Co-optimization of energy and ancillary services

In an unconstrained transmission network, all resources can be dispatched to meet load at all locations, and the value of energy is the same at each location on the network. If the transmission system were never constrained, locational prices would have no meaning. However, when transmission capacity is limited, not all resources can be dispatched to meet all loads under all circumstances. When the preferred dispatch would violate a system constraint, a less economic resource must be operated in order to meet load downstream of the constraint, and a resource upstream of the constraint must be dispatched off.

This description of transmission system congestion is true for ancillary service products as well as for energy. An optimal dispatch of ancillary service resources would reflect transmission system constraints in the same way as an optimal dispatch of energy resources. In fact, since ancillary service requirements are a function of the location of loads and resources across the network, an optimal dispatch would consider energy and ancillary services needs simultaneously.

The objective function for simultaneous co-optimization of energy and ancillary services might look as follows:

$$Minimize \sum_{i=1}^{n} \sum_{j=1}^{m} P_{i,j} * Q_{i,j}$$

where:

$P_{i,j}$ is a bid to supply product i at location j and
$Q_{i,j}$ is the quantity supplied of product i at location j

This would simultaneously optimize the use of transmission to provide energy and ancillary services. An "injection" of capacity would be treated as if it were an injection of energy, i.e., capacity would be assumed to consume transmission just as energy does. This would ensure that transmission capacity is available when the resources were called upon.

Whether a constrained transmission path is used to provide energy or ancillary services would depend on the relative bids. Energy bids would usually be higher, so the model would tend to allocate transmission capacity to remote energy resources over remote ancillary service resources. However, there may be instances where the best use of the transmission system would be to transport ancillary service products from remote locations. This system would explicitly evaluate that tradeoff during each hour.

The output of such a system would be nodal prices for each product, reflecting the value of transmission system constraints in each hour. This raises the question of whether entities that wish to self-provide or self-track their ancillary service needs could hedge the differences in nodal ancillary service prices between their resource locations and load locations. There doesn't appear to be any reason why FTOs couldn't be used for this purpose.

The quantity of ancillary service products required at each location could be defined exogenously, based on a pre-determined criterion (e.g., a steady-state estimate of the system's most severe single contingency), or could be determined endogenously as a function of energy supply and demand bids. For example, if the technical requirements state that regulation capacity must be two percent of load at each location, the relationship would be $L_{2,j} = .02 * L_{1,j}$, where $L_{1,j}$ is the energy load at j and $L_{2,j}$ is regulation required at j. These relationships could be incorporated as constraints in the optimization:

$$L_{2,j} = a * L_{1,j}$$
$$L_{3,j} = b * L_{1,j}$$
$$L_{4,j} = c * L_{1,j}$$
$$L_{5,j} = d * L_{1,j}$$

Where $L_{2,j}$ is regulation, $L_{3,j}$ is load following, $L_{4,j}$ is spinning reserves and $L_{5,j}$ is non-spinning reserves.

If some ancillary products such as contingency reserves were required to be provided on a zonal basis, one way to reflect this would be to allocate the zonal requirement among all nodes in the zone according to a fixed weight. This would translate the zonal requirement into a nodal requirement with granularity that matches the nodal requirements for other products. The prices for each node in the zone would vary, recognizing the different impact an injection of energy or capacity at each node would have on a binding transmission constraint (i.e., there would be no "uplift" of intrazonal congestion).