The Role of Grid Codes in Isolated Power Systems

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Energynautics Experience: Isolated Power Systems

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- Microgrids India (2012)
- System Study Seychelles (2014)
- Grid Code Barbados (2015)
- Island Studies Indonesia (2018)
- Technical Assistance Indonesia (2018-20)
  - Island capacity expansions studies
  - Development of PPA and tender documents
  - Revision of distribution code
  - Capacity building and training
- Bahamas Capacity Expansion (2019-21)
- Bahamas Dynamic Stability (2019-21)
- Dominican Republic Grid Code (2020-21)
- Galapagos Capacity Expansion (2020-21)
- Trinidad and Tobago Capacity Expansion (2020-21)
- Guyana Capacity Expansion (2020-21)

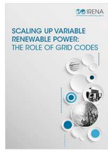




Energynautics Experience: Grid Codes

- Technical Requirements Seychelles (2014)
- Grid Code Barbados (2015)
- IRENA Role of Grid Codes (2015-16)
- Wind Grid Code Lebanon (2016)
- Distribution Code Armenia (2017-18)
- EU Network Codes Estonia (2017-18)
- ASEAN Grid Code Comparison (2018)
- Grid Code Mongolia (2018-19)
- Distribution Code Indonesia (2019-20)
- Grid Code Dominican Republic (2020)

Scaling up Variable Renewable Power: The Role of Grid Codes



May 2016
ISBN : 978-92-95111-85-1

Increasing the share of renewable power from variable sources, namely solar and wind energy, requires technological developments to be accompanied by well-designed regulations for grid management and operation. Grid connection codes for variable renewable energy (VRE) sources have evolved hand-in-hand with technological and operational practices, driving the adoption of the best available technologies for VRE grid integration. Lessons from pioneering countries can help in drafting a grid code for VRE integration.

Yet national codes should not be appropriated wholesale from other countries. Precise technical requirements need to reflect local conditions, including the character of the existing power system. System size, voltage, interconnections, generation and distributions loads, the conventional energy mix, and the prevailing policies on renewable energy must all be taken into account. Codes must define the respective roles and responsibilities of the government and the grid operator, as well as set compliance verification mechanisms.

http://energynautics.com/en/services/grid-code-development/

https://www.irena.org/publications/2016/May/Scaling-up-Variable-Renewable-Power-The-Role-of-Grid-Codes

Isolated Power Systems

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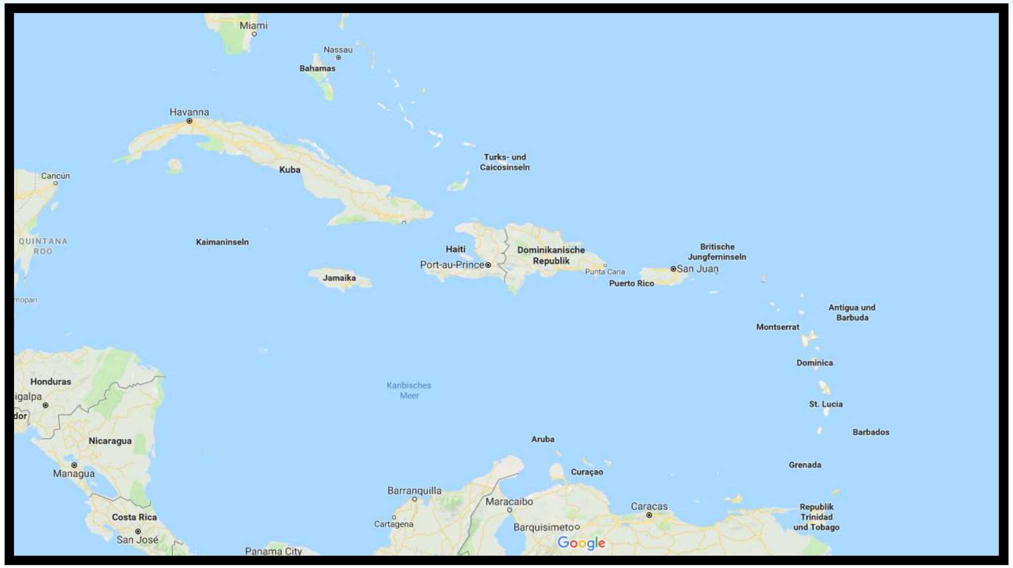
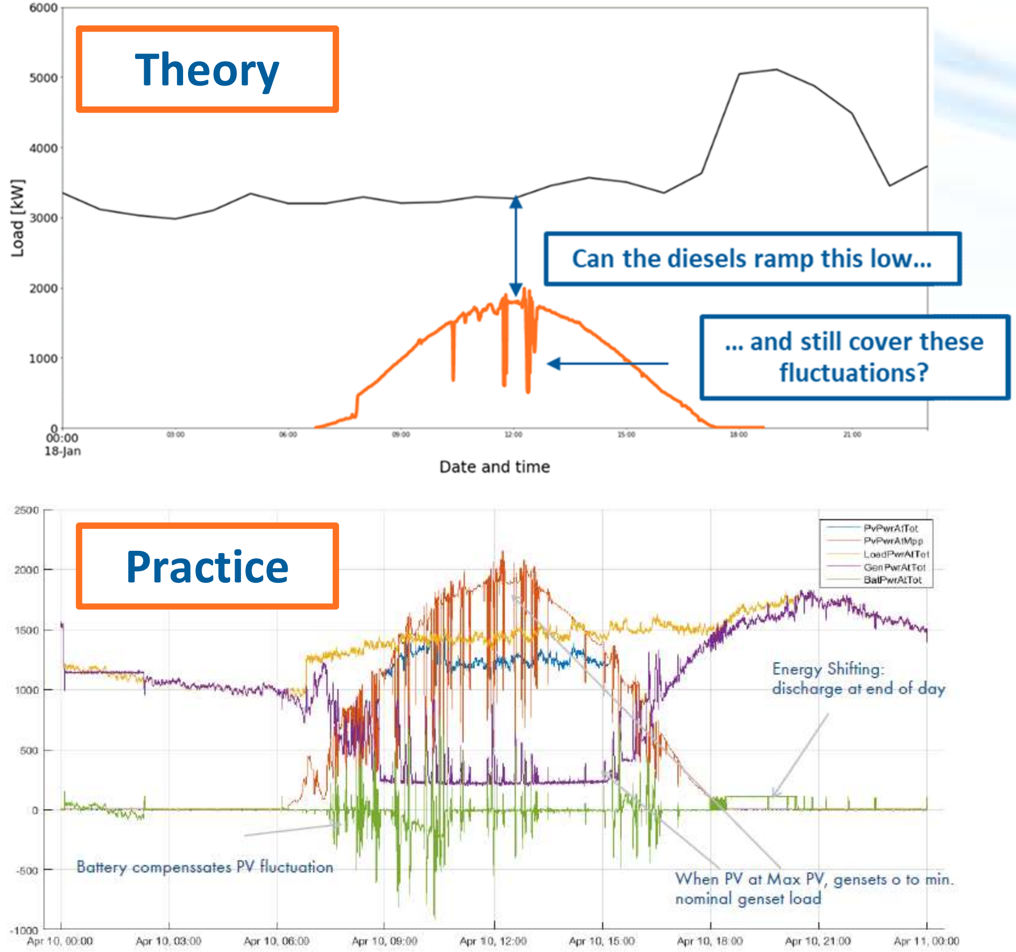


Hot spots: Africa, Caribbean and South East Asia

- Several 100,000 inhabited islands world wide
- Most permanently inhabited islands are located in the tropic seas
- Most are high sea islands that are too far out to be connected to main grid
- Remote areas in developing countries are also often supplied by similar small grid systems
- Almost all are powered with 100 % fossil fuel (diesel)

VRE Integration Challenge

- VRE integration is usually economically feasible as renewables are cheaper than diesel
- High VRE penetration levels can be reached quickly
- VRE need to participate in a number of system services
- Individual VRE installations can be quite small, comparable to distributed generators in larger systems



Source: International Hybrid Power Systems Workshop 2016: Caribbean Largest PV-Diesel-Storage System St. Eustatius (Phase 1). SMA.

Operator's Perspective

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Renewables can save fuel and reduce generation cost

Great, let's go!

We have heard 100 % renewables is already possible in island grids – can we please build something like that by next year?

Nice, but...

If 50 kW of PV will be installed on my 10 MW island – will we get dynamic stability problems? Do we need batteries?

No thanks...

This may work somewhere else, but here it is obviously infeasible. (Also, we earn money with diesel generation.)

Take it easy – give it a chance – allow for some development – and learn as you go along!
(Nobody starts at 100 % right away.)

Please find a technical reason why we can't do it.

Isolated Power Systems and Grid Codes

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Key Challenge #1: Suitable technical requirements for small systems

- VRE and batteries have to participate in system services, especially frequency control
- Parameters have to be tuned to system characteristics
- Requirements can be quite strict as high VRE shares will be reached quickly
- “Slow start” is recommended, but requirements should be forward-looking

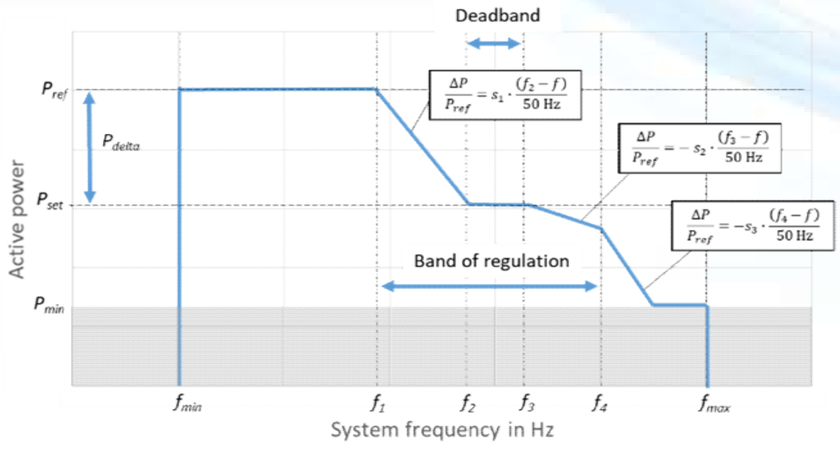
Key Challenge #2: Implementation and enforcement

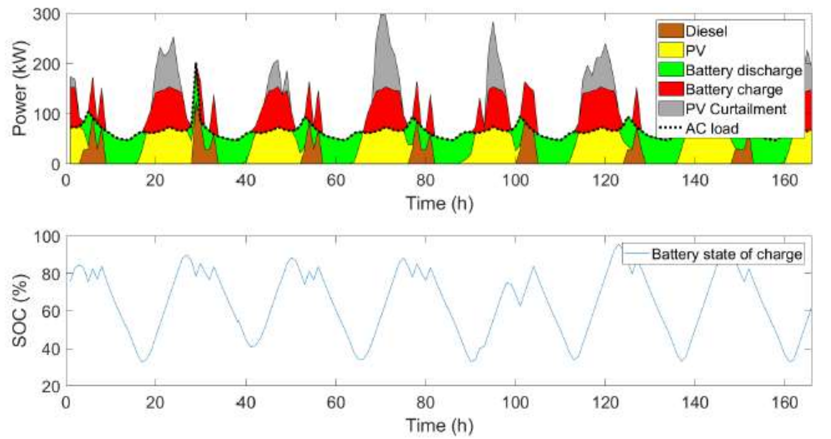
- Island nations: Single system controlled by single utility
- Also common: One utility controls multiple (and potentially very different) systems
- Single systems have low market power and cannot drive development
- For multiple systems under the same governance, it is difficult to apply uniform requirements

Requirements for Generators

Frequency and active power control are crucial in isolated systems

- VRE have to be controllable
- VRE have to participate in frequency control
- Some curtailment is unavoidable
- Fault behavior is extremely important
- Battery systems play a larger role
- Grid-forming inverters allowing for 100 % VRE penetration are becoming economically feasible





Isolated Systems vs. Distribution Codes

Isolated systems typically operate at voltages between 0.4 and 20 kV.

In some countries, this makes them subject to the distribution code.

Detailed frequency control requirements are usually found in transmission codes.

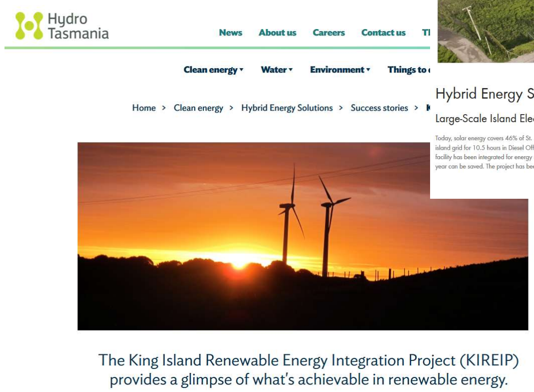
We have a problem here: We basically need a transmission code for distribution voltage levels, and transmission style requirements for small generators

- Isolated systems can profit from smart grid codes in the future!

Do we even need a grid code for that?

VRE-ESS-diesel hybrid systems are already being implemented successfully!

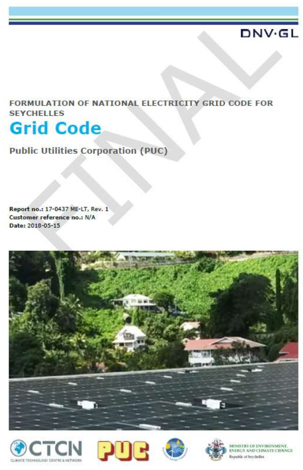
- Mostly with no grid code in place
- Custom designs work very well
- Fine for pilot projects
- May become problematic for large-scale rollout (cost!)
- Especially system operators in developing countries struggle with the development of custom requirements for each of their systems
- Private sector development is often desired, especially if the utility has no previous experience

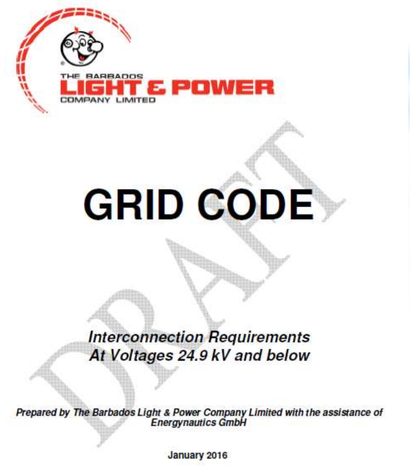


Single Utility, Single System

Utilities operating one (or a low number) of isolated power systems are common

- Island nations like Barbados or the Seychelles
- Quite a few of them do have grid codes in place
- Systems usually from a few to a few hundred MW
- Problem: Grid codes should not contain any requirements that go beyond the requirements of larger systems
- Result: Limitations to VRE integration



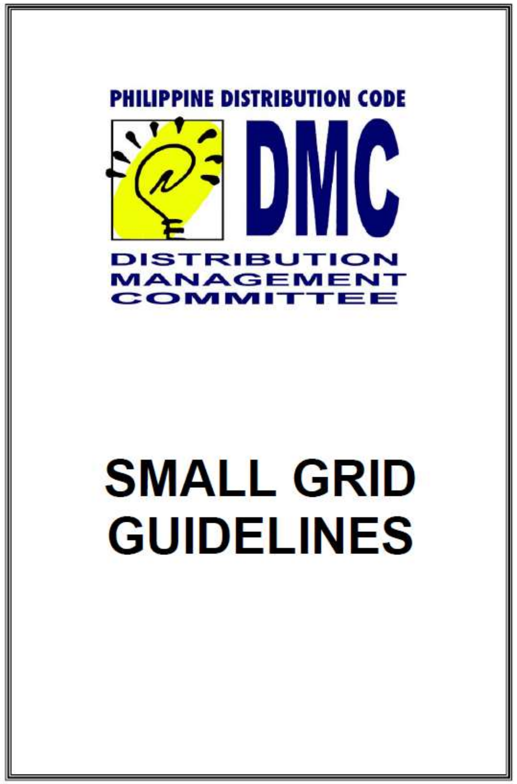


Developed by consultants based on international good practice

Multiple Systems under Common Governance

In some countries, high numbers of isolated systems are either operated by the same utility or governed by the same regulator

- Indonesia, Philippines, multiple countries in South America and Africa
- Isolated systems either not subject to any grid codes, or subject to (insufficient) distribution code
- Good example: Small Grid Guidelines in the Philippines, technical framework for small systems (somewhat outdated, but it's something)
- Potential problem: Uniformity of requirements


PHILIPPINE DISTRIBUTION CODE

DMC

DISTRIBUTION MANAGEMENT COMMITTEE

SMALL GRID GUIDELINES

National and International Harmonization

Everyone is facing the same problems, and VRE make sense economically in most cases. Can we bring everyone together?

- Utilities or regulators controlling a high number of small systems can develop quite significant market power if they follow a clear strategy
  - Internal harmonization and clear rules recommended

- Utilities or regulators controlling a single system need to find common ground to increase their market power
  - International knowledge sharing and harmonization recommended
  - Can benefit from clear frameworks of larger utilities (Indonesia, Philippines, etc.)

Unified vs. Custom Requirements

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Some degree of customization is always required.

- Similar case: EU Network Codes
- Framework for grid code requirements in Europe
- Details are left to the individual TSOs
- Similar approach could be a good idea for isolated systems
- Either as national or international framework
- Benefit: Clear rules for everyone, investment security, less paperwork, lower cost

Synchronous areas	Limit for maximum capacity threshold from which a power-generating module is of type B	Limit for maximum capacity threshold from which a power-generating module is of type C	Limit for maximum capacity threshold from which a power-generating module is of type D
Continental Europe	1 MW	50 MW	75 MW
Great Britain	1 MW	50 MW	75 MW
Nordic	1,5 MW	10 MW	30 MW
Ireland and Northern Ireland	0,1 MW	5 MW	10 MW
Baltic	0,5 MW	10 MW	15 MW

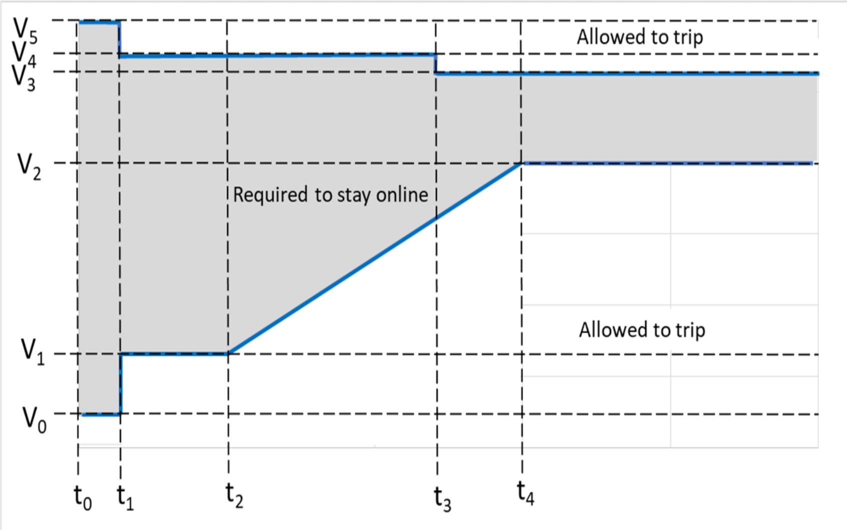
System Category	A (Very small)	B (Small)	C (Medium)	D (Large)
Peak load threshold	-	≥ 5 MW	≥ 20 MW	≥ 100 MW
Highest voltage level	≤ 20 kV	≤ 20 kV	≤ 20 kV	≥ 20 kV
Number of power stations	1	≥1	≥1	≥1
Grid structure	Radial	Radial	Radial	Radial or meshed

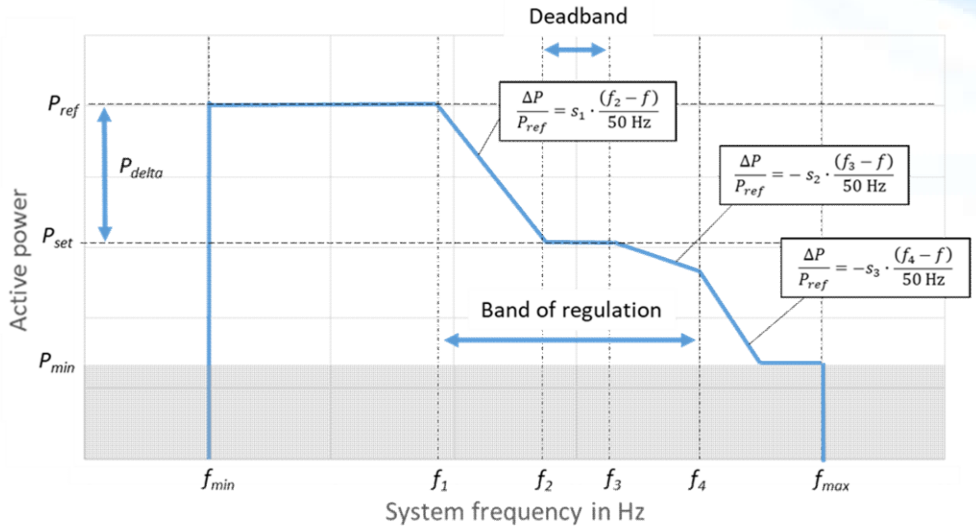
Generator Category	1	2	3
Connection voltage	< 20 kV	≤ 20 kV	> 20 kV
Threshold Category A	-	-	150 kW
Threshold Category B	-	150 kW	500 kW
Threshold Category C	-	500 kW	1 MW
Threshold Category D	-	1 MW	5 MW

Compliance with distribution code is sufficient

Distribution code + additional requirements of different levels

Configurable Requirements



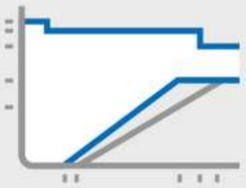


Value	Voltage inverter [p.u.],	Voltage synchronous [p.u.],	Description
V_0	0.20	0.30	LVRT 1
V_1	0.20	0.70	LVRT 2
V_2	0.85	0.85	Undervoltage protection
V_3	1.10	1.10	Overvoltage protection
V_4	1.20	1.20	HVRT 2
V_5	1.35	1.35	HVRT 1

Value	Time inverter [ms],	Time synchronous [ms],	Description
t_0	0	0	Beginning of fault
t_1	180	180	System protection time
t_2	500	500	Voltage return step 1
t_3	1000	1000	Overvoltage step 2
t_4	2000	2000	Voltage return step 2

Parameter ranges to be recommended based on system size

Thank you for your attention!



Grid Code Development

Grid Codes are crucial to a safe integration of renewable energies into the grid. We design and revise them for you! With international experience and expert knowledge.

http://energynautics.com/en/services/grid-code-development/

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