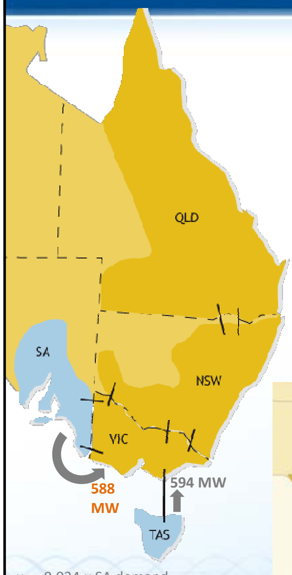
Grid Integration Studies: What Type of Studies are Needed and When?

Integrating Variable Renewable Energy into Power Grids

21 October 2014

Thomas Ackermann, Ph.D. Dipl.-Ing.
CEO Energynautics GmbH
t.ackermann@energynautics.com

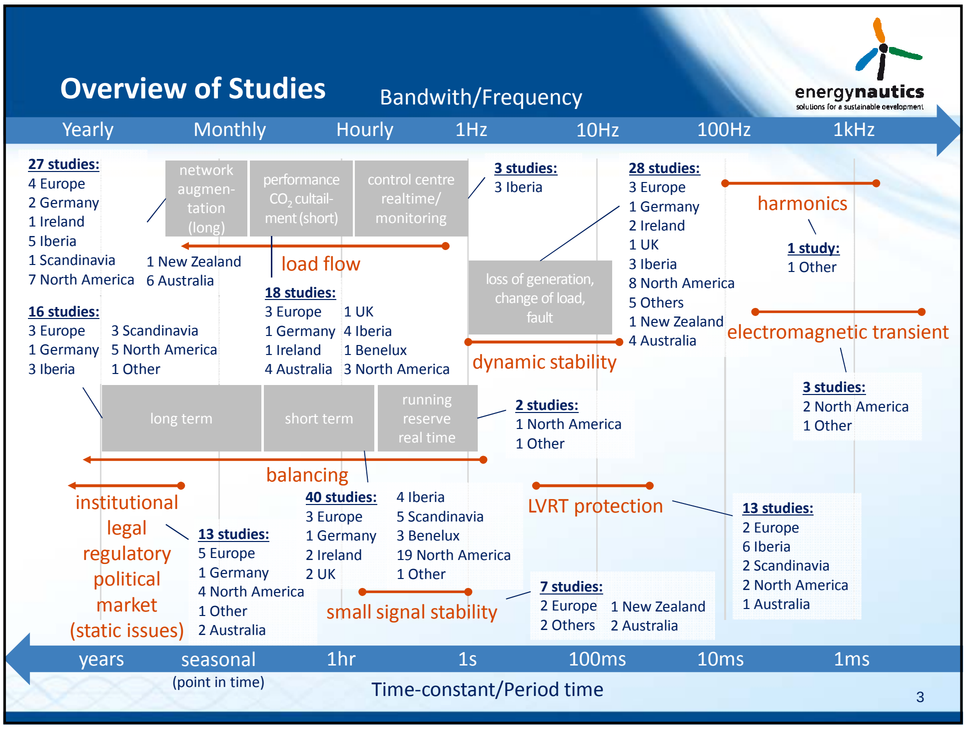
Wind Energy in Island Systems

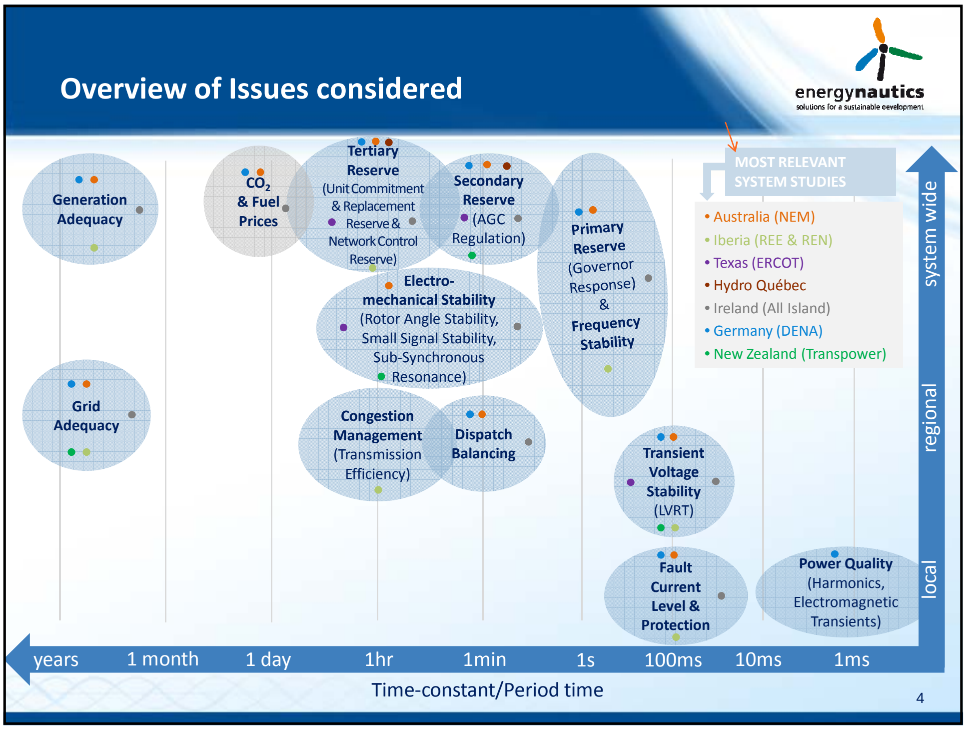


	installed wind capacity (MW) (2013)	min. demand (MW)	max. inter-connector transfer capacity (MW) (+ possible upgrade)	max. inst. wind penetration (without I/C)	max. inst. wind penetration (max. export)
SA	1,205	1,088	588	110 %	56.7%
Texas	12,355	22,426	860	55 %	53 %
Ireland	2,607 (2,275)	2,279	580	114 % (99 %)	91.1% (70%)
Iberia	27,477	19,205	3,600	143 %	120 %

x_3 = 0.034 x SA demand

2





Thomas Ackermann
t.ackermann@energynautics.com

Example: Seychellen

energynautics
solutions for a sustainable development

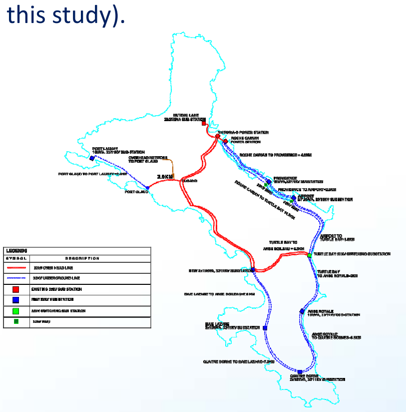
- **Seychelles wants to raise the share of renewable generation in its power system**
  - Reduce fuel imports
  - Save money
  - Contribute to fight against global warming
- **Today around 2% of electricity consumption from wind**
- **Targets of 5% renewables by 2020, 15% by 2030**
- **Report analysis grid absorption potential**

5

Step 1: Grid Adequacy Study (11/33 kV) and Voltage/Protection Study (Distribution Network) Problem: Demand Increase and Network and PV Data

energynautics
solutions for a sustainable development

Due to the **load alone** the network will require reinforcements in the South of Mahe well before 2020 and in the North by 2030 (latter finding is a result of this study).



33 kV network extension to South to solve voltage problems and bottlenecks well before 2020.

33 kV network extension needed to North well before 2030 due to problems there.

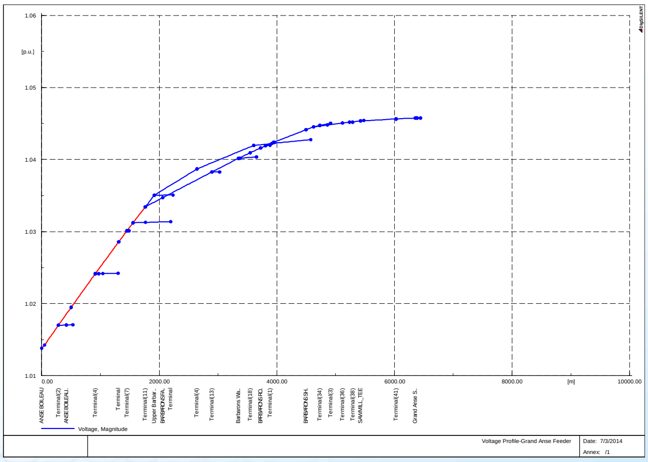
6

Thomas Ackermann
t.ackermann@energynautics.com

Voltage rise and overloading due to PV at 11 kV Feeder: No impact on total PV Limit

energynautics
solutions for a sustainable development

With PV feed-in exceeding the load at midday, the voltage now rises along the feeder and overloadings lines at the start of the feeder

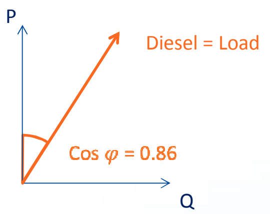


7

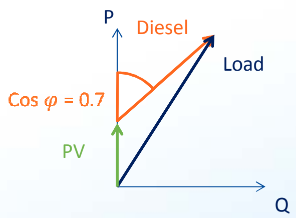
Step 2: Reactive Power in the Power System: Impact of PV on Diesel Operation

energynautics
solutions for a sustainable development

Operation without PV.



Operation with PV, but PV feeds in no reactive power.



If PV doesn't provide its share of the load's reactive power needs, over-burdening the diesel generators. Therefore need PV to feed-in at 0.9 over-excited to avoid extra reactive power load on generators.

-> Grid Code!

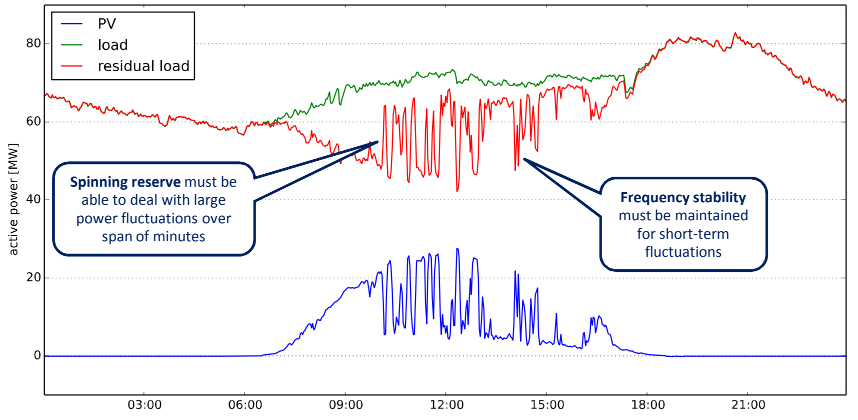
8

Thomas Ackermann
t.ackermann@energynautics.com

Step 3: Frequency and Spinning Reserve Issues

energynautics
solutions for a sustainable development

Looking at the **daily residual load** (load minus variable generation) with PV on Mahe:

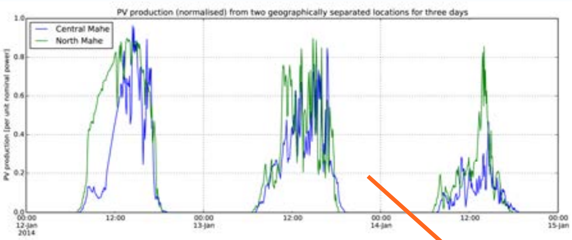


NB: PV profile scaled up from a single profile; in reality fluctuations would be smoother.

9

Smoothing Effect of PV: Often a Data Problem!

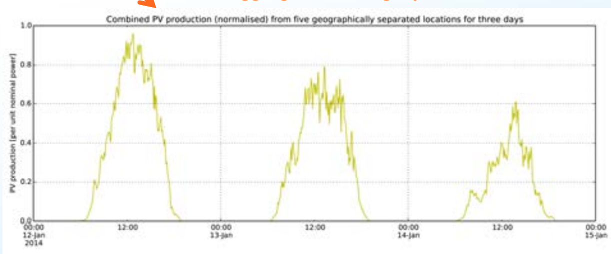
energynautics
solutions for a sustainable development



- The generation profiles from individual PV units show **very fast changes** (up to 80% loss of production within 2 minutes, due to clouds)
- There are big differences between units at different locations on Mahe

5 units aggregated to single profile

- The aggregated profile of 5 different units shows **smoothing effects**
- Given the small data set and uncertain synchronisation between time series, **worst case assumption** is loss of 80% of total PV production in 10 minutes
- Future measurements may show that worst case is milder



10

Germany: Example Day-Ahead - Forecast Error on 11.05.14 (@ 13:00 76% renewables in the system)

energynautics
solutions for a sustainable development

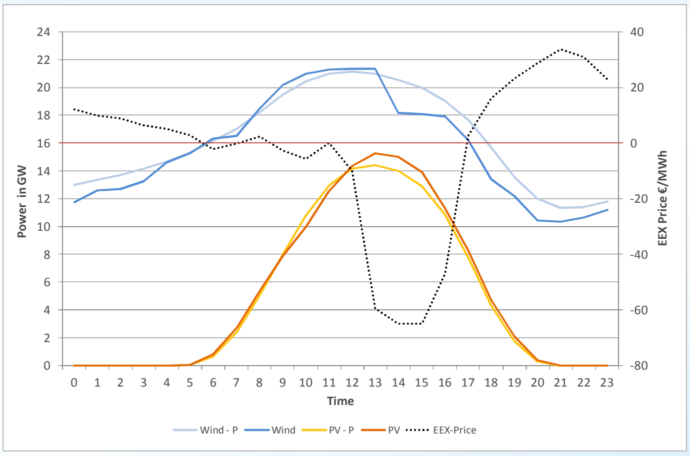


Figure: Actual wind- and pv-power-generation as well as the forecast and EEX-price.

- Deviations from the forecast are particularly obvious for the wind – power-generation
- EEX - price is significantly negative because of high RES-feed in

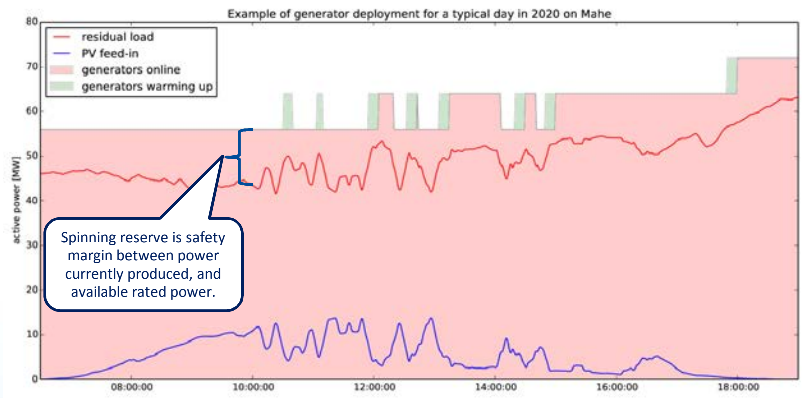
Source : EEX, own diagram, last downloaded on 04.08.2014

11

Spinning Reserve Requrements

energynautics
solutions for a sustainable development

Generators take 10 minutes to come online, so spinning reserves must cover any losses of power production that takes place with 10 minutes (e.g. generator trip or loss of PV).
Spinning reserve achieved by running diesel generators at loading levels below full power.

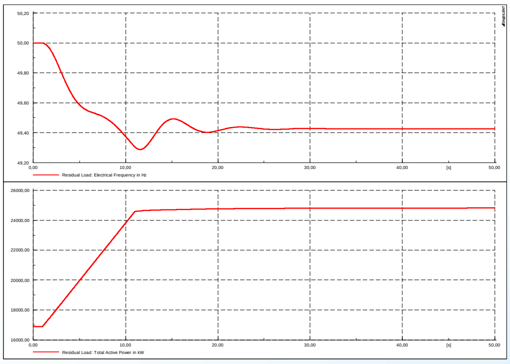


12

Frequency stability: Impact of PV Ramp

energynautics
solutions for a sustainable development

The power production of wind and PV is **weather-dependent** and can change quickly, e.g. due to a passing cloud covering the PV panels.



- This **simulation** used the dynamic model from PUC for the 2015 generator configuration.
- The PV generation decreases by 8 MW over a period of 10 seconds, causing a ramp up of the residual load (bottom graph).
- The frequency remains above 49.25 Hz, thus avoiding load-shedding.
- In reality (based on measurements from PV systems) the ramp would happen over longer periods, up to 10 minutes.
- **Not covered: Loss of large transmission line**

13

Example: Scenarios for Seychelles

energynautics
solutions for a sustainable development

Maximum PV by Technology Scenario [MW Panel Size] (load coverage by PV in %)	2015	2020	2030
Conservative - No changes to current operational practices - 75% minimum diesel loading level	0.72 (2.2%)	1.54 (3.3%)	2.39 (2.8%)
Moderate - 65% minimum diesel loading level - Limit inverter size to 80% of panels - Curtailment during bottlenecks of plants > 500 kW - Demand-Side Management of 2 MW by 2030	n/a	3.5 (7.4%)	8.4 (9.9%)
Ambitious - 50% minimum diesel loading level - Limit inverter size to 80% of panels - Curtailment during bottlenecks of plants > 500 kW - Demand-Side Management of 2 MW by 2030 - 3 MW Generator on standby to start at short notice	n/a	7.2 (15.5%)	12.3 (14.6%)

14

Conclusions/Recommendations

energy**nautics**
solutions for a sustainable development

- Start early with **measurements of solar insolation/wind conditions for different location for at least two years**, with recordings made at least every minute, in order to assess the worst PV/Wind production variations possible.
- Consider development of **Solar/Weather Forecasting Systems**
- **Collect data** of power systems (network/generation plants), develop at least a load flow model.
- Type of studies depend on power system design and renewable penetration level, but **grid adequacy and balancing/reserve is typically the starting point and related studies for grid code!**
- **The integration of renewables is a learning process.** It is recommended to proceed conservatively at first, monitoring the integration of the first renewable energy units very carefully and assessing their impact on the power system. As system operator gains confidence with the system's behaviour, higher penetration level can be investigated and the more advanced technology options can be leveraged to increase the penetration levels. **(-> time and money required for studies)**

15

energy**nautics**
solutions for a sustainable development

Thank you for your attention!

16

Thomas Ackermann
t.ackermann@energynautics.com