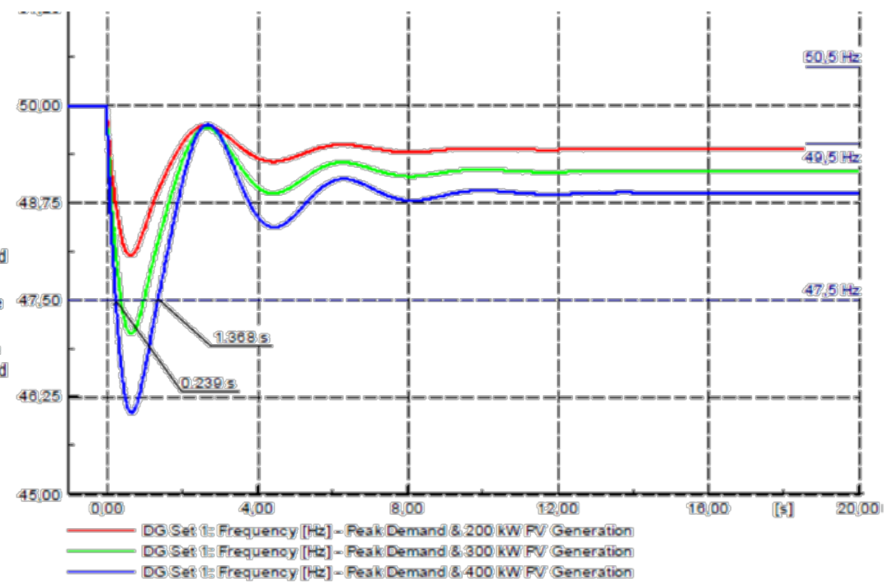


Based on : IRENA 2017

Dealing with variability, uncertainty and stability



Italian demand and VRES effect
Source: TERNA



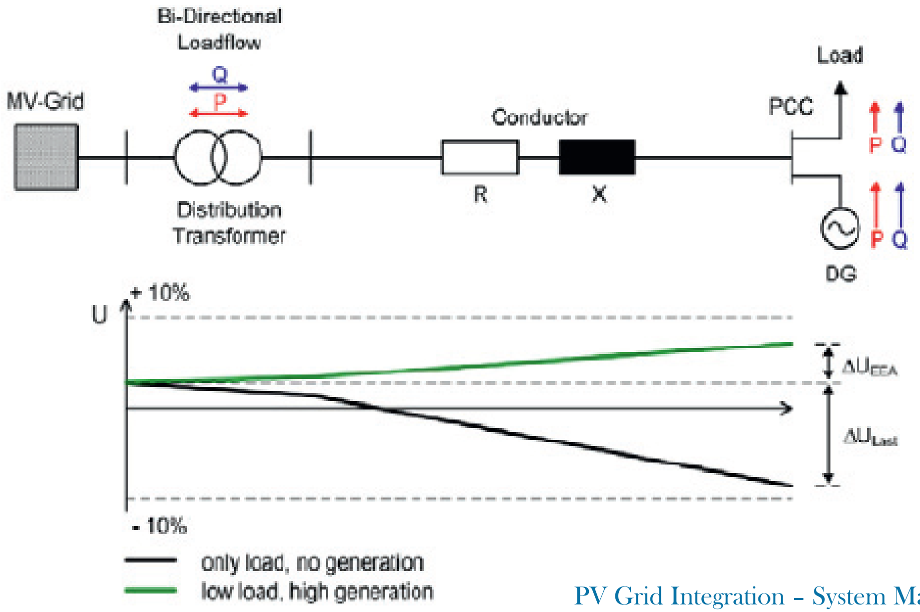
Source: IRENA 2016 Unpublished

Utility scale generation-TSO's

- Impact to conventional Generation
- Ensuring firm capacity/Reserves
- No correlation with load
- Location and modularity
  - Away from load centers

- Non synchronous nature-Inverter based generation -Inertia
- Frequency
- Voltage
- Rotor angle stability-Dynamic and Static security

Dealing with point of interconnection



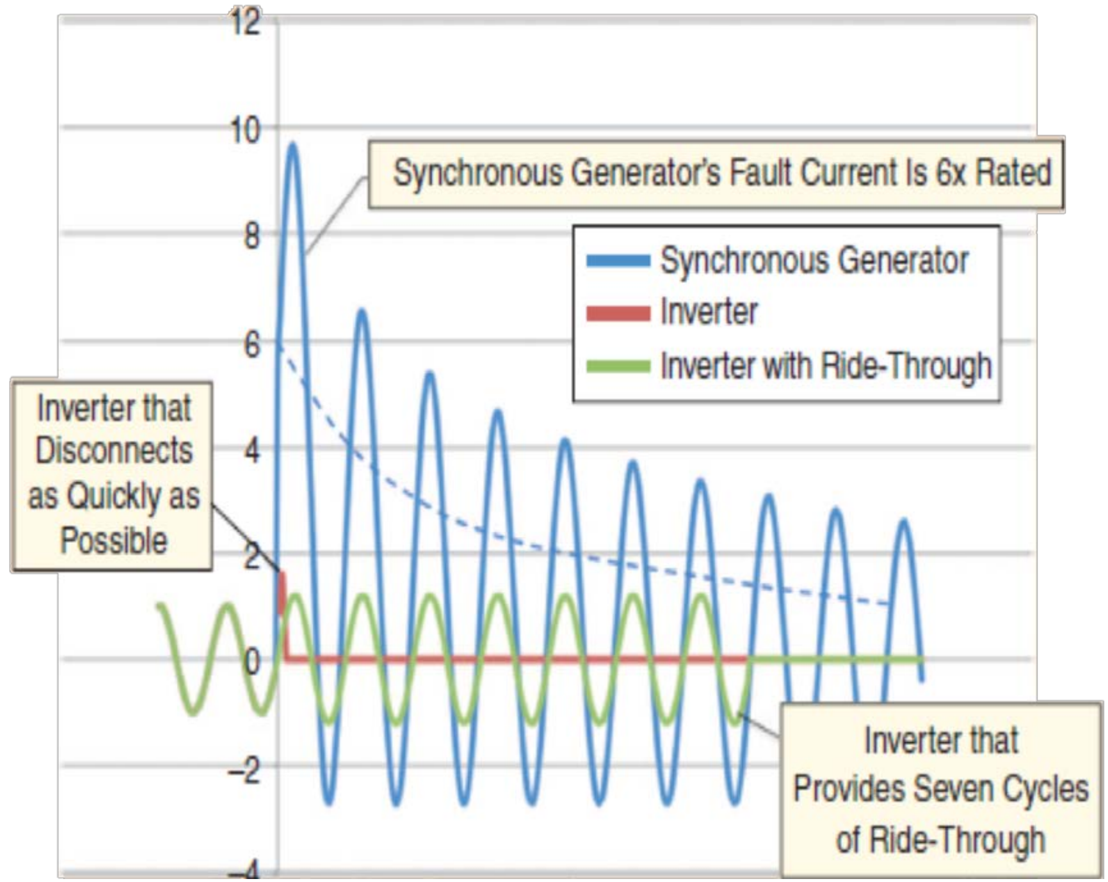
PV Grid Integration – System Management Issues and Utility Concerns-Article *in* Energy Procedia · December 2012

Problems faced at DSO level

- Feeder impacts-Leads to increasing power-flows in primary and secondary substation
- PV as distributed generation at LV/MV level
- Challenge to control from national dispatch center
- Increasing pressure on measurement and protection systems
- Impact of fault may be spread wider causing power quality to suffer
- Reduced rotating machines so inability to withstand unplanned events

Power system protection and power quality

- Ensure effective functioning of protection systems
- Maintaining the voltage and frequency
- Harmonics
- Control and communication between VRE and control centers

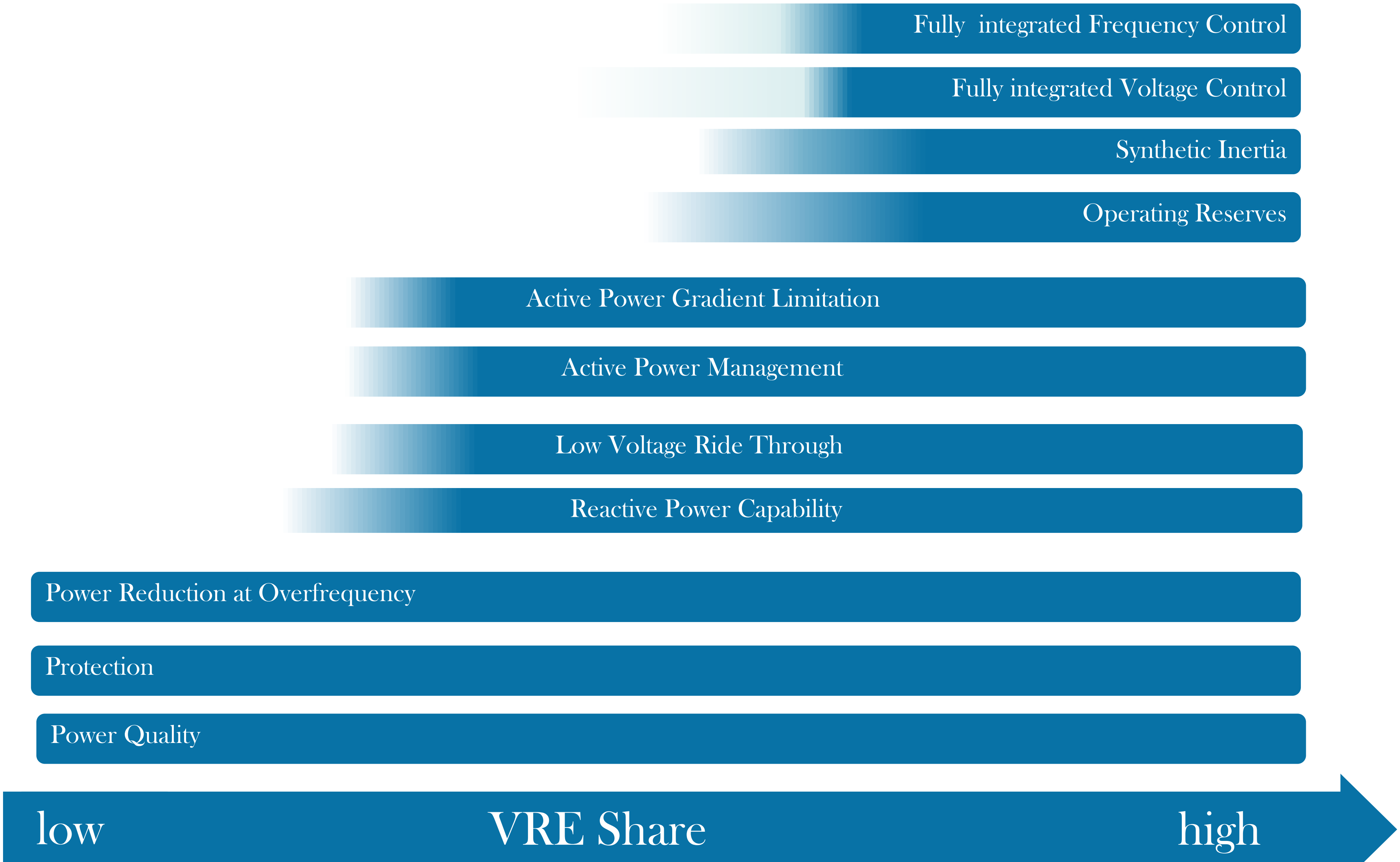


Source: "Achieving a 100% Renewable Grid"-IEEE Power and Energy magazine 2017

Issues in SEE:

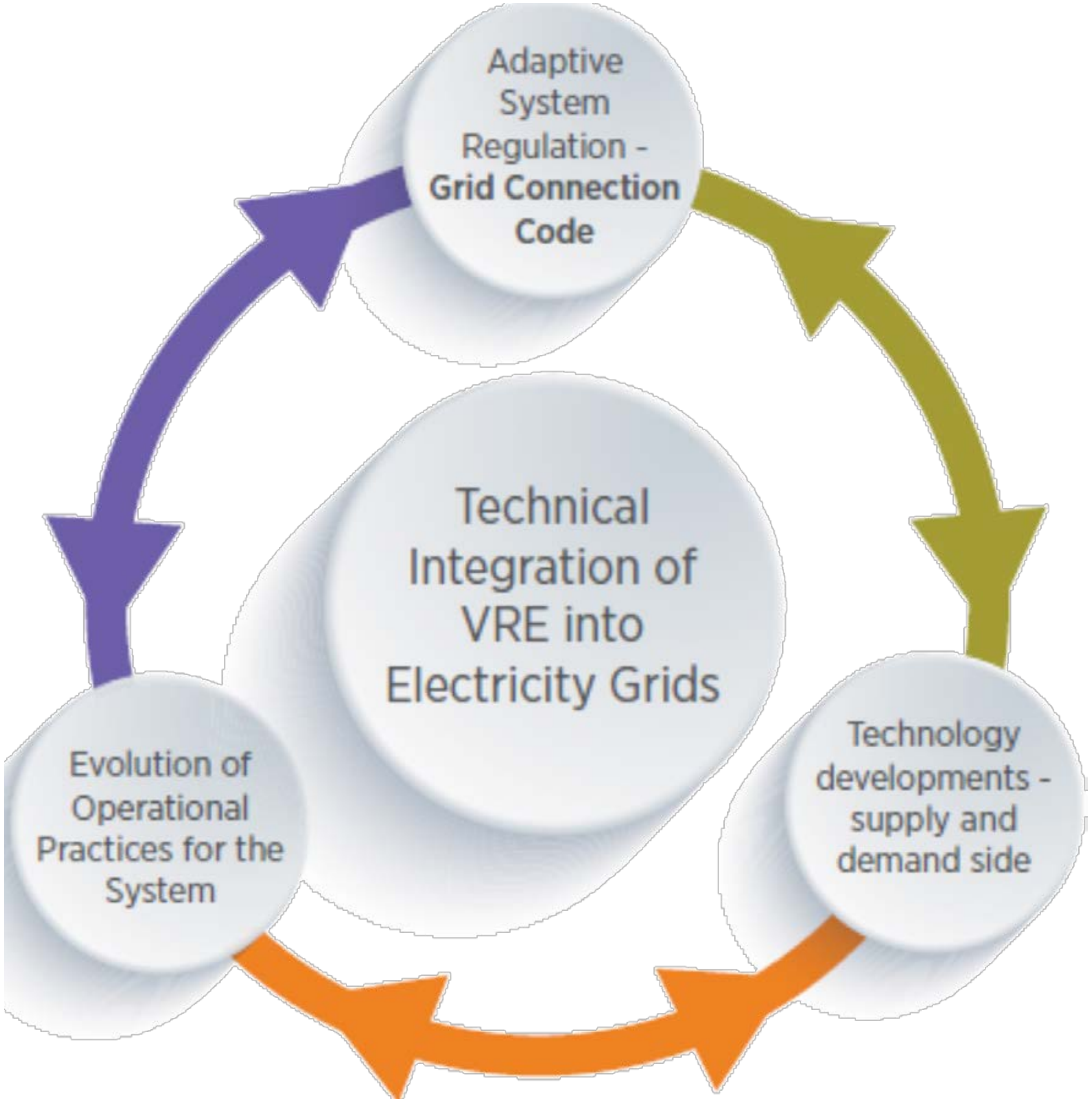
- Grid connection issues
- Ability of grid to integrate large renewable energy projects
- Technical inability to allow RE expansion
- Restrictions on amount of VRE
- Lack of technical capacity

Relation between VRE share and technical issues



Based on: IRENA 2016

Mitigation measures



Source: IRENA 2016

Operational Measures : Stability obtained from studies

IRENA
International Renewable Energy Agency

Voltage stability

TSO level

Reactive power compensation equipment- network reinforcement

Develop grid code requirements for low voltage ride through (LVRT) and ensure compliance

DSO level

Review transformer’s tap position and/or voltage set-points

Reinforcement of transformer capacities

Investment in cables

Corrective actions from the operator

Optimal usage of reactive power compensation devices

Adapting voltage set points

VRE curtailment

Generation redispatch

Upgrading to a higher voltage level, splitting/meshing the network, upgrade circuit breakers

- Communication
- Adjustable reactive power
- Constraining active power (active power management)
- LVRT including current contribution
- Stand-alone voltage control
- Full integration into general voltage control scheme

Frequency stability

- **TSO level**
- Increase frequency regulation from VRE sources
- Deployment of energy storage
- Generation redispatch and/or
- **DSO level**
- Improvement of under frequency load shedding (UFLS) settings.

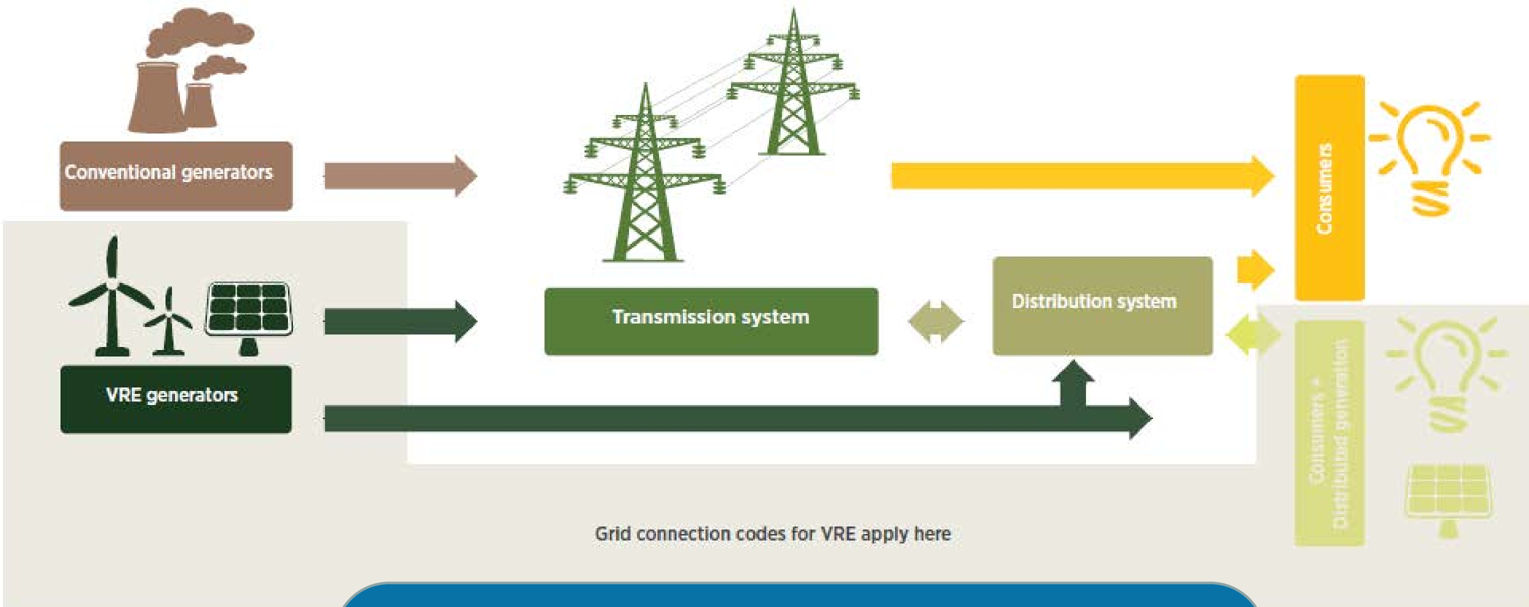
- **TSO level**
- Active power management
- Active power gradient limitation
- Reduced output operation mode for reserve provision
- Synthetic inertia
- Full integration into general frequency control scheme
- **DSO level**
- Stand-alone frequency control

Operational Measures: variability and uncertainty…

International Renewable Energy Agency

DSO level
- Demand response programs
- Enhanced protection plans

TSO level
- Generation adequacy
- Limited curtailment for extreme events



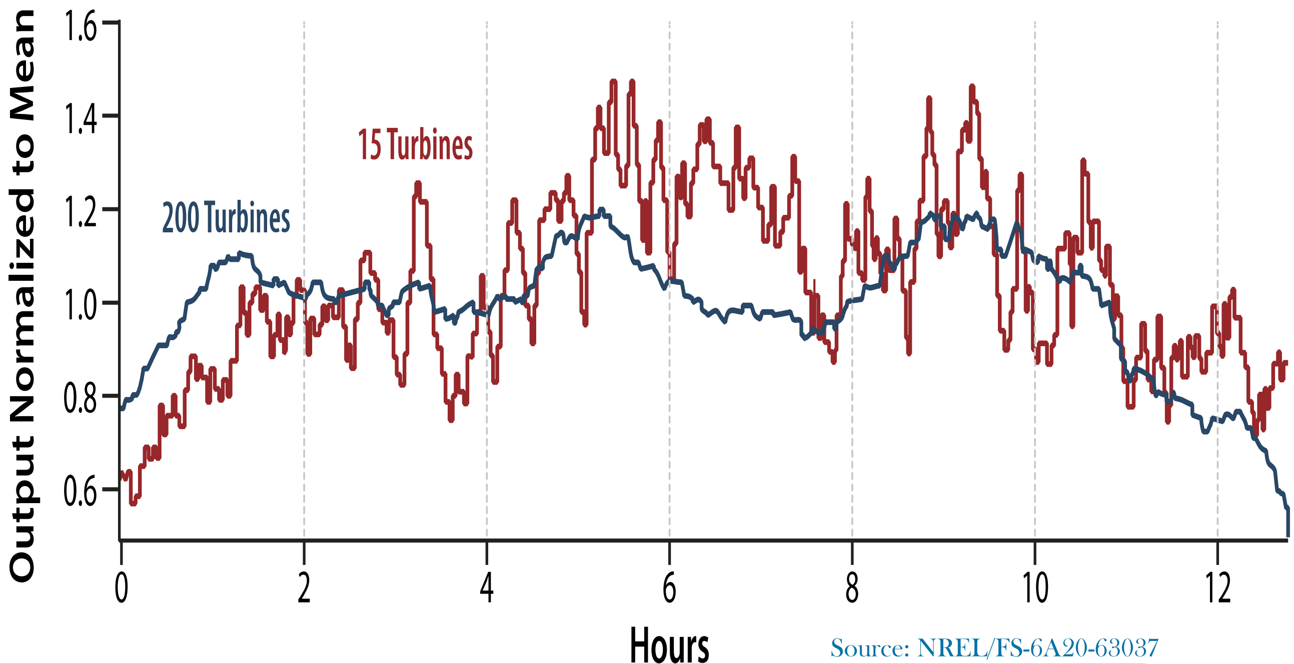
- Adapted generation dispatch and control
- Automatic power control and network monitoring- Automation and smart grid technologies

Source: IRENA 2016

Infrastructure investments: Location and modularity- Improve Grid Flexibility

International Renewable Energy Agency

- Energy storage systems
- Interconnection with neighboring systems
- Enlarging grid inter connections
- Conventional T and D grid reinforcements.
- Diversification / aggregation of VRE installations
- Improved forecasting
- Energy management systems

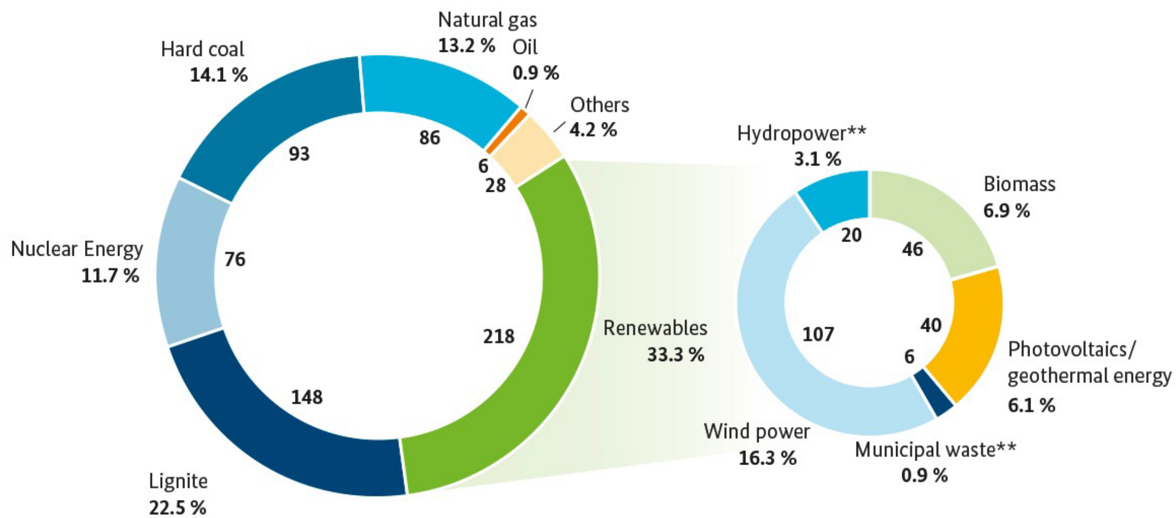


Source: NREL/FS-6A20-63037

- Smart protection systems
- Active anti-islanding techniques
- Adapting to instantaneous thermal rating of transmission lines
- Automation and smart grid technologies
- Smart centralized generation
- Using High Voltage DC cables and superconductors
- Off grid and grid connected micro and mini-grids.-Smart cities
- Smart Inverters and switches, capacitor banks
- Using Inter communication systems (ICT) systems, sensors- wide area measurements systems

The German/ European Experience

- Solar-1.6 million installations
- Wind power-5407MW offshore capacity
- Biomass- 24% of RE



Gross-electricity-generation-Germany 2017 in TWh
Source:https://www.bmwi.de

- The 50.2 and 49.5 Hz problem
- Reactive power-RE to deliver Q
- Incentives- decentralised battery storage support schemes
- Citizens drive for energy transition

International Renewable Energy Agency

IRENA Case studies

Antigua and Barbuda

Scenarios studied:
- Analysis without VRE and peak demand
- Analysis of maximum penetration of VRE with peak demand-voltage and loss of largest generator
- Analysis of maximum VRE with minimum demand-frequency stability due to large frequency deviations

Recommendations

- Automatic curtailment at times of low demand and high penetration of PV and wind
- ±0.95 power factor to be maintained by inverters
- Third diesel unit to cover low load and low PV for provision of reactive power.
- Distributed units with Fault Ride Through capability
- Implement AGC and automatic and centralised control system
- **9 MW of Solar-PV and 18 MW wind was feasible keeping the reliability of the system intact**

Samoa

2014

- 29.8 MW of diesel generation,
- 8.5 MW of hydropower,
- 2.85 MW of solar PV and
- 0.55 MW of wind power.
- Electricity demand -115 GWh

2017

95% of RE with major impact solutions such as

- reactive power compensation device,
- Battery Energy Storage Systems and
- Automatic generation control including hydro units,
- Adjustment of UFLS settings,
- FRT capability for new PV plants,
- Voltage control in all PV plants with ±0.95 power factor

Fiji

1.Objective: Identify the **PV hosting capacity** at distribution and system level in Viti Levu island of Fiji.

2. Methodology:

- Obtain high resolution solar data
- Identify the locations with highest solar resource capacity and accessibility to grid connection
- Modelling and Grid assessment of the distributed level (11kV) and system level (33 kV) with PV, including the frequency, voltage and transient stability studies.
- Identify thumb-rule for connection of PV in distribution level

3.Outcome: **25 MW at system level and 20 MW at distribution level without major investment**

Vanuatu

1. Objective: Assessment of **VRE integration** into LuganVille grid with possibility of grid extension in Port Olry
2. Methodology:

- Obtain high resolution solar data
- Identify locations with solar resource and connection to grid
- Conduct dynamic simulations and economic dispatch for 2018 and 2030 for 16 scenarios with maximum and minimum demand, considering system security and VRE enablers

3.Outcome: **Using BESS, diesel UPS and dynamic resistor 12 MW of PV can be incorporated in the system**

Key messages

- Low shares of VRE can be implemented without major investment and if system specific measures are adopted
- Very high shares of VRE integration is possible with greater grid flexibility
- Exploring interconnections with neighboring countries allows more VRE integration

Technical studies and subsequent recommendations will ease this process.

International Renewable Energy Agency

Thank You

Gayathri Nair
Associate Programme Officer
Gnair@irena.org