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ENERGY

Dynamic Study of Bonaire Island Power System

Model validation and project experience

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About DNV GL - Energy

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Agenda

- Background info
- Model Validation
- Project Experience
- Conclusions

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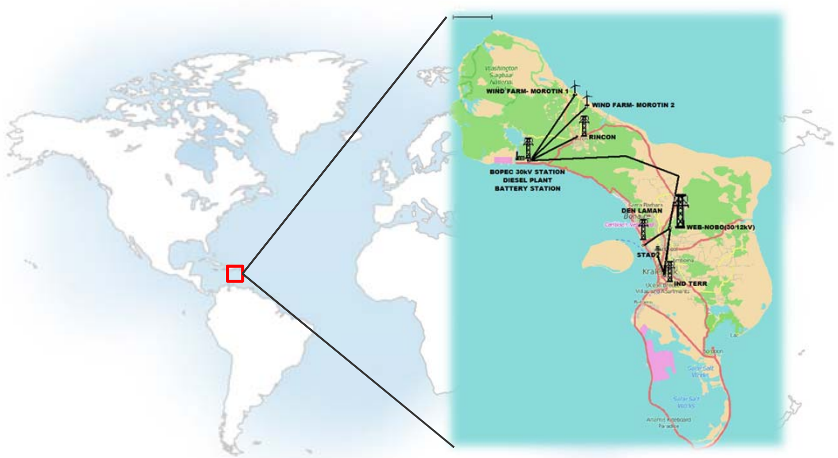
Background Info – Bonaire Island



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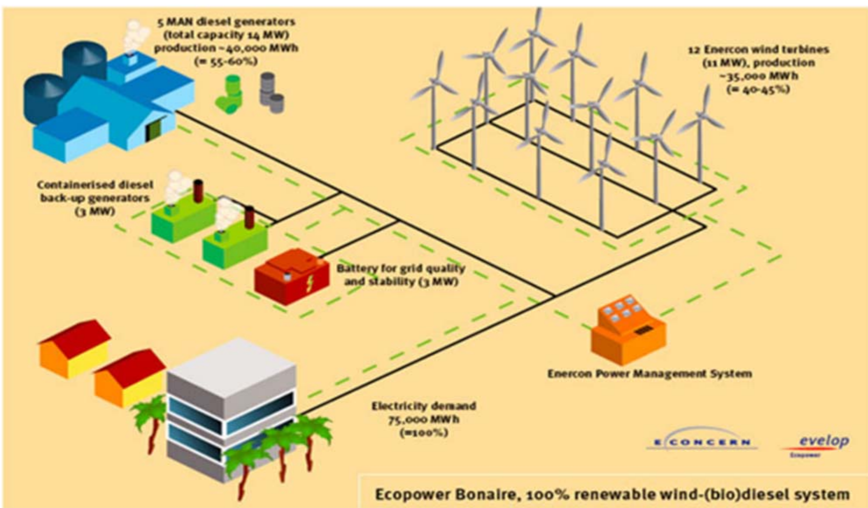
Background Info – Bonaire Island Power System Overview



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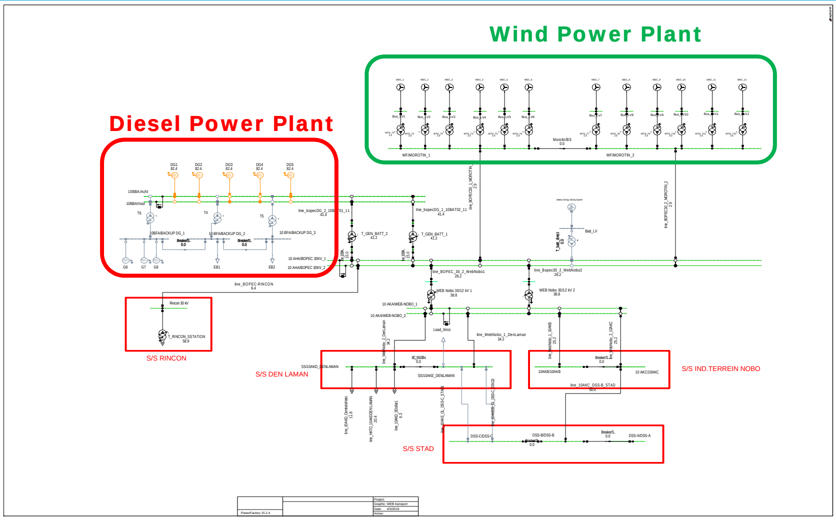
Model Validation – Bonaire power system model



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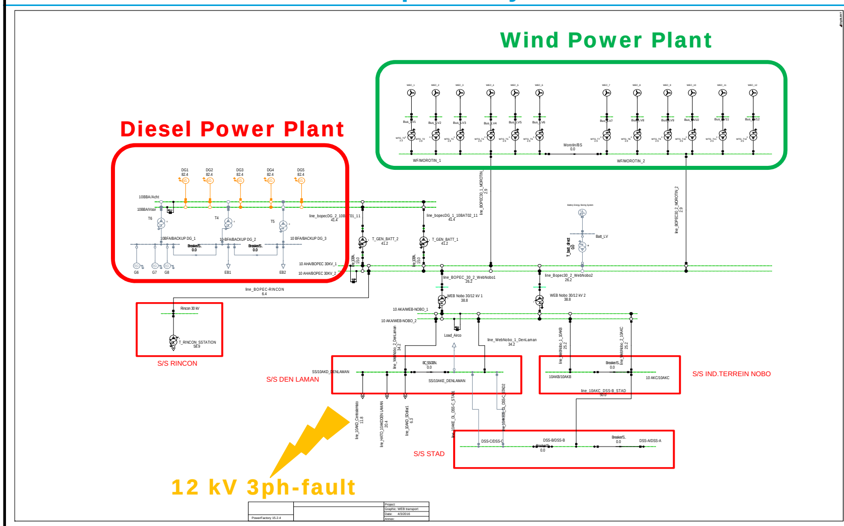
Model Validation – Bonaire power system model



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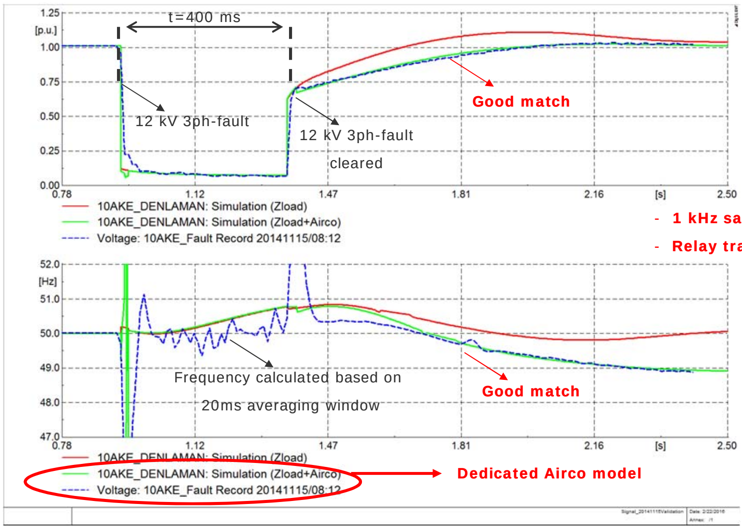
Model Validation – three-phase fault event

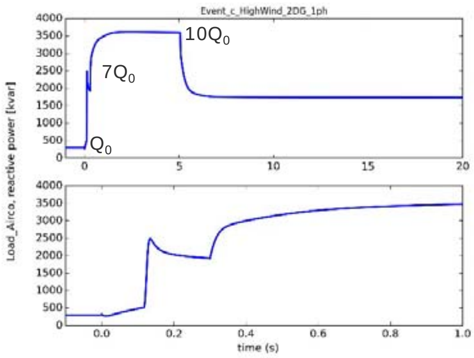


- 1 kHz sampling resolution
- Relay transient record

Dedicated Airco model

Airco model

- Dedicated airco model was developed:
  - via analysis of fault recordings
  - reactive power and voltage impact during and after fault clearance



- Reactive power:
  - during fault increases $7Q_0$
  - after fault clearance $10Q_0$.
- Due to increase reactive power:
  - voltage can not recover
  - airco motor stalls (lack of torque)
- Network voltage remains low and the wind power output can not recover

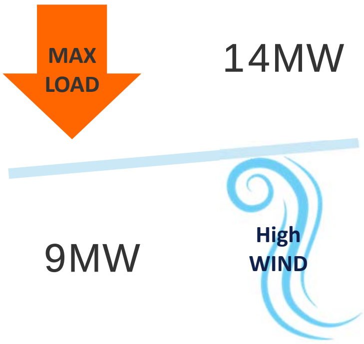
=> wind power trips on under voltage after 5s.

Project Experience – High wind system configuration

Bonaire island power system installed capacity

- 5 Diesel Generators – 14 MW
- 12 Wind Turbines –10.8 MW
- 1 Battery Energy Storage – 3 MW (100 kWh)

Event_c, fault impedance 2 ohm		Frequency (DG Speed)			Voltage (12 kV WEB Nobo)			
		CB open (0.3 s)	1 s	5 s	min.	CB open (0.3 s)	1 s	5 s
1-phase to ground	HighWind_3DG	95.5%	97.6%	100.3%	40.0%	90.0%	104.0%	100.0%
	HighWind_2DG	99.7%	103.0%	103.0%	27.4%	72.0%	77.0%	78.0%
2-phase	HighWind_3DG	101.0%	99.8%	99.1%	26.0%	75.0%	90.0%	92.0%
	HighWind_2DG	103.9%	99.3%	101.8%	26.0%	76.0%	57.3%	53.9%
2-phase to ground	HighWind_3DG	97.5%	99.4%	99.3%	26.0%	70.0%	90.0%	92.0%
	HighWind_2DG	99.6%	104.3%	103.0%	21.0%	70.0%	76.0%	78.0%
3-phase	HighWind_3DG	97.6%	100.8%	99.2%	30.0%	65.0%	87.0%	92.0%
	HighWind_2DG	101.8%	101.0%	101.6%	9.8%	58.0%	56.0%	54.0%



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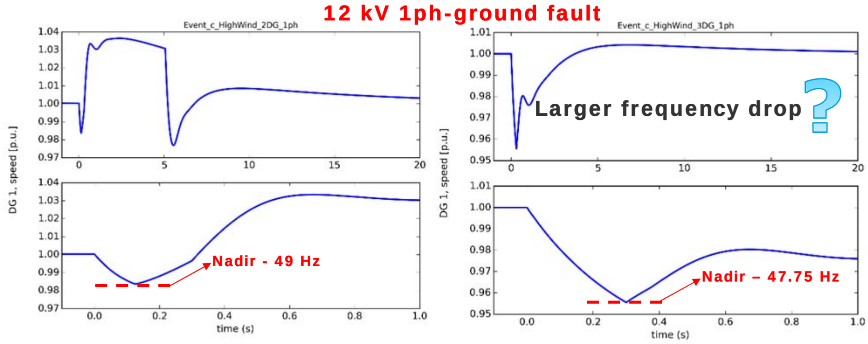
Project Experience – Frequency stability in high wind scenario

12 kV 1ph-ground fault



2 Diesel Generators

3 Diesel Generators

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- Short circuit current

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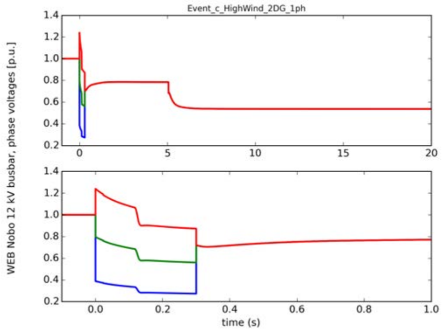
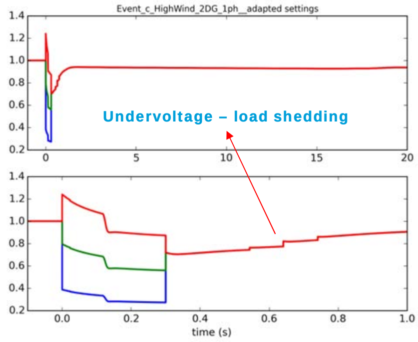
Project Experience – Voltage stability in high wind scenario

12 kV 1ph-ground fault



2 Diesel Generators



2 Diesel Generators

High Wind 2 DG Event_c		Frequency (generator speed)			Voltage (12 kV WEB Nobo)			
		CB open (0.3 s)	1 s	5 s	min.	CB open (0.3 s)	1 s	5 s
1-phase to ground	New settings	99.6%	104.2%	104.6%	27.4%	72.1%	90.7%	93.8%
	Old settings	99.7%	103.0%	103.0%	27.4%	72.0%	77.0%	78.0%
2-phase	New settings	103.9%	105.8%	104.7%	25.9%	75.9%	91.1%	94.9%
	Old settings	103.9%	99.3%	101.8%	26.0%	76.0%	57.3%	53.9%
2-phase to ground	New settings	99.5%	105.7%	104.9%	21.2%	71.0%	90.6%	95.0%
	Old settings	99.6%	104.3%	103.0%	21.0%	70.0%	76.0%	78.0%
3-phase	New settings	101.8%	107.5%	105.1%	9.5%	57.9%	89.6%	96.2%
	Old settings	101.8%	101.0%	101.6%	9.8%	58.0%	56.0%	54.0%

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Project Experience – Improved load shedding scheme

- Changed 12 kV load shedding scheme via under voltage setting and under frequency.

Bay	Proposed U-shedding (%/s)	Proposed f-shedding (Hz/s)	Bay	Proposed U-shedding (%/s)	Proposed f-shedding (Hz/s)
10AKE07	85% / 1.1	48.0 / 0.4	10AKB04	85% / 0.7	47.3 /0.1
10AKE05	90% / 1.3	48.0 / 1.0	10AKC05	85% / 0.8	47.1 / 0.1
10AKE04	85% / 0.5	47.7 / 0.1	10AKC04	85% / 0.9	46.9 / 0.1
10AKB03	85% / 0.6	47.5 / 0.1			

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Conclusions

- Short circuit fault with **fault impedance** (representing an overhead line) causes **active power** consumption **rise** as short circuit current flow through **fault path**.
- In **low inertia** island power system, the **fault current** could already produce significant **power losses**.
- Load shedding scheme shall consider both under frequency as well as under voltage as the **airco** load in the tropical island could delay the **voltage recovery** and in the extreme case could lead to **voltage collapse**.

Thank you

Ir. Yin Sun
yin.sun@dnvgl.com
Mobile: 0031 615 861217

www.dnvgl.com

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