Establishing the Value of DER to the Grid

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A method is proposed to compute the Locational Marginal Value (LMV) of DER active (kW) and reactive (kVar) power contribution to the grid in terms of avoided cost as a Non-Wires Alternative. The LMV is calculated on an hourly basis against a locationally distributed allocation of the cost of traditional investments. The method is precise in an engineering and economic sense, utilizes full AC representations, and can handle integrated sub-transmission and distribution system problems for NWA analysis. It can value DER for Ampere overloads, over voltages, under voltages, voltage volatility, and reserves in various real world combinations. This methodology includes a novel full AC distribution optimal power flow and security constrained dispatch that is formulated to work successfully with commercial Mixed Integer Programming solvers such as Gurobi. It has been demonstrated as a pilot on a few real world distribution capacity planning problems as part of a response to Illinois legislation requiring a methodology to value DER against grid costs.

Since the proposed methodology is computationally efficient, determination of value for DER, in terms of when, where and how much active and reactive power support is provided, is possible. Integration of the methodology with the existing planning practices, this process will be further streamlined and provide scalability to any circuit on the planning horizon. The methodology proceeds in four established steps:

First, a distribution planning model from a commercial planning tool is translated to a branch-node model for use in the LMV calculations, and data time series for loadings are cleaned of anomalies. Network reduction can be performed so that reasonably granular LMV values can be obtained along a circuit. This is done via an automated process.

Second, a series of 8760 hourly load flows are performed to establish the loading and voltage violations along the circuit in each hour. According to the magnitude of these, the conventional upgrade/remediation cost is allocated to each location in each hour. This is the Allocated Cost of Capital (ACC). This ACC becomes the basis of a penalty function for violating the loading/voltage constraints.

The LMV are the shadow prices of an optimal dispatch of kW and kVar where the objective function is the aggregated penalty function and the loading/voltage constraints are removed. These can be calculated as the LaGrangians of an optimization problem or equivalently, can be directly calculated from the network model and equations.

Finally, the optimal DER dispatch can be determined using the LMV as DER prices. This can be used to reconcile the original conventional cost with the cost of acquiring DER kW and kVar to maintain system conditions. This reconciliation proves to be exact as well.

This paper illustrates the methodology with real world examples and examples from the IEEE 33 bus distribution circuit.

The method can be extended as a foundation for a Distribution System Operator market that integrates capacity cost avoidance with market dispatch. Wholesale LMP at the station and DER energy prices can be used in conjunction with the LMV as a basis for DSO market clearing. Another variation is that the LMV can be used as the reserve price or cost to be incorporated in a DER capacity auction. This framework helps develop a foundation for facilitating DER energy exchange and provides the basis of valuing and compensating DERs fairly and accurately. It provides the intricate analysis necessary to provide DERs the ability to support the distribution system.