

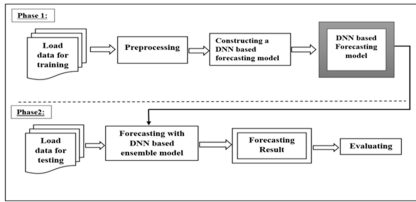
Introduction

- Household EV (Electrical Vehicle) charging schedule optimization based on forecasted energy usage
- Novel concept of clustering based neural-network to improve the forecasting accuracy
- Takes into account the customer preference along with energy price and battery constraints
- Linear Programming based optimization model

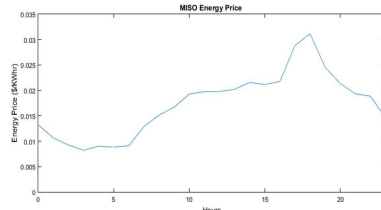


EV Scheduling Based on Energy Forecast

- Day-Ahead Energy Price (Midcontinent Independent System Operator)
- Forecasted Household Demand (200 Households)
- Forecasted EV Demand (348 EVs)



Framework Of Constructing The DNN Forecasting Model



MISO Day Ahead Energy Price

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
No of household	7	58	9	27	99
No of EVs	22	112	20	53	141



Bosch L2 Charger

- Schedule time (1 hour)
- Consumer preferred charging time (6PM-7AM)
- Final State of Charge (80%)
- EVs in each household (1-6)
- Households in each cluster (7-99)
- Consumer preferred charger type (L1 or L2)
 - L1 charger (110V-1920W)
 - L2 charger (220V-6600W)

Problem Formulation

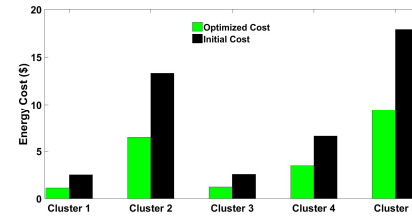
- Objective function

$$\text{Min} \sum_{i=1}^M \sum_{j=1}^N P_{ij} C_j$$

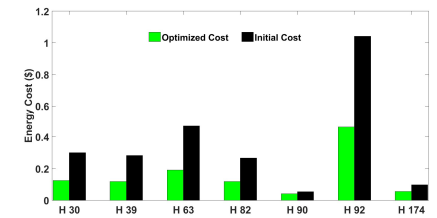
Constraints

- Demand Constraint $\sum_{j=1}^N P_{ij} = E_j$
- Consumer Preferred Time $P_{ij} \geq 0 \text{ if } T_{ij} = 1 \text{ else } 0$
- Consumer Preferred Charger 1 or 2 to represent L1 and L2
- EV Charger Rating $P_{ij} \leq \text{Charger rating}$

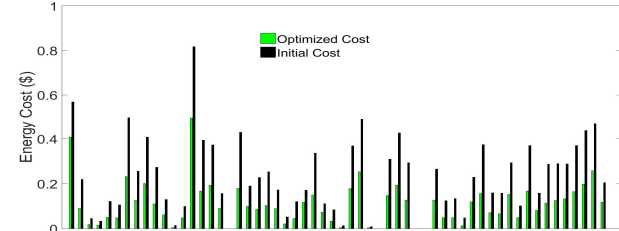
- SOC $\sum_{j=1}^N P_{ij} = (FSOC) * E_j$
- EVs Connected to the Household $\sum_{e=1}^{E_i} \sum_{j=1}^N P_{ij} = K_i H$
- Households in a cluster $\sum_{i=1}^{E_c} \sum_{j=1}^N P_{ij} = K_c \sum_{h=1}^{H_c} H_j$



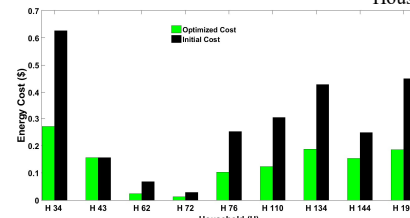
Cluster cost analysis



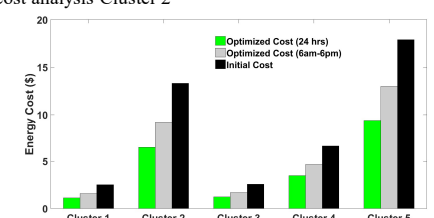
Household cost analysis Cluster 1



Household cost analysis Cluster 2



Household cost analysis Cluster 3



Household cost analysis in cluster

References

- [1] D. Ruiqin and M. Zhongjing, "Resident electric vehicles charging optimization strategy in the smart grid," *Chinese Control Conf. CCC*, vol. 2015-Sept, pp. 9054-9059, 2015.
- [2] A. Dubey and S. Santos, "Electric Vehicle Charging on Residential Distribution Systems: Impacts and Mitigations," *IEEE Access*, vol. 3, pp. 1871-1893, 2015.
- [3] M. Usman et al., "A coordinated Framework for Optimized Charging of EV Fleet in Smart Grid," *Procedia Comput. Sci.*, vol. 94, no. Fnc, pp. 332-339, 2016.
- [4] J. M. Cavanillas, E. Curry, and W. Wahlster, *New Horizons for a Data-Driven Economy: A Roadmap for Usage and Exploitation of Big Data in Europe*. 2016.