Demand side support in power system control allowing to accommodate more renewable energy sources

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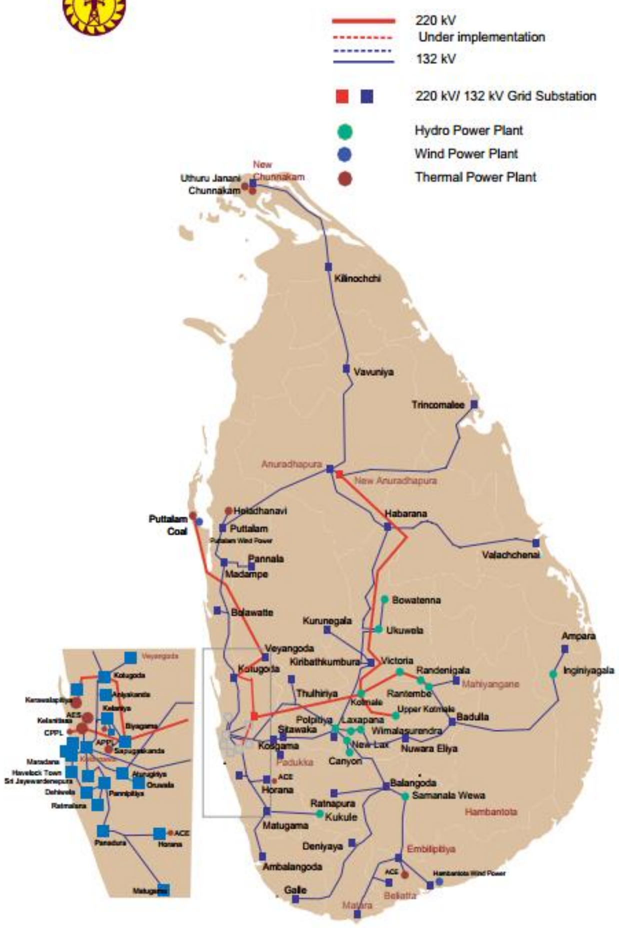
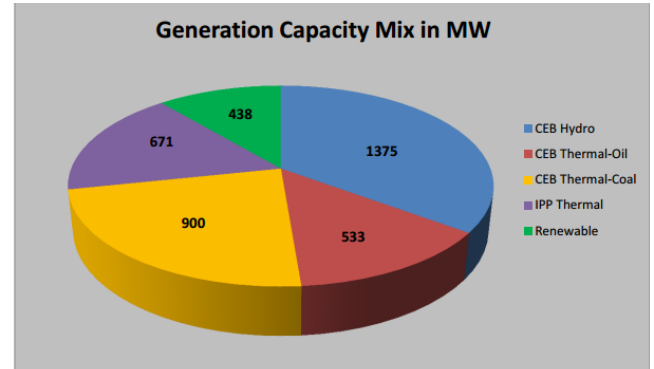
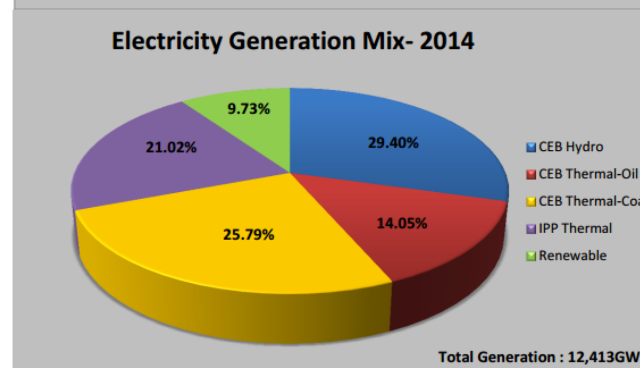
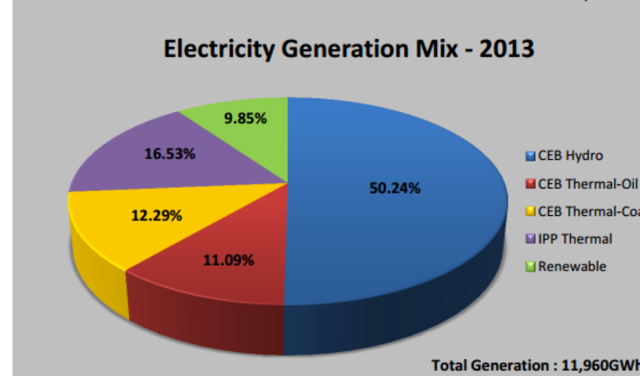


Constrained Sri Lankan power system

- Capacity constrained
  - Generation Capacity 4000 MW
  - Peak Demand 2150 MW
  - Large single coal plant 3x300 MW
  - Hydro + Renewable = 1800 MW
- Financially constrained
  - 2013 $ 227 million profit
  - 2014 $ 95 million loss
- Hydro potential is exhausted







The remaining options

- Large Thermal (coal or LNG) – Utility Prefer

- Renewables
  - Wind, Solar, Mini Hydro (already built many)
  - Connected to distribution networks
  - Net metering promote solar

- They cause operational problems

Operational problems with Thermal plants

- They are large (300, 500 MW)
- Hence need large spinning reserve for N-1
- Costly: Minimum 90 million USD for 300 MW
- CO_2 emission

- Do not run on partial loads providing spinning reserve
  - Inefficient or not designed
  - Private companies want to run at maximum

- In an event of a generation loss
  - Frequency drops rapidly (.7 Hz/s) and trip the thermal plants
  - Leading to total black out

Operational problems with Solar plants

- Do not support frequency control

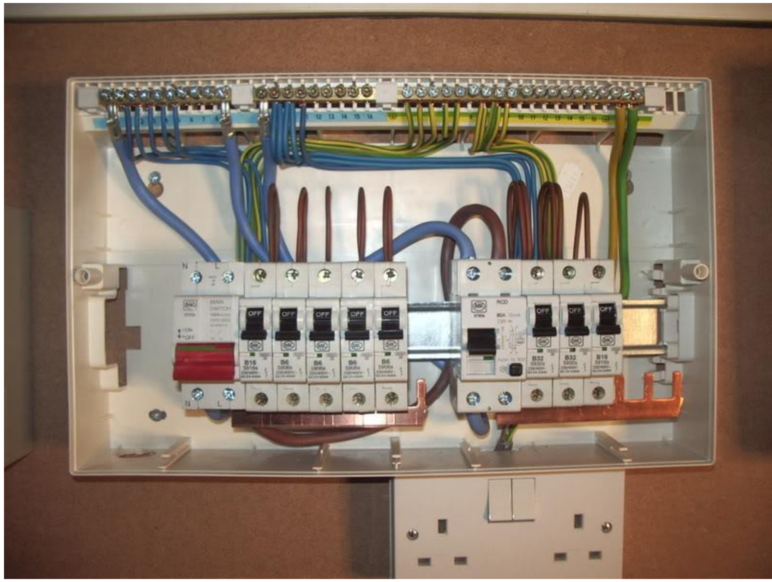
- Hence rely on under frequency load shedding
  - Denies power to all in the lines
  - Disrupt consumers life

- Economic loss of unplanned interruptions is high
  - Sri Lanka's GDP $72.82 billion
  - 0.3% of GDP = $218 million

- Load shedding cut off renewables when it is needed most

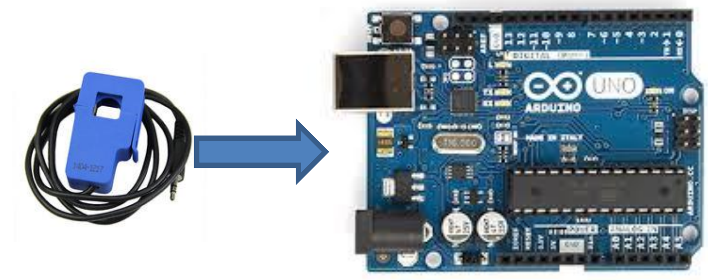
Solution: Use demand response from all consumers

- Add two bus bars
- Essential lighting and sockets
  - Low intensity lamp in every room
  - TV and electronic devices
- Non-essential lighting and sockets
  - That can be switched off for a short period
  - A/C, Fridges, cookers, hobs and ovens, washing machines

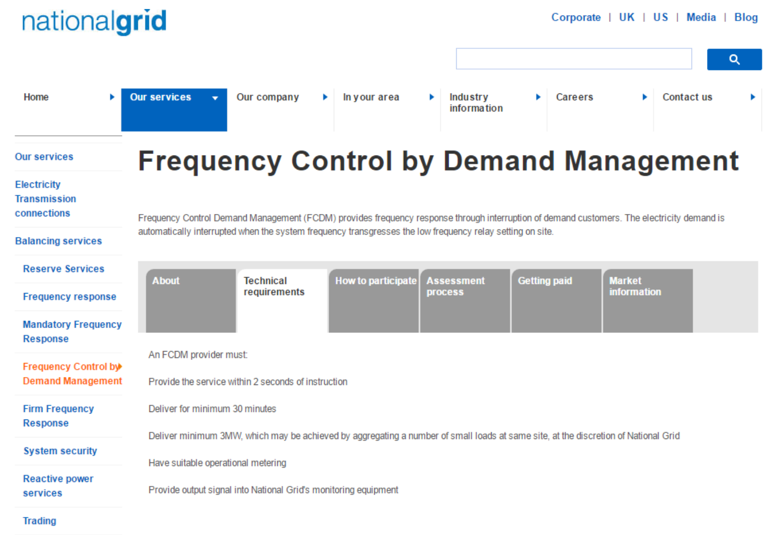


Low cost device control non-essential bus bar

- Measure frequency and power input
- Frequency drops
  - switch off non-essential circuit
- The Device
  - measure load reduction and at the time of switching
  - calculate the energy until the frequency returns
  - display the energy not used
- Utility pays consumers for the energy reduction




Demand response is used in developed countries from large consumers



- In the UK
  - National Grid Ancillary Service
  - Frequency Control Demand Management (FCDM)

- In USA: EnerNOC

Frequency responsive device installed inside appliances

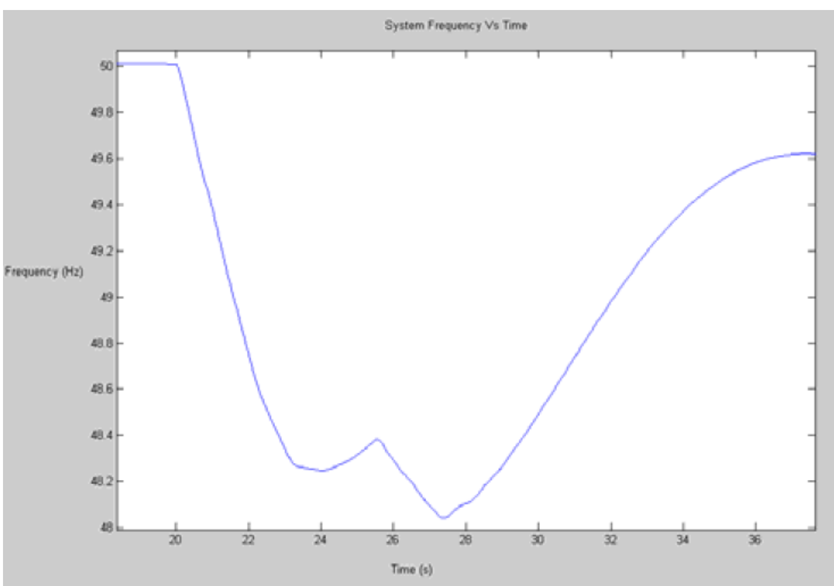
- Dynamic Demand, UK
  - RLtec^{TM}
- Pacific Northwest National Laboratory, USA
  - GridFriendly^{TM}

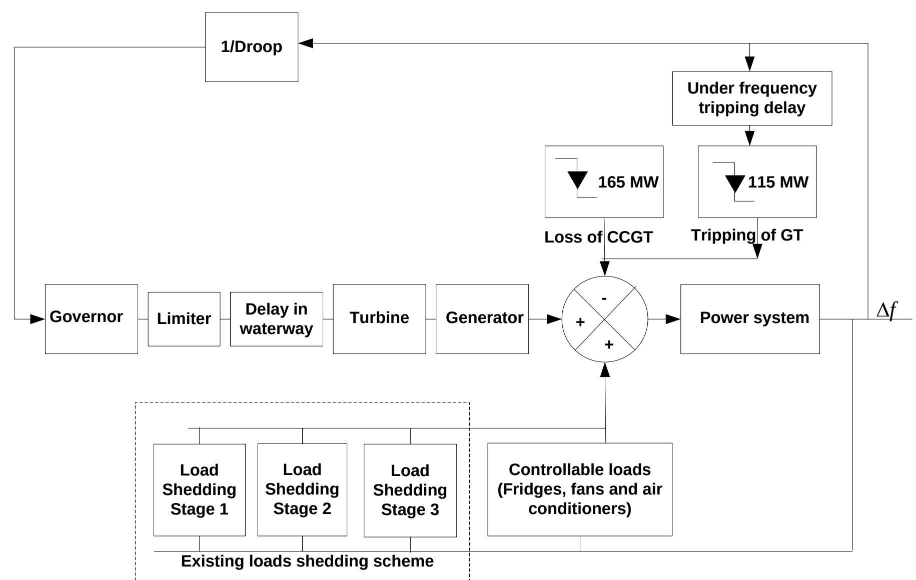
Financial implications

- 5.4 million consumers
- Cost per modification = $20
- Spending ½ of the economic loss ($218 mil) in one year sufficient to do the modification
- Ignoring other benefits
  - cost of spinning reserve, economic, customer comfortability, and satisfaction

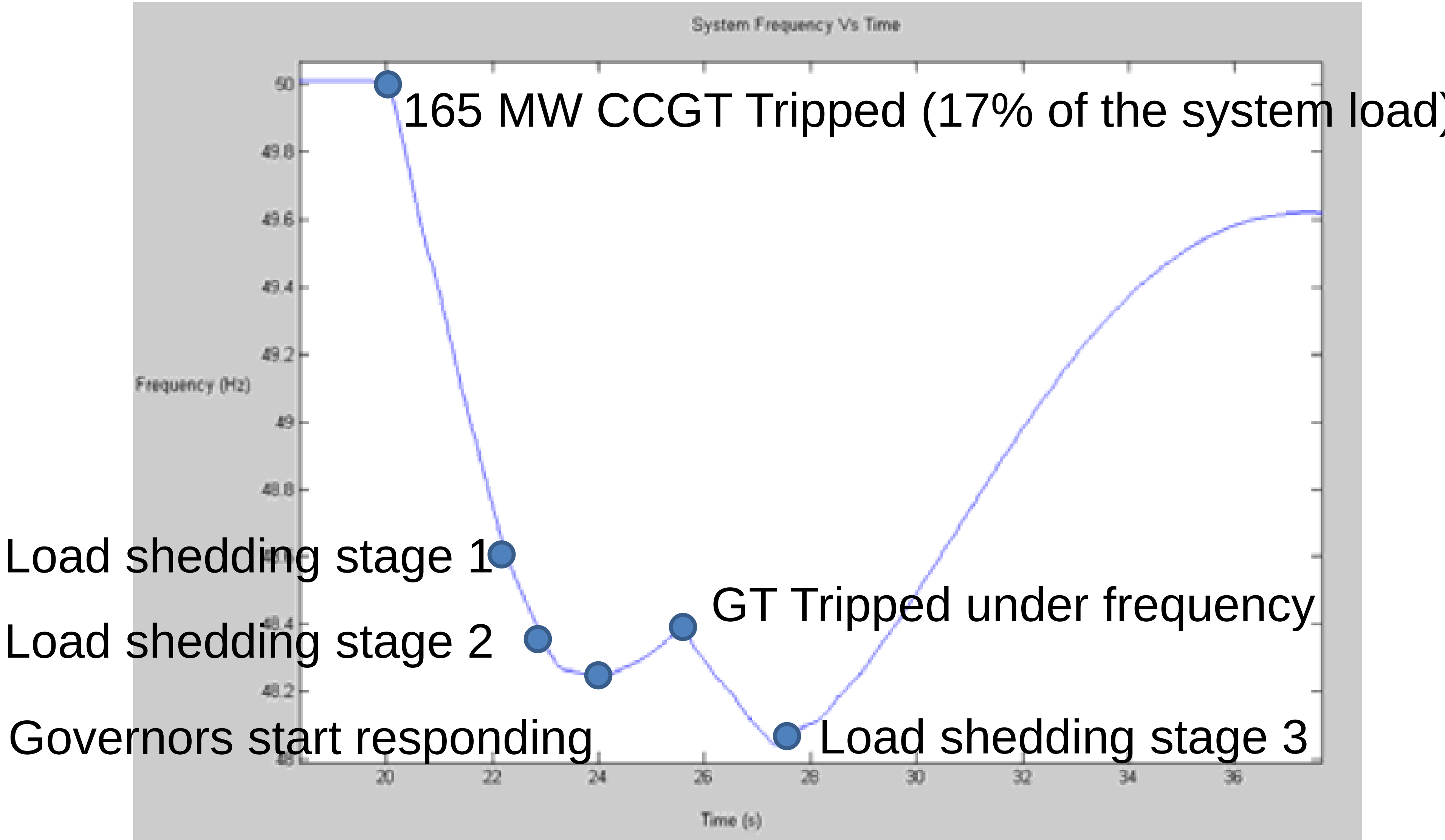
Simulation model

- No event data is available to the public
- Event occurred in 19th September 2003 was simulated in a reference
- 165 MW generator trip when load is 970 MW
- The model is tuned to replicate the events occurred



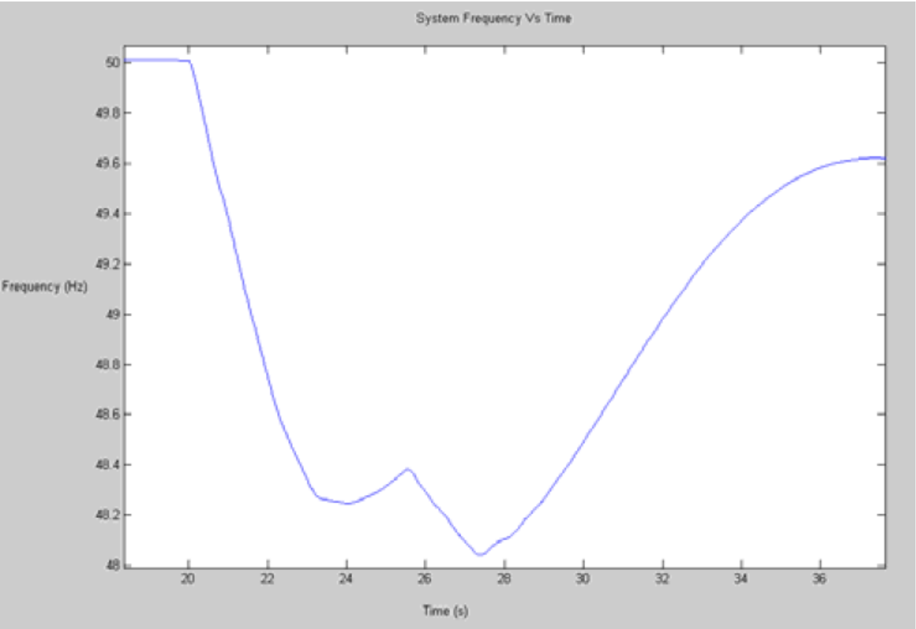


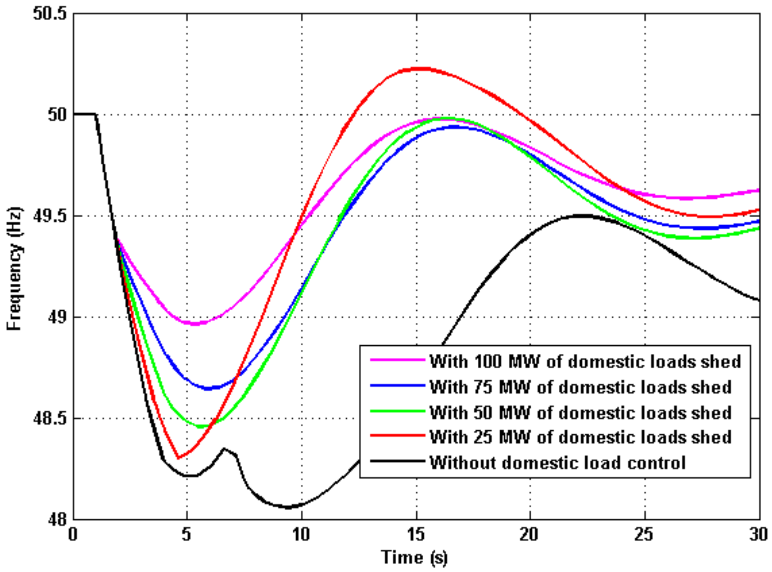
The event simulated



Four cases of simulations

- 25-100 MW loads were shed at 49.7 Hz
- GT plant was not tripped in any case
- Case 25 MW- Only present load shedding stage 1 is operated
- Cases 50-100 MW No present load shedding operated





Conclusion

- Maintaining spinning reserve is desirable
  - Distributed renewables are non-dispatchable
  - Running in partial loads is inefficient
  - Costly
  - CO_2 emission

- Consumers should help by providing demand response when the system is in difficult conditions
- Consumers will be compensated when they helped

- Simple device will work, but controllers are becoming cheap

- This will be a paradigm shift in future power system operation