Towards Efficient Power Flow Modeling: A Bottom-to-Top Approach for Dynamic Integration of Distributed Energy Resources

The power system is conceptualized as a network of buses and branches, resembling an oriented graph of interconnected nodes (buses) and impedance branches (transmission lines). This paper proposes a novel approach to simplify network analysis by considering it to be clusters of basic cells. The basic cells adhere to a structure comprising 4 nodes and 6 branches configured in a delta embedded with wye, ensuring graph isomorphism. The selection of this minimum configuration is grounded in practical observations, with most nodes in power systems connecting to a maximum of 3 others. Furthermore, this gives a tetrahedron configuration providing a meaningful 3D analogy. Fig. 1 shows a sample scenario where a portion of the transmission network in the state of Virginia is reconstructed as a cluster of basic cells interconnected through nodes with selected active branches.

Extending this concept to static power flow analysis in DC systems involves the meticulous definition and calculation of parameters (node voltages, injected/drawn currents, and power transfers) for basic cells. Subsequently, interconnection rules are formulated based on two possibilities: sharing nodes or sharing branches. The impedance matrix for a complex meshed network is then derived through the manipulation of impedance matrices of individual basic cells. This results in a step-by-step algorithm that is applicable to intricate networks. To ensure its practicality and validate the proposed algorithm, it is verified using data from standard IEEE test feeder cases, as well as through a scaled-down experimental setup that allows for testing the algorithm from a 6 to 12 node system.

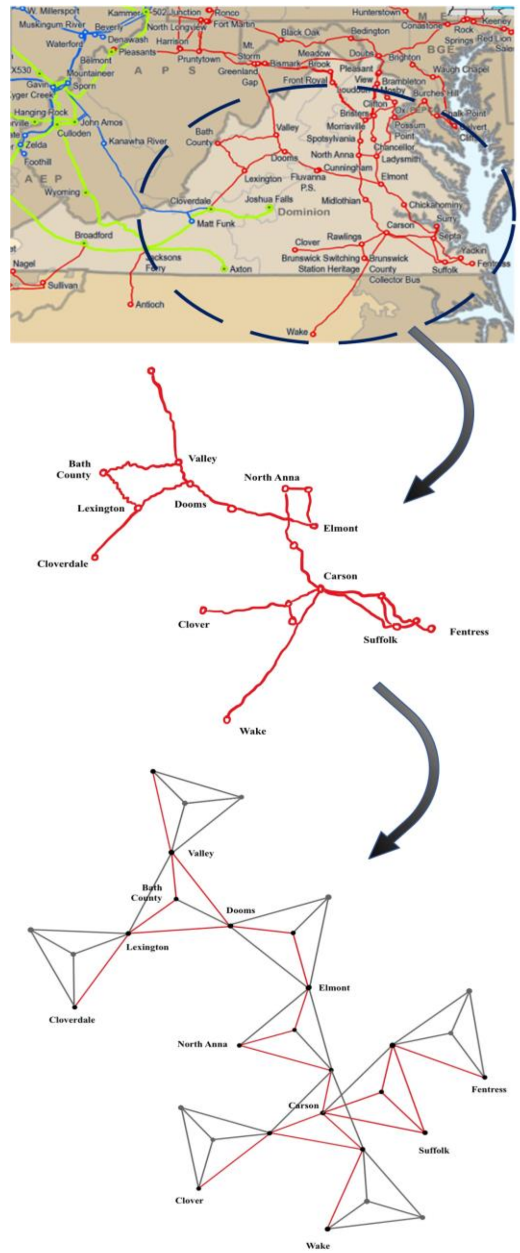

Fig.1. Portion of Virginia transmission network replicated using interconnected basic cells