CHAPTER 6

CONCLUSIONS

This thesis has focused on some key issues related to the independent grid operator (IGO)'s allocation and management of unbundled services in multiple-transaction networks. The three services treated in the thesis are transmission real power losses, reactive support requirements from generators, and transmission congestion management.

6.1 Summary

We have developed in Chapter 2 a comprehensive multiple-transaction network framework that explicitly represents multiple real power transactions simultaneously using the network. The real and reactive power flows in the transmission network are recast within the transaction-based framework. This framework has served as the basis of the formulation of the various issues treated in the thesis.

Chapter 3 has presented the physical-flow-based mechanism to determine the allocation of the total system losses to each transaction using the network. We represent the power flows explicitly in terms of the transactions in the system using the multiple-transaction network framework. Under the assumptions of the usual DC power flow conditions, we have developed the physical-flow-based allocation expression of the losses for each transaction. Using sensitivity information, we develop schemes that allocate losses in an appropriate way that is physically reasonable. A key feature of the scheme is its capability to deal effectively with counter flows. The results of the allocation scheme are then used to develop a flexible and efficient loss compensation procedure in multiple-transaction networks. We develop the equivalent loss compensation concept and apply it to such networks to establish the basis for compensating losses at any bus in the system. We have constructed a loss compensation procedure that provides each transaction with the choice of specifying the desired compensation buses with the corresponding amounts of compensation or of having its loss allocation covered by the IGO. The IGO may provide its loss compensation as a value-added service to transmission customers by acquiring energy for this purpose from willing generators or loads in the least-cost manner. The two compensation mechanisms may coexist and any physically feasible combination of the two is possible. The flexibility and cost effectiveness of the procedures have been extensively tested on various systems.

Chapter 4 has presented a new physical-flow-based mechanism for allocating the reactive power support requirements provided by generators in multiple-transaction networks. The allocatable reactive support requirements are defined with respect to the support required for the network with no transactions in place. The requirements in the presence of the proposed transactions are formulated as the sum of two specific components -- the voltage magnitude variation component and the voltage angle variation component. The formulation utilizes the multi-transaction framework developed earlier and makes use of certain simplifying approximations. The formulation leads to a natural allocation as a function of the amount of each transaction. The physical interpretation of each allocation as a sensitivity of the reactive output of a generator is discussed. The extensive testing indicates that the allocation scheme approximates with good fidelity the actual net reactive power outflow from the generator buses. The numerical results also indicate that the proposed scheme behaves in a physically reasonable and intuitive way.

We have developed a congestion management allocation scheme for multiple-transaction networks in Chapter 5, again making use of the multiple transaction framework. The scheme provides the IGO with an appropriate and useful tool to allocate the transmission congestion relief costs incurred by the IGO among the transactions. The proposed scheme determines the overload allocation on a physical flow basis; provides a congestion relief mechanism that allows the IGO to acquire the congestion relief services to remove the congestion attributed to each transaction in the most economic manner; and, determines the appropriate transmission charges to each transaction for its usage of the system.

The characteristics and capabilities of the schemes developed in this thesis have been extensively tested, and representative results on a number of test systems, including the widely-used IEEE systems, are given for each scheme. The numerical results provide good insights into the capability of these schemes to appropriately address allocation and management issues for the three unbundled services considered in this thesis.

6.2 Future Work

This thesis has focused on three of the unbundled services. There are other network-based unbundled services that need to be investigated. In particular, it would be of significant interest to explore the allocation and management issues associated with the regulation and frequency response service and the various types of capacity-based reserve services. While these services may be acquired and priced by the IGO through competitive markets, the allocation of these services and their costs to each transaction in multiple- transaction networks is an unexplored area that deserves investigation. The extension of the multiple-transaction network framework in Chapter 2 to these services should be an interesting research area.

There are a number of issues that need to be explored for the work described in Chapter 4. While the nonhomogeneity of the reactive support is well understood and consequently necessitates the treatment of each MW of transactions on a differentiated basis, the choice of the weighting factor needs considerably more investigation. The weights $\partial V_j / \partial t^{(m)}$ used in Equation (4.19) are one of many possible candidates that may be used to reflect the local nature of the reactive power support. However, the weighed sum that combines positive and negative terms may result in a small number and has the potential to lead to numerical instability. It would be worthwhile to explore other weighting terms and to perform some extensive testing and comparative analysis to identify improved weighting schemes. Another area that requires work is the combination of the reactive support requirement allocations with reactive support pricing. This is a highly challenging undertaking for a number of reasons. The pricing of reactive power is considerably more complex than that of real power due to generator capability curve impacts [52]. The presence of positive and negative terms in reactive support requirement allocation presents a further complication. While a generator needs to be compensated for its reactive support for each transaction, the fair compensation mechanism must explicitly ensure that no double-charging or any overcharging for the positive and negative allocations occurs. Another extension is concerned with reactive power reserves. In addition to the role of reactive power for voltage control of the steady state power system, a key role is the response to contingencies and potential angle and voltage instabilities, which creates the need for reactive reserves. Further work is needed to examine the role of reactive support sources and reserves in maintaining appropriate margins to instabilities and to quantify their value. The management and allocation of the reactive reserves and the payment charged to each transaction also need to be studied.

The work in Chapter 5 gives rise to several issues that require further investigation. One of the chief simplifications made in the development of the congestion management allocation scheme is the representation of all the transmission constraints in terms of line flow limits. However, this modeling approach may be inadequate. In particular, for the case in which the transmission system congestion is due to voltage or stability limits, the model in terms of the line flow limit may fail to provide a realistic representation of the network. In such a case, we need to explicitly represent the congestion in terms of the voltage or stability constraints. The allocation among the transactions of transmission congestion caused by voltage or stability constraints constitutes a major challenge. In addition, the need to ensure the security of the system necessitates the incorporation of contingencies into the congestion management to take into account those cases where the system becomes congested under certain specified contingencies. This problem will require considerable effort to address the issues of the modeling and computational aspects of the problem.