CHAPTER 8

MULTI AREA UCP IN A DEREGULATED ENVIRONMENT

8.1 INTRODUCTION

The introduction of deregulation and the subsequent open access policy in the electricity sector have opened the door for power transactions between generators and bulk consumers, under many different market-driven contractual forms including bilateral contracts. In the competitive power market, electricity prices are determined by the balance between demand and supply in electric power exchanges or bilateral contracts.

An important goal behind the restructuring of the power industry is to bring more choice in the way individual loads supply the needs permitting them to buy either from a centralized spot market or directly from the generators or marketers through pre-arranged bilateral contracts. These are typically of longer duration and tend to offer financial stability to the generators and lower prices to loads, when compared with the more volatile pool market prices. They can be of two types: financial hedging agreements or physical transactions, directly affecting the generation and demand levels. In the competitive environment, customers request for high service reliability and lower electricity prices, while generation companies (GENCOS) have to make their own profits. Thus, it is important to maximize one’s profit with high reliability, and minimize the overall operating costs and meet demand
contracts, while satisfying the relevant generation and network constraints, with respect to financial hedging contracts.

The Unit Commitment Problem (UCP) is a constrained optimization problem in which the optimal turn-on and turn-off schedules need to be determined over a given time horizon for a group of power generation units under some operational constraints. The objective is to minimize the power generation costs while meeting the hourly forecasted power demands. The UCP is an important area of research, which has attracted increasing interest from the scientific community due to the fact that even small savings in the operation costs for each hour, can lead to major overall economic savings. In the economic dispatch problem for each hour, the power outputs for the units scheduled to be online for that hour are obtained in such a way, as to minimize the fuel costs while meeting the forecasted power demands for that hour.

In a deregulated market, the market price signal in each area can be modeled as a pseudo unit whose generation cost is the forecasted market prices. Financial hedging agreement, such as call or put options and forward contracts are proposed to the multi-area UC and ED. LR-based methods solve the thermal unit commitment problem in its dual form. The problem decomposition resulting from the dual formulation reduces the dimensionality of the unit commitment problem, but the price based coordination often requires considerable "tuning" from system to system (e.g., modifying the heat rate characteristics of the identical and/or similar units). It is noted that the advantage of the DP based methods corresponds to the disadvantage of the LR based methods, and vice versa. This is quite logical considering that the primal decision space resembles a regulated decision environment and the dual decision space resembles the decision environment with free competition.
8.1.1 UC and ED In Deregulated Power Industry

After separation of generation from TRANSCO's, DISTCO's, and LSE's, the GENCO's pay more attention on how to maximize their profit and less on whether the demand and reserve are completely met. Since reducing production cost of generation means more chance of competing with other suppliers in the regional market whose transmission network is controlled by the ISO or RTO, many developers have been trying to increase the efficiency of the UC. All power producers who participate in the competitive electricity market must submit their supply bid curves which reflect the incremental cost curves of their generating units. Likewise, LSE's also have to summit their demand bid curves consisting of a set of quantities at certain prices.

Madrigal and Quintana (2001) has explained about the Independent System Operator (ISO) and Regional Transmission Organization. The ISO or RTO then uses the supply and demand bid curves to determine the balancing energy market clearing price which is the intersection of the combined supply bid curve and the combined demand bid curve. All suppliers who procure the bids are paid the same price – the market clearing price. This mechanism intends to encourage generators to submit the low supply bid curves. These curves are supposed to reflect generating units’ marginal cost curve because theoretically, in perfectly competitive markets, profit is maximum when supply is sold at marginal cost. Conventionally, UC and ED use generating units’ monotonically increasing cost curves in either piecewise linear format or quadratic format to determine minimum production cost. Once, energy market became centralized and competitive, UC and ED have been applied to use with bid curves submitted by market participants. These bid curves are typically in piecewise linear format. The UC and ED, therefore, can determine which generating units owned by different firms will procure the bids or be committed and how much they will be dispatched.
8.1.2 UC and ED with Market Operation Components

In addition to participating in a bid-based market, the GENCO’s and the LSE’s can sell and buy power through the bilateral contracts. With the encouragement of SMD issued by FERC and the benefits of long-term contracts, the bilateral contracts between the GENCO’s and the LSE’s and reliability must-run contracts between ISO’s and GENCO’s, began to play an important role in the generation planning. The details of these market operation components are discussed as follows.

8.1.3 Electricity Trading Contracts

Under uncertainty of competitive electricity market, electricity trading contracts or derivatives, such as options, futures contracts, and forward contracts, are used to hedge against the risk of price uncertainty in spot market and have better market liquidity due to providers being able to contract for energy for longer terms. These electricity derivatives, except futures contracts, are bilaterally exercised between two market participants over the phone, by electronic transactions, or through a broker. This is called bilateral contract in over-the-counter markets. On the other hand, electricity futures are traded in exchange markets. Therefore, the futures prices are more transparent to the public than the forward prices or settled option prices. Both forward and futures contracts are agreements between two parties to buy or sell electricity at a certain future time, either short-term or long-term, for a certain price. The payoff of these contracts is the difference between the contracted price and the spot price at the contracted time. However, futures contracts are often significantly smaller than that in forward contracts and more standardized in details as well as contain lower credit risks due to being paid out daily when compared to being paid out in a lump sum at maturity time as in forward markets (John C. Hull 2006 and S. J. Deng, S. S. Oren 2006).
Although it does not cost anything to participate in the forward or futures markets but the holders must exercise the right. On the other hand, the holders of options are not obligated to follow the agreement but there is an expense for acquiring an option. The plain options can be categorized into two types which are put option and call option. A put option holder can sell the electricity when the price is equal to or greater than the settled price during a certain period. This settled price is known as exercise price or strike price. In contrast, a call option gives the holder the right to buy the electricity during a certain period when the price is equal to or below a strike price.

Oren in claims that call and put options is the most effective tools available to power producers and power marketers for hedging the price risk. Options also create an incentive for investment in generation capacity and a solution for resource adequacy. Additionally, call options can be used as the option-based capacity mechanism to secure reserve capacity.

8.1.4 Reliability Must-Run Contracts

In addition to electricity trading contracts, there is another type of agreements, Reliability Must-Run (RMR) contracts, that affects the generation schedule of some generating units. These contracts are employed for the system reliability purpose. The RMR contract is established by ISOs or RTO's to ensure that power supply is adequate in certain areas to which power cannot be transferred from the cheaper source due to transmission constraint or voltage support issues. RMR participants can define a generating unit or a combination of units to be designated RMR unit(s). Generally, ISO's/RTO's have to contract for the entire capacity of each RMR unit and owners of RMR units are paid in accordance with RMR contract. When the RMR units are requested to run less than its full capacity, the rest energy of RMR units, which are in must-run status, can be participated in the ED.
8.2 MULTI AREA UCP WITH BILATERAL CONTRACT

Chitra Yingvivatanapong (2008) has proposed multi-area unit commitment with market operating component. To maximizing the profit or minimizing the operating cost among the generating companies, incorporating bilateral-contract into multi-area unit commitment and economic dispatch. For helping the generating unit and load-serving entities to choose appropriate relative levels of pool versus bilateral trades, while considering the risk, economic performance, and physical constraints. A multi-area generation scheduling scheme can provide proper unit commitment in each area and effectively preserve the tie-line constraints.

The objective of the multi-area generation scheduling scheme is to coordinate area generations in order to minimize the operation cost. The constraints are composed of the system power balance, spinning reserve requirements in every area, unit upper/lower generation limits, unit minimum up/down times, tie line limitations and so on. Call and put options, forward contracts and reliability must run contract are incorporated into the multi-area UC and ED as an effective tool to procure the resource and supply the demand. A bilateral contract is an agreement between two parties, to exchange electric power under a set of specified conditions, such as MW amount, time of delivery, duration, and price. Bilateral contracts can take the form of future or forward contracts, where the former are generally traded in an exchange and can be traded continuously up until their time of delivery. In contrast, forward contracts are typically negotiated directly between the load and the generator, with the terms of the contract remaining fixed until the time of delivery. To find the nearly optimal solution among the available generating units in the interconnected multi-area system, the units are sequentially identifies via a procedure that resembles bidding, the most advantageous units to commit until the multi-area system obligations are
fulfilled. Likewise other units are recommitted to reduce the spinning reserve and minimize the total operating or production cost. They have been considered the sample multi-area system with three areas is taken for investigations for solving the multi-area UC and ED with a large-scale system with the import/export capability and tie line capacity constraints. All market operation components including call options, put options, forward contracts, and reliability must-run contracts are also integrated into the simulations. This all market contract are explained in section 8.2.1.

In that sample multi-area system, each area consists of two subareas and twenty six generating units and system contains three tie lines for area interconnections. They considered shift factors and there are four assumptions in order to use phase shifters with that sample multi-area system. First, a direct current (DC) power flow model is used. Second, voltage at each node (area) is simply assumed to be equal to one per unit (1p.u.). Third, the effective impedance inside each area must be the same or power is injected at the same bus as that is withdrawn. Finally, two subareas in the same area share the same bus for interchanges and area 1 is the reference area.

8.2.1 Bilateral Contracts

Bilateral transactions are usually long-term agreements determined through individual negotiations between a buyer and a seller. The price agreed in a bilateral exchange is based on the market forces and other than under potential system security violations. The levels of the bilateral transactions are arrived at independent of any centralized pool with optimal dispatch. In this research work, a set of bilateral contracts has been determined through some power exchange mechanism that facilitates such power contracts. In a competitive market, participants often employed power contracts to hedge their risks.
Bilateral contracts are incorporated into forward contracts and options. Forward contract holders are obligated to buy or sell power at a predefined price for a specified period, which can be from an hour to years. Unlike forward contracts, options give their option purchasers the right, but not the obligation to buy (for call option) or sell (for put option) a fixed amount of power at a predefined strike price during the option term which is usually a few months to a couple of years. The option and forward contracts between internal generators and internal LSE's, between internal generators and external LSE's, which is counted as sale transactions with the external system or between external generators and internal LSE's which is counted as purchase transactions with the external system. When the forward contracts are exercised, the following procedures must be completed before the multi-area UC and ED problems are solved.

8.2.1.1 Forward contracts between internal generators and internal load serving entities

First, the generation requirements of areas where the designated source generating units are located are increased by the amounts of power and in the periods specified in the contracts. Second, the generation requirements of the designated sink load areas are decreased by the amounts of power and in the periods specified in the contracts. Consequently, the adjusted generation requirements of the source areas are the demand of the source areas plus the contracted amounts of power and those of the sink areas are the demand of the sink areas minus the contracted amounts of power. Third, the contracted amounts of power in the specified periods are counted against the export limits of the source areas and the import limits of the sink areas.

Fourth, the designated source generating units are assigned their status as must-run with a predefined minimum generation, equal to the amounts specified in the agreement. With this status, these units are excluded
from the unit commitment due to their predefined status and their minimum power outputs are counted towards supplying only the amounts of the generation requirement reduced from the sink areas. If the predefined minimum generation level of the source generating unit is less than its full capacity in any hour the remaining capacity can participate in the economic dispatch.

8.2.1.2 Forward contracts between external generators and internal LSE's

The forward contracts between the external generators and the internal LSEs are considered as purchase contracts with the external systems. When they are exercised, the generation requirements of the designated sink load areas need to be decreased by the amounts of power and in the periods specified in the contracts. The contracted amounts of power are then counted against the import limits of the sink areas.

8.2.1.3 Forward contracts between internal generators and external LSE's

The forward contracts between the internal generators and the external LSE's are considered as sale contracts with external systems. When they are exercised, the generation requirements of areas where the designated source generating units are located are increased by the amounts of power and in the periods specified in the contract. The contracted amounts of power are counted against the export limits of the source areas. Meanwhile, the designated source generating units are assigned their status as must-run with predefined minimum generation equal to the amounts specified in the agreement.
8.2.1.4 Options

The main difference between the forward contracts and options is that the holders of the forward contracts are obligated to buy and sell power, while the holders of the options have the right to choose whether the contracts should be exercised. Once the call option or the put option is exercised, the procedures which must be completed before the multi-area UC and ED problems are solved. Finally, the tie line capacity limits must be adjusted, with respect to the flows contributed by the contracted amounts of power.

8.3 SUMMARY

In section 8.2 has clearly explained about the Multi-area Unit Commitment with limited import/export limit incorporated into bilateral contract. In this research work, the multi-area unit commitment problem is solved with EP, PSO, and EIIPSO method without including bilateral contract but it includes the import and export limits and tie line constraints. The bilateral contract may be incorporated with four area system for solving multi area unit commitment problem.