Smart Grid Consumer Behavioural model

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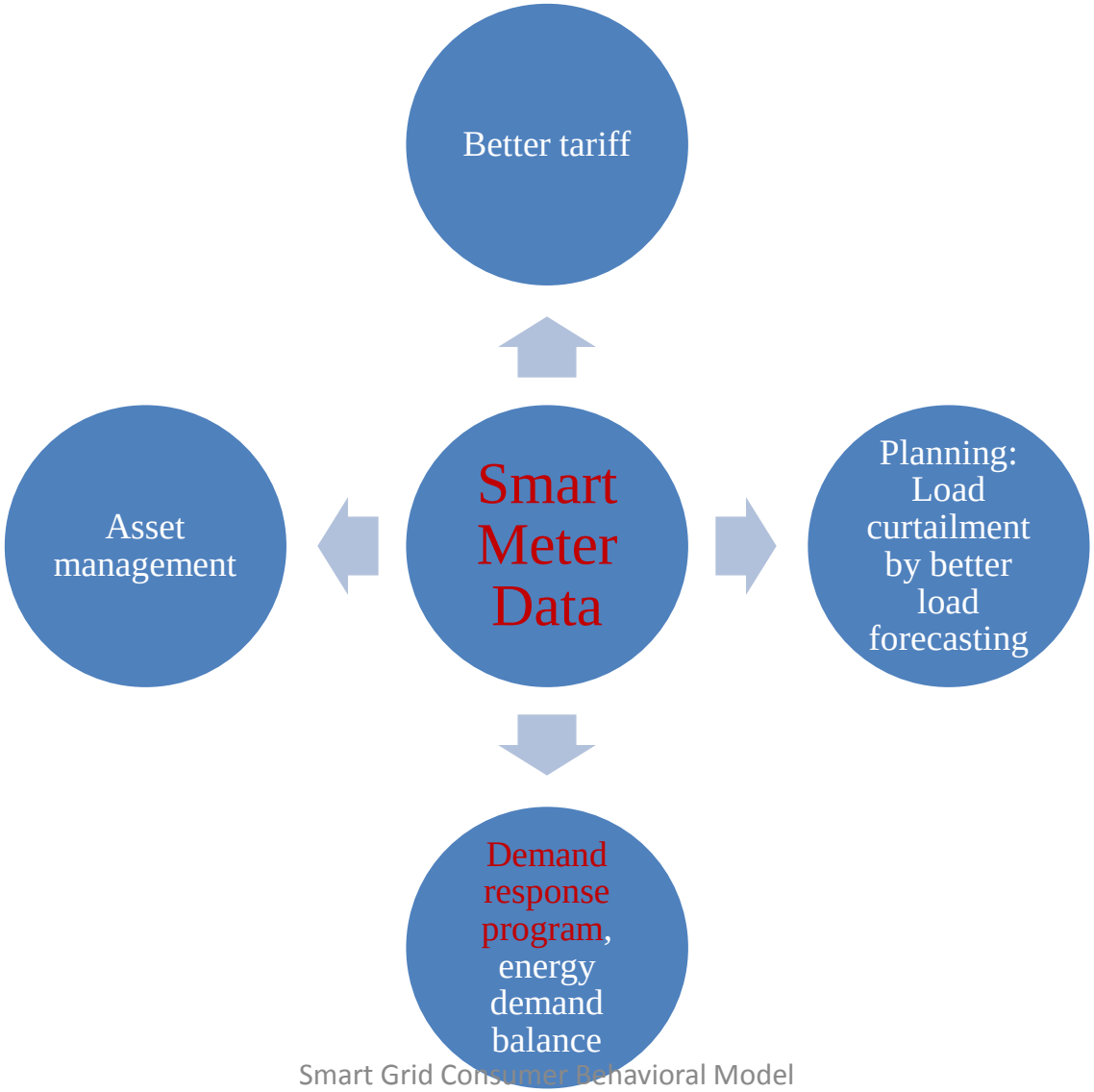
Outline

- Motivation
- Clustering methods
- Sample system
- Feature selection
- Results
- Comparison
- Conclusion
- Future work

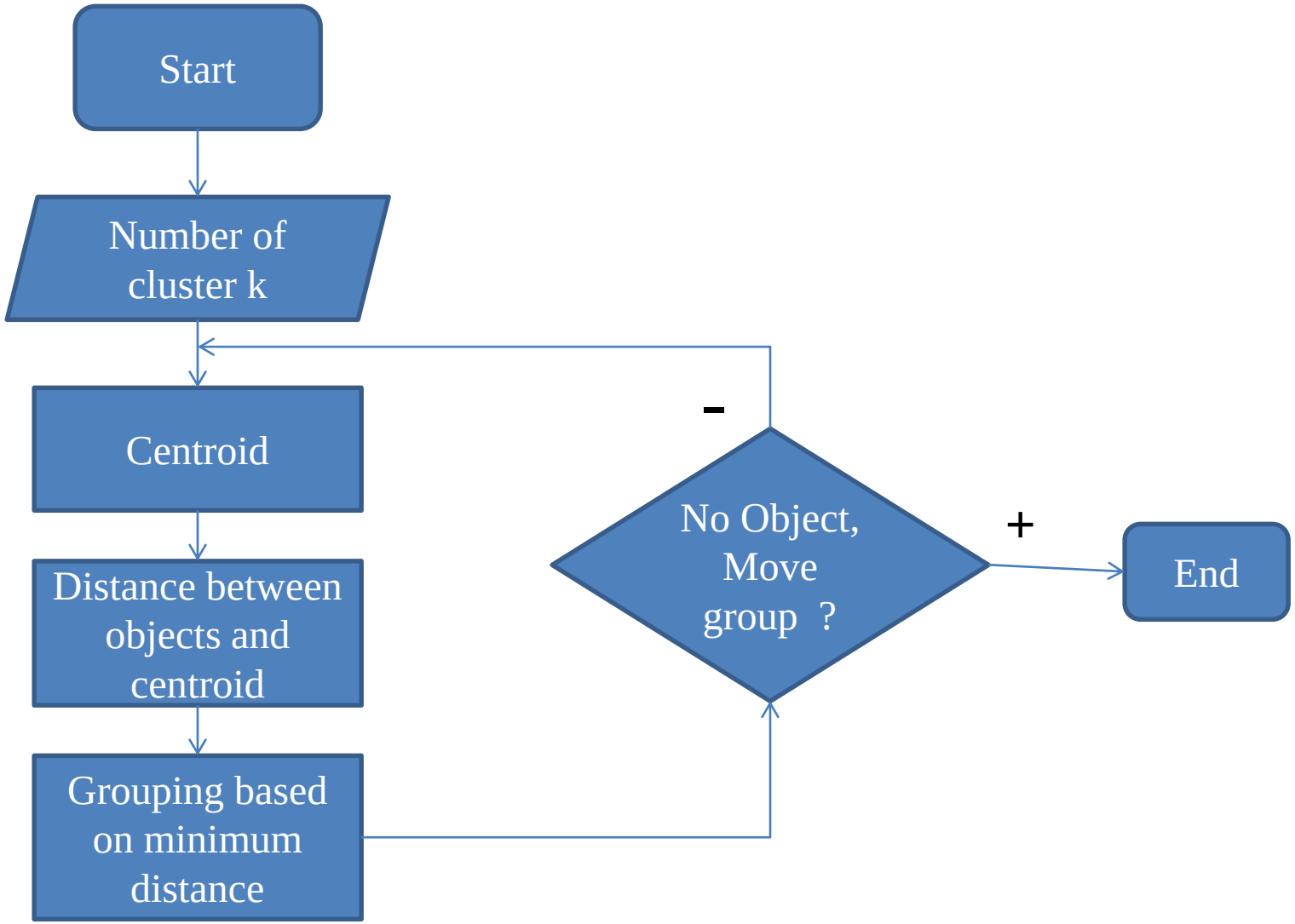
Motivation


Better tariff
Asset management
Smart Meter Data
Planning: Load curtailment by better load forecasting
Demand response program, energy demand balance

Clustering Methods

- Cluster analysis or clustering is the task of grouping similar set of objects in a group.
- There are different clustering methods like:
  - K-means algorithm
  - hierarchical clustering algorithm
  - Expectation Maximization algorithm
  - Fuzzy clustering

k-means clustering method



Expectation Maximization (EM)

- The EM algorithm iteratively finds a local maximum of the system by alternating between E and M-steps.
- In the Expectation-step(E-step),
  - Calculate the expected log-likelihood, given the current values, to update the posterior probabilities of the component label vectors, where the probability of the j^{th} observation being in the i^{th} cluster is denoted by $\tau_{i,j}$.
- In the Maximization-step,
  - Using the posterior probabilities, the expected log-likelihood function is maximized to update the mixing proportions and the distribution parameters.
- Once convergence has been achieved a soft or hard clustering can be produced.

Sample System

- The sample system contains the energy data of 5567 London households that participated in the UK Power Networks led by the Low carbon London project.
- For the analysis, mixture of the data of different classes of people is considered.
- In total 186 consumers are considered for the analysis. The data collected is at an interval of 30 minutes, so 48 time stamps a day

Sample System

Total : 186 consumers
Interval : 30min
Stamps : 48 time stamps/day

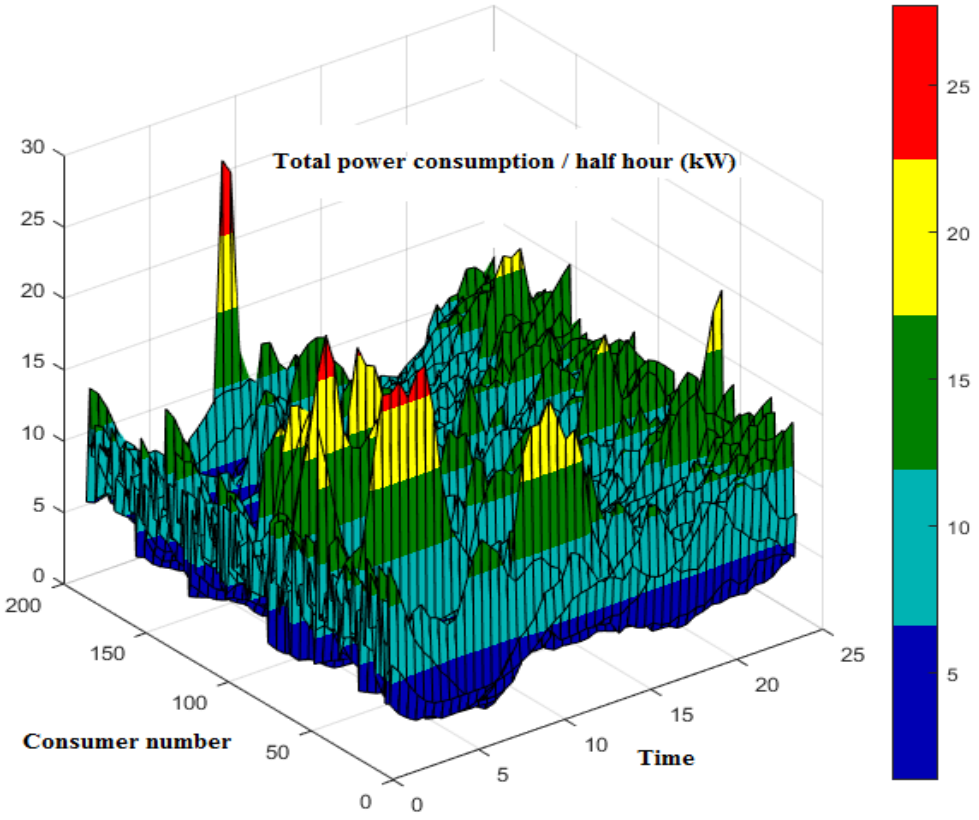


Figure 1: 3-D surface plot of total power consumption of all consumers in a year

Feature Selection

- Normalization of data is performed

$$a = \sum_{t=1}^{48} l(t) \text{ and } s(t) = \frac{l(t)}{a}$$

where,
a is the daily total consumption,
s(t) is the normalized data profile.

- A representative curve of the normalized power data value for individual consumer has been plotted by adding all 365 days data of a particular time stamp, so a total of 48 time stamps in a year.

Feature Selection

- Feature 1 (F1)-
  - Peak power consumption : The maximum power consumption of the each consumer is calculated. A total of 186 peak points are obtained.
- Feature 2 (F2)-
  - Ratio of peak to off-peak : Ratio of peak power consumption to off-peak power consumption is calculated for each consumer. A Total of 186 ratios are obtained.

Feature Selection

- Feature 3 (F3)-

  Ramp rate : For the calculation of ramp rate, 00:00hrs is considered as 1^{st} instant, 11:30hrs as 23^{rd} instant and 23:30hrs as 48^{th} instant.

  Formulae :

$$\frac{P(i) - P(i-4)}{4}, \text{ if } i > 4$$

$$\frac{P(i) - P(44+i)}{4}, \text{ if } i \leq 4$$

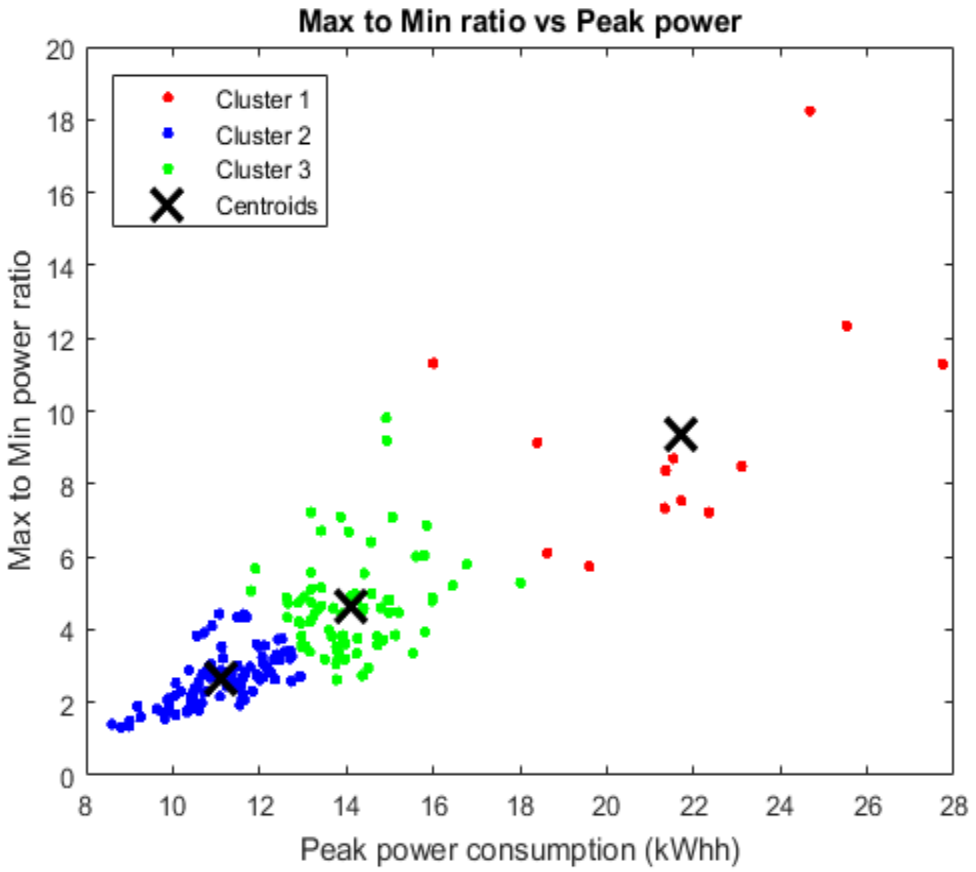
  Where,
  i is the time instant of maximum power consumption,
  $P(k)$ is the power consumption at the k^{th} time instant where $k = 1, 2, \ldots 48$.

Results

F1 & F2

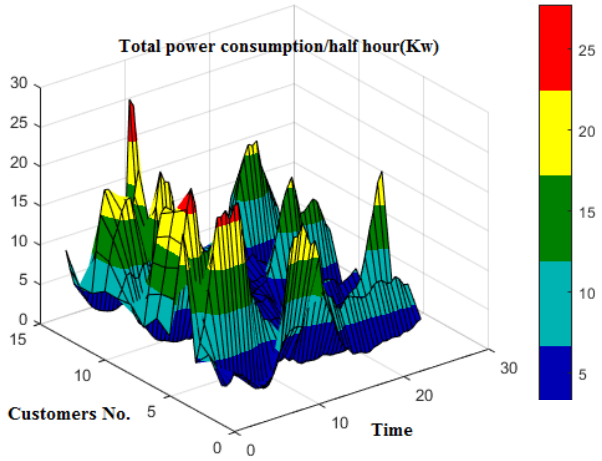
- k-means

Cluster 1 : 13 consumers
Cluster 2 : 97 consumers
Cluster 3 : 76 consumers

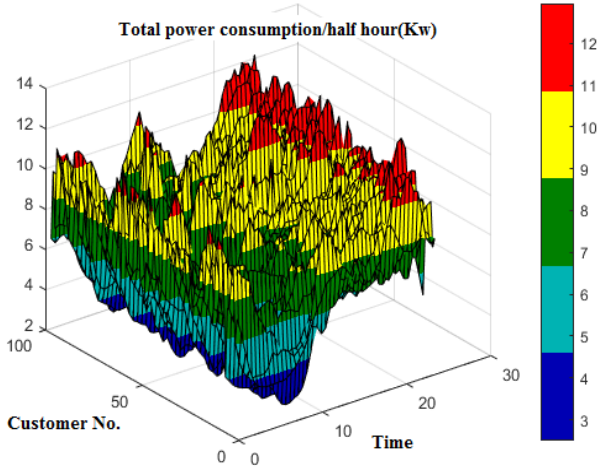


3-D surface plots of different clusters using k-means(F1 & F2)

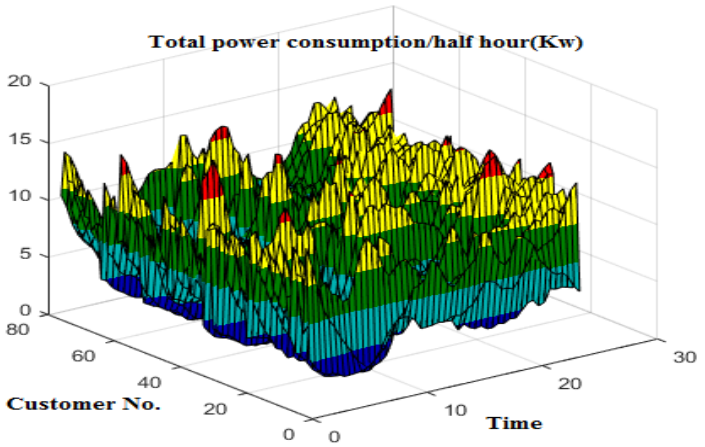
Cluster 1



Cluster 2



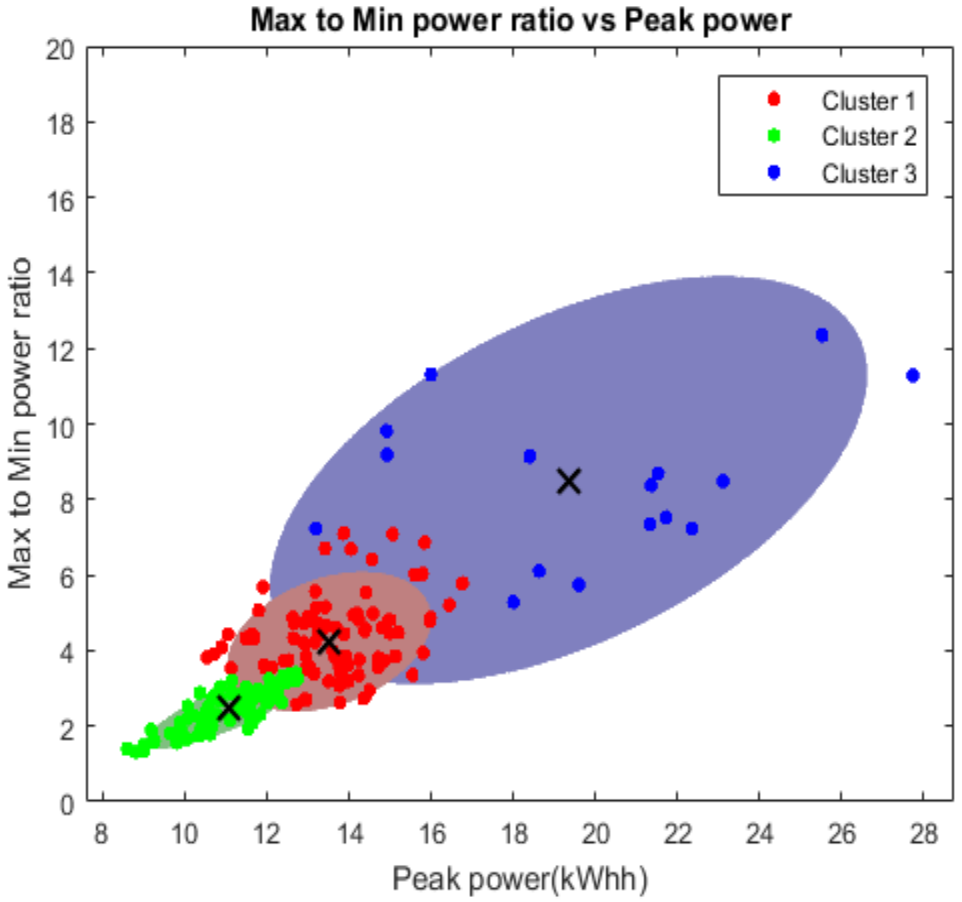
Cluster 3



F1 & F2

- EM method

Cluster 1 : 88 consumers
Cluster 2 : 81 consumers
Cluster 3 : 17 consumers



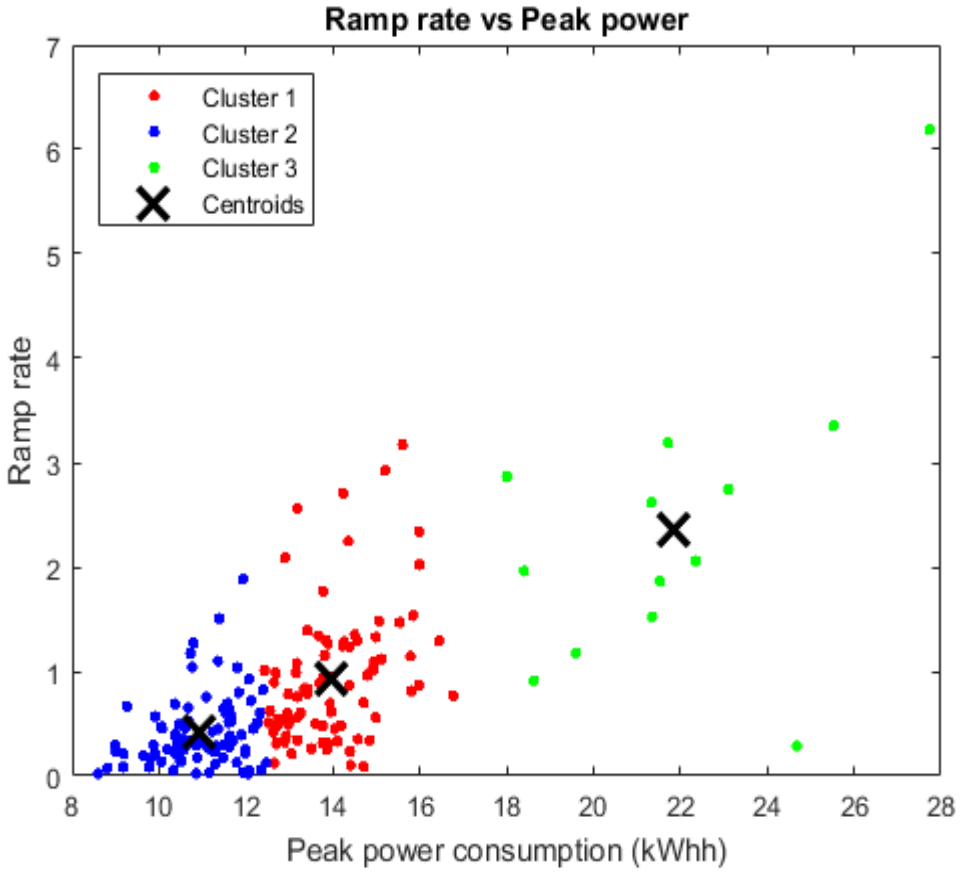
F1 & F2

- Observation
  - If the ratio of maximum to minimum power consumption is high, it implies that these particular set of consumers are good candidates for the demand response program. The utility can use this data for peak shaving.

F1 & F3

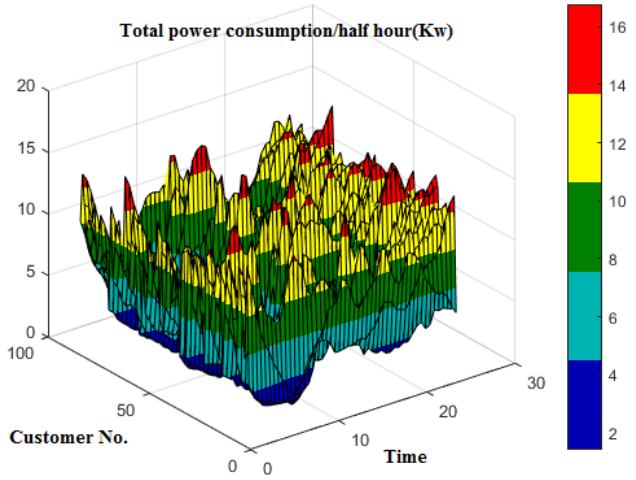
- k-means

Cluster 1 : 84 consumers
Cluster 2 : 89 consumers
Cluster 3 : 13consumers

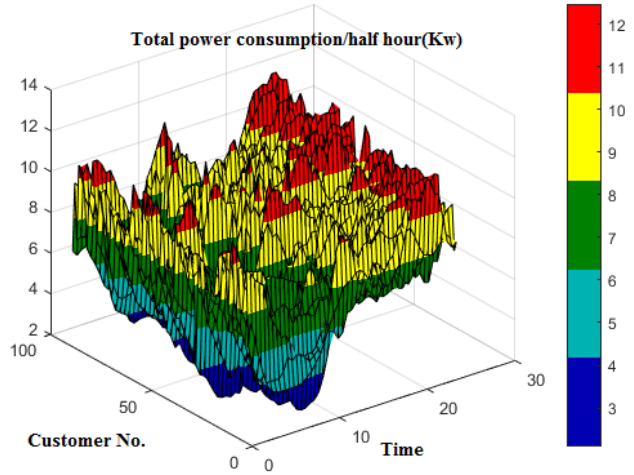


3-D surface plots of different clusters using k-means(F1 & F3)

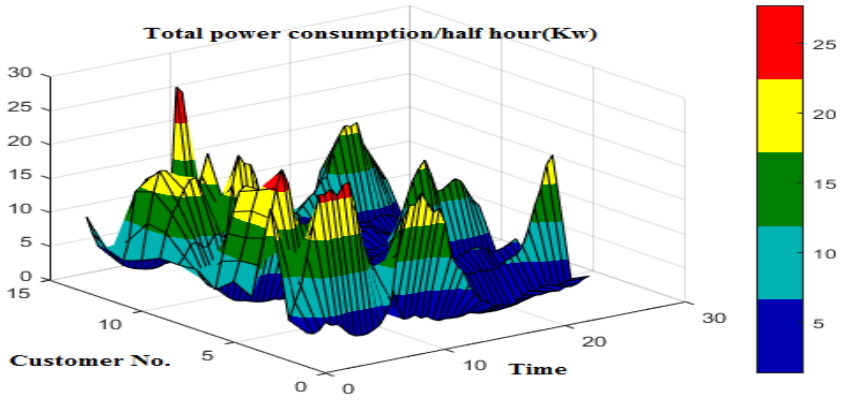
Cluster 1



Cluster 2



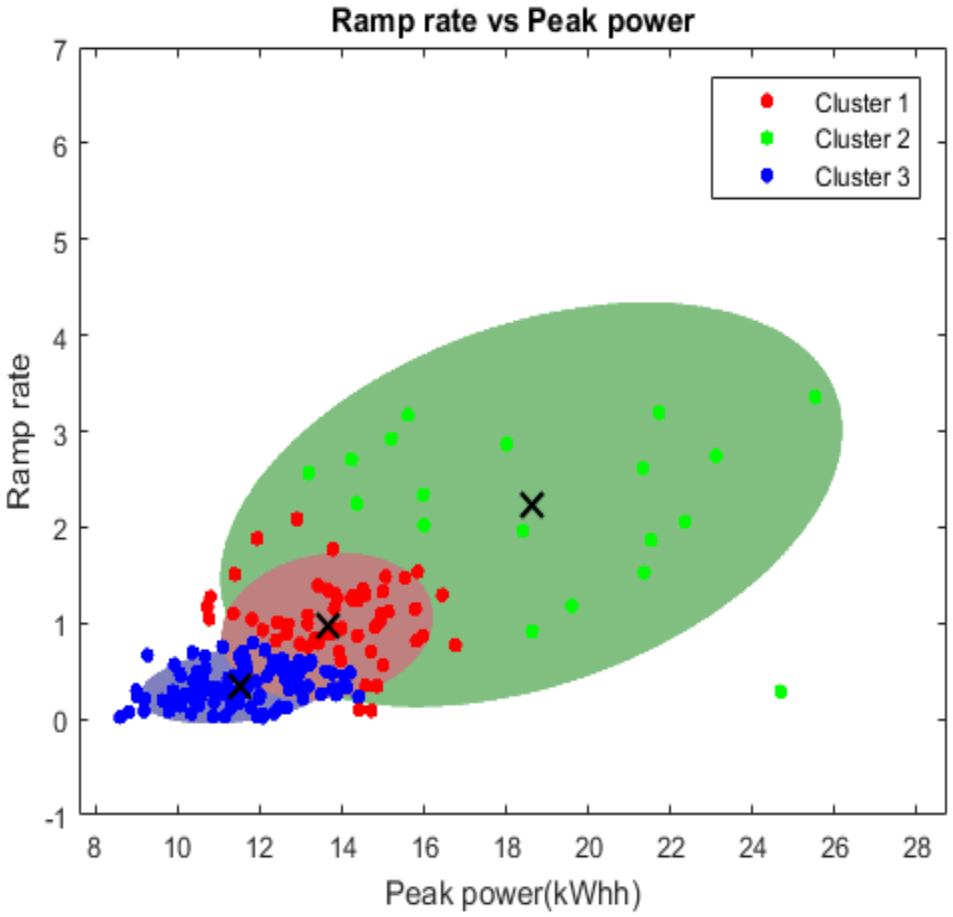
Cluster 3



F1 & F3

- EM method

Cluster 1 : 57 consumers
Cluster 2 : 20 consumers
Cluster 3 : 109 consumers



F1 & F3

- Observation
  - If ramp rate is high, it implies that the generator load balancing will be difficult for these particular set of consumers. So, in this regard the utility should be prepared well in advance to meet the load requirements.

Comparison

- Performance Index (PI)
  - It is defined as the Euclidean distance between centroids divided by sum of areas of respective clusters. i.e.,

$$PI = \frac{||C_i - C_j||_2}{A_i + A_j}$$

where,
$i, j = 1, 2, 3$ and $i \neq j$
A_i is area of a cluster where $i = 1, 2, 3$

Assumption:- Shape of clusters are assumed to be elliptical.

Comparison

PI values:

1. Considering Features F1 and F2:

Method	PI
K-means	1.1028
EM	1.0073

2. Considering Features F1 and F3:

Method	PI
K-means	2.2809
EM	1.8262

Conclusion

- Ratio of maximum to minimum power consumption is high → Peak shaving.
- Ramp rate is high → difficulty in generator load balance.

Future work

- The analysis carried out was keeping in mind of a particular application that is the demand response program.
- The work will be further expanded for different applications using dynamic clustering algorithm which identifies the most suitable algorithm and the features.
- The algorithm is tested by varying the weights given to the features.

THANK YOU