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Agenda

- **Introduction**
- Simulation Model Description
- Model Verification
- Stability Study
- Model Response Analysis
- Conclusion

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Introduction

- Our use of PowerFactory:
  - Grid connection studies for renewable resource integration.
  - Assess the need for grid stabilisation.
  - Solution studies to overcome stability issues.
- Purpose of present study:
  - Windfarm extension on island system.
  - Create verified simulation model.
  - Find voltage, frequency or stability issues due to windfarm extension.
- Purpose of this paper/presentation:
  - Show approach for island simulation models
  - Show the importance of model verification
  - Show simulation accuracy against real measured data

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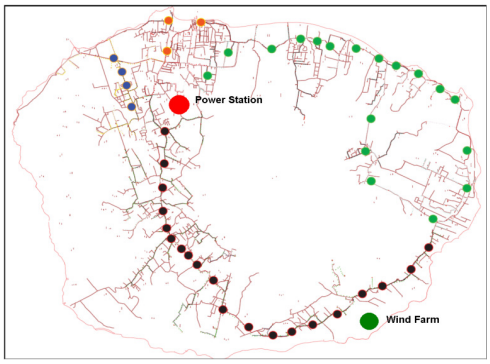
General Information

- Island in the Caribbean Sea
- Pop (2006): 12,106
- Existing grid - diesel only Power Station
  - 6 heavy fuel oil generators
  - Power range 0.9-2.7 MW
- Max. Demand: 8 MW



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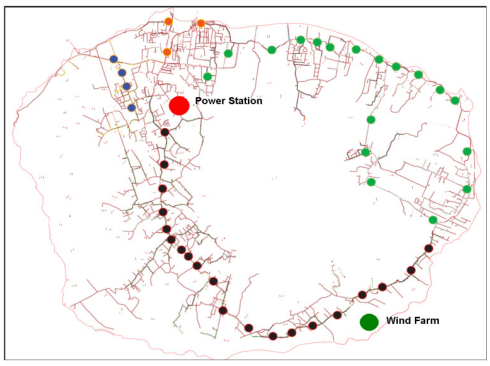
General Information

- Renewable Integration
  - 8 Wind Turbines
  - No grid stabilisation
- Model input data
  - Wind speed and turbulence factor
  - Load data



- System measurements recorded after commissioning in windfarm substation and at generator terminals

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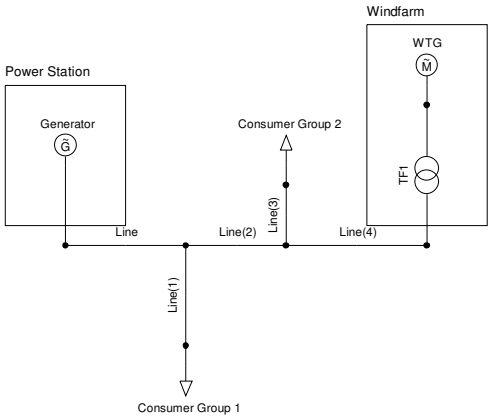
Grid model description

- Grid model
  - Sub-model power station
  - Sub-model windfarm
  - Sub-model grid
- Dynamic models for:
  - Generator
  - Wind turbine
  - Wind profile
- Model inputs
  - Wind speed for WTG
  - Static consumer loads



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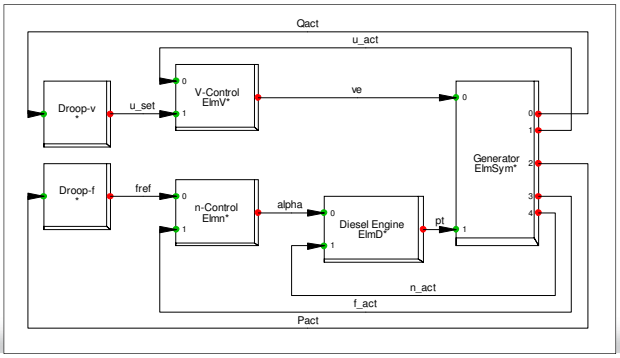
Generator model description

- Dynamic model for the generator
  - Droop functionality
  - Speed and voltage control
  - Engine model for turbo-lag effects



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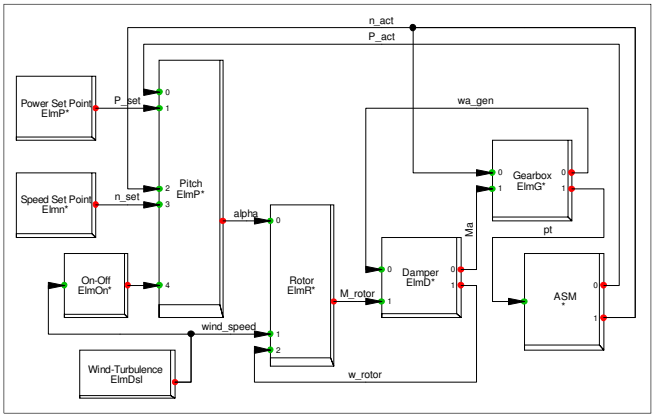
WTG model description

- Dynamic model for the wind turbine
  - Pitch-controller
  - Rotor
  - Damper (Shaft)
  - Gearbox
  - ASM



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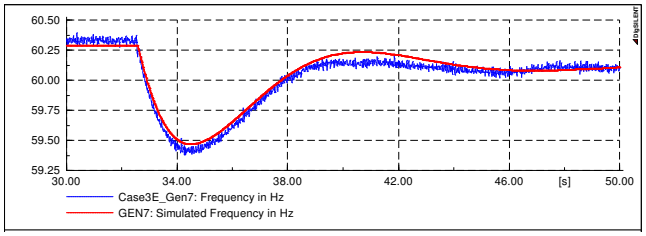
Model verification

- Generator model verification
  - On site step load testing
  - High resolution data recorder
  - Different load steps (Generator behaves different)
  - Parameter adjustment in PowerFactory model
- Wind turbine verification against field data



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Stability study

- System construction with verified models
- Simulation setup:
  - WTG limited to max power output
  - Wind model determines wind speed for WTG
  - Frequency and voltage control by 1 generator
  - Other generators in power set point mode
- Simulation system allocations:
  - Simulation duration 360 seconds
  - Mean wind speed 8m/s with 12% turbulence
  - No wind park spatial dispersion
  - Load is constant

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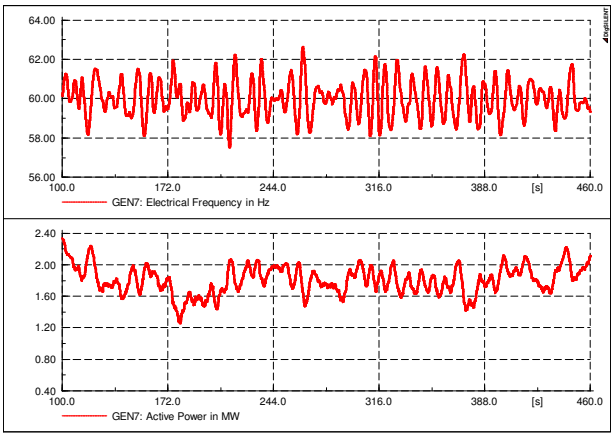
Simulation results

- Initial model before commissioning
  - Frequency variation 4Hz
  - Average variation in Power 400kW
  - Timeframe 360sec



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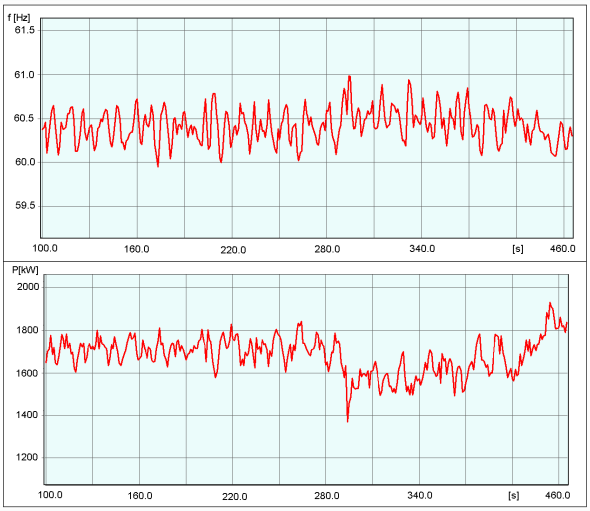
Real System Measurements

- Frequency variation 1Hz
- Average variation in Power 200kW
- Timeframe 360sec



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Analysis of model response

- Generator step response
  - Poor measurements for initial step response tests; larger steps were needed to see the full (nonlinear) response of the engine
  - Resultant model frequency stiffness was lower than reality; this gave the false indication of high frequency variation
- Wind turbulence factor
  - Turbulence factor very difficult to measure
  - High turbulence factor gave high system frequency variation
- Wind park spatial dispersion
  - Wind park spatial dispersion factor ignored in initial simulations – spatial dispersion factor reduces frequency variation

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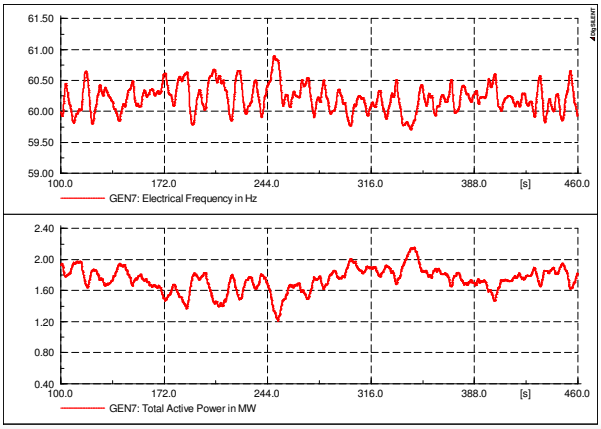
After commissioning

- Simulation response after commissioning and adjustment
  - Frequency variation 1Hz
  - Average variation in Power 200kW
  - Timeframe 360sec



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Model verification results

Model	Wind Turbulence	Frequency deviation
Real System	Unknown	1.0 Hz(peak)
Initial modelling of system	12%	4.0 Hz
Model after first step load tests	12%	3.0 Hz
Model after commissioning	12%	1.5 Hz
Different Turbulence	6%	1.0 Hz
Wind park model with spatial dispersion	12%	1.0 Hz

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Conclusion

- Three main aspects of the paper:
  - Dynamic model development
    - Correct design of generator and WTG models
  - Parameterization of models
    - Generator model parameters wrong due to measurements
  - Input data for the simulations
    - Modeled wind profile correct but turbulence undefined
    - Wind park spatial dispersion
- Conclusions
  - Wide range of generator step tests required for proper model verification
  - High resolution wind data required for wind profile
  - Consider other factors such as WTG spatial dispersion, load dynamics, etc.

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