TEM Reading Discussion on Smart Grid Utilities

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DISCUSSION OUTLINE :

- A Previous Related Work (Motivation)

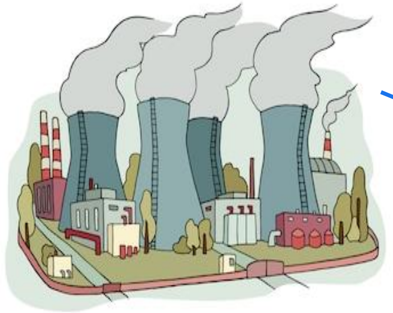
  Paper: V. V. S. Lanka, M. Roy, S. Suman and S. Prajapati, "Renewable Energy and Demand Forecasting in an Integrated Smart Grid," *2021 Innovations in Energy Management and Renewable Resources(52042)*, 2021, pp. 1-6, doi: 10.1109/IEMRE52042.2021.9386524.

- Current Work at MSR [In Progress]

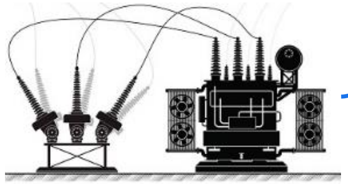
  Related Paper: J. Cao, D. Harrold, Z. Fan, T. Morstyn, D. Healey and K. Li, "Deep Reinforcement Learning-Based Energy Storage Arbitrage With Accurate Lithium-Ion Battery Degradation Model," in *IEEE Transactions on Smart Grid*, vol. 11, no. 5, pp. 4513-4521, Sept. 2020, doi: 10.1109/TSG.2020.2986333.

- Future Scope and Perspectives

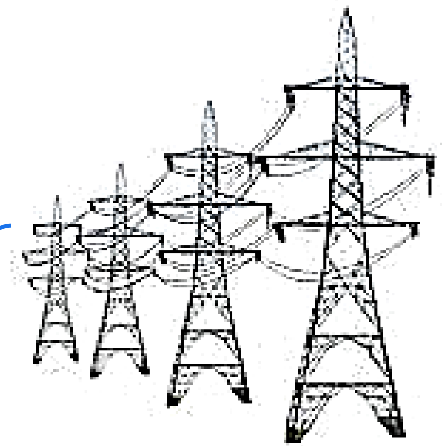
Existing vs Target Indian Scenario:



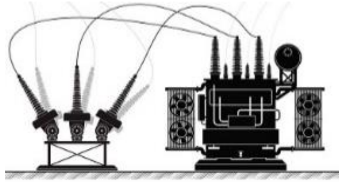
Power Plant generates electricity
11kV – 25kV



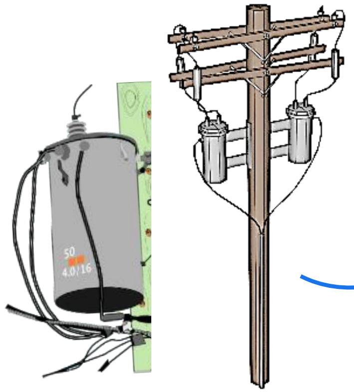
Transformer steps up voltage for transmission
220kV – 765kV



Transmission lines carrying electricity over long distances

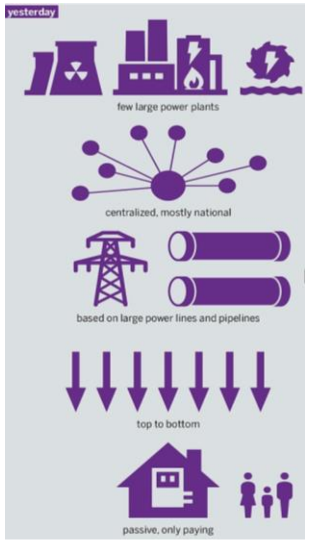


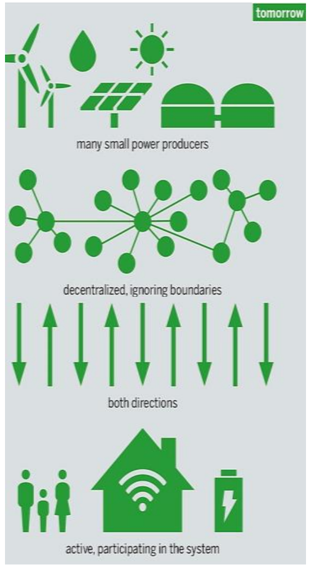
Transformer steps down voltage for distribution
33kV -132kV



Transformers on poles steps down voltage before entering homes
$230V_{\phi}$ – $415V_{LL}$

Final Consumers





Previous Work – Scenario [Problem Statement]:

Problem

Renewable sources are affected by environmental factors, which can cause fluctuations in power generated.

↓

Power Mismatch makes grid unstable

Solution

- Grid Stability
- Gain Profit

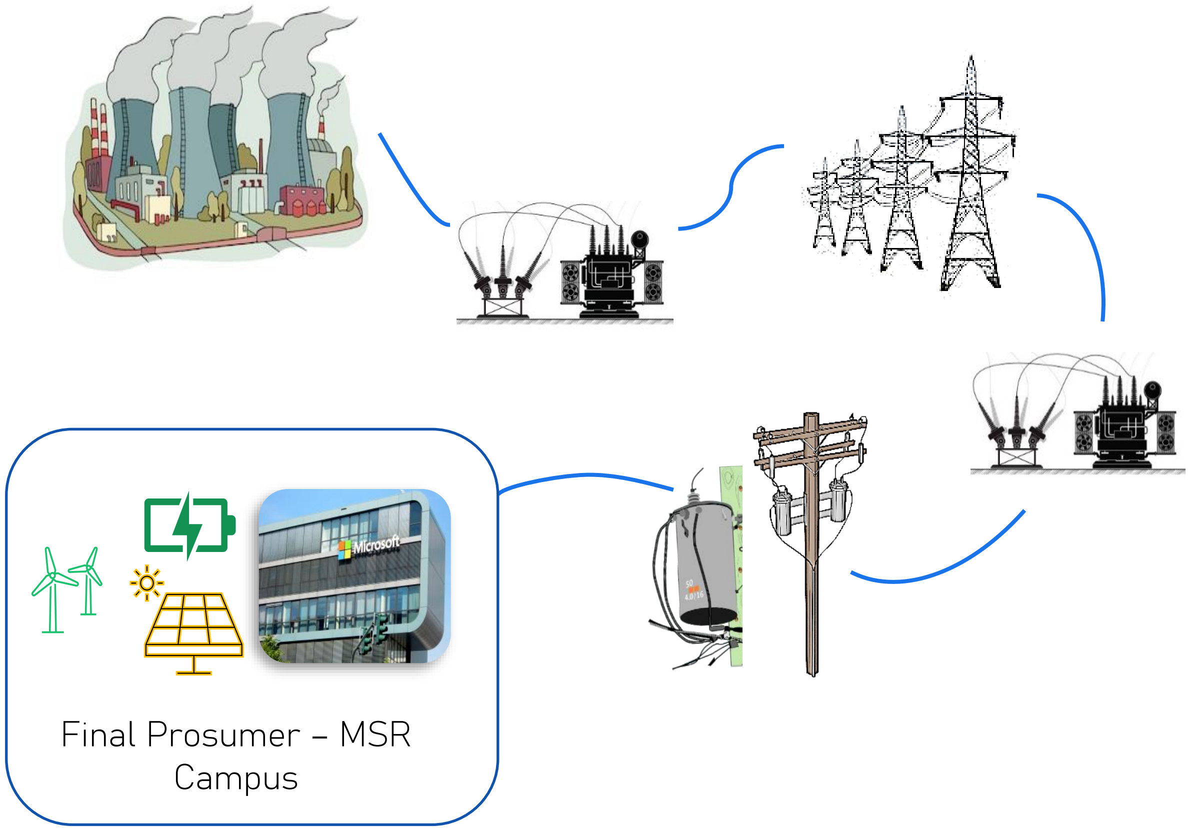
1. Forecast cost values, load demand & renewable power

↓

2. Simulate a realistic electric grid model [Utility + Micro-Grid]

↓

3. Integrate with a cost-optimized scheduler ensuring Day-ahead scheduling



Forecasting:

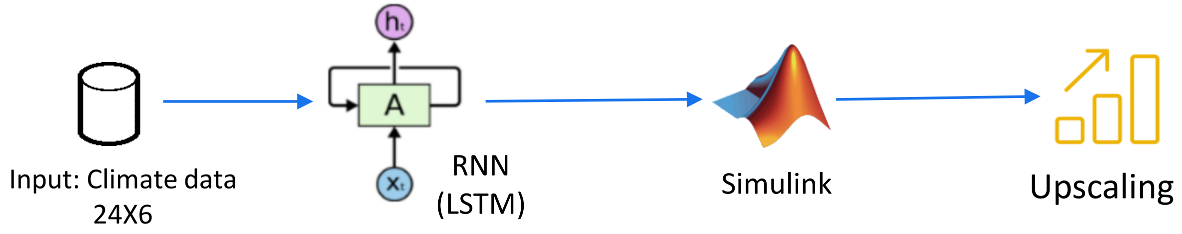
Forecasting models here are as follows:

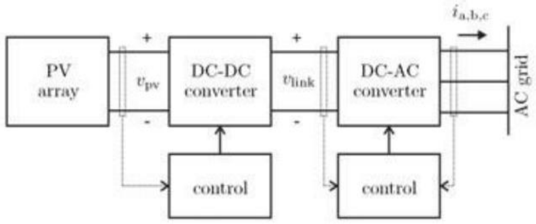
1. Price prediction (R2 score – 0.94)
   - Features – Historical Price Data (24 X 1)

2. Load/Demand Forecasting (R2 score – 0.91)
   - Features – Historical Price, Temperature, Historical Load Pattern (24 X 3)

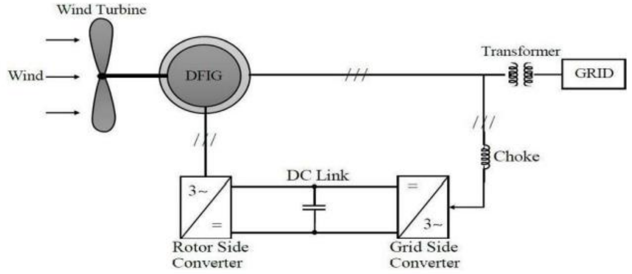
3. Renewable Energy Forecasting (Solar R2 score – 0.93, Wind R2 score- 0.82)

Precipitation,
Snowfall,
Snow Mass,
Cloud Cover,
Air Density,
Historical Irradiance/Windspeed



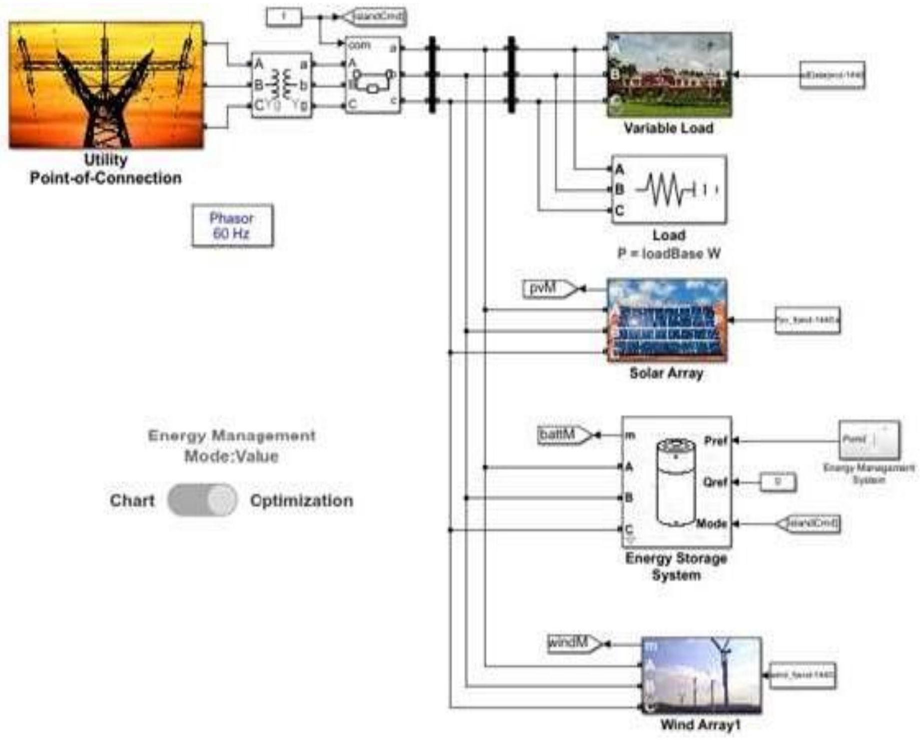


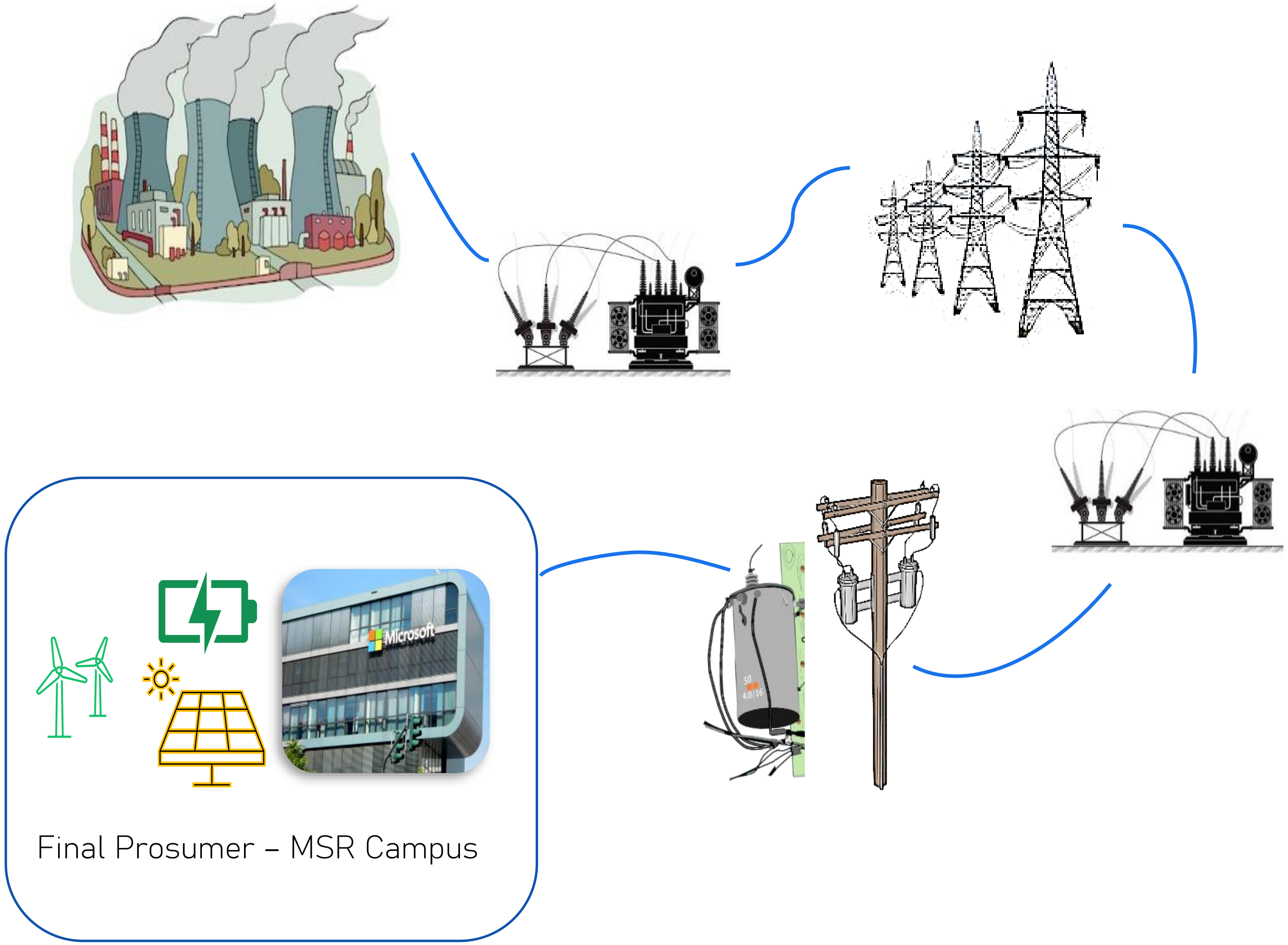
Simulink PV Power Simulation



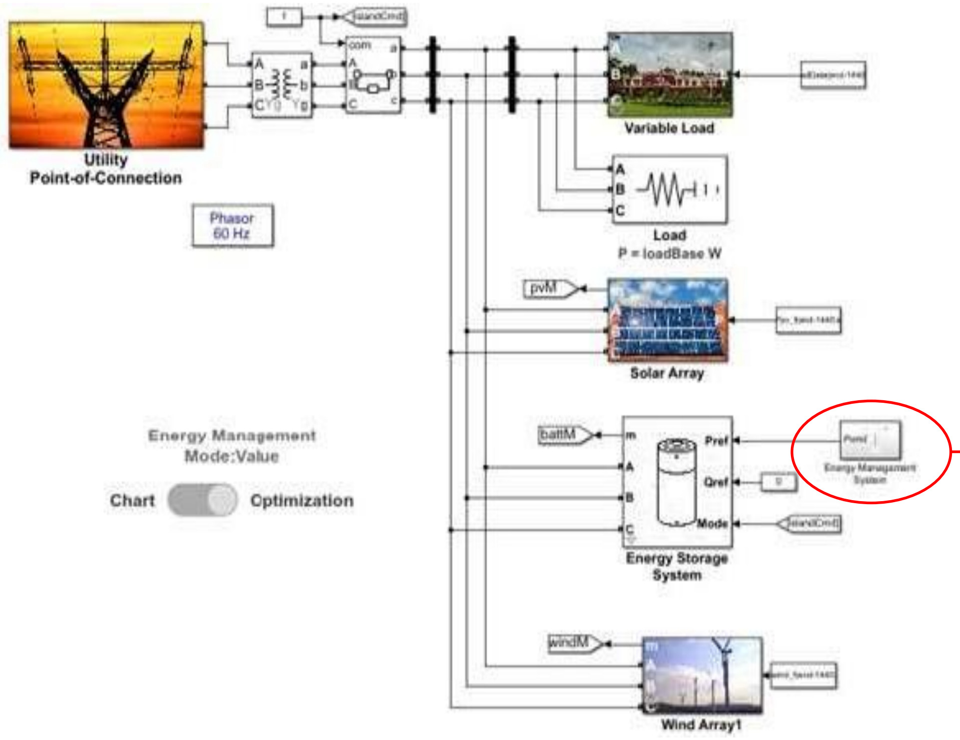
Simulink Wind Power Simulation

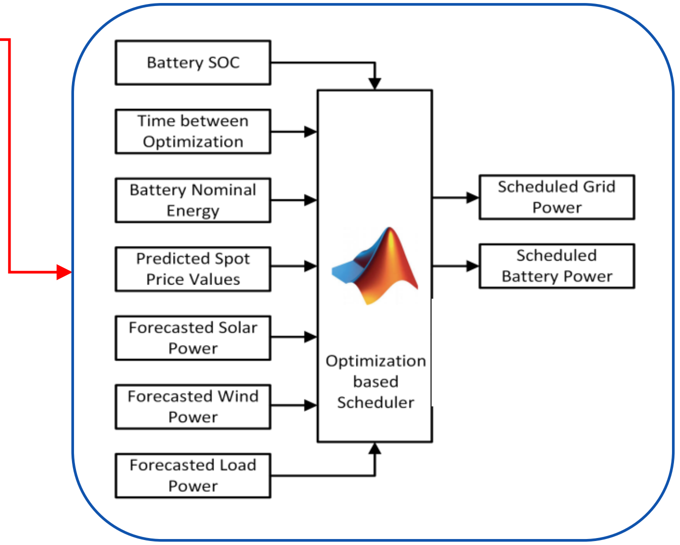
Micro-Grid Model & Scheduling:





Micro-Grid Model & Scheduling:





Optimization Constraints:

1. Energy input/output to the battery:

$$E_{batt}(k) = E_{batt}(k-1) + P_{batt}(k)\Delta T$$

2. Power balance:

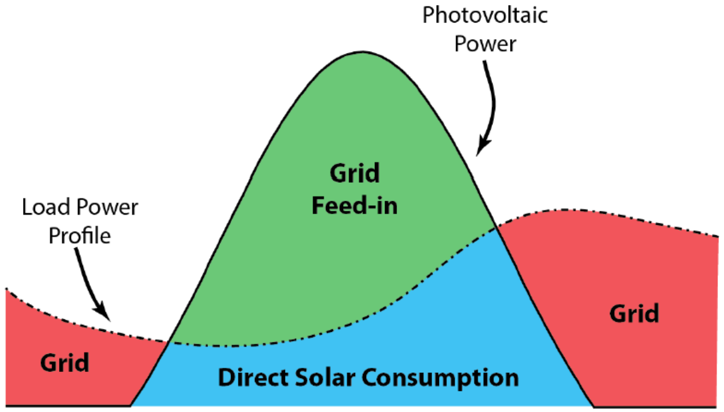
$$P_{pv}(k) + P_{wind}(k) + P_{grid}(k) + P_{batt}(k) = P_{load}(k)$$

The objective is to minimize the total cost of variably priced electricity:

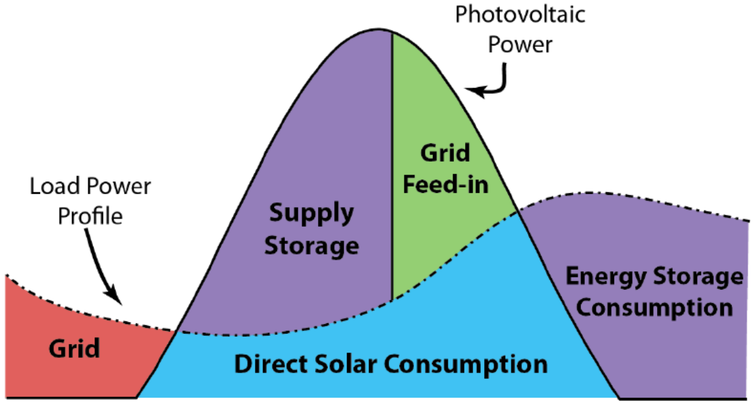
$$C_{tot} = \sum_{k=0}^{N} C_{grid}(k).E_{grid}(k)$$

288 slots of 5 minutes

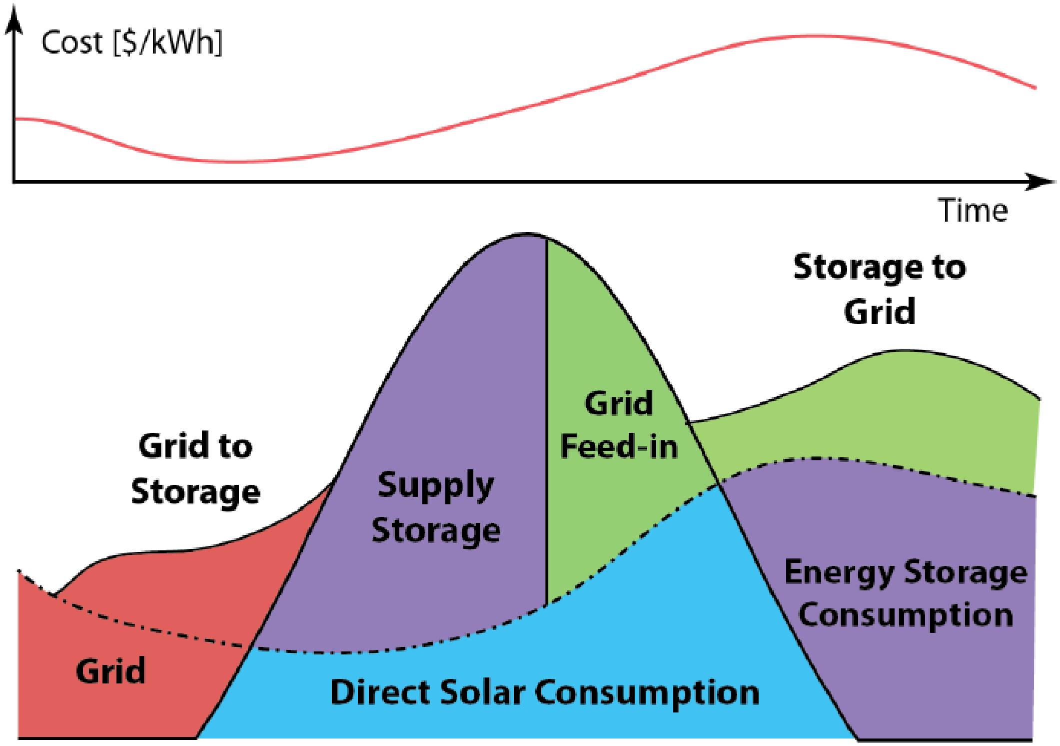
Expected Scheduling Outcome [Load Dispatch Strategy]:



Case 1: Without considering cost and storage



Case 2: Without Considering Cost



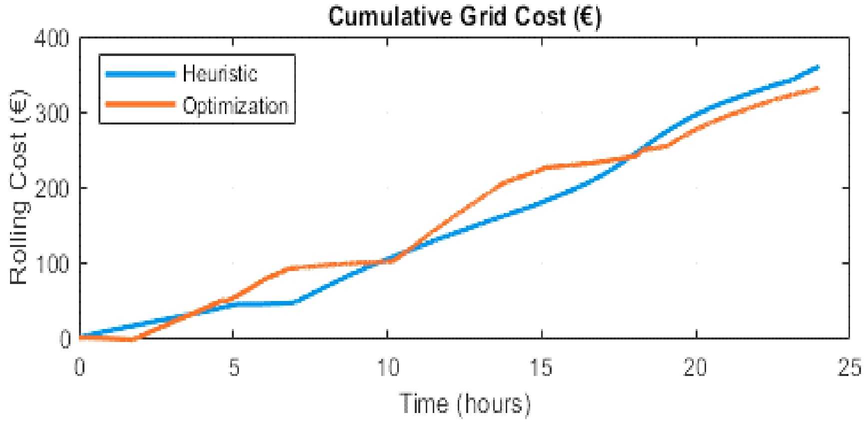
Case 3: Considering Cost

Observations:

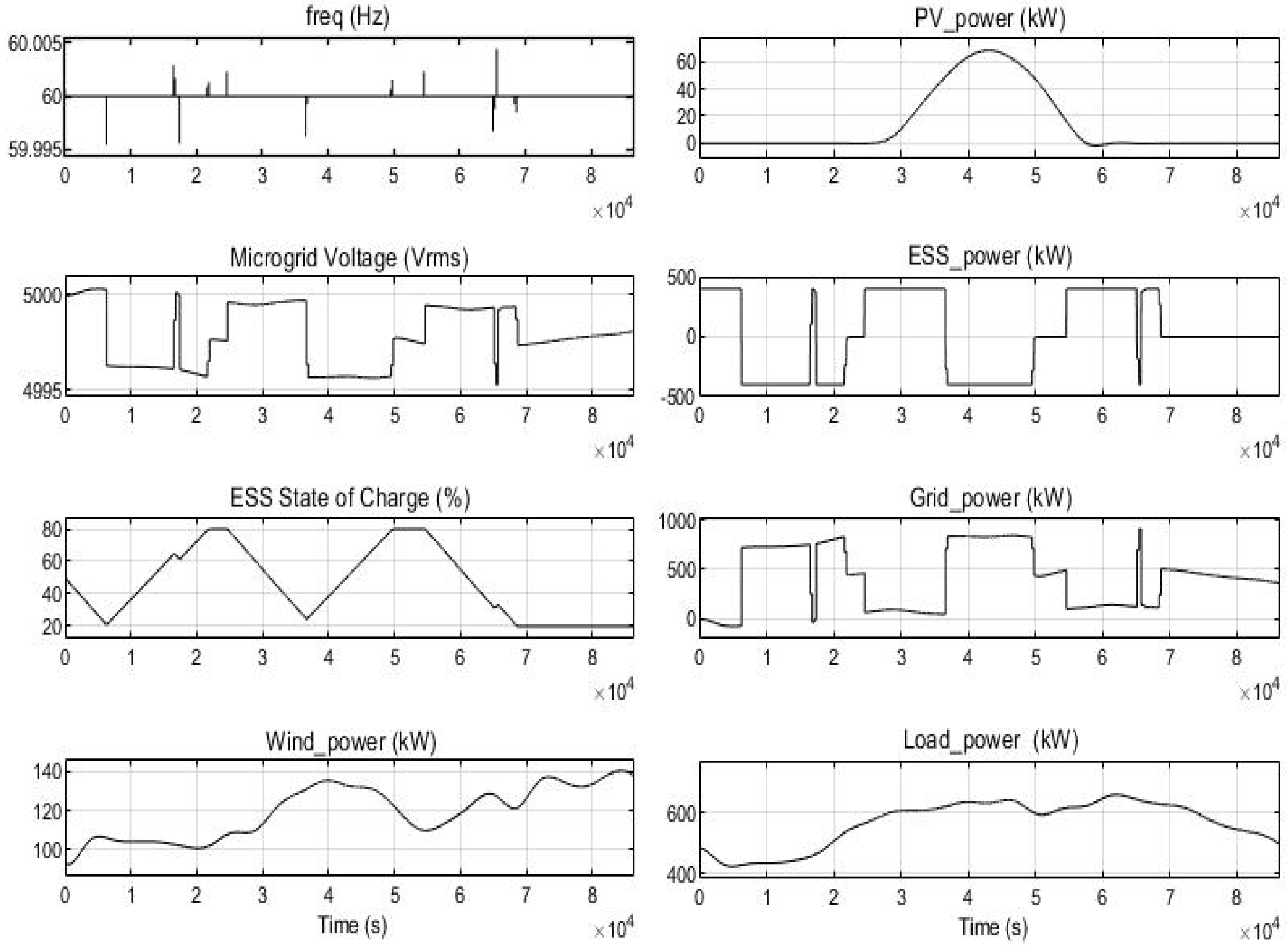
Solution
- Grid Stability
- Gain Profit

1. Heuristic Cost: € 360.4
2. Linear optimization Cost: € 331.1

Total Cost Optimization : 8%



Scope Output for a Day - Simulation: [Grid Stability]



Limitations of Previous Work & Inclusions in Current Work:

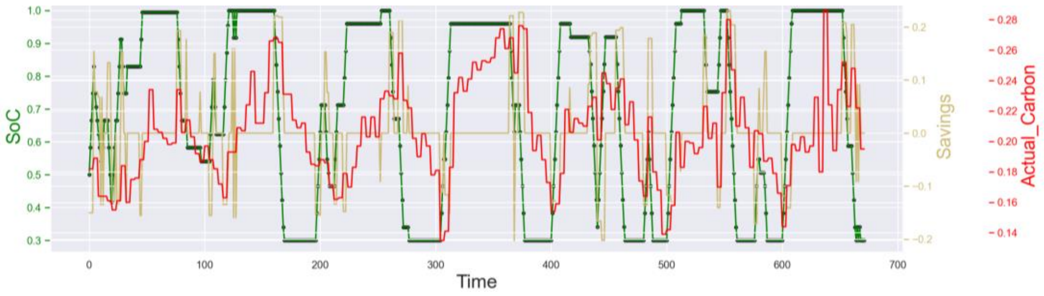
- Did not include battery degradation model
- Simpler Optimization Strategy
- What happens during difference of forecasts & actuals happen?

Current Work: Optimization of Battery Usage for carbon arbitrage

Scenario: For SSE Airtricity, who has provided battery storage to its customers, It is required to operate these batteries in such a manner that it would **reduce carbon footprint due to consumer demand**.

Objective:-

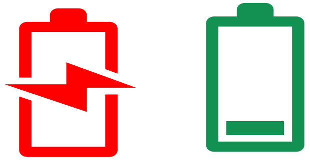
For carbon arbitrage, in order to keep the CO2 emission (which is a function of grid power generation) in check, it is very desirable to **discharge battery** power during those times of the day where CO2 emission is high(so does the power) and **charging** it only in duration of lower emission.



- Battery Parameters:
  - Ch/Discharging Efficiency
  - Battery Degradation
- Optimization Parameters:
  - Horizon Hours
- Grid Parameters:
  - Uncertainty in Forecast prices/CO_2 emissions
  - Price/CO2 emission distributions

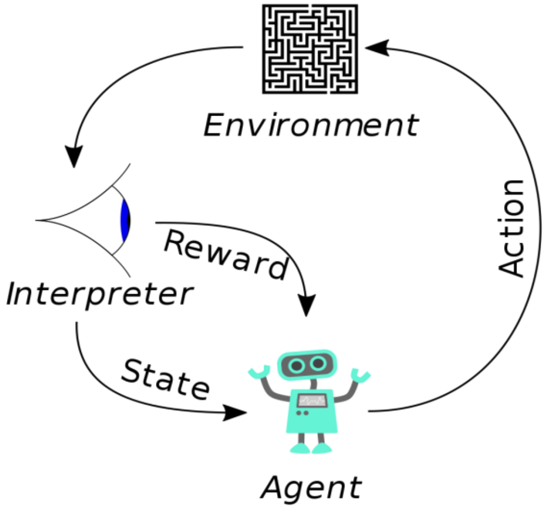
Models:
RL/MILP/Heuristics

Evaluation: Total Carbon Savings (in kgCO2)/Total Price Savings (in EUR)

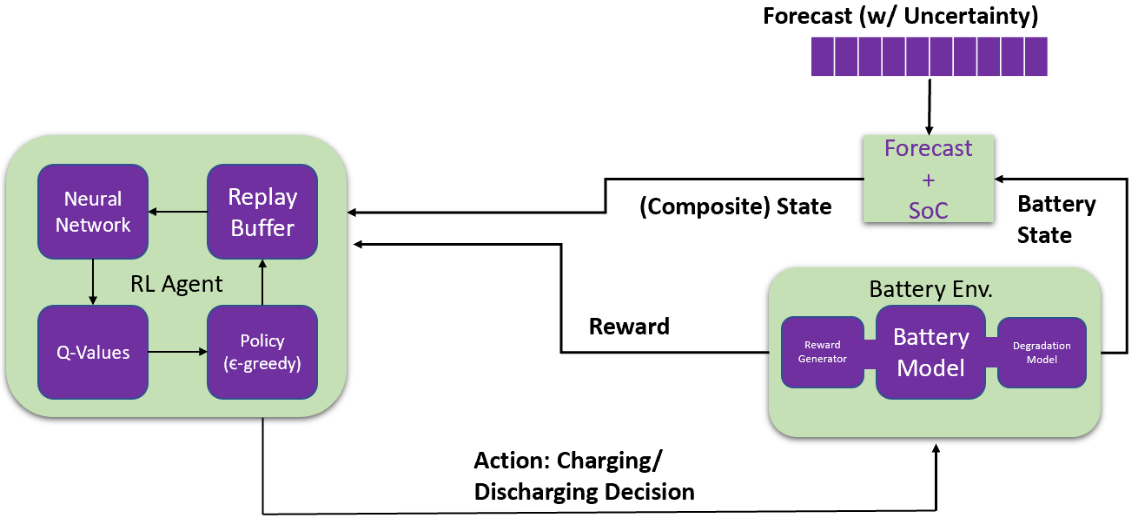


Optimum charging and discharging schedule(for 24 hours) for the batteries

RL Formulation:



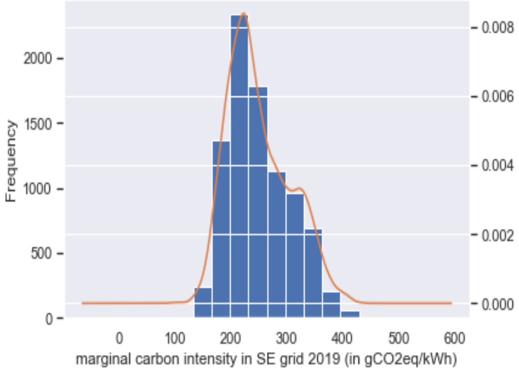
DQN - RL

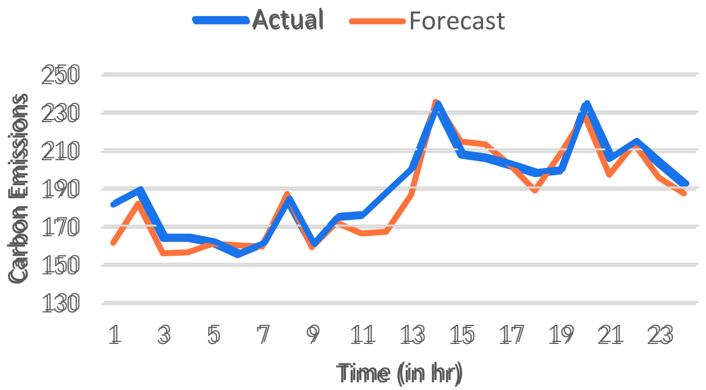


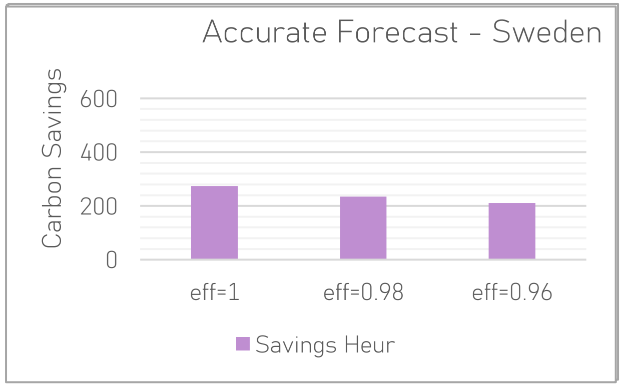
Results: Storage Arbitrage

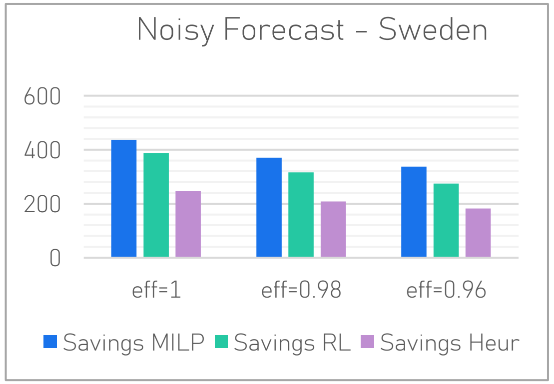
Battery Configuration-10 KWh Lithium-ion Battery

Sweden

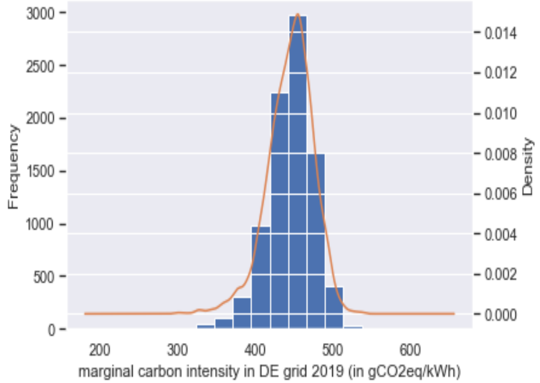


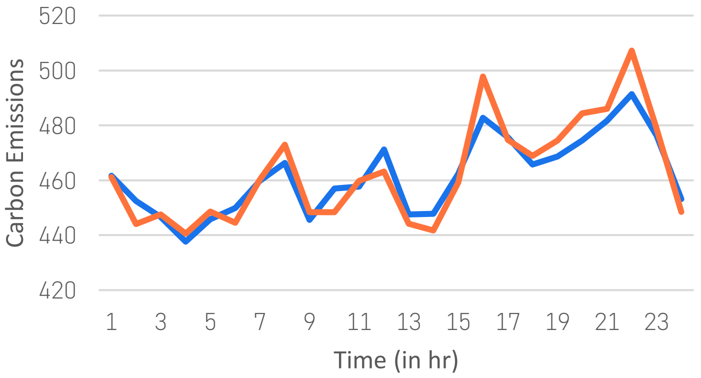


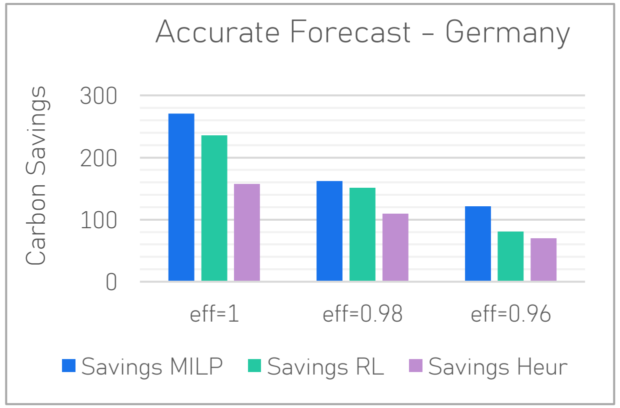


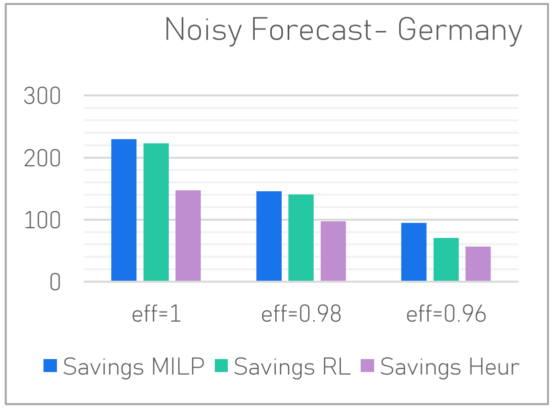


Germany

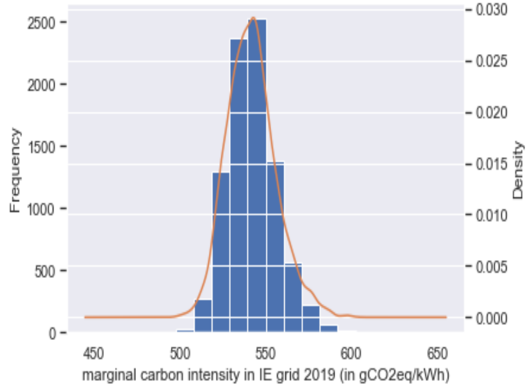


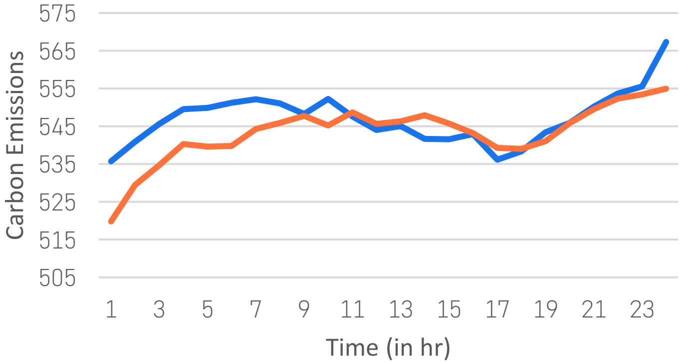


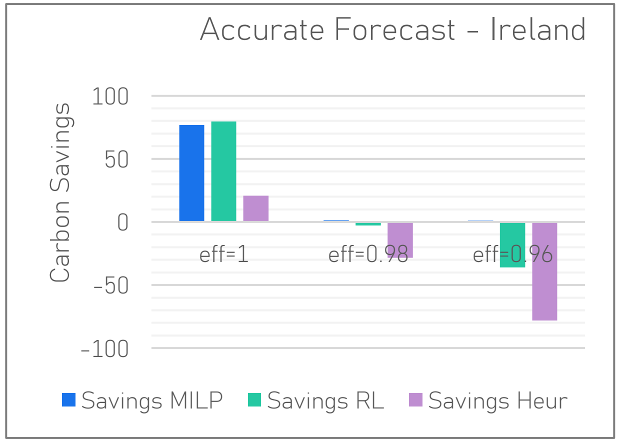


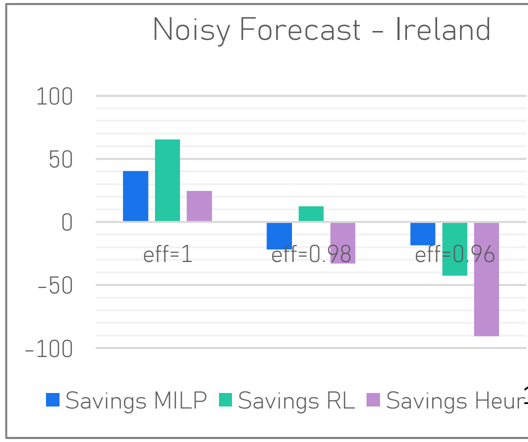


Ireland

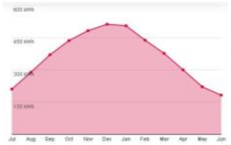
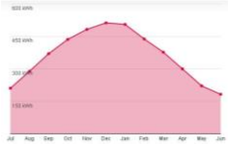








Future Scope & Perspectives through a Toy Problem:

Precedence Order		Daily Profile	Yearly Profile
1.	75 MW		
2.	15 MW		
3.	200 MWh		
4.	As required		

Energy Producer

Market place

- Dynamic Assignment of resources
- **Battery Schedule Optimization**
- Minimization of Carbon Emissions
- Excess production sell
- Penalty Structure

Consumption Profile (Day)	Energy Consumers	
		Residential 10 MW
		Factory 40 MW
		Malls 25 MW
		25 MW

Thank You!