Networked Rural Electrification

Jerry C.F. Li, Daniel Zimmerle
Colorado State University

Keywords: Rural electrification, A* algorithm, minimum spanning tree, optimal network

While mature technologies are available for providing electricity to off-grid villages, correct capacity planning remains challenging. A single village is geographically so small that large-area resources statistics (i.e. solar radiation / wind) cannot be used as a reliable predictor of power generation. Historical demand records are typically unavailable and highly variable due to the small number of users. Load growth / decline is also uncertain because population and activities of the village can change substantially. Finally, the location of villages was historically determined by access to water, soil, storage, etc., rather than access to rich solar or wind resources. As a result, generation resources within each individual village are often substantially less than the overall regional resource availability.

These issues can be mitigated if villages in a region are linked together via an optimally an electrical network which connects a few resources-rich centralized generation sites to the region's villages. Each village is supplied by (a) the centralized generation sites, and (b) flexible generation in the village that can be added or removed depending upon demand. Viability of this approach is determined by the cost of building such a network. Two design stages are: (i) finding near-optimal connection paths village-to-village and village network-to-generation sites, and (ii) selecting the appropriate paths to form the optimal network.

The A* algorithm is widely used to search for optimal paths. However, for this problem the A* search is computationally inefficient due to substantial, but smooth, topographical variation in a region, which differs substantially to routing problems where A* is typically deployed. In this work, the authors expand on previous developments of an modified A* algorithm, the "multipler-accelerated A* (MAA*) algorithm," which generally reduces computation time by 80-90% while sacrificing <10% of optimality. This paper illustrates optimal network design by applying MAA* in conjunction with minimum spanning tree (MST) method. It will also be demonstrated that this approach offers flexibility for changing network design according to practical constraints identified during project implementation.