SWINBURNE UNIVERSITY OF TECHNOLOGY

Managing Demand by Modeling an Optimal Charging Schedule for Energy Storage

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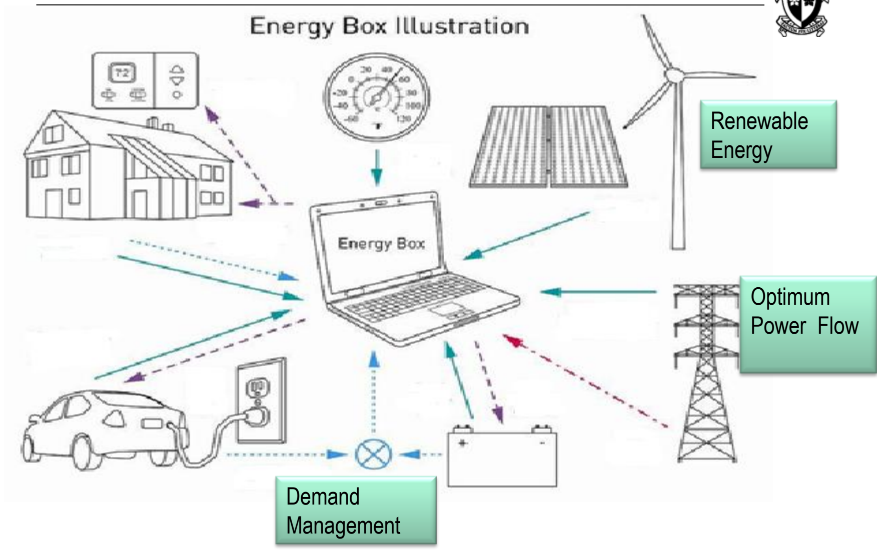
Importance of Energy

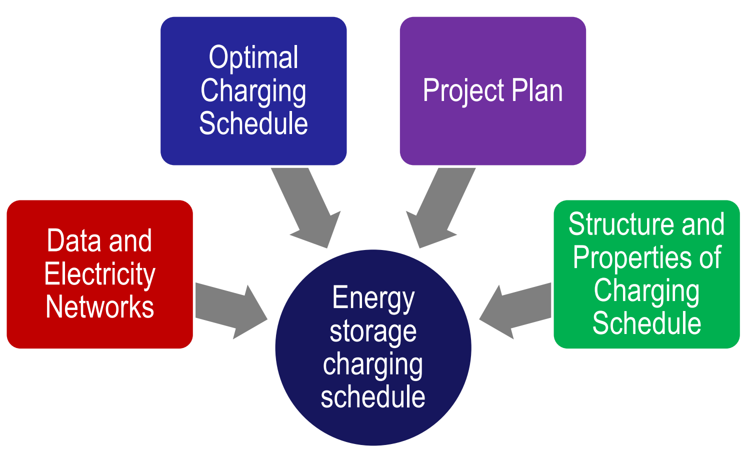
- Why is Energy Important?
  - Used by billions for almost everything
  - Electricity :one of the most critical forms of energy
  - Used for transport, ICT, etc...

- The problem ?
- High Demand = More Energy =
- Climate change

Solutions



Outline



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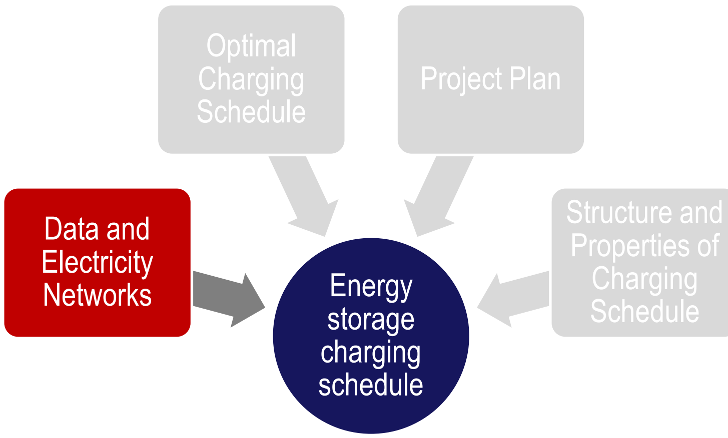


Data and Energy Networks

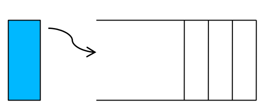
	Data	Energy
Transport	Transport of data traffic	Transmission of electricity
Routing	Routing decisions	Power flow
Pricing	Peak and Off peak pricing in telephony networks	Time of day price based on demand
Load shaping	Traffic policing	Demand Response
QOS	Provisioning based on packet class	Reliable and continuous energy supply

Data and Energy Networks

	Data	Energy
Scheduling	Packet Scheduling	Charging Schedules, Generation Schedules
Storage	Buffers, buffer allocation	Energy storage, demand management
Storage size	Sizing of queues	Storage capacity
Anticipatory Control	Dimensioning future control	Generation and demand forceasting

Queues and Storage

Queues



$$dq/dt = \text{Inflow} - \text{Outflow}$$

Storage

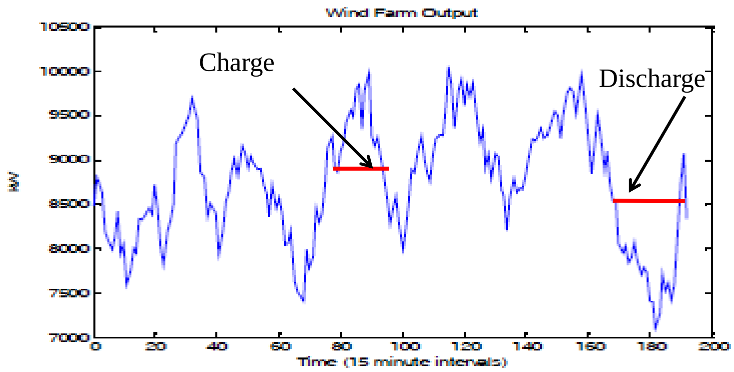
Charge

$$dq/dt = \text{Inflow} - \text{Outflow}$$

Discharge

Importance of Storage

- Renewable energy such as wind and solar are intermittent
- Need to fill in generation gap



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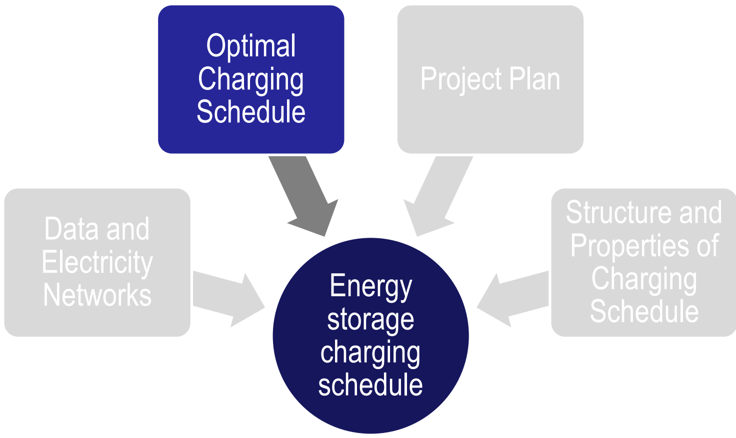
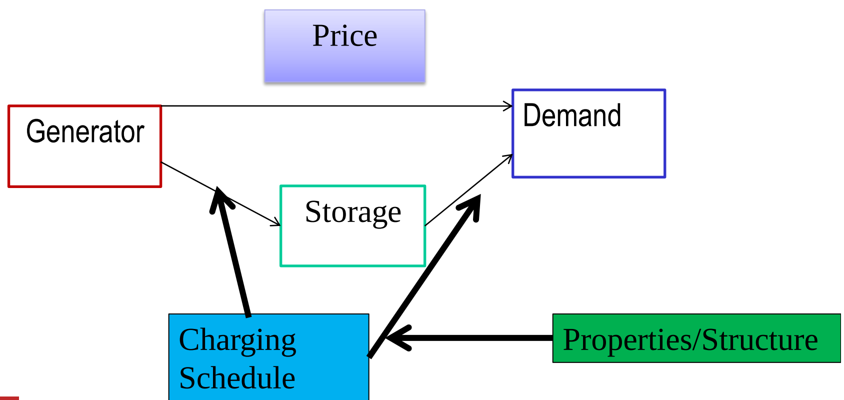
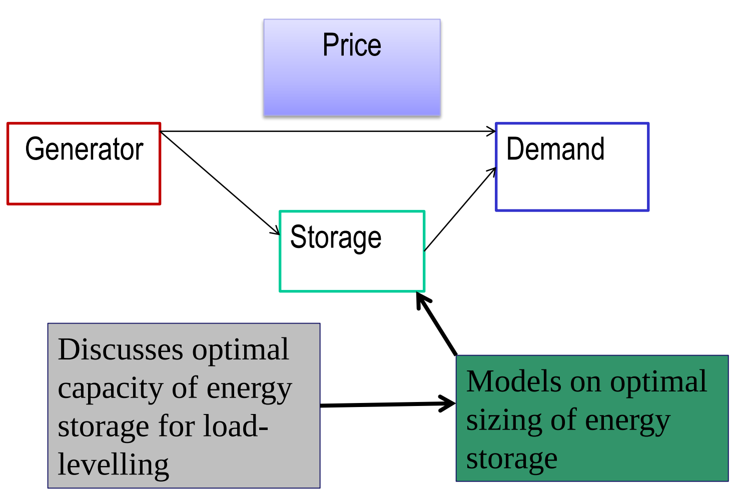


Generation, Demand and Storage

- With single storage device connected to the grid and to a customer demand management interface



Optimal Charging Schedule -Taxonomy



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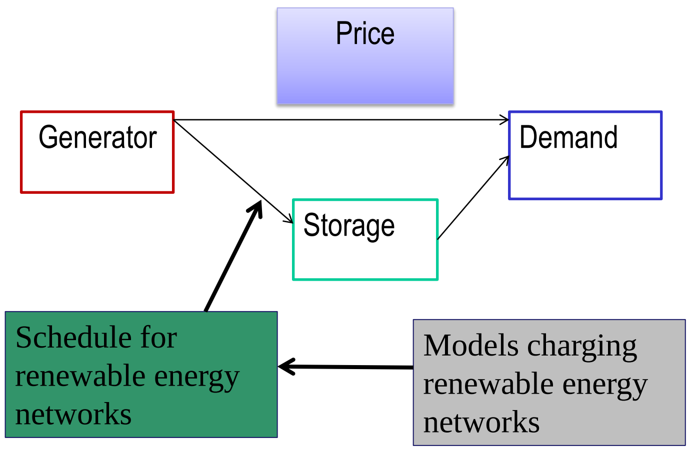

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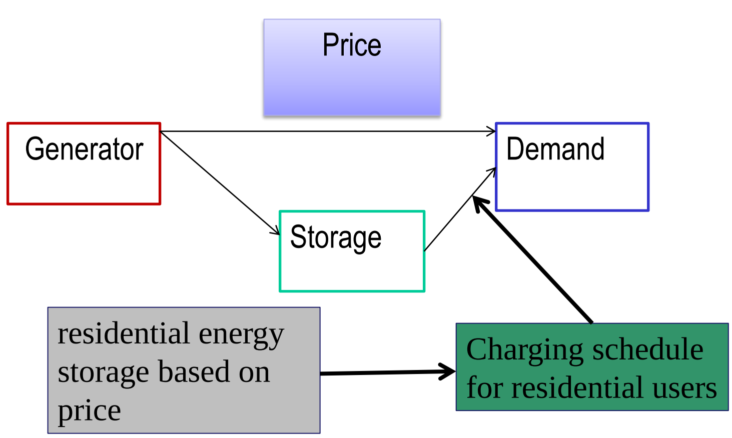
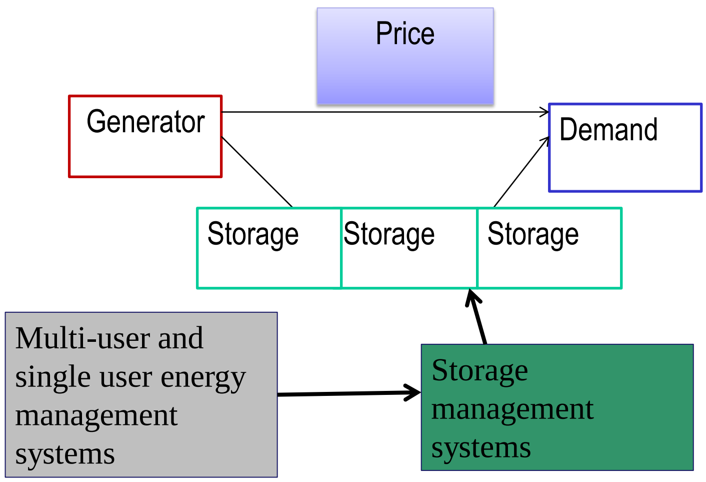
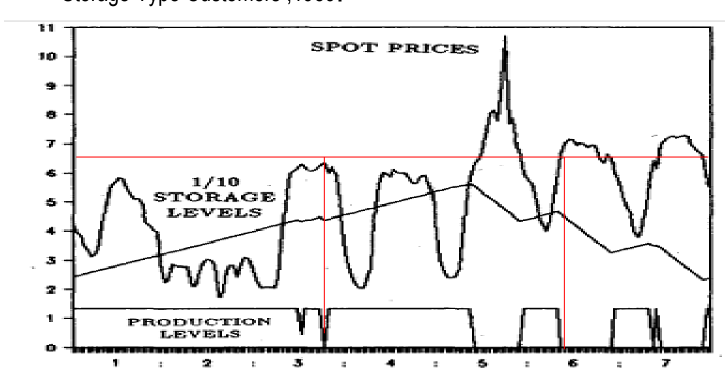


Optimal Charging Schedule -Taxonomy



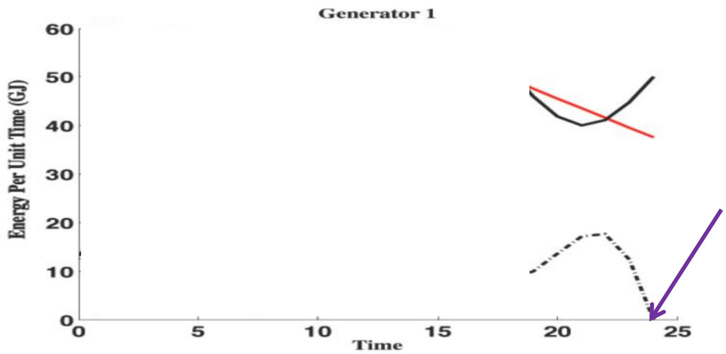
Optimal demand-side response

- Models optimal charging schedule with linear programming by considering a linear objective cost
  - B. Daryanian et al. " Optimal Demand-Side Response to Electricity Spot Prices for Storage-Type Customers",1989.



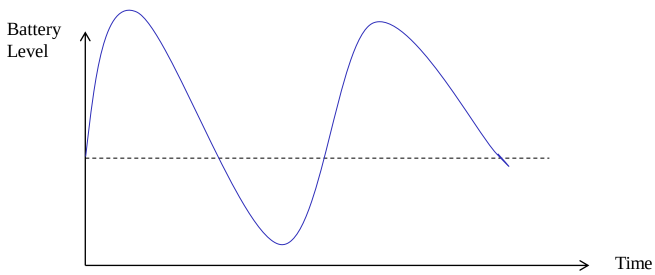
Simple optimal power flow model

- Models on charging schedule and shows the optimal charging policy. Model consists of generation cost and holding cost
  - M. Chandy et al, "A simple optimal power flow model with energy storage"2010.



Simple optimal power flow model

- Battery charge always tends to zero : Unreal
- Solution : periodic boundary conditions



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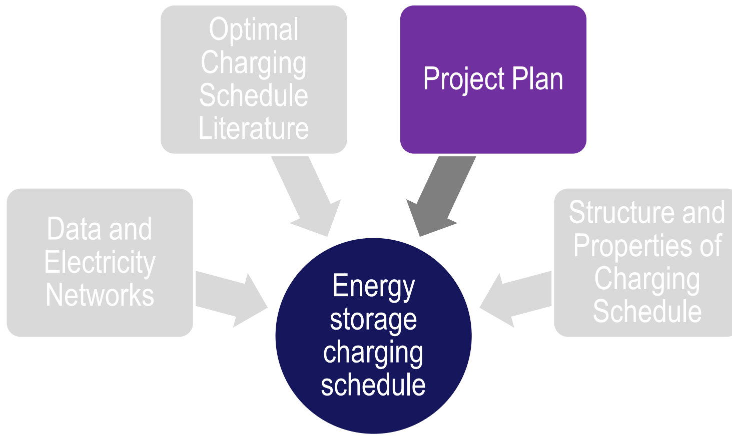
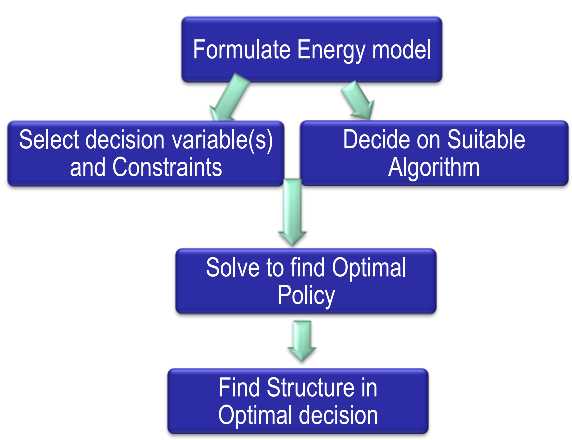
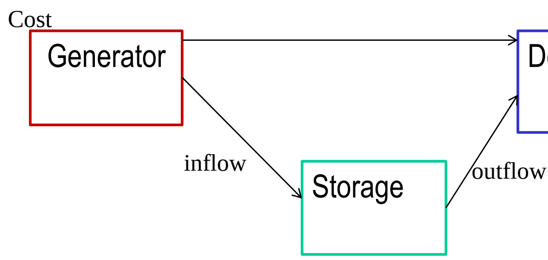


Plan



Model

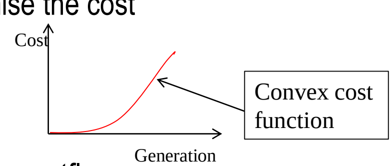
- ❑ Optimise operational cost given known demand and prices



Model

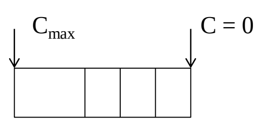
- ❑ Control inflow and outflow to minimise the cost

Objective : Min $\sum_{\text{Time}}$ cost(generation)

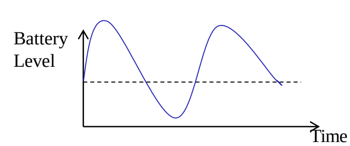


Constraints:

- Rate of Charging dq/dt = inflow – outflow
- Battery Capacity



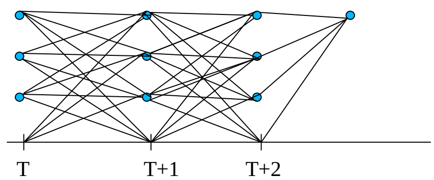
- Meeting Demand: Generation + outflow = Demand + Inflow
- Periodic Boundary Conditions



Optimisation Tool

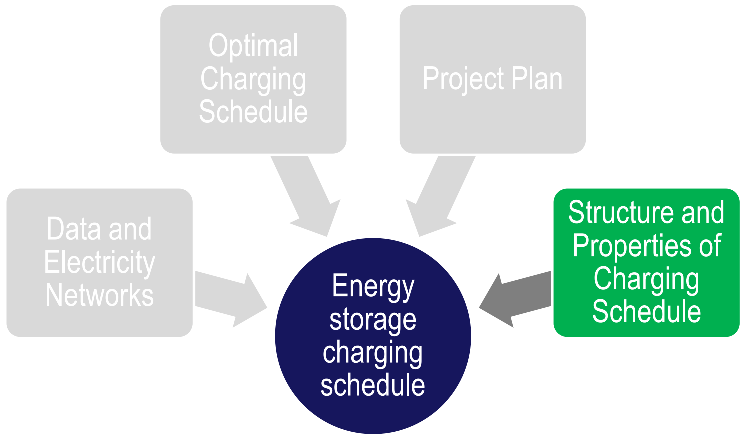
- Dynamic programming(DP)
- Bellman-ford routing and Viterbi algorithms use DP
- Multistage decision problem-:solved by finding the optimal at each state recursively.
- Information necessary :cost of the previous state and the cost of moving to a new state.
- Limits memory state since only optimal of previous state is recorded

Optimisation Tool



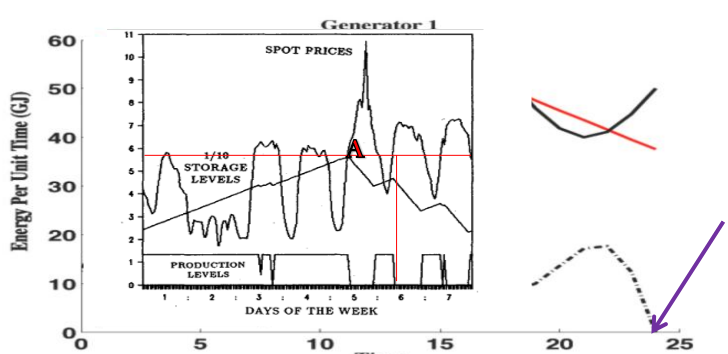
- Path(state) from T to T+1 is calculated from each point
- The path with the least cost is recorded
- When all paths are calculated, the optimal path is found by tracing backwards from the point
- In our model the state is the charge of the battery

Outline



Structure

- Our main goal is to find structure for the optimal policy
- Properties that always hold if assumptions change slightly



Structure

- We want to find the sensitivity of the structure
- Robustness of structure found by testing with realistic variations
- Our base model will be extended by considering peak charge and renewable energy
- Consider if a minimum capacity must be held in the battery during the complete time horizon.

Summary

- Storage can be used to manage demand for customer premises.
- An optimal charging schedule is able to manage demand by selecting charging/discharging times
- We will study optimal charging schedule for demand response based on prices
- We want to find structure in the optimal charging schedule
  - That is not an artefact of the model or its approximations