Term Project Report

on

Power System Partitioning

SUBMITTED TO

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Introduction

The complexity of the power system network's structure increases along with the difficulty of power system analysis and monitoring. Because of the complicated working mode and state of the power system, as well as the extreme weather conditions, there is always a chance of power outage.

In order to facilitate scientific and efficient grid operation, control, and management, a reasonable division of the power system can simplify the network structure.

One of the most important tasks following a significant power outage is power system recovery. To speed up the recovery process in a power grid with multiple black-start units, it would be beneficial to partition the system into several island and initiate the parallel self healing process independently.

Partitioning of power systems is a crucial strategy for managing and operating linked power systems. One effective technique for dividing power networks into zones according to the electrical distance between buses is spectral clustering.

Electrical distance-based partitioning aids in determining the best sites for new infrastructure while developing new transmission networks or expanding existing ones. This reduces the overall cost of the transmission system and facilitates the best possible network expansion.

Electrical distance-based partitioning can also improve power systems' resilience. Through the process of identifying and isolating critical nodes from less critical ones, the system becomes more resilient to disruptions and can continue operating with minimal disruption.

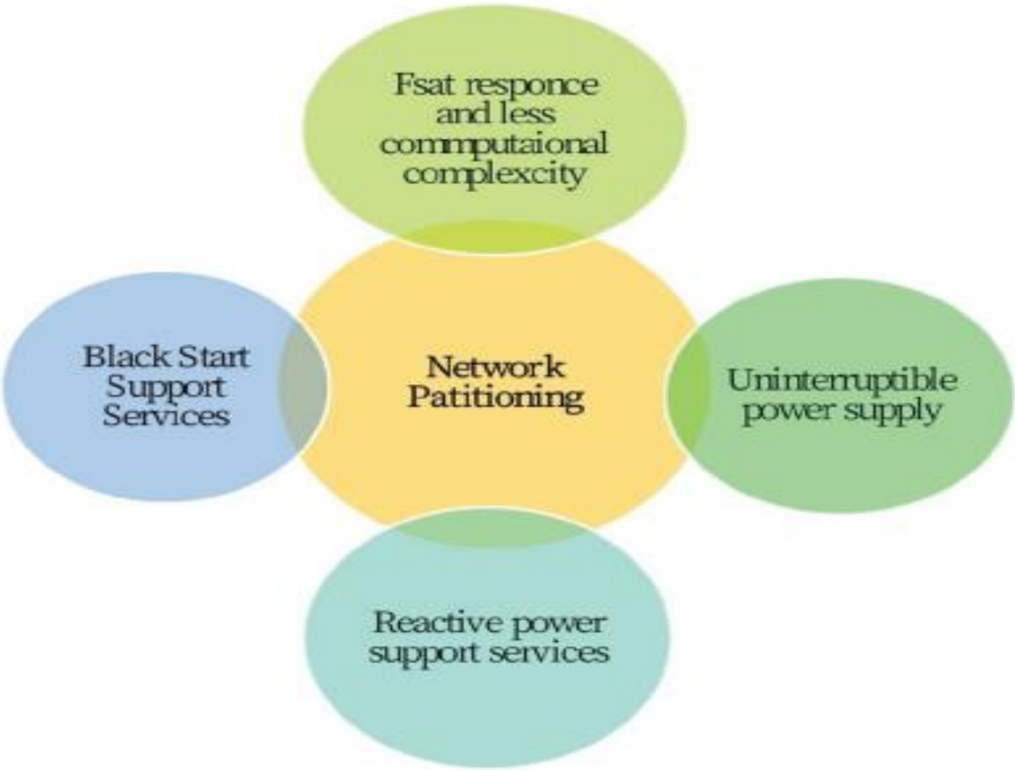

Fig. 1: Needs of Network partitioning

Methodology

We are using static approaches for partitioning the system. And spectral clustering algorithm is used to partition the graph into zones. Spectral clustering uses the spectral properties i.e. Eigenvalues and Eigenvectors of Graph Laplacian matrix and K-means technique to divide the given network into ‘k’ number of cluster. We are taking edge weight as function of magnitude of admittance.

Procedure

We are using admittance of the line as a weight of the line. Weak connectivity of lines is generally due to higher impedance of transmission lines or fewer connections between buses. If two buses are strongly connected then the magnitude of the line will be high. If they are not well connected a lower value of admittance is expected and if there is no connection between the buses then admittance will be zero.

We are using IEEE bus data to divide into the three clusters. At first, we calculated the Ybus of the system which will represent the connectivity between buses. After that, we calculated the diagonal and weightage matrix and with the help of them, we calculated the Laplacian matrix.

Now we calculated the eigen values and eigen vectors of the laplacian matrix. And with the help of the Kmean algorithm, we cluster the IEEE 14 bus and 30 bus system into the three clusters.

The K-Means algorithm performs mainly two tasks first it determines the best value for K center points and second it assigns each data point to its closest k-center and this process goes on until a stable solution is reached.

Spectral Clustering Algorithm

Input: n sample points $X=\{x1, x2, ..., xn\}$, the number of clusters k.

1. Calculate the similarity matrix W for fully connected graph.
2. Calculate the degree matrix D: $d_i = \sum_{j=1}^{n} w_{ij}$. D is the $n\times n$-order diagonal matrix composed of d_i, which is the sum of each row of the similarity matrix W.
3. Calculate the Laplacian matrix $L=D-W$.
4. Calculate the eigenvalues of L, sort the eigenvalues from small to large, take the first k eigenvalues, and calculate the eigenvectors of the first k eigenvalues $u1, u2, ..., uk$.
5. Form the above k column vectors into a matrix $U=\{u1, u2, ..., uk\}$, $U\in R^{n*k}$.
6. Let $yi\in R^k$ be the vector in row i of U, $i=1,2, ..., n$.
7. Use the k-means algorithm to cluster the new sample points $Y=\{y1, y2, ..., yn\}$ into clusters $C1, C2, ..., CK$.

Desired results -

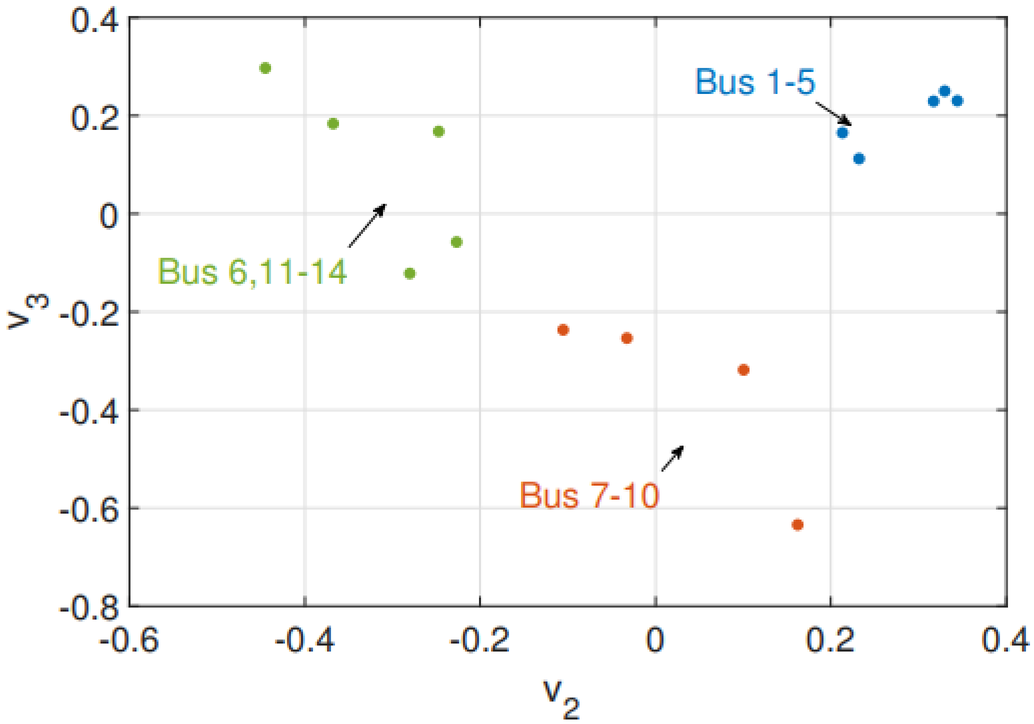

Fig. 2 : expected result for 14 bus system

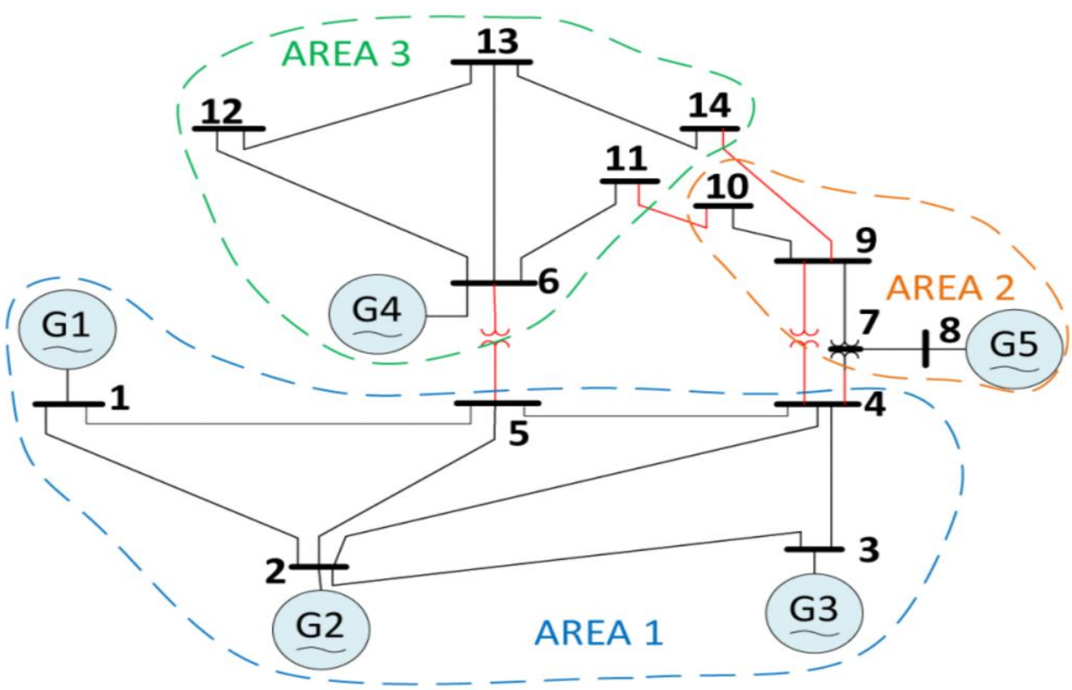

Fig. 3 : 14bus system partitioning

Observations

Laplacian matrix -

21.3840	-16.9005	0	0	-4.4835	0	0	0	0	0	0	0	0	0
-16.9005	33.3743	-5.0513	-5.6715	-5.7511	0	0	0	0	0	0	0	0	0
0	-5.0513	10.8982	-5.8469	0	0	0	0	0	0	0	0	0	0
0	-5.6715	-5.8469	41.8457	-23.7473	0	-4.7819	0	-1.7980	0	0	0	0	0
-4.4835	-5.7511	0	-23.7473	37.9499	-3.9679	0	0	0	0	0	0	0	0
0	0	0	0	-3.9679	20.5811	0	0	0	0	-5.0277	-3.9092	-7.6764	0
0	0	0	-4.7819	0	0	19.5490	-5.6770	-9.0901	0	0	0	0	0
0	0	0	0	0	0	-5.6770	5.6770	0	0	0	0	0	0
0	0	0	-1.7980	0	0	-9.0901	0	26.4209	-11.8343	0	0	0	-3.6985
0	0	0	0	0	0	0	0	-11.8343	17.0408	-5.2064	0	0	0
0	0	0	0	0	-5.0277	0	0	0	-5.2064	10.2341	0	0	0
0	0	0	0	0	-3.9092	0	0	0	0	0	8.9122	-5.0030	0
0	0	0	0	0	-7.6764	0	0	0	0	0	-5.0030	15.5528	-2.8734
0	0	0	0	0	0	0	0	-3.6985	0	0	0	-2.8734	6.5719

Eigen values -

```
E =

   -0.0000
    2.1540
    2.8999
    5.3212
    6.2524
   11.6458
   12.2764
   16.3232
   18.9188
   22.8860
   27.7847
   38.3926
   46.3474
   64.7892
```

Eigen vectors -

```
V =

    0.2673    0.3463    0.2234
    0.2673    0.3325    0.2045
    0.2673    0.3562    0.2024
    0.2673    0.2455    0.1002
    0.2673    0.2321    0.1504
    0.2673   -0.2485    0.1803
    0.2673    0.0775   -0.3321
    0.2673    0.1248   -0.6788
    0.2673   -0.0589   -0.2370
    0.2673   -0.1303   -0.2069
    0.2673   -0.2386   -0.0233
    0.2673   -0.4056    0.2885
    0.2673   -0.3538    0.2058
    0.2673   -0.2794   -0.0776
```

Clusters – cluster no. for their corresponding bus number

```
S =

     2
     2
     2
     2
     2
     1
     3
     3
     3
     3
     1
     1
     1
     1
```

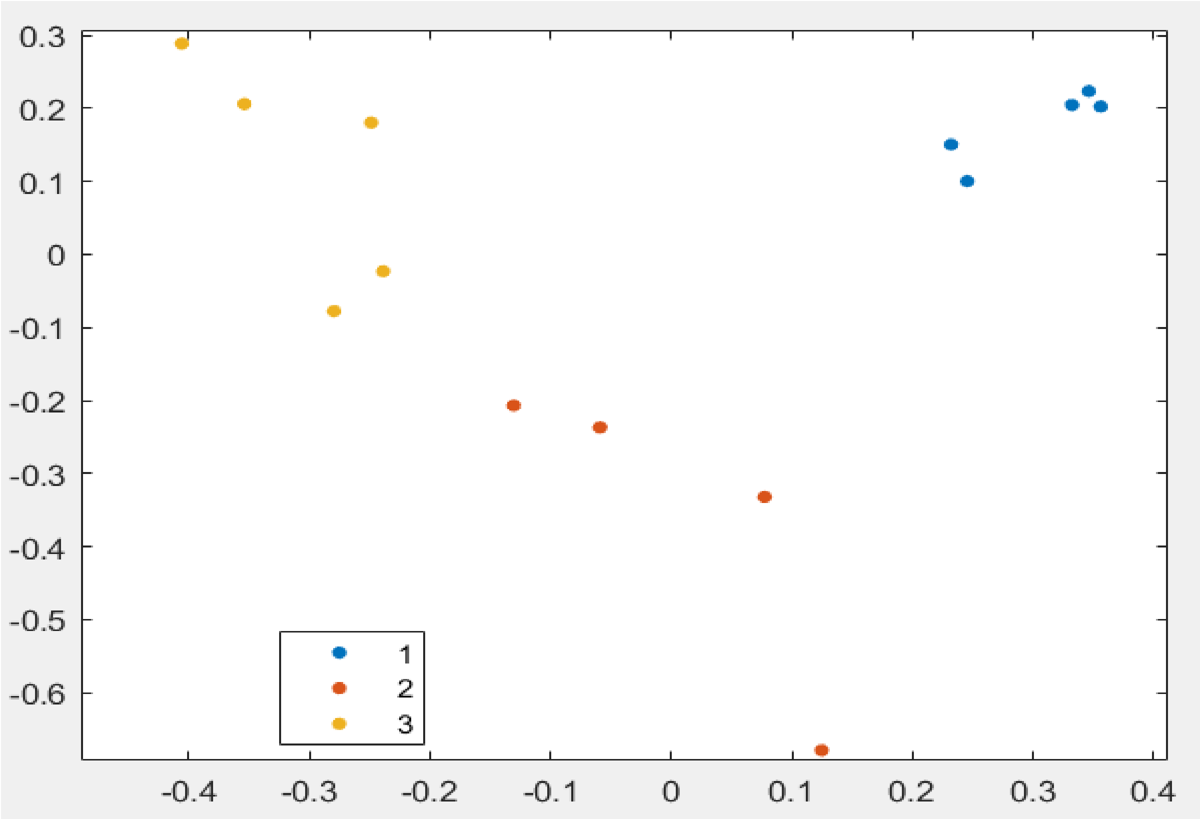

Fig. 4 : IEEE 14bus system clustering result

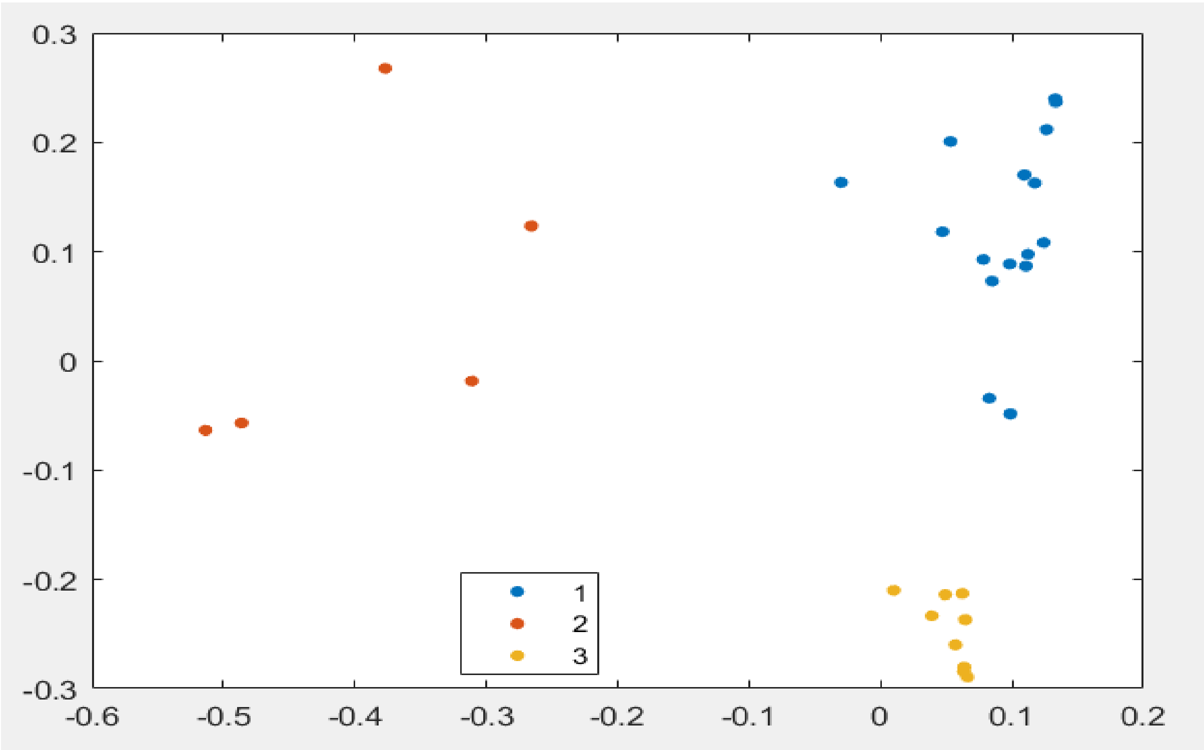

Fig. 5 : IEEE 30 bus system clustering result

In the above clustering result blue, red and yellow colors representing the different clusters.

In the 14bus system result bus 1 to 5 are in a same cluster which is represent by cluster no. 2 and blue color . Bus 7 to 10 are in cluster 3 and red color while bus 11 to 14 and bus no. 6 are in cluster 1 which are represented by yellow color.

Result

The static approach tested on a IEEE 14bus power system, and the results showed that the network partitions generated by the spectral clustering-based method is similar to desired result. Also we cluster the IEEE30 bus system into three clusters.

Conclusion

One effective technique for dividing power networks into zones according to the electrical separation between buses is spectral clustering. The suggested technique can be applied to distribute power resources, enhance system safety, and optimize the structure of power consumption.

The power system partitioning based on electrical distance opens the opportunities for further research for particular application . for example we can enhance operation and control of smart grid and microgrids, to quickly and accurately identify the location of fault in transmission network.

References

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