MODELLING ISLAND ENERGY SYSTEMS FOR ENHANCED CLIMATE RESILIENCE AND SECURITY OF SUPPLY

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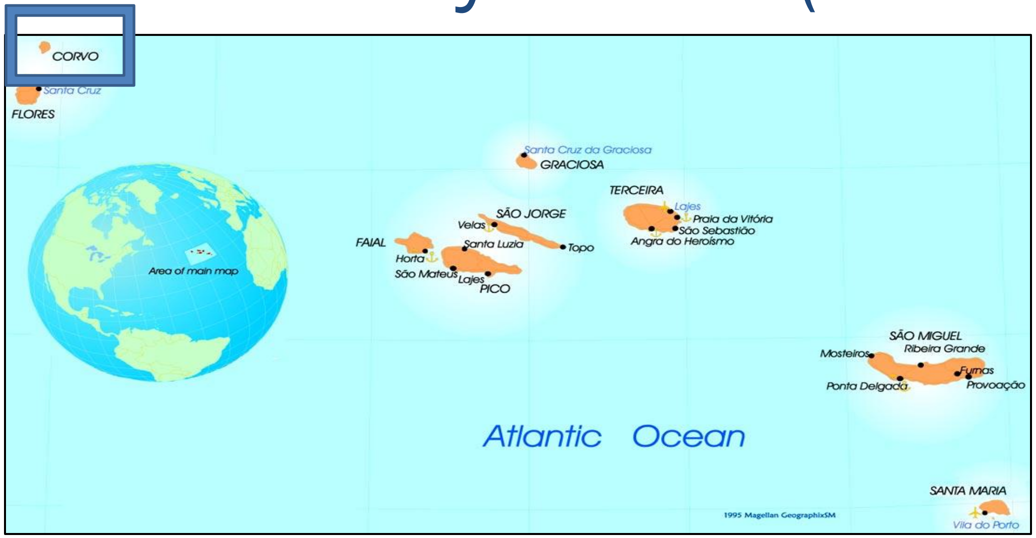
Context

This work was carried out as a part of the **MIT Portugal Program** (a collaboration between the Massachusetts Institute of Technology and the Government of Portugal) at IST – Lisbon, Portugal, in a project called the **"*Green Islands Project*"**.

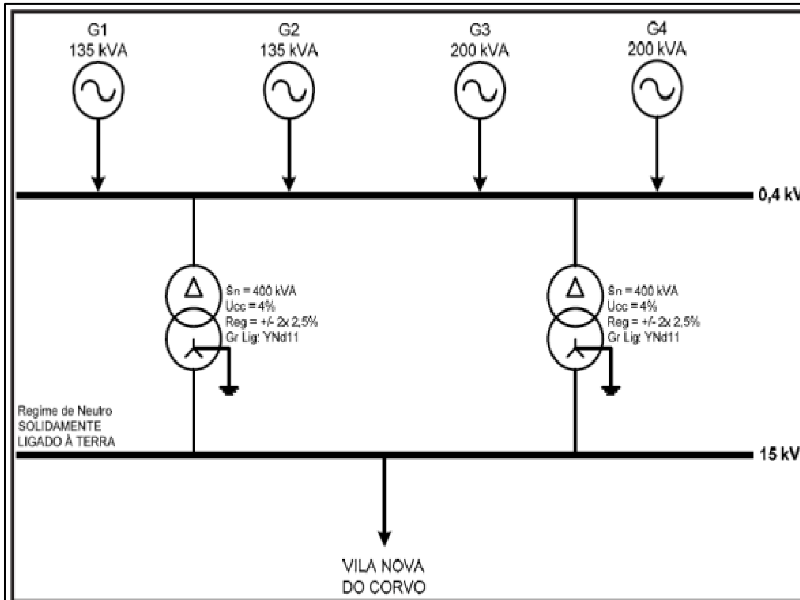
The aim of the project is to transform the energy networks of the islands in the **Azores** archipelago, Portugal into a 100 % renewable energy based systems.

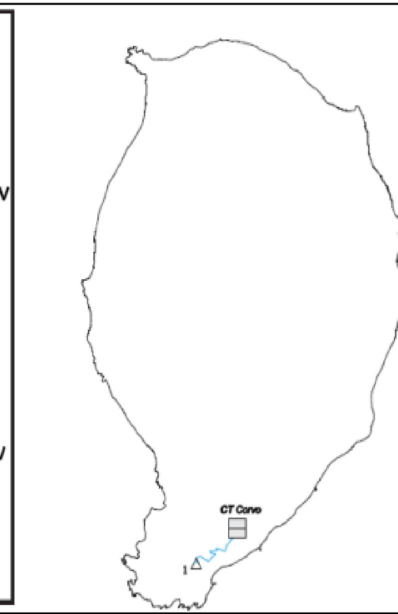
While the model developed in the study was focused on accurately simulating the energy system of the island of Corvo, many aspects are generic with the intention of applying the model to different island energy systems of similar scale.

Case Study: *Corvo (Azores), Portugal*



Land area: 17 km^2
Population (2008): 488
Number of vehicles: 93
Number of households: 145





Objectives

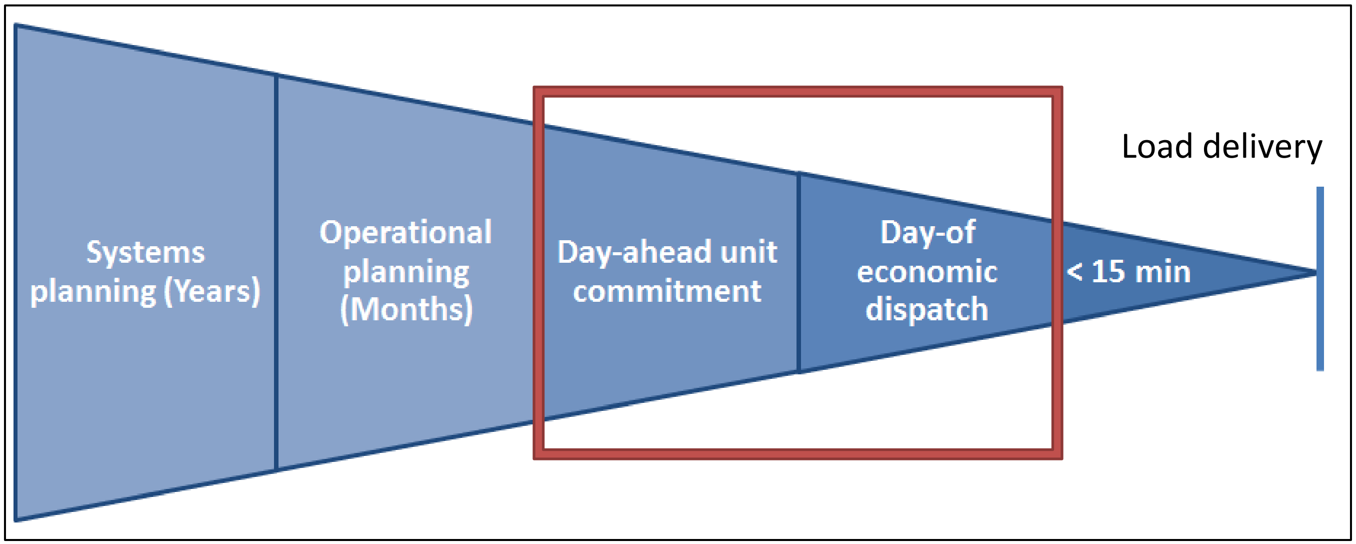
- Optimisation of the **operation of an existing power generation system**
- Modelling and optimisation of an existing power generation system operation, with the **integration of wind power**
- Modelling a new power generation system with the integration of **wind power** and the implementation of a **demand response** strategy
- Assessing the need for an improved **supervisory grid control system**

Energy system planning process

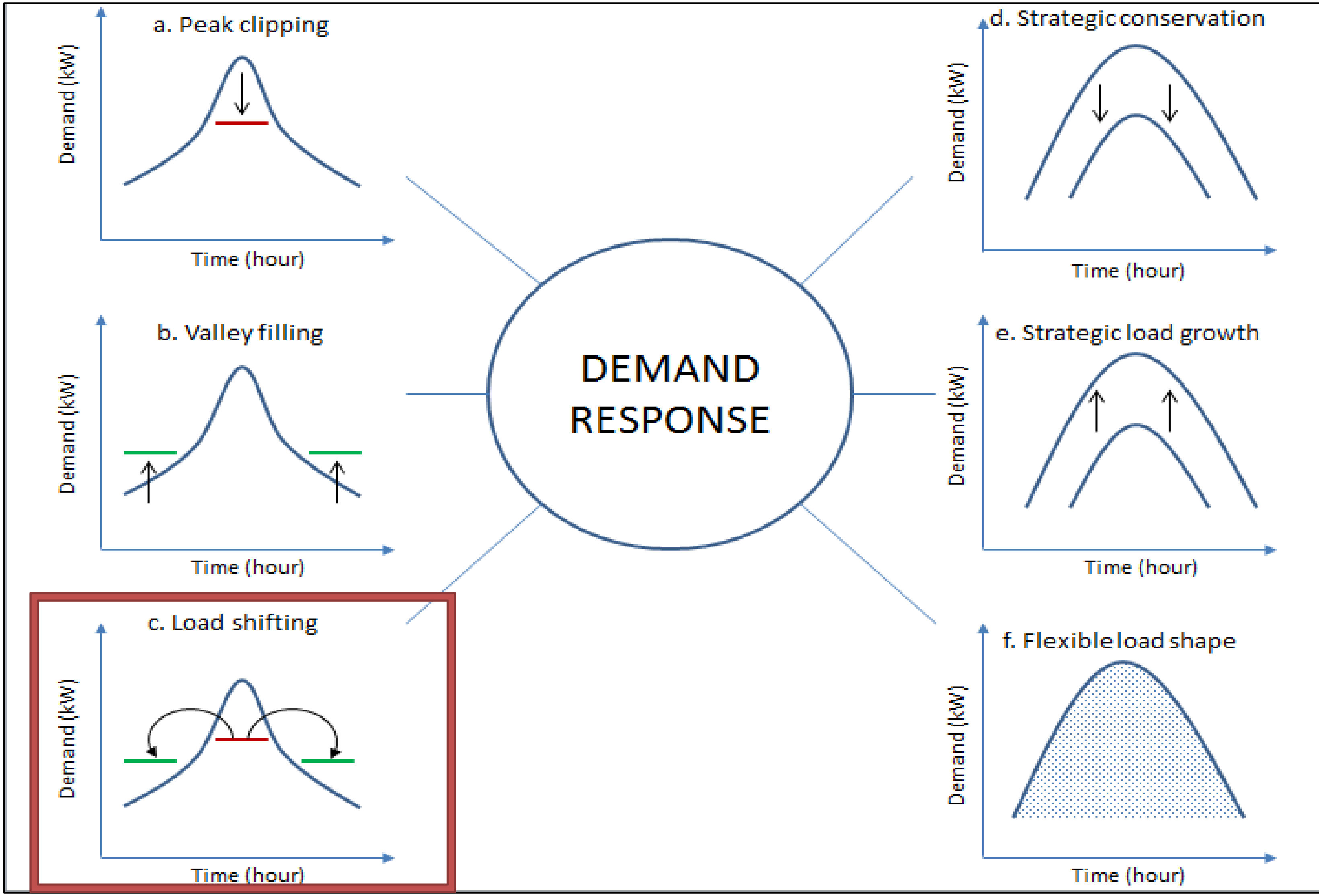
Generation planning aspect is focused on

1. Begins with electricity load/demand forecasting
2. Followed by optimally scheduling the operation of generators to satisfy the forecasted load reliably
3. Finally, specific generating level of each generator is set based on economic considerations

- Unit Commitment
- Economic Dispatch



Demand Response (DR) objectives



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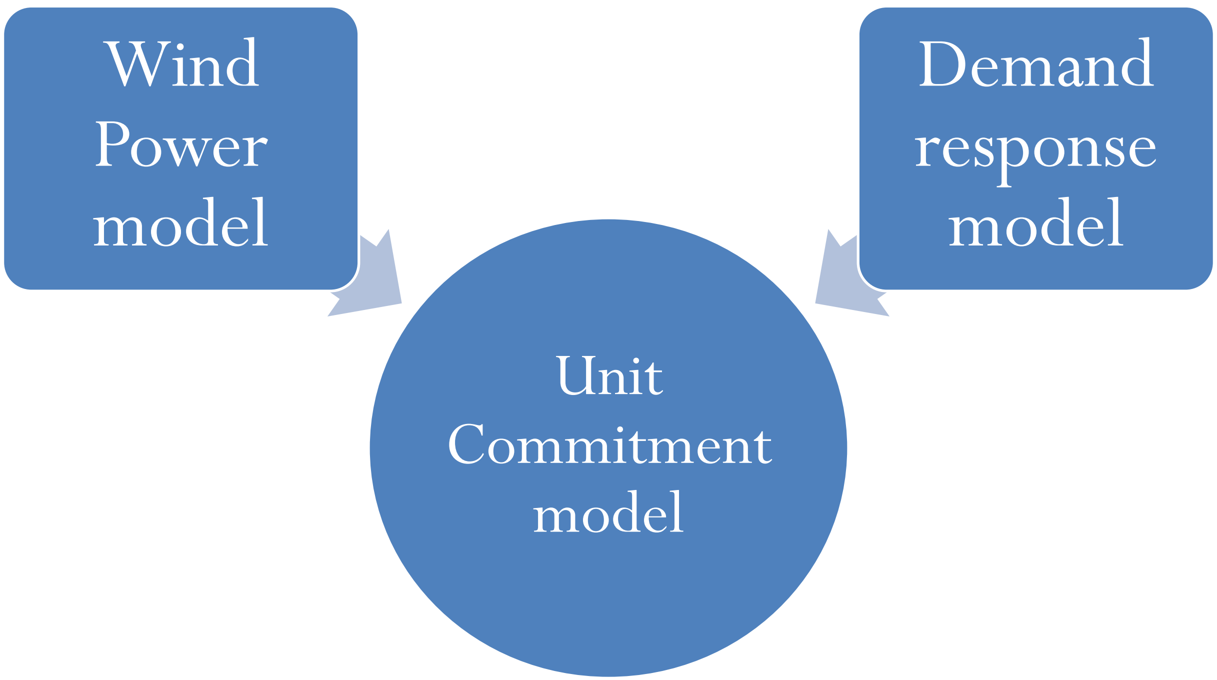
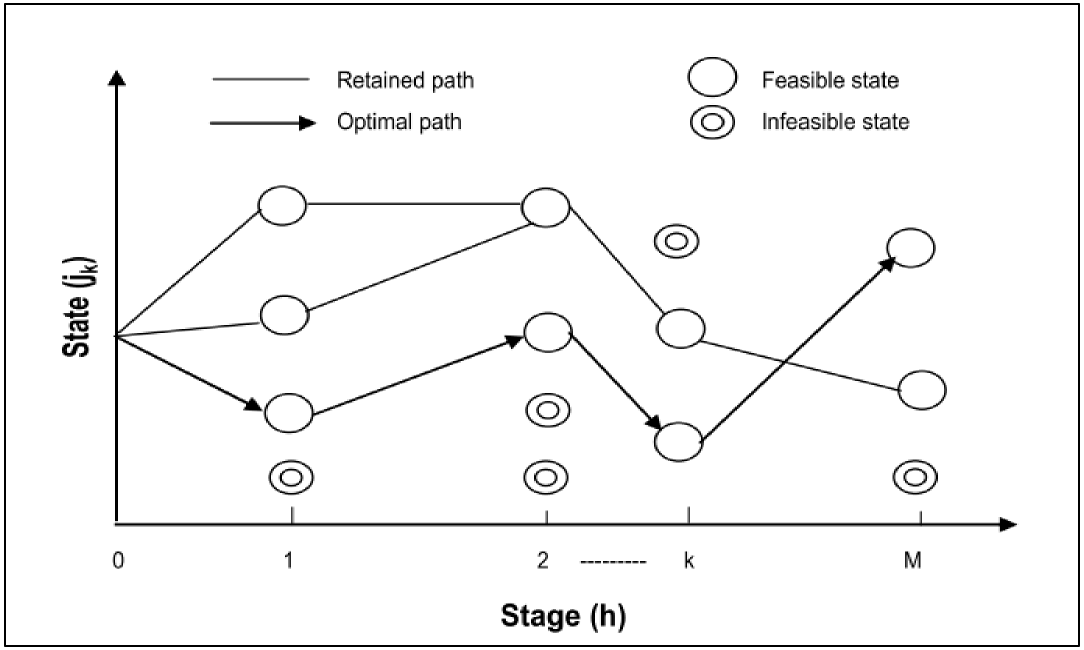
Structure of models

- All models built in MATLAB, with an OSeMOSYS implementation in progress
- Unit Commitment (UC) Model forms the core, with the Wind model and Demand Response (DR) feeding into it



UC Model: Dynamic Programming



$$F_{cost}(K,I) = \min_{\{L\}}[P_{cost}(K,I) + S_{cost}(K-1,L:K,I) + F_{cost}(K-1,L)]$$

where,

$$F_{cost}(K,I) = least\ total\ cost\ to\ arrive\ at\ state\ (K,I)$$
$$P_{cost}(K,I) = production\ cost\ for\ state\ (K,I)$$
$$S_{cost}(K-1,L:K,I) = transition\ cost\ from\ state\ (K-1,L)\ to\ state\ (K,I)$$

UC model: Constraints

- Generation Capacity:

$$\bar{p}_{min}^{i} u_t^i \le p_t^i \le \bar{p}_{max}^{i} u_t^i$$

- Ramp-up Limit:

$$p_t^i - p_{t-1}^i \le u_{t-1}^i \Delta_+^i + (1 - u_{t-1}^i)\bar{p}_{min}^{i}$$

- Ramp-down limit:

$$p_t^i - p_{t-1}^i \ge -u_t^i \Delta_-^i - (1 - u_t^i)\bar{p}_{max}^{i}$$

- Minimum up-time constraint:

$$u_t^i \ge u_s^i - u_{s-1}^i,$$
$$s \in \left[t - \tau_+^i, t - 1\right]$$

- Minimum down-time constraint:

$$u_t^i \le 1 + u_s^i - u_{s-1}^i,$$
$$s \in \left[t - \tau_-^i, t - 1\right]$$

Wind Model

Model characteristics:

- Forecasting of wind power based on wind speed data
- Can be assumed to be close to reality (24/48 hour basis)
- Limit on 'Instantaneous Wind Penetration' in the system set to 50 %
- Can be increased to 100 % (and greater) with better supervisory control systems and energy storage

DR Model

Model objectives

- Maximise the use of wind energy
- Minimise the overall cost of electricity usage

$$Wind\ energy\ added + diesel\ generator\ power\ =\ base\ demand + WH\ demand$$

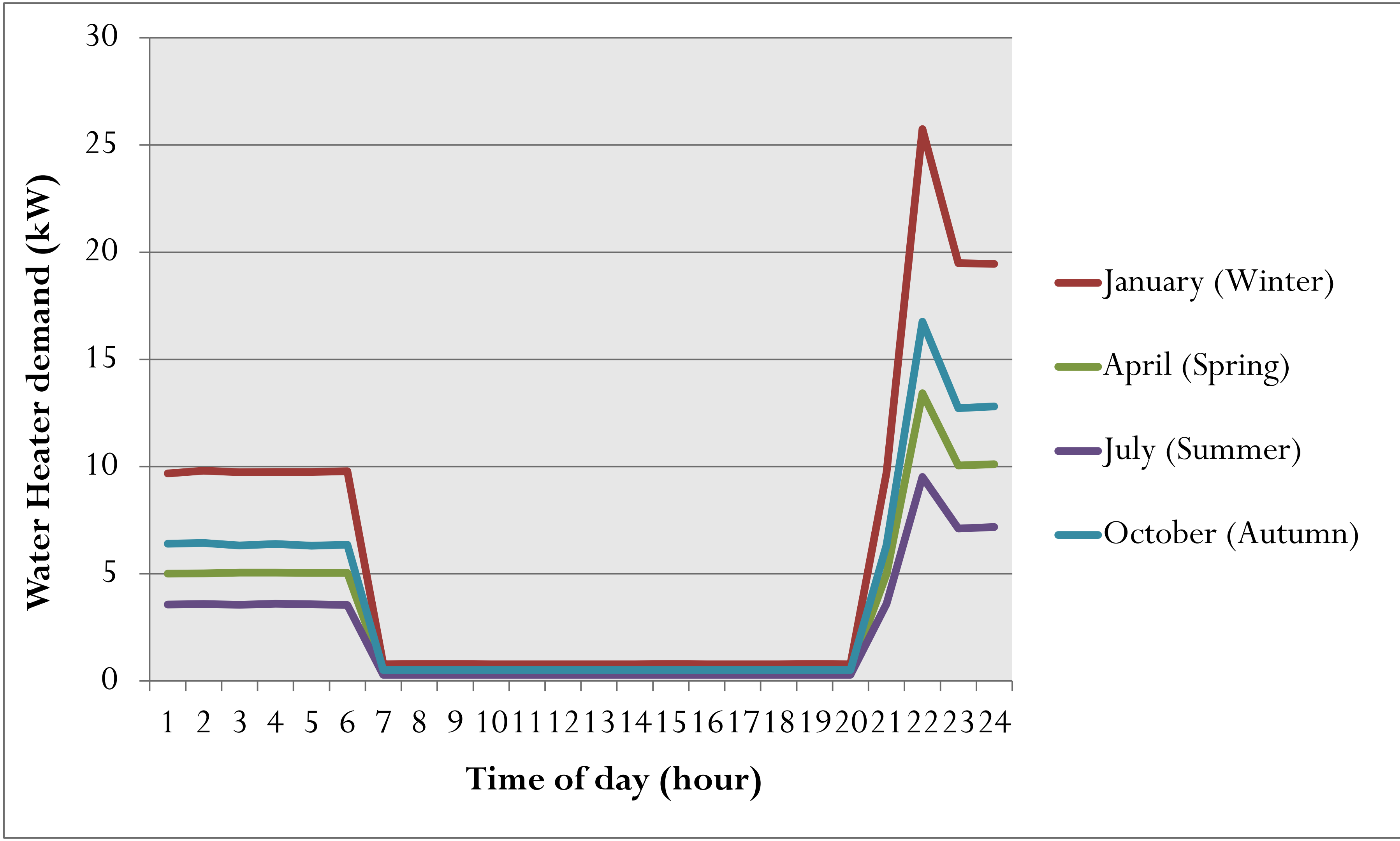
$$Inst.wind\ penetration\ limit \geq \frac{Wind\ energy\ added}{(Wind\ energy\ added + diesel\ generator\ power)}$$

Current Scenario - Power Generation System

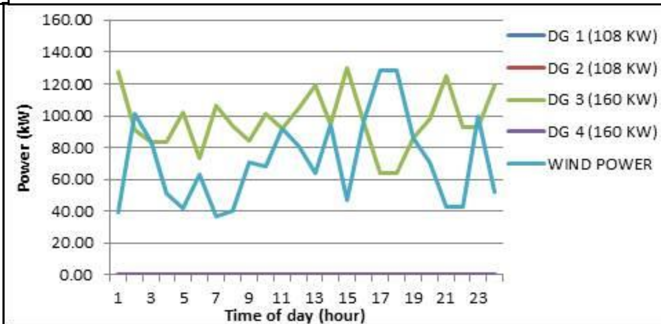
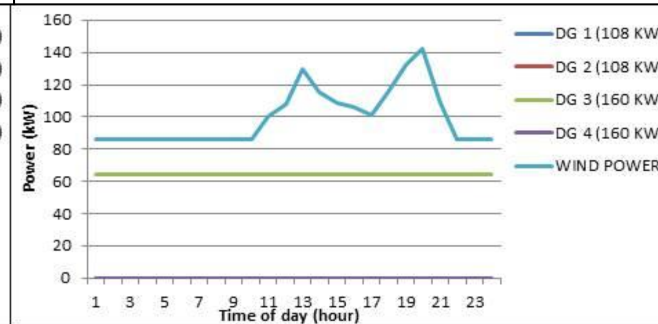
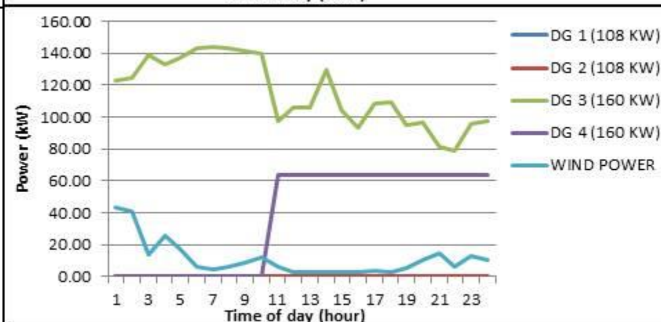
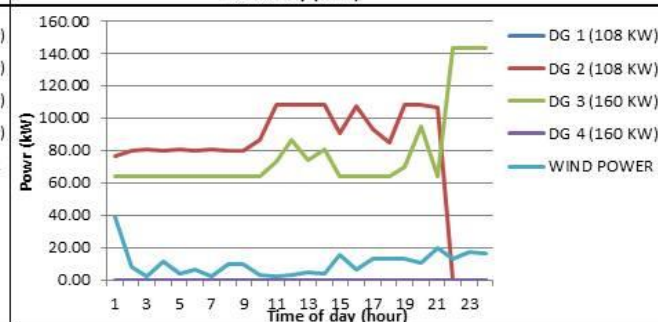
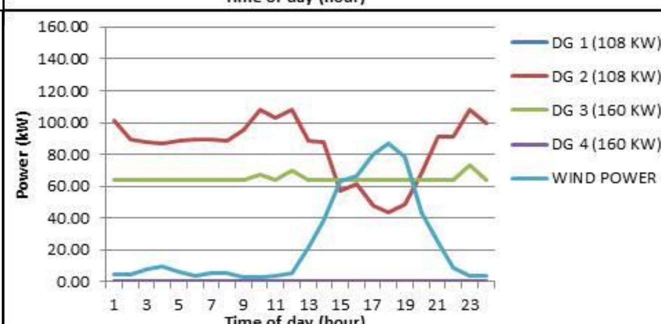
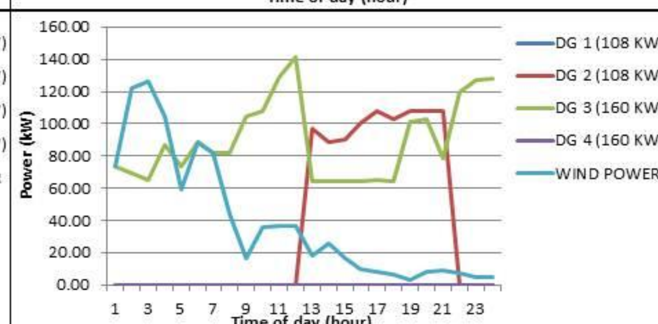
- DG Set 1 – 108 kW
- DG Set 2 – 108 kW
- DG Set 3 – 160 kW
- DG Set 4 – 160 kW

- Wind turbines – 275 kW (as proposed by the Azores Electricity Authority)

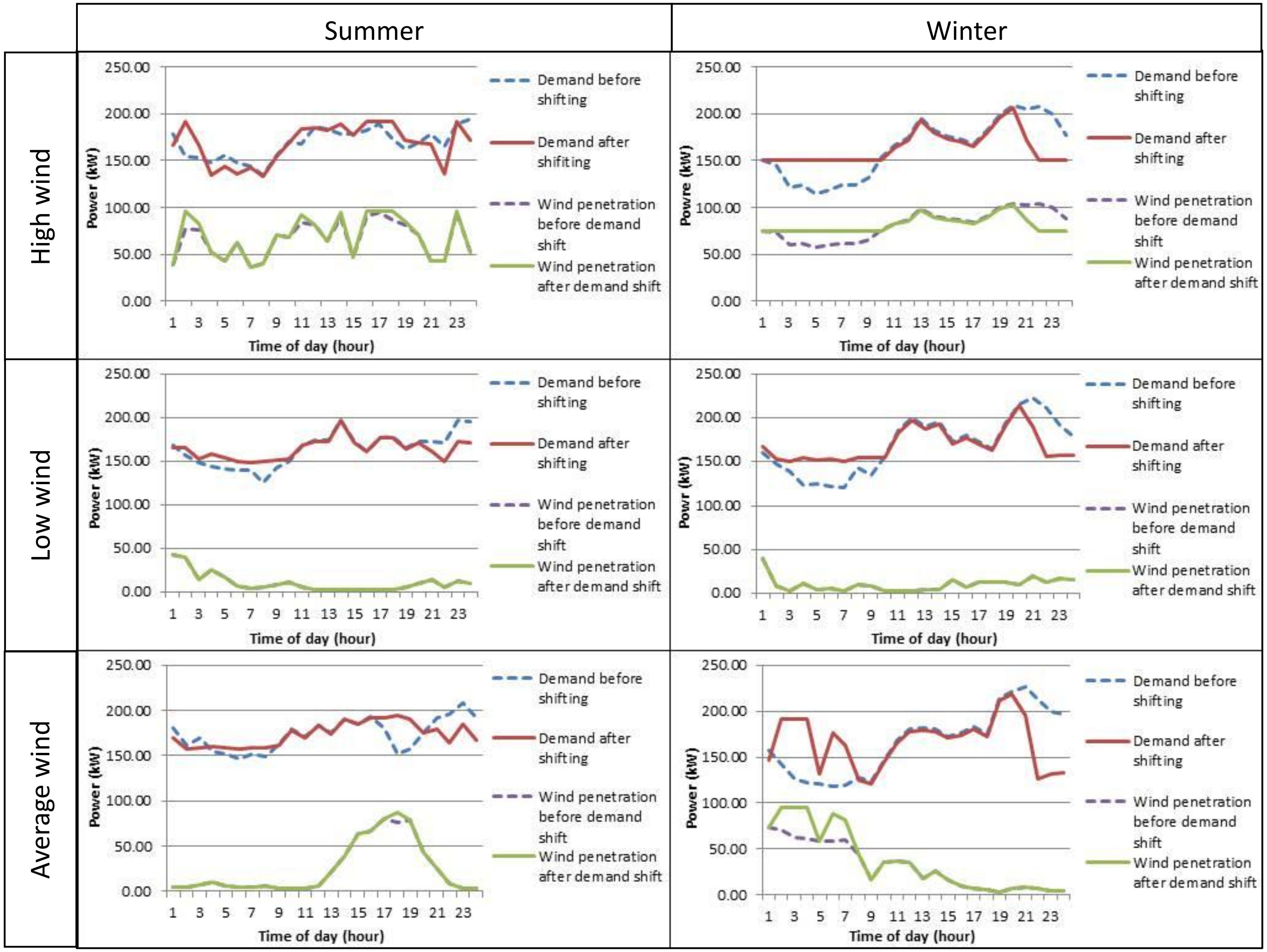
Water Heater profile: Seasonal Average



Result 1: UC + Wind Model

	Summer	Winter
High wind		
Low wind		
Average wind		

Result 2: UC + Wind + DR Model

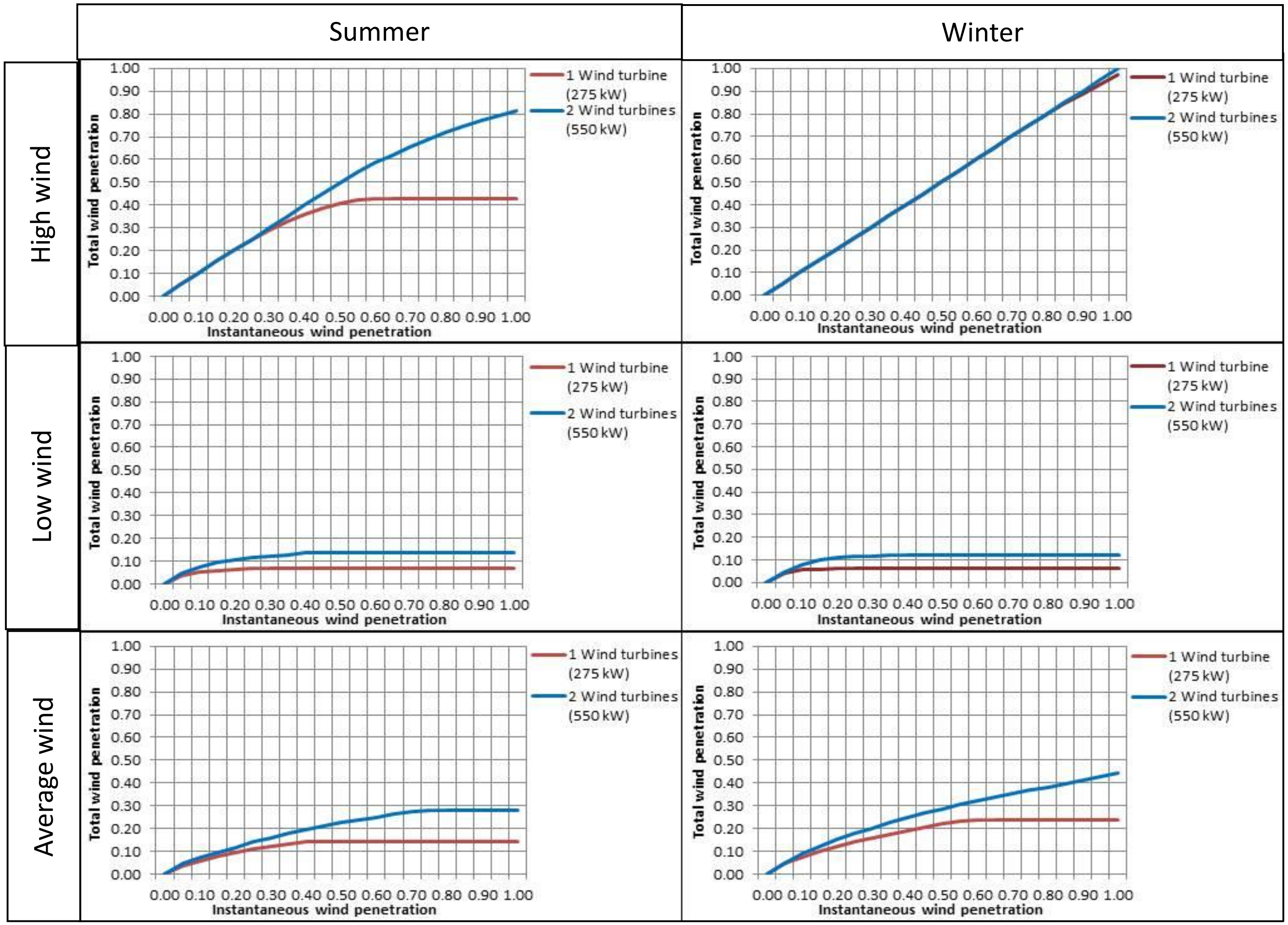


Result 2: Total wind penetration

	Summer			Winter		
Wind speed	Low	Average	High	Low	Average	High
1 Wind generator	7 %	14 %	41 %	6 %	22 %	50 %
2 Wind generators	14 %	28 %	50 %	12 %	29 %	50 %

Total wind penetration is the fraction of the total demand in the system satisfied by wind power

Instantaneous Vs. Total wind penetration



General Conclusions

- Viability of integrating wind energy into the existing power system of Corvo was confirmed
- UC model was made flexible enough to analyse the power generation system operation in future scenarios on the island
- Demand response strategy caused the water heater loads to shift to hours with greatest excess wind energy
- Effect of Instantaneous wind penetration restrictions on the total wind penetration was found to be significant only during days with high average wind speed
- Adding any more wind turbines will only cause greater curtailment of wind power, and will not increase the total wind penetration significantly

Future Work

- OSeMOSYS implementation of models
- Expansion of the **fishing dock**, **airport**, and **waste management facility** have already been planned on Corvo. These demands will be included.
- Model to be improved to include the future scenarios of possible **grid expansions**
- Model will be applied to the **other islands** in the Azores archipelago
- UC-Wind-DR model to include **Solar PV**
- DR Model will be improved to include other 'shiftable' loads such as **electric vehicles**

Thank you

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