Renewable Energy Integration Issues

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21st PPA Annual Conference
Pre-conference Workshop
July 15th, 2012
Vanuatu

Document number

Agenda

- Integration of Intermittent Renewable Energy Generation on small island systems

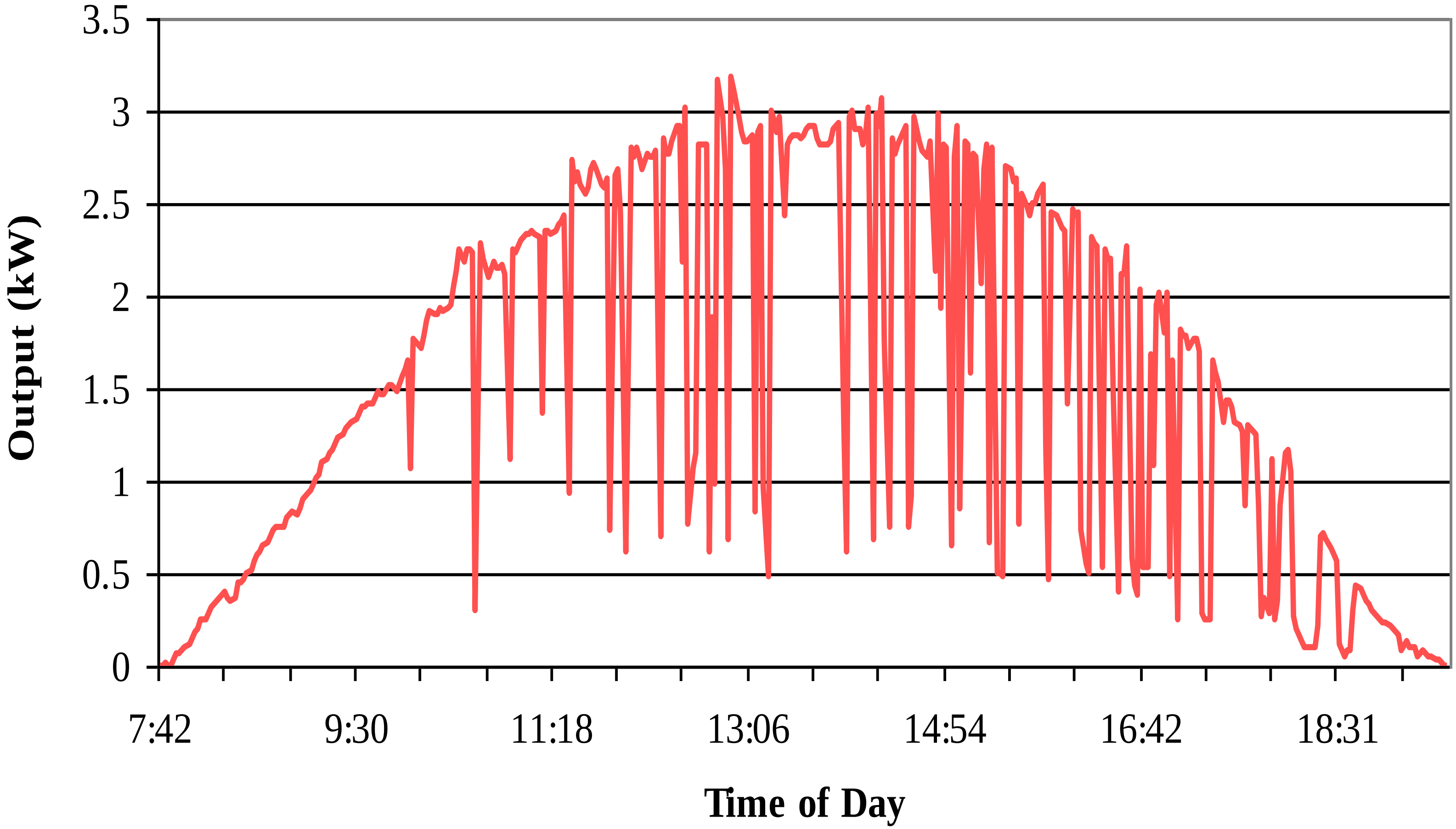
- Case Studies:
  - Integration of Solar Energy Generation into the VIWAPA Power System in St. Thomas
  - Integration of Solar Energy Generation into the NPC Power System in Niue

Renewable Energy Sources

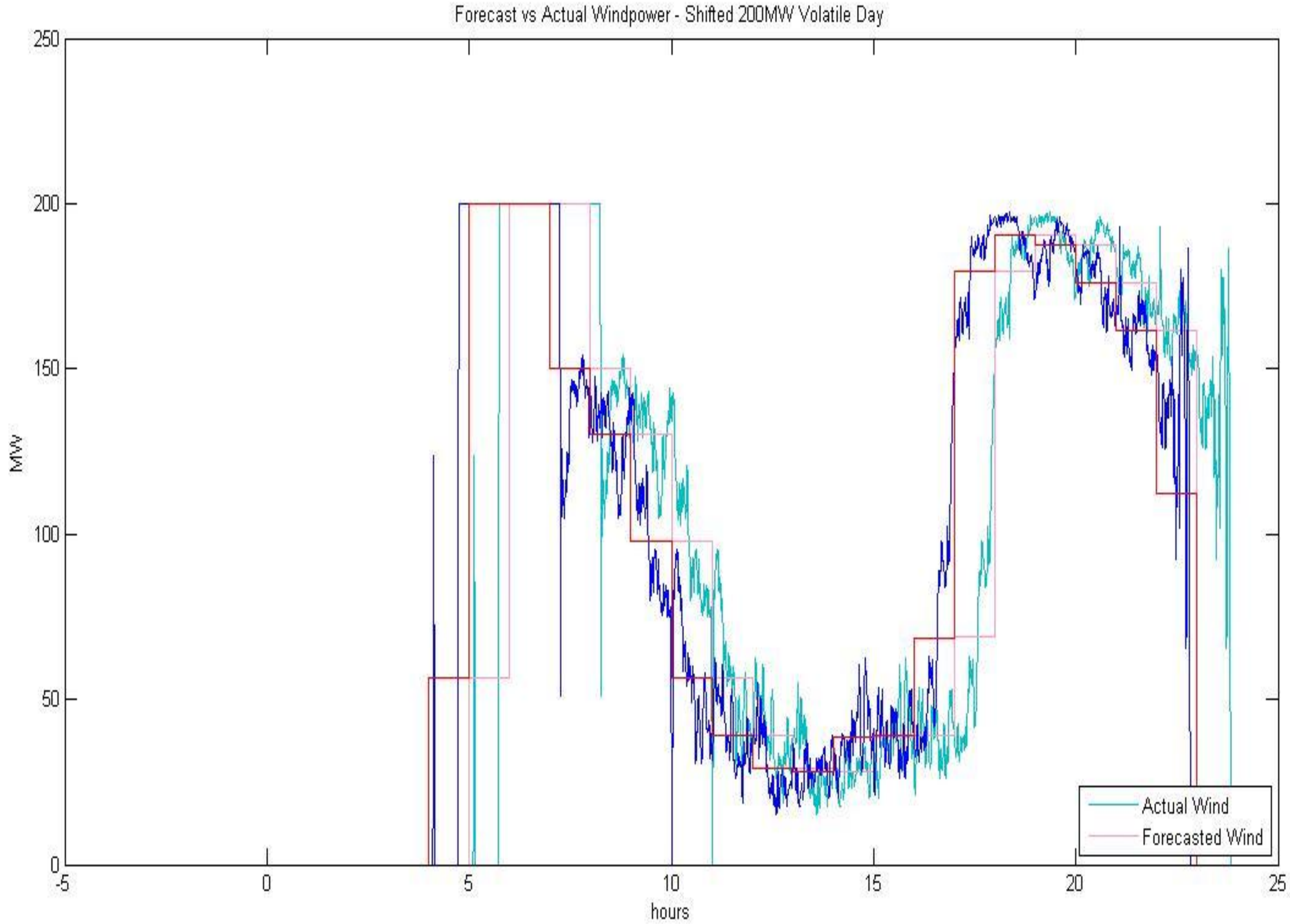
- Intermittent Renewable Energy Sources:
  - Solar
  - Wind

- Non-intermittent (base load) Renewable Energy Sources:
  - Hydro
  - Geothermal
  - Waste to Energy
  - Biomass
  - Coconut oil
  - Others (mostly not proven technologies)

Example of intermittent PV Output



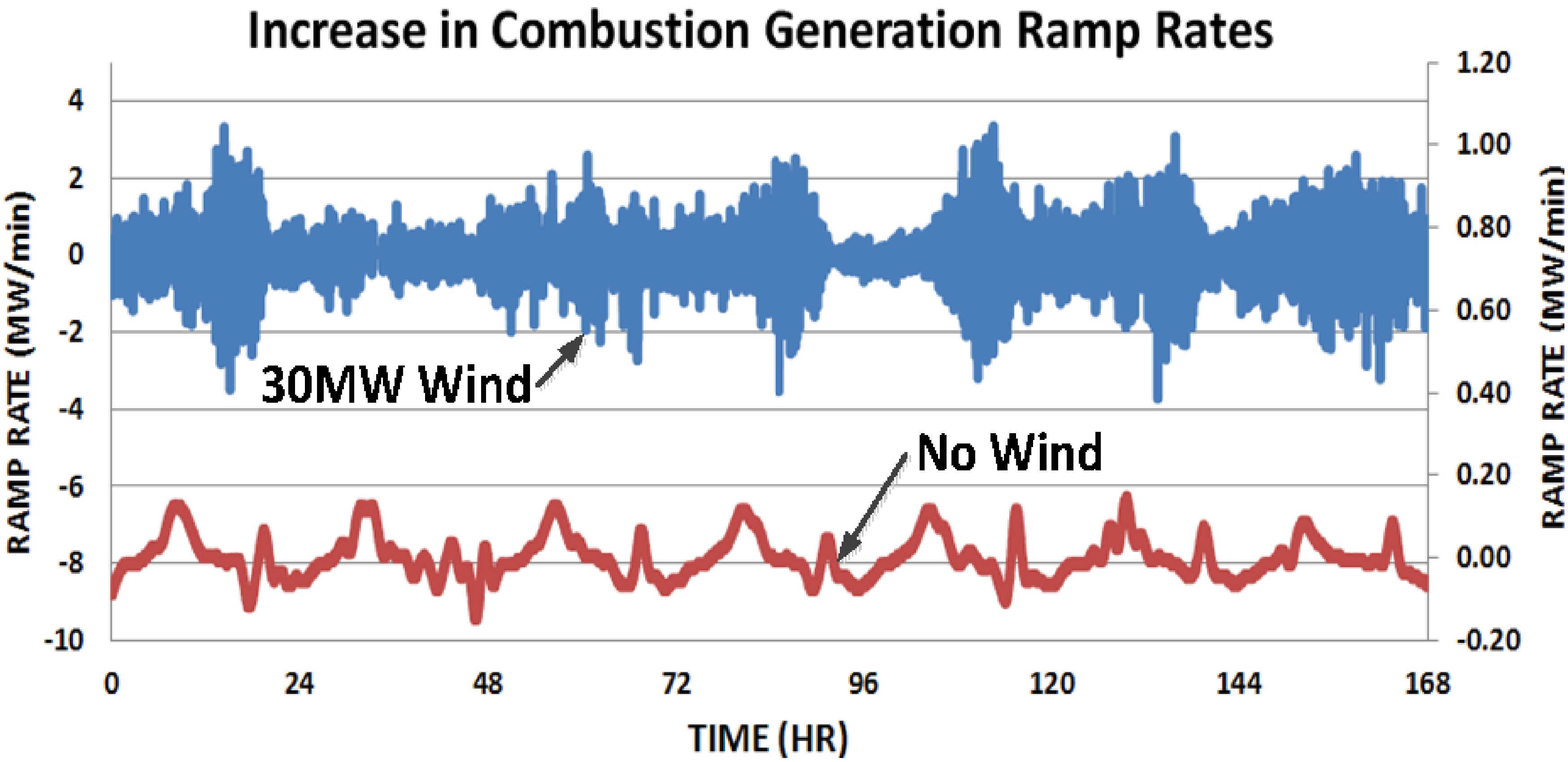
Example of Wind Power Output



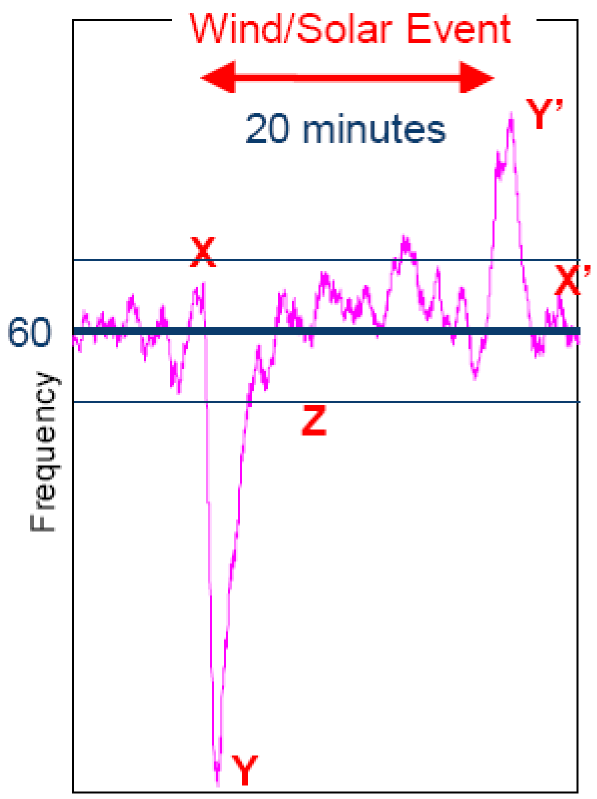
High Level Penetration of Intermittent Renewables

- Risks associated with high levels of penetration must be understood
- Solutions and their associated costs need to be clearly defined
- Exacerbating these issues, commercially available power system simulation tools have inherent limitations in performing the required time domain simulations.

Example of Wind Power Effects on Combustion Generation Ramp Rates



Effects on System Frequency

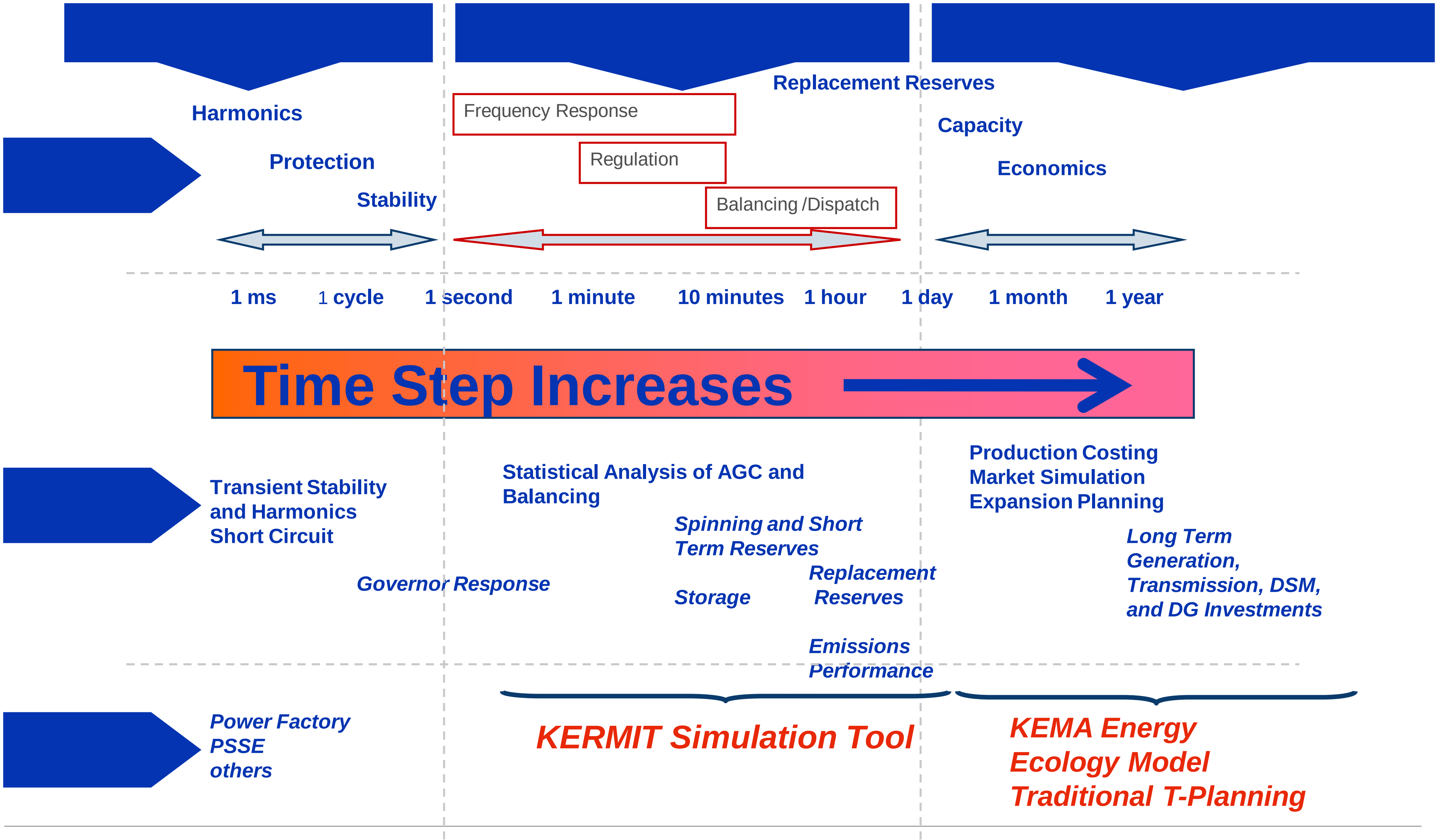


- Point “X” corresponds to the instant in time when the system is in steady state, just before the start of the renewable-ramping event. Point “Y” corresponds to the time instant at which the frequency is at its lowest, or where the frequency deviation from its nominal value of 60 Hz is maximum. Point “Z” corresponds to the time instant when the frequency returns to its nominal value for the first time.
- Grid calculation software tools like for example PSSE, ETAP, are not designed to analyze an event of this duration.
- KEMA developed software tool KERMIT as a “screening” tool, in order to quickly decide at which point during an event, an elaborate analysis with for example PSSE is needed. The term “screening” is used because KERMIT can execute a 24-hour simulation in 5-10 minutes.

KERMIT – a KEMA developed tool

- Developed by KEMA in Europe and the US
- Simulates 24h Real Time Power System Dynamics
- Quantifies Impact of Variable Power Sources on System Operation
- Capabilities include:
  - Visualize impact of volatility on system control
  - Effect on system dynamic when adding wind or solar to the generation mix
  - Assess opportunities for energy storage
  - Comparison of operation control strategies
  - Investigate system response to outage or cable loss
  - Test mitigation strategies for intermittent generation

Analysis Timeline

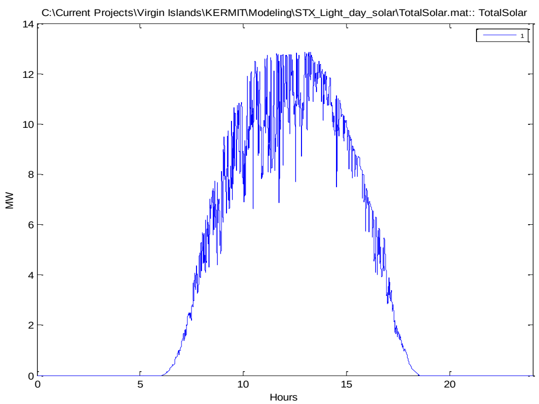


KERMIT Dynamic Simulation Features

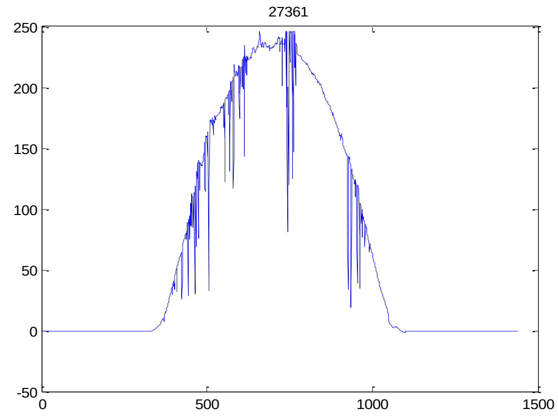
- Useful in analyzing response AND in developing / assessing new solutions
  - Governor controls and droop settings
  - AGC algorithms
  - Integration of fast storage
  - New scheduling / dispatch paradigms
  - Varying reserve levels
  - Use of Demand Response

KERMIT allows testing various PV output patterns

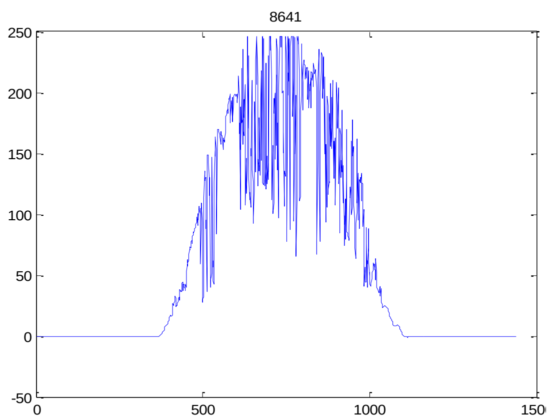
Typical



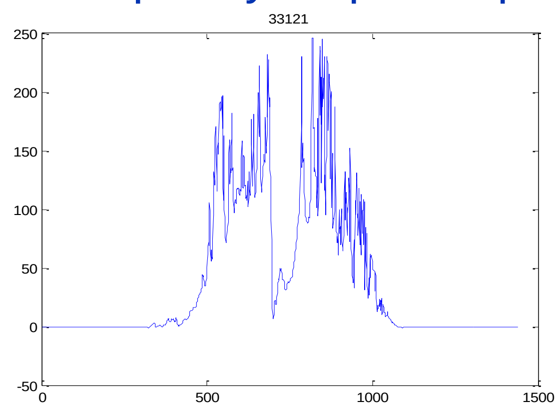
Smooth



Volatile

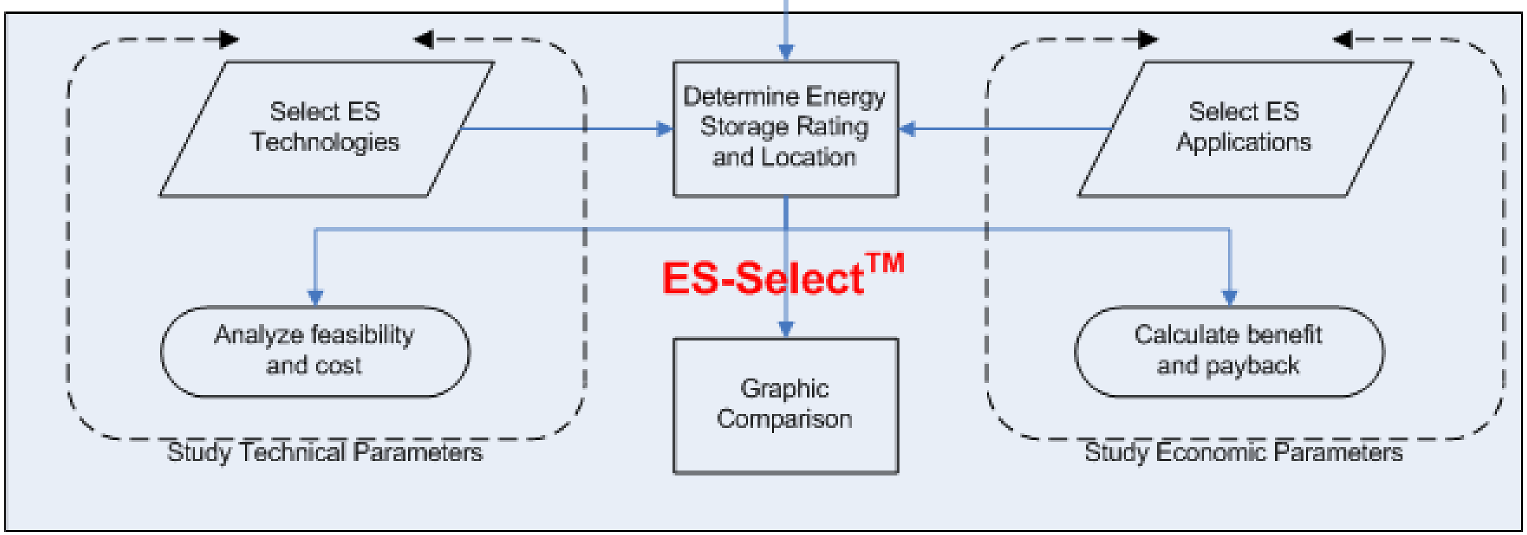


Temporary output drop



KEMA ES-Select software

Input from KERMIT and (for example) PSSE study results for determining technical and economical feasibility of Energy Storage



CASE STUDIES

- KEMA performed Renewables Integration Studies for island systems like Oahu (Hawaii), Aruba, Niue, for a number of US West Coast Utilities and currently a study is ongoing, using the tools as mentioned again, for US Virgin Islands

Two case studies

- Findings of the US Virgin Islands Study so far
- Integration of Solar Energy Generation in the Power System of the South Pacific Island of Niue

US Virgin Islands

KERMIT Modeling – preliminary results

St. Thomas basics

- VI-WAPA requested study of
  - Technical limits to maximum wind and PV
  - Connection studies for six specific proposed projects
- KEMA uses a unique computer tool (KERMIT) for evaluation
  - Evaluates entire days in sub-second intervals
  - Especially suited for evaluating random generation during entire day
  - Evaluates dynamic response of system through entire day
- System characteristics
  - 80 MW peak load
  - Six generators
    - Total 132 MW
    - Largest 39 MW
- Proposed PVs
  - Three sites total 9 MW
  - Largest 5 MW

KERMIT Simulation – St. Thomas

- Three PV sites on STT:
  - Home Depot 5MW
  - Mall roof 2MW
  - Mall canopy 1.833MW
- PV profiles are assumed as follows:

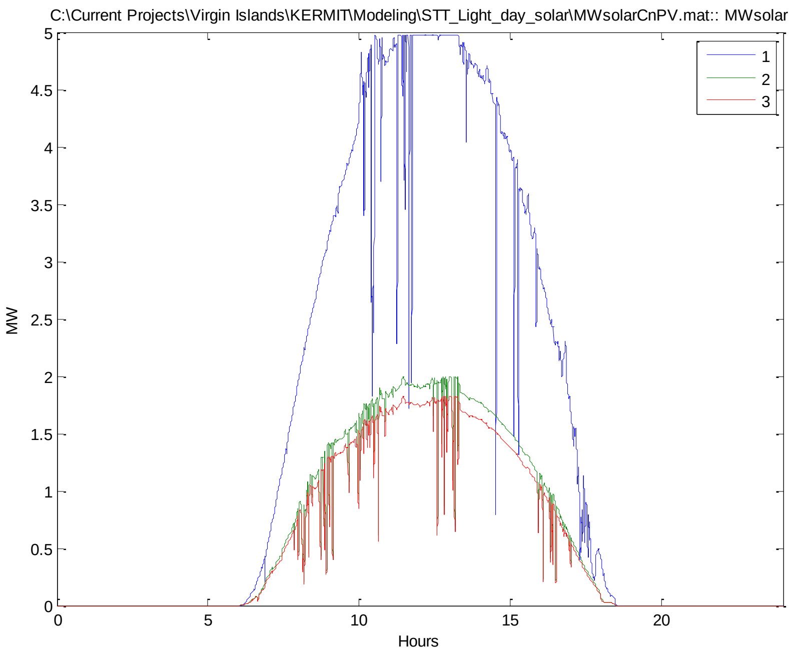


Fig.1 Individual PV site output power

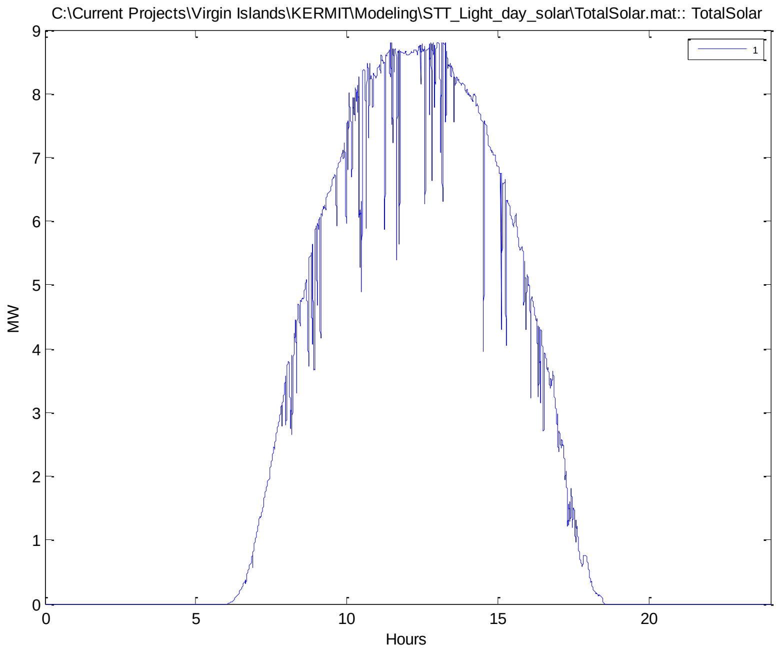


Fig.2 Total PV output power

KERMIT Simulation – St. Thomas

- System frequency with and without PV
- The frequency deviation is caused by the short term fluctuation of PV power that the SCADA system and line engine are not fast enough to compensate.

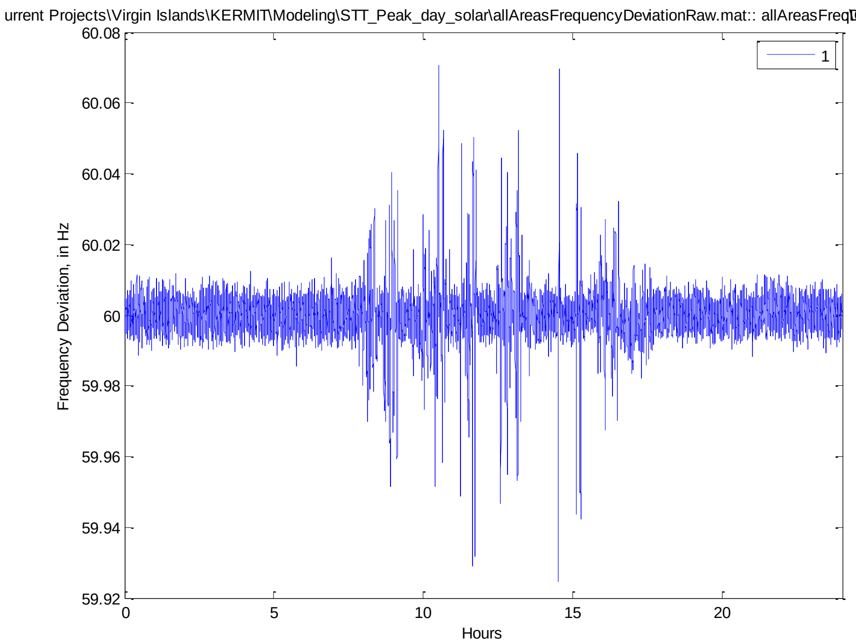


Fig.3 System frequency with PV

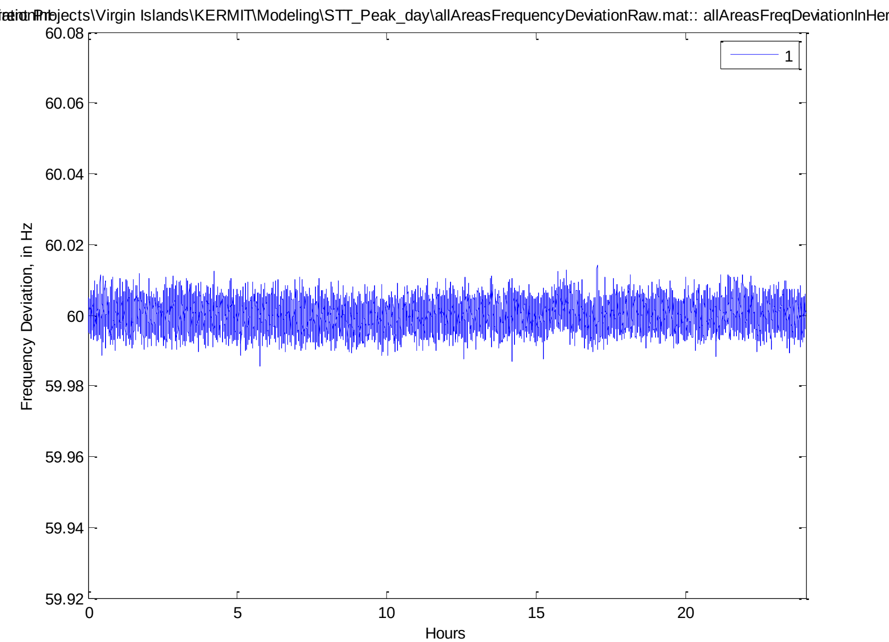


Fig.4 System frequency without PV

KERMIT Simulation – St. Thomas

- System frequency in the case the largest PV site (5 MW) is tripped
- System frequency drops due to the lack of generation. Then the line engine is picking up the imbalance by increasing the dispatch.

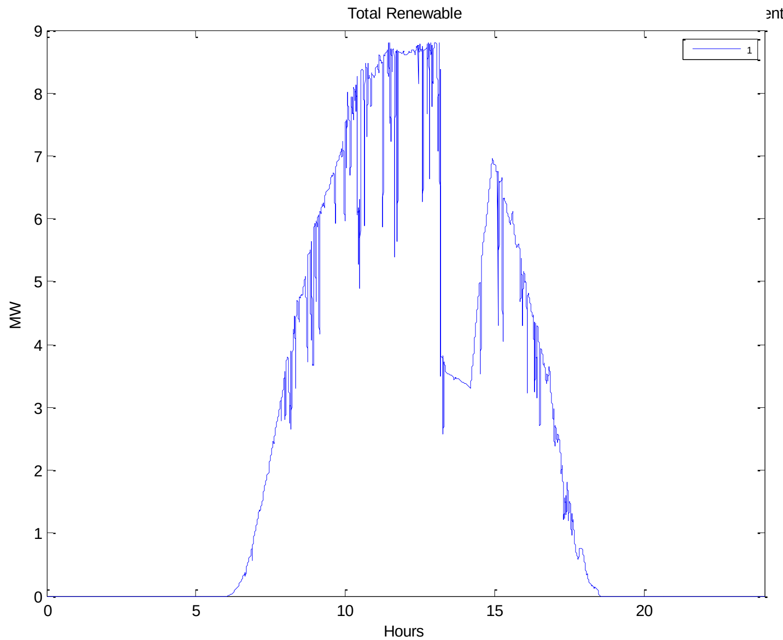


Fig.5 Disturbance in PV generation

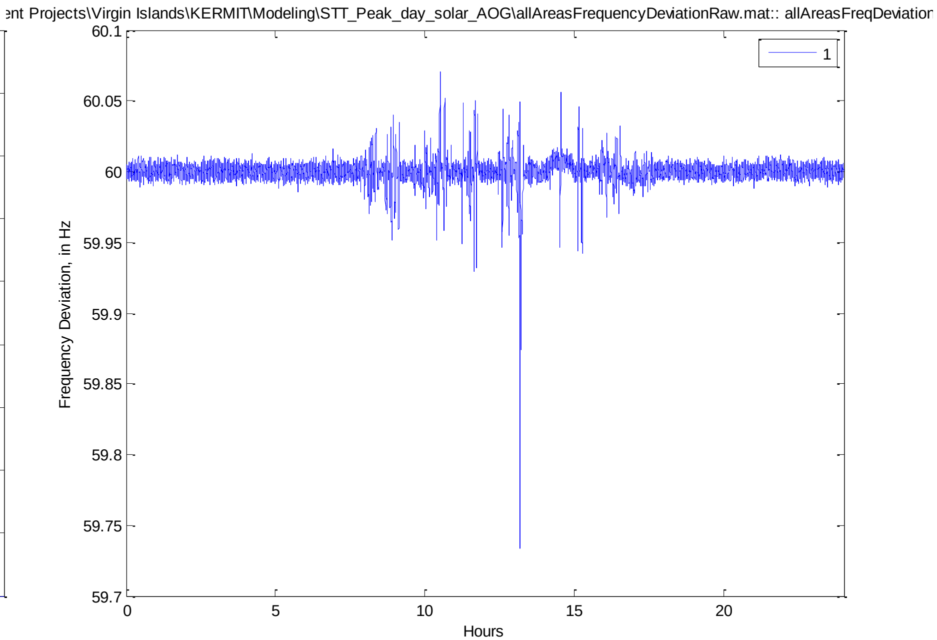


Fig.6 System frequency with PV disturbance

Looking for solutions

- For mitigating solutions, we will look at the existing solution and the new solution—in that order.
- For the existing solution it is likely to review the policy of maintaining spinning reserves. More simulation are currently ongoing to determine whether there is enough capacity and units to meet the new spinning reserve requirement.
- An alternative solution is energy storage, which is more effective at maintaining the frequency.
- On both solutions a cost/benefit analysis will be worked out.
- US-VI does not have a “frequency standard”. In fact, like in many islands, they don’t record the frequency, while such historical record would be needed for model calibration. All UFLS is set at below 59Hz for St Thomas. This means that as long as the fluctuations in wind and solar power are not too large, spinning reserve should be able to keep the UFLS from being triggered.

NPC Niue

Preliminary results

Niue system basics

- Very small system
  - 500 kW peak load
  - Population about 1,600
  - Limited commercial activity
- Four 500 kW diesel generating units
- Some ‘difficult’ motor loads
  - Water pumping
  - Rock crusher at quarry

Niue challenge

- Must be able to support rock crusher and water pumping
- Now must operate second diesel to support motor starting

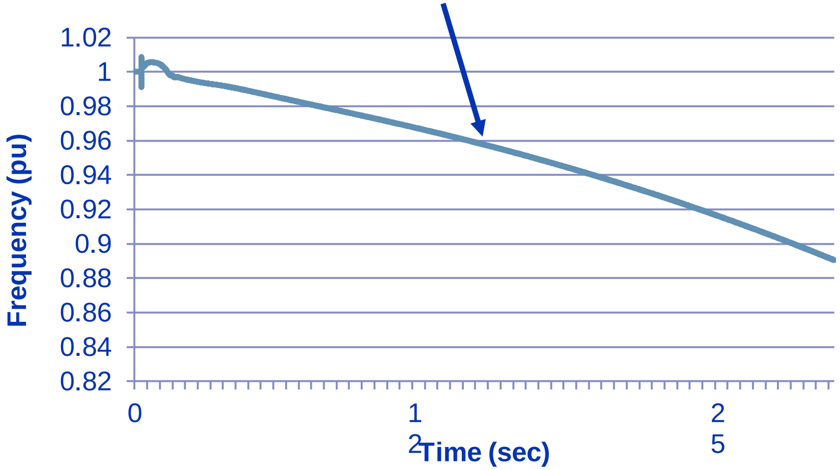
- Want to avoid running second diesel for motor starting
- Want to integrate maximum amount of renewables

- These are preliminary results

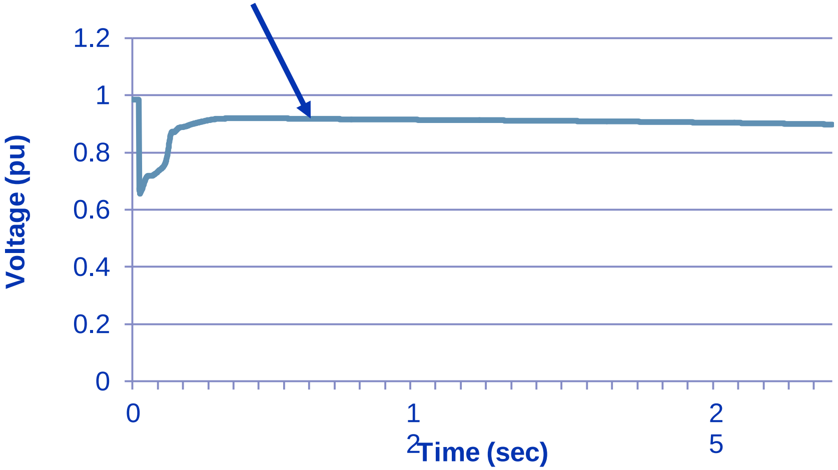
One diesel is not enough for motor starting now

One Diesel Online; 60 kW PV, 150 hp motor start

But the system will collapse



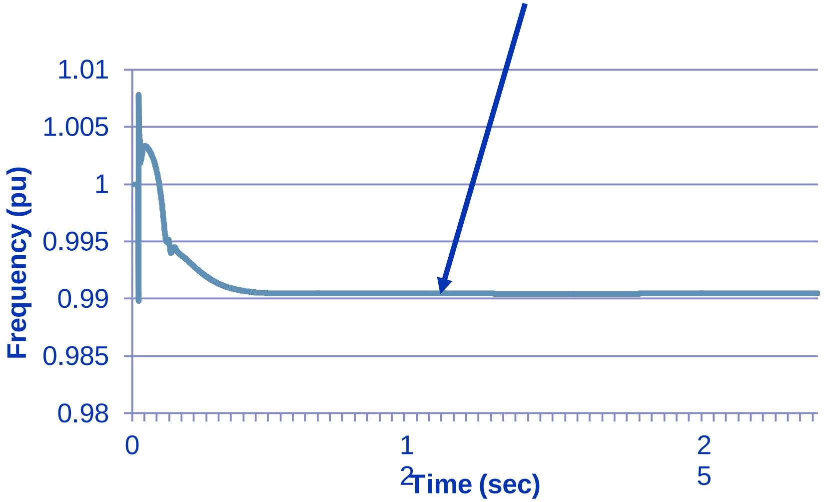
Voltage is OK



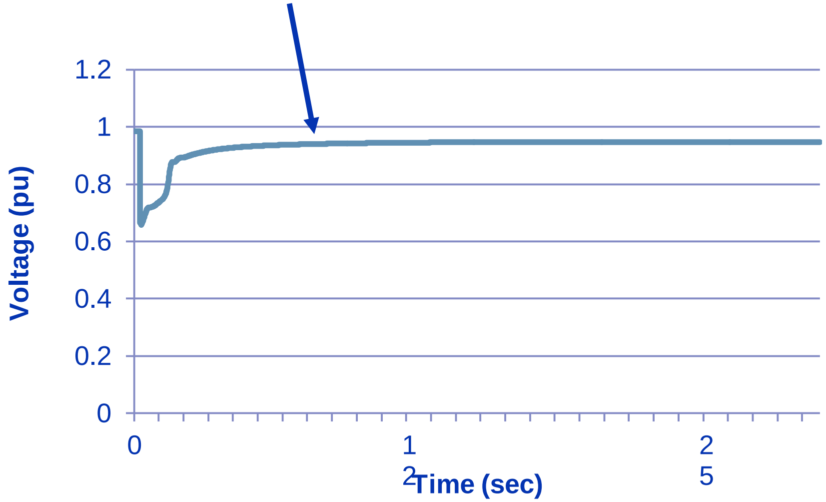
Increased PV puts more reserve in the diesel

One Diesel Online; 120 kW PV, 150 hp motor start

The frequency dips to 99%, but holds on



Voltage is a little better

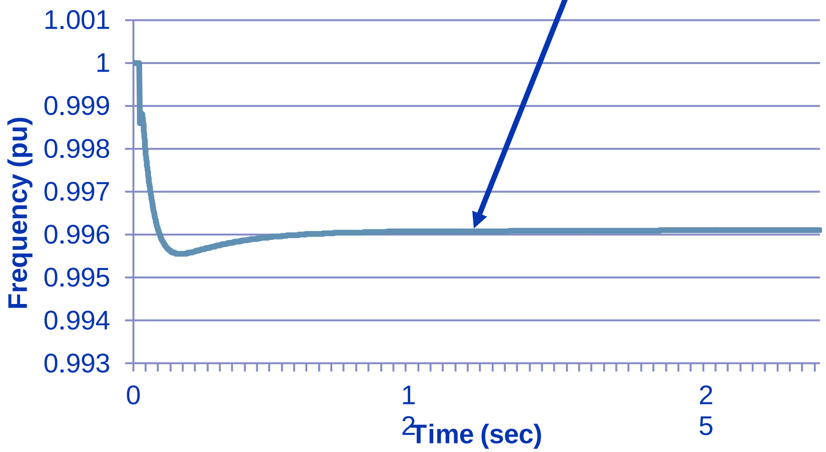


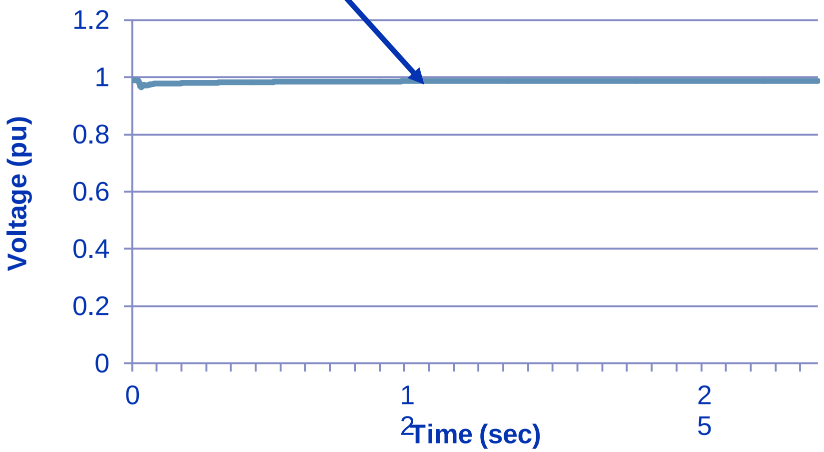
Also works with max PV and loss of large PV

One Diesel Online; 400 kW PV (80% system peak load); loss of large PV (40 kW)

The frequency dips to 99.6%, and holds on

Voltage is fine





Preliminary findings

- NPC must always operate one diesel generator
  100% supply with solar is not possible
- One diesel should handle normal renewable output variations
- System frequency variations because of high solar power fluctuations can most likely be covered by one diesel generator as it looks now (no UFLS). If not, a second diesel generator should run as spinning reserves during the hours per day with most solar power
- Renewable inverters susceptible to low-voltage drop-out during motor starts
  - Will require low-voltage ride-through
- Motor starting is a problem
  - PV instead of a second generator online provides limited starting current (105% max output)
  - With increased PV however more reserve in diesel is allowed
  - Solution with capacitors is currently being studies
- Maximum of renewables is limited by minimum load on diesel (≈100 kW)
- Will review results with NPC in Niue at end of July

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