The Power Grid as River Network: Using Notions of Tributary, Distributary and Stream Order Number to Identify Clusters of Related Nodes

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INTRODUCTION

- The security of power grid operations relies on ensuring that set of branches come together to carry equivalent amount of power they need to deliver within the system.
- Due to intricate dynamic of power flow within the grids, the analysis of this flow behaviors during critical situations like cascading failures proves to be demanding.
- Given the complex nature of power flow, we need new paradigms to think about aggregate energy flows through networks.
- Therefore, analyzing a power grid through a river network analogy will provide useful insights in terms of flow of energy.

Objectives

✓ To detect bottlenecks and enhance situational awareness in grids.

✓ Identifying the set of nodes and edges that will have severe impacts when removed from the network.

✓ Finding out the relationship between each node/edges or group of nodes/edges and the sources or sinks in the network that they can reach or be reached.

METHODOLOGY

- Modelling power grids as Directed Acyclic Graphs (DAGs) based on the power flows directions.
- Cluster the nodes & edges based of the sources, sinks, and sources-sinks they can reach or be reached.
- Using the concept of stream order numbering for a river network, assign order number to each cluster.

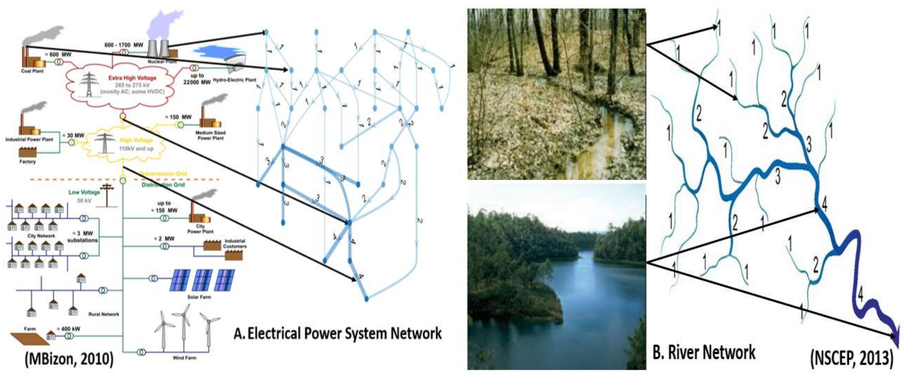

Fig. 1 - Power System - River Network Comparison

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RESULTS

The proposed clustering technique and order numbering is applied to IEEE Case118, Case30 test systems. The results for the cases is as follow:

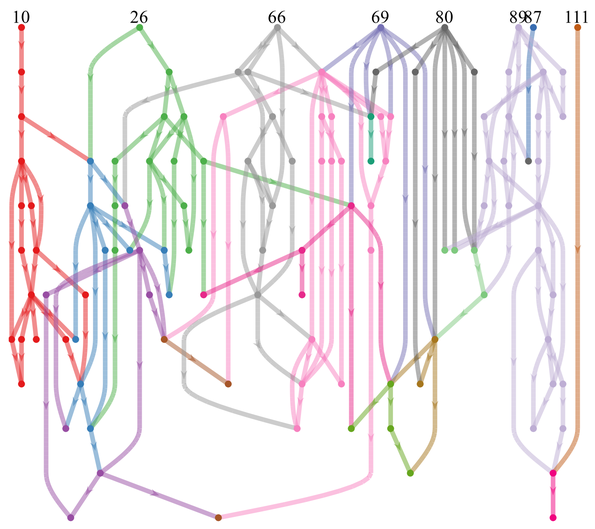

Fig.2: Source Reachability

TABLE I.
TOTAL LOAD DEMAND AND POWER GENERATED FOR EACH CLUSTER BASED ON SOURCE REACHABILITY FOR CASE118

Cluster	Total Load Demand (MW)	Total Generation (MW)
1	433	535
2	304	7
3	239	534
4	173	0
5	121	0
6	693	271
7	499	1098
8	184	0
9	0	516.4
10	84	0
11	216	0
12	132	0
13	184	477
14	168	0
15	684	899
16	21	0
17	0	4
18	107	0
19	0	36

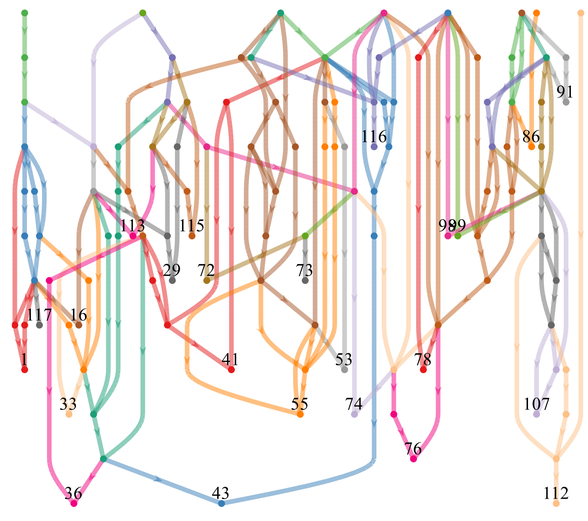

Fig.3: Sink Reachability

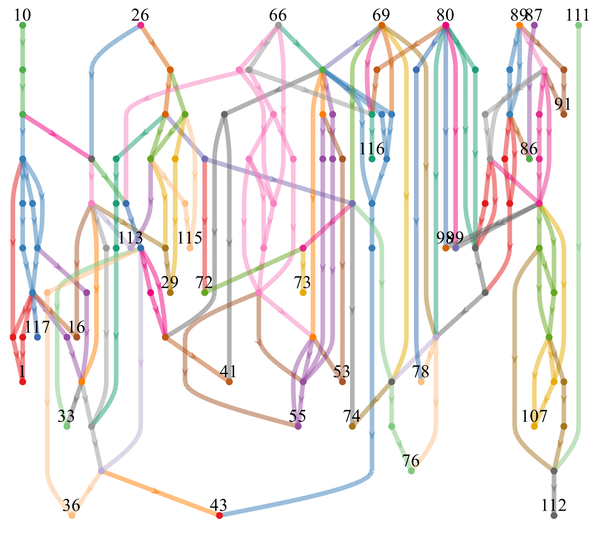

Fig.4: Source-Sink Reachability

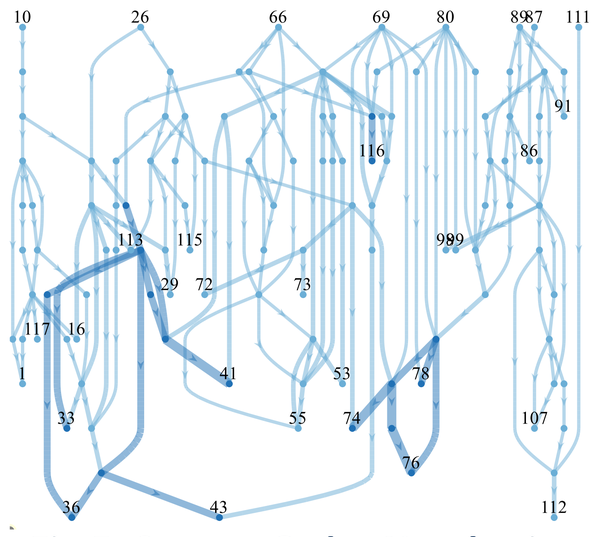

Fig.5: Stream Order Numbering

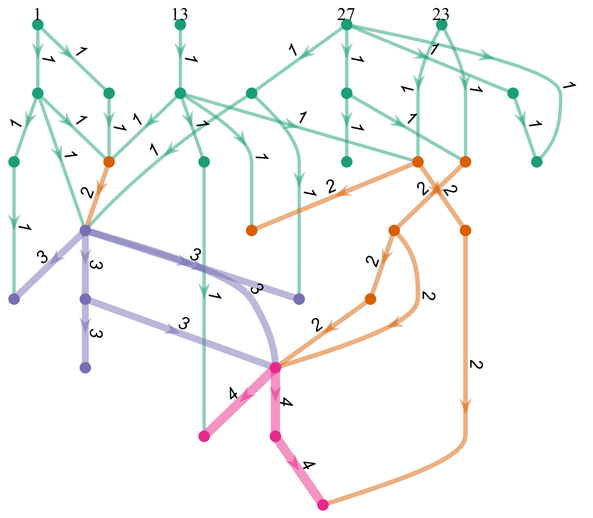

Fig.6: Stream Order Numbering Case30

CONCLUSIONS

- In this research, a new technique to cluster any complex network e.g., power grid to evaluate the structural vulnerabilities is presented.
- To assess the topological vulnerabilities and other insights from the network, the proposed clustering technique groups the nodes and edges based on the pure sources, sinks, and both that they can reach.
- An order number analogous to stream order numbering of river network is assign to each cluster based on tributaries (clusters that are supplied by a pure source) and distributaries (clusters that supply a sink).
- As one of the advantages of the proposed methods, splitting the power grid into clusters will enhance situational awareness, and power system planning.

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