OPTIMAL GENERATION CAPACITY ALLOCATION AND NETWORK EXPANSION SIGNALING USING OPF

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Abstract:

The aim of this paper is to present a novel method of allocating new generation capacity on the existing grid, using Optimal Power Flow (OPF). New generation capacities are modeled as generators with quadratic cost functions with negative coefficients. These generators are connected to predetermined locations at the grid, the “Capacity Expansion Locations” or CELs. Existing generation capacities are modeled as generators with constant active power output and given reactive power injection capabilities. Energy transfers from/to external grids are also modeled as generators with quadratic cost functions. We will refer to them as Export/Import Points or E/IPs. The coefficients of the cost functions are negative for exports and positive for imports, while the outputs of generators are negative when they represent exports and positive when they represent imports. Demand, transmission or distribution lines, transformers with or without tap changers and other power system devices are simulated as usual in power flow models.

The optimal power flow problem reflects the allocation of new generation capacity at CELs and the setting of energy transfers at E/IPs, with respect to the power system constraints. Such constraints are the ones managed by regular OPFs, such as: lines thermal tolerances, voltage constraints on system buses, ratings of transformers and other power system devices etc. Additional constraints are introduced by the models of new capacities and energy transfers. The installation of new generation capacity is limited by statutory regulations, environmental concerns, social policies, technological limitations. E/IPs represent physical connections to an external network. Therefore, the capacities of these connections set a technical limit to the maximum amount of power that can be transferred to and from the external network. However, in cases where the quantity of the exported or imported power is comparable to the size of the external grid, more conservative bounds than the connection capacity must be applied to limit the voltage rise or drop at buses of the external network. By setting the appropriate bounds at generators on CEL’s and E/IPs the additional constraints are taken into account.

The augmented OPF objective function is the total cost of generation. This includes the negative cost of generation at CELs and exports at EPs, as well as the cost of imports at IPs. Minimization of the above objective function results to the maximization of new generation capacity. A 12-bus system model, with 3 CELs, several loads and 1 E/IP is used to demonstrate the efficiency of the new method. A Sequential Quadratic Programming (SQP) method is used to solve the OPF.

The new method carries several interesting features. The most important is that the environmental and social impact of new capacities can be formulated mathematically in the cost functions of CELs. The cost function coefficients represent locational preferences. Finally, the LaGrange multipliers, derived from the SQP and corresponding to the system’s constraints, indicate optimal investment strategies on the power system.