Loss Minimization & Grid Stability in the Azores

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Talk outline

- Introduction about Flores Island and its electric network
- Minimizing delivery losses in the island
- Dynamic stability of the island
- Potential solutions to stability problem
- Conclusions and future work

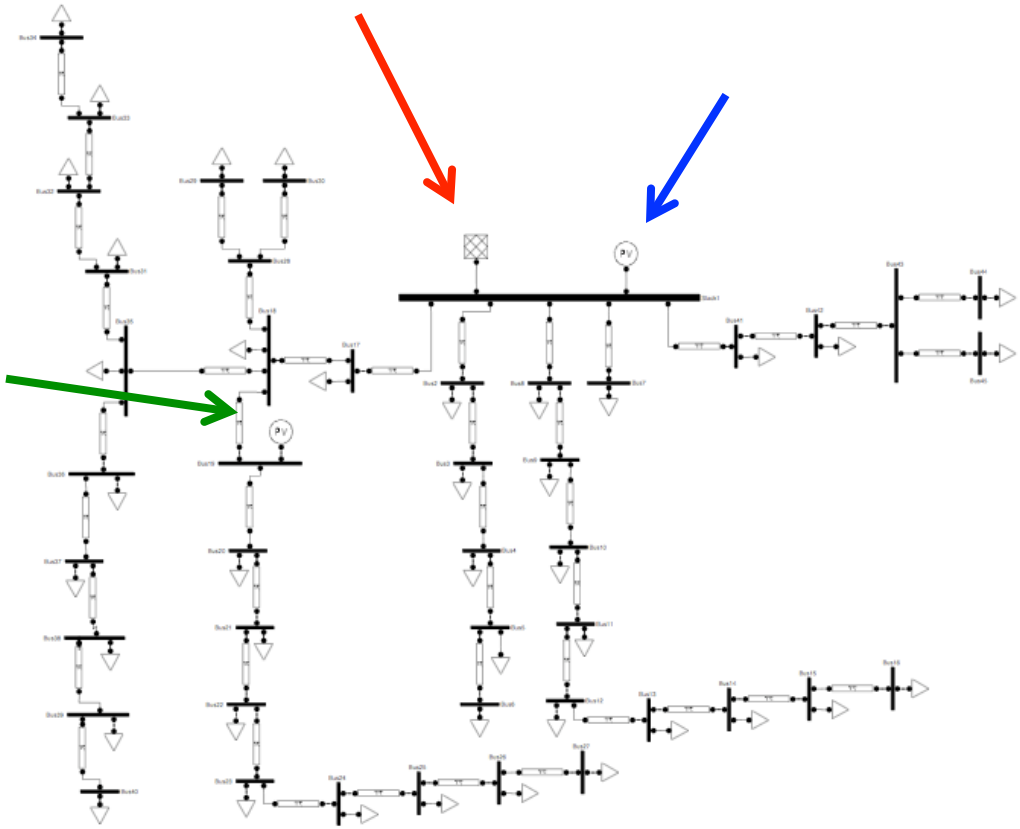
Flores Island

- One of the islands of the Western group of the Azores
- It has an area of 143 km²
- A population of approximately 4000 inhabitants

Source: Wikipedia

Electric Network of Flores

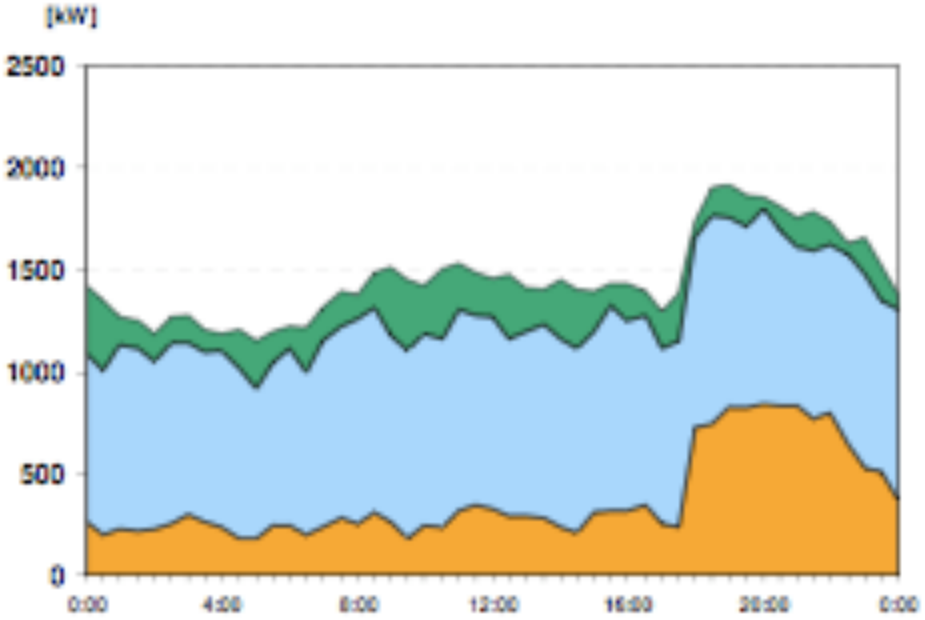
- Radial 15 kV distribution network
- Total demand is 2MW

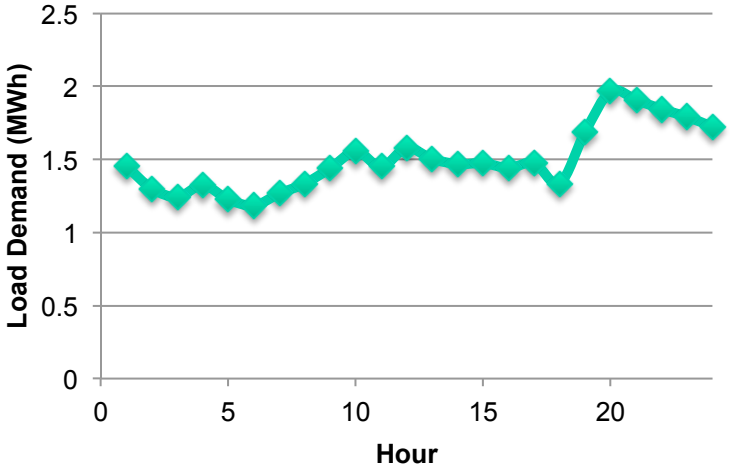


One-line diagram is produced by PSAT

Availability of Renewable and Load Pattern

- Data about typical winter day.





- Green wind
- Blue hydro
- Red diesel

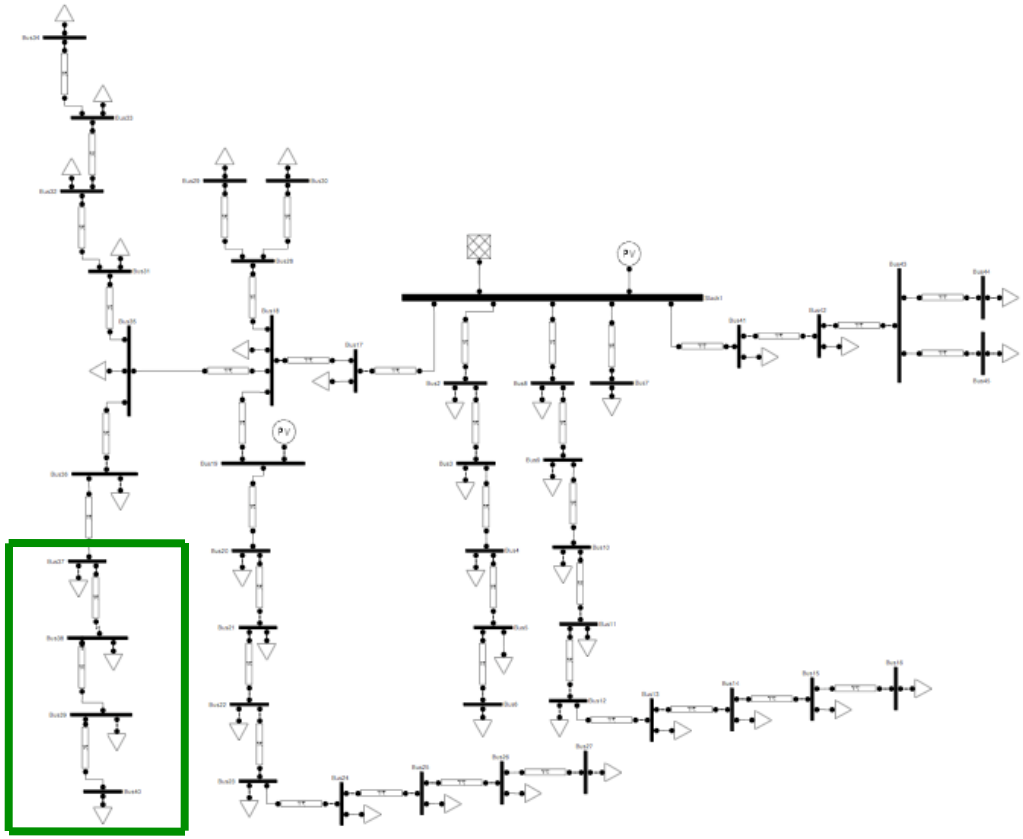
Winter	Max (MW)	Min (MW)
Hydro	0.9	0.8
Wind	0.6	0.05

Distribution Losses

- Distribution Losses in the island is around **2%**
- It accounts for ~1MWh daily energy losses and **~365MWh/yr**
- It costs the island around **60,000$/yr**
- It causes **117 tons/yr** of CO_2 emission
- This happens when wind turbine has 0.88 power factor and has not control over voltage

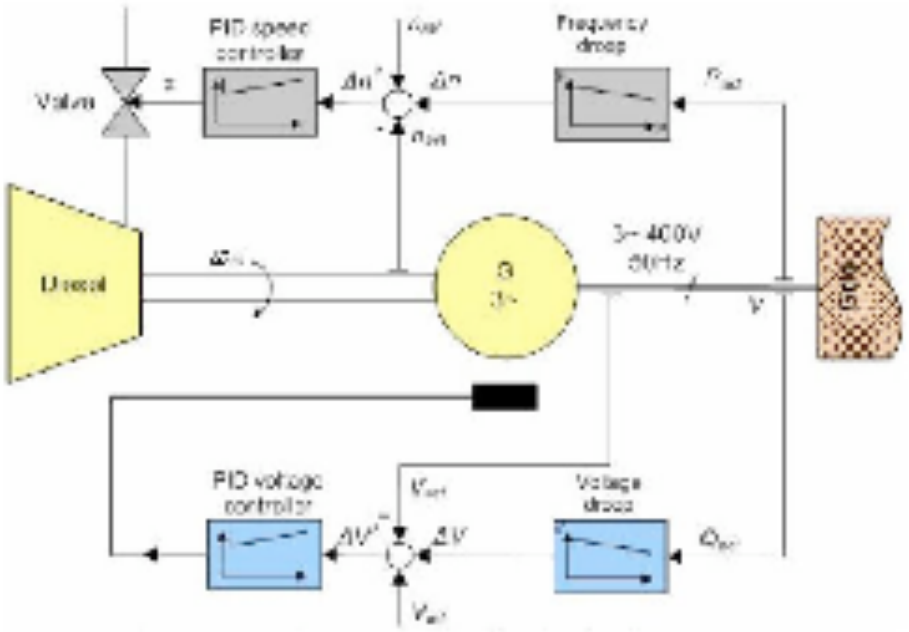
Minimizing Delivery Losses

- Delivery Losses could reduce by **50%**
- By controlling voltage of the wind turbine
- Optimally locating new wind turbines in the system
- This accounts for **183MWh/yr** saving of energy
- This causes reduction of CO_2 by **58.5 tons/yr**



Dynamic Modeling

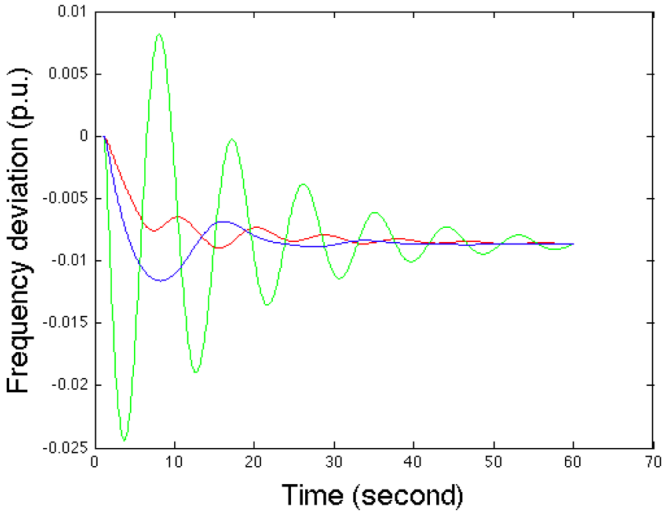
- Diesel generator has fast governor control
- Hydro turbine has slow governor control
- Wind plant has no active control over voltage and frequency

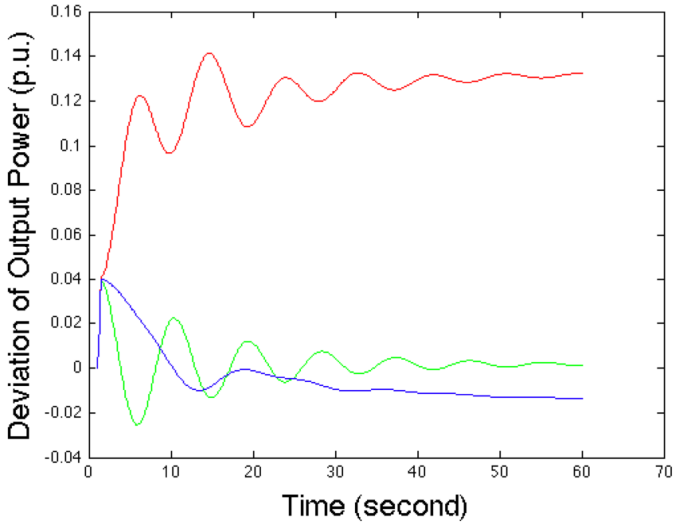


Source of graph: N. Hamsic et al, Power Eng Conf.

Dynamic Simulation

- Decoupled real-reactive power model





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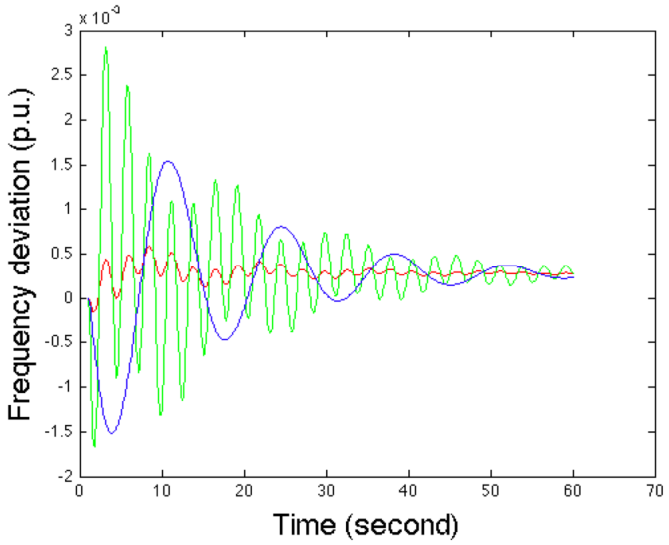
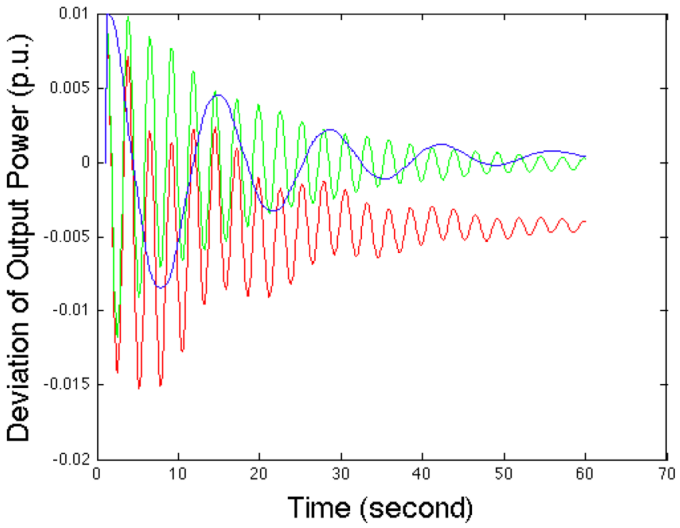
Dynamic Simulation

- Coupled real-reactive power model





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Issues of Using Diesel Generator for Primary Control

- Diesel generator is the only source to compensate fluctuations of wind
- Diesel cannot warrant stability when penetration of wind is high
- This could cause wear-and-tear of governor control
- Increasing emission of diesel generator
  - CMU work shows using gas turbine for compensating fluctuations of wind increases ~20% CO_2 and 50-70% No_x emission, compared to full power steady state operation.

 Source: J. Apt et al, Environmental Science and Technology

Potential Solutions to Dynamic Stability Problem

1. Designing faster control (e.g. bang-bang or high gain) for the hydro turbine

2. Implementing flywheels with fast dynamic response

3. Designing advanced power electronics control for diesel (PSS) and/ or for wind plants

Conclusions

- By controlling voltage set of available wind turbines and optimally locating new wind turbines, more than **50%** of losses could be reduced
- This accounts for saving **30,000 $/yr** and reducing CO_2 by **58.5 tons/yr**

Conclusions and Future Work

- Governor control of diesel generation should not be used for compensating fluctuations of wind
- Wind fluctuations could be compensated by implementing flywheels or designing advanced power electronics for wind or diesel
- Future work is to design optimal control for flywheel and/or advanced power electronic control

Questions ?