Solutions for VRE Integration in Developing Countries

energynautics
solutions for a sustainable development

Focus on island systems

4th International Hybrid Power Systems Workshop

Crete, Greece, May 22nd/23rd 2019

Peter-Philipp Schierhorn, M.Sc.

Dr. Dipl-Ing. Thomas Ackermann

energynautics
solutions for a sustainable development

1.BACKGROUND

ISLAND POWER SYSTEMS WORLDWIDE

energynautics
solutions for a sustainable development

Hot spots: 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
- Almost all are powered with 100 % fossil fuel

TYPICAL ISLAND SYSTEM SETUP

energynautics
solutions for a sustainable development

Power generation from diesel engines

- Often old and inefficient
- Slow ramp rates and long startup times
- High minimum stable output
- High pollutant emissions

Medium voltage distribution grid

- Usually 10 – 30 kV
- Overhead lines
- Relatively long feeders, one central power plant
- Customers often connect directly to MV/LV transformers

ENERGYNAUTICS EXPERIENCE

Energynautics have been commissioned to conduct PV integration studies on various tropical islands since 2013 – these are a few examples.

Studies were commissioned by development banks in cooperation with local utilities.

	Seychelles*	Kaledupa	Belitung	Barbados	CENSORED		Bahamas*
Size	28 x 19 km	24 x 11 km	84 x 80 km	35 x 25 km	70 x 10 km	200 x 100 km	30 x 10 km
Population	77,000	30,000	300,000	278.000	100.000	700.000	250.000
Peak demand	Ca. 45 MW	Ca. 1 MW	Ca. 40 MW	Ca. 200 MW	Ca. 6 MW	Ca. 150 MW	Ca. 230 MW
Generators	Diesel	Diesel	Diesel, coal, gas turbines, biogas, biomass	Diesel, gas turbines, steam turbines	Diesel, gas engines	Diesel, coal, gas turbines, biogas, biomass	Diesel
Grid	33 kV, 11 kV	20 kV	70 kV, 20 kV	24 kV	20 kV	150 kV, 20 kV	
Objective	Find max. penetration rate	Develop techno-economic strategy for 25 % renewable energy in 10 years		Review and improve grid code	Save cost	Save cost	Technical + regulatory issues for PV

Ongoing projects

* Data for main island – other local islands were included in the studies

2. INTEGRATION STUDY ISSUES

ISLAND RENEWABLES STUDY

energy**nautics**
solutions for a sustainable development

A clean, all-encompassing study requires time, effort and lots of data

- Models: Investment model, dispatch model, steady state and dynamic grid models
- Scenarios: Forecasting the future is hard, so extensive sensitivity analysis is a good idea
- Technology: Assessment of existing system, review of future technologies etc.

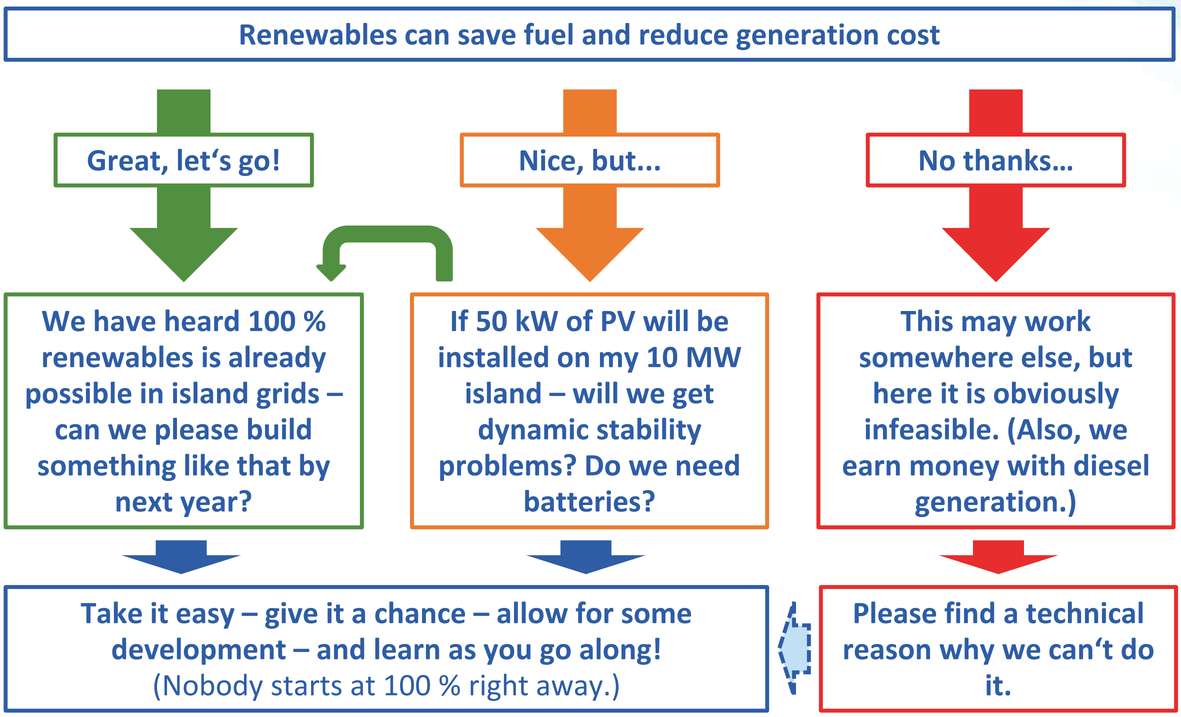
Collect all the data, develop all the models, evaluate all possibilities…

… unfortunately, especially in developing countries it often does not work that way!

- Time constraints (results ASAP, often politically driven!)
- Budget constraints – study often only possible with development aid
- Capacity building is often a prime objective – local operators have no experience with VRE

ISSUE 1: OPERATOR‘S PERSPECTIVE

energy**nautics**
solutions for a sustainable development



ISSUE 2: DATA COLLECTION

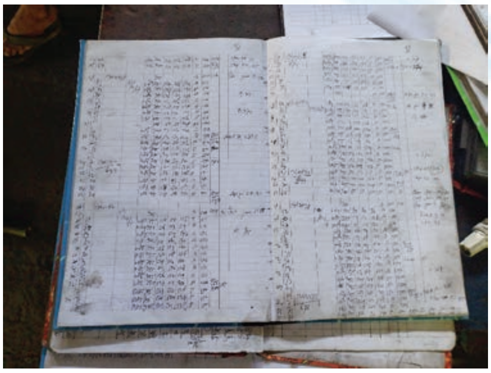
energy**nautics**
solutions for a sustainable development

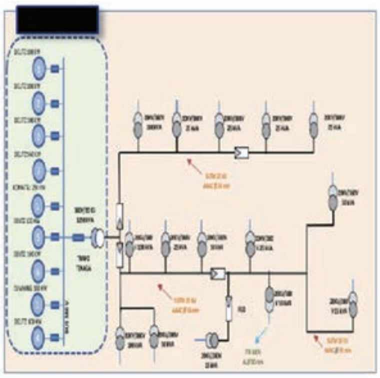
Especially in remote locations in developing countries, data on power system characteristics is often not even available to the operator.

- System is operated based on experience
- Operators can handle their typical situations, but have little background knowledge
- Monitoring and transparency are often not considered important

➢ Academic approach of a grid study based on good data and validated models requires extensive site visits and measurement campaigns.

➢ Often, a simplified approach needs to be applied.

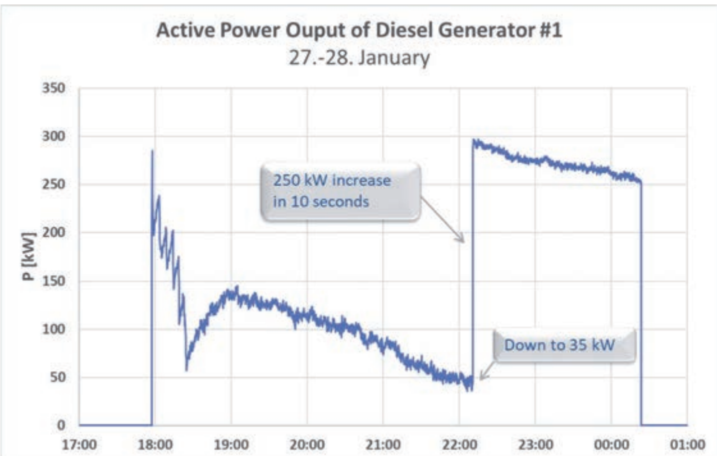




ISSUE 3: GENERATOR OPERATION

energy**nautics**
solutions for a sustainable development

Operators, power plant crews and manufacturers may each have a different perspective on the capabilities of their generators.



Measured data from a 650 kW high speed diesel in Indonesia.

Operator: Fast ramping is not possible!

Crew: Of course we can ramp fast, watch this!

Manufacturer: Of course you can ramp… but…at your own risk.

Economist: Ramping is expensive, please avoid!

ISSUE 4: DYNAMIC MODELS

energynautics
solutions for a sustainable development

Dynamic stability may become an issue at high levels of non-synchronous generation, and everyone has heard about it.

Most island grid operators want the dynamic stability of their system assessed.

Validated dynamic models of generators are often only available to the manufacturer – if at all!

(One could make estimates from event data – but that's not available in high resolution either.)

If no validated models can be obtained for these generators…

… good luck finding anything for this one!

BUT WE STILL WANT GOOD RESULTS

energynautics
solutions for a sustainable development

„Garbage in garbage out" should be avoided as far as possible!

- Identify the shortcomings
- Prioritize the ojectives (often, teaching the local operator the basics is #1!)
- Start with the simplest questions and answer these well – half baked answers to overly complex questions help nobody in the long run
- Develop simple and efficient approaches
- Encourage small VRE installations along with better data collection and monitoring systems. **Start small, grow large! Learning by doing!**
- **Many systems are still a step behind – but we can start the conversation!**

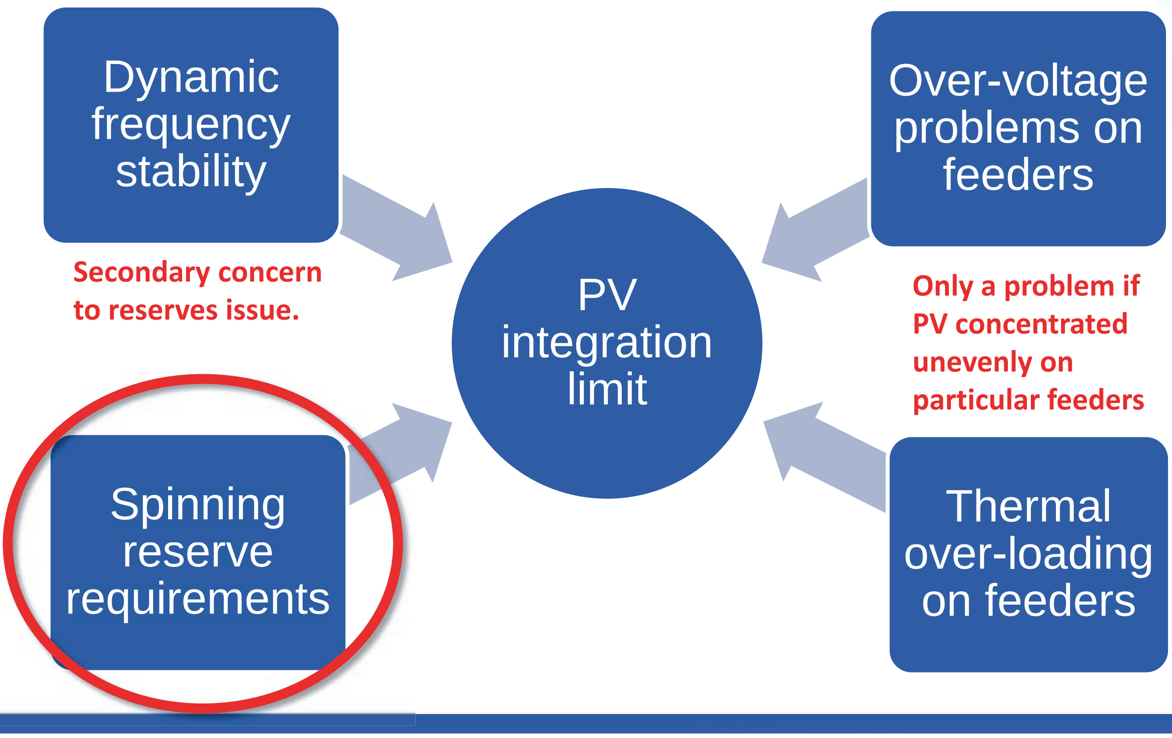
energy**nautics**
solutions for a sustainable development

3. SIMPLE METHODOLOGY

WHICH ISSUES DOMINATE?

energy**nautics**
solutions for a sustainable development

The various issues are **not** equally problematic. Based on simulations:



RENEWABLE INTEGRATION STUDY

Assessment of renewable energy potential and selection of technologies

Question 1: How much RE can be installed without any change to the system?

- How far can conventional generation be reduced?
- How much spinning reserve can be provided?
- How fast can frequency control (reserves) react?
- Assessment of expected RE fluctuation
- Are there any grid constraints? Where can RE be installed?

Question 2: What enabling measures can be taken to raise the RE share?

- Optimization of generator controls and/or overhaul of existing generators
- Are there alternative ways of obtaining spinning reserve?
- Is there any pontential for demand side management?
- What degree of controllability must RE generators provide?
- Is energy storage an economically feasible option?
- Is there any need for grid reinforcements?

ISLAND GRID SYSTEMS (1)

Classification by Baring-Gould / Lundsager

Low Contribution System (LCS): Instantaneous penetration of renewables is so low that it can be regarded as negative load, with no upgrades to control systems or dispatch regimes.

Medium Contribution System (MCS): Instantaneous penetration of renewables must be considered when dispatching conventional generation due to issues with spinning reserve and minimum stable output of generators. May involve storage.

High Contribution System (HCS): Instantaneous penetration of renewables is > 100 % and conventionals are switched off completely at times. Requires grid forming inverters and/or flywheels as well as battery storage.

ISLAND GRID SYSTEMS (2)

Classification by Baring-Gould / Lundsager

Low Contribution System (LCS): Applicable for larger islands, where VRE development can be started slowly

Medium Contribution System (MCS): Target for medium small systems (1 – 100 MW) where VRE has a significant cost advantage

High Contribution System (HCS): Very small systems (< 1 MW) could start here ("get the diesels out of the way"), while it is step 2 for medium systems and far away for larger systems

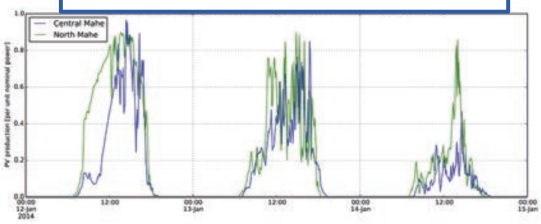
4. FROM STUDY TO IMPLEMENTATION

STUDY IMPACT

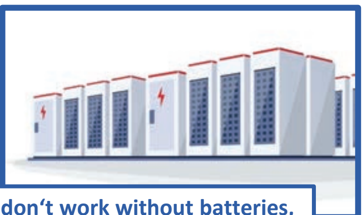
A good study can convince utilities to look into VRE…

… but once they start looking, they may not like what they are seeing.

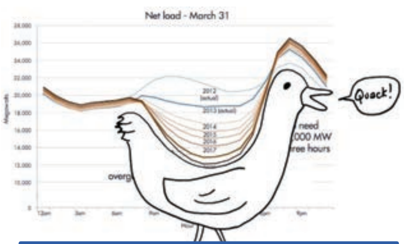
Fluctuations – we can't handle them!



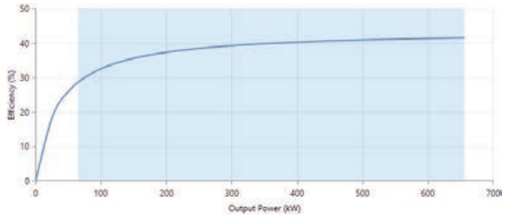
Our equipment will get damaged



VRE don't work without batteries, and those are expensive

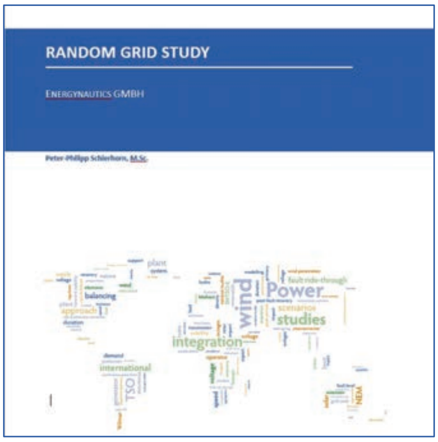


The power of the duck curve compels us!



Diesels are so inefficient at low load!

PILOT PROJECT



This can wake interest in renewables…

… but **only this** is something that people will actually look to as a **good example.**

There are way too many theoretical studies that never lead to implementation.
Studies are good and necessary, but only operational pilot projects will have a beacon effect.

➢ Implementation must be kept in mind already during the study phase

BARRIERS TO VRE INTEGRATION

Even if the local utility decides to go forward, there are usually a number of non-technical barriers.

- Land permits and environmental regulation
- Communication with local communities (these NEED to be involved for a successful project)
- Decision: Independent power produces (IPP) or utility?
  - Problem with IPP: Utility may not be in favor of IPPs and offer only very low FIT for PV
  - Problem with IPP: Hybrid island system needs to be integrated, boundary is hard to determine
  - Problem with utility: May be willing, but not able to successfully operate and maintain a hybrid system
- Local content rules – it can be rather challenging to build a PV system with 50 % domestic content
- Long approval processes within the utility

There is no easy way around this – but analyzing the situation and addressing issues early on can prevent unpleasant surprises

STEPS TO IMPLEMENTATION

AVOID COMPLEXITY

"European developers offered us good systems, but all of them were very complex and expensive. We're new to this, we can't handle it."

(undisclosed utility manager)

This is a quite common reaction.

"So we decided to build it ourselves, and kept it as simple and stupid as possible."

(same person)

This was a pleasant surprise, but in most cases this does not happen. (This particular system was built and is running now.)

SIMPLE SYSTEM

Graphics for visual purposes – this is not the real system in question.

- Small island with ca. 80 kW peak load (night), daytime load ca. 40 kW
- Pre-existing offgrid system with 90 kW PV and lead acid batteries, upgraded with grid forming inverter
- 100 kW diesel generator added recently
- Simple control algorithm: If PV can cover load and batteries are charged, diesel shuts down – if battery SOC falls below a certain value, diesel starts back up (possibly with 1-2 minutes of outage)
- No battery autonomy, so security of supply is limited – but a great improvement over the offgrid system
- Controller structure implemented by utility staff based on Deepsea Electronics open source controllers

This system provides much less operational security than European engineered systems – but it is a great way to start on PV hybridization, because it is cheap, simple to maintain, and it works!

energynautics
solutions for a sustainable development

5. CONCLUSIONS

energynautics
solutions for a sustainable development

CONCLUSIONS

- **Carefully assess the available data**
- **Instead of trying to guesstimate answers to complex questions, answer the simple ones well**
- **Keep in mind the financial and technical capabilities of the local utility**
  - Storage and smart grid approaches are still far away from reality in many places
  - The basics of VRE integration and operational regimes need to be built up
- **Encourage small steps along with better monitoring and data collection**
- **Focus on fostering pilot / demonstration projects**

THANKS FOR YOUR ATTENTION!