CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This chapter provides conclusions of this dissertation and recommendations for future research.

6.1 Conclusion

6.1.1 Operating Strategy based on Deterministic Criterion

In Chapter 3, the work was focused on the determination of best strategy and its associated total cost under vertically integrated structure with consideration of demand uncertainty and generating unit unavailability. The problem associated with demand uncertainty was approached by applying a decision analysis method. With regard to the application of this method, demand uncertainty was modelled by three load levels which represent low, medium, and high load level. Meanwhile, the unavailability of generating unit was modelled by using a simple two-state Markov model. Nine scenarios were proposed which represent the combination of three spinning reserve strategies and three load levels model. Spinning reserve requirement was determined based on deterministic criterion. The objective of each scenario is to determine total cost which comprises generation cost and risk cost. The best strategy was selected among scenarios which give the minimum total cost.

The proposed method was tested using IEEE-24 bus test system which shows that the obtained best strategy depends on several factors, i.e. system size, value of loss load, standard deviation, and probability of load level. The conclusions of the best strategy for different system size at a certain value of probability load level is summarized in Table 6.1, while the best strategy for a certain value of standard deviation is shown in Table 6.2. Relating to the simulation in Chapter 3, the system which consists of 26, 78, and 130 units are categorized as small, medium, and large system size respectively. Meanwhile, the criteria of low, medium, and high spinning reserve (SR) strategies correspond to the scheduling of spinning reserve at 8%, 10%, and 12% of forecasted demand. The demand uncertainty is modeled by using three load levels, i.e. low, medium, and high load levels. The uncertainty parameters which correspond to each load levels, i.e. probability of medium load level and standard deviation, are varied depend on the investigated parameter.

Table 6.1 Selected strategy with a fixed standard deviation for various system sizes

System size	Probability of medium load level	SR strategy			Load level strategy		
		Low	Med	High	Low	Med	High
Small	≤ 0.6			√			√
	>0.6			√			√
Med	≤ 0.6		√				√
	>0.6			√		√	
Large	≤ 0.6	√					√
	>0.6		√			√	

Table 6.2 Selected strategy with a fixed probability load level for various system sizes

System size	Standard Deviation (%)	SR strategy			Load level strategy		
		Low	Med	High	Low	Med	High
Small	1			√			√
	2			√			√
	3			√			√
	4			√			√
Med	1			√		√	
	2			√		√	
	3			√		√	
	4		√				√
Large	1		√		√		
	2	√					√
	3	√					√
	4	√					√

6.1.2 Operating Strategy based on Probabilistic Criterion

In Chapter 4, the objective of the proposed method was still similar with the presented in Chapter 3, i.e. determination of best strategy by considering system uncertainty. Similar treatment for the problem associated with demand uncertainty and generating unit unavailability were also used such as described in Chapter 3. The difference occurs due to the determination of spinning reserve requirement, which utilizes probabilistic criterion. By using this criterion, the amount of spinning reserve is determined based on the predefined reliability index, i.e. the sum of expected unserved energy (EUE) for the whole time interval should be less than the predefined EUE_{max}.

Application of the proposed method to IEEE-24 bus test system shows that the best strategy was sensitive to the change of the utilized variable, i.e. value of loss load, standard deviation, and probability of load level. By increasing EUE_{max}, the best scenario tends to be appropriate at lower load level strategy. By increasing the EUE_{max} as of 5%, it leads to the increase of expected total cost as of 5.3%. It can be concluded that the increase of expected total cost is mainly due to the increase of expected risk cost. Meanwhile, by varying the probability of load level, it is also found that at higher accuracy of load forecast, i.e. higher probability of medium load level, the best scenario also tends to be appropriate at lower load level strategy. The expected risk cost increase as of 0.28% when the probability of medium load level is increased from 0.4 to 0.9.

Comparison of the expected total cost resulted from probabilistic criterion to the results of deterministic criterion shows that with the variation of probability of medium load level there is a slight increase of expected total cost due to the use of 1% of EUE_{max} which cause an increase of expected risk cost. Based on the results by varying EUE_{max}, it is found that to obtain the equal of expected total cost, the EUE_{max} should be set at lower than 0.5%.

6.1.3 Spinning Reserve Pricing under Partially Deregulated Structure

Spinning reserve pricing under partially deregulated structure become the main issue of the proposed method in Chapter 5. In this chapter, demand uncertainty and generating unit unavailability is treated similarly as has been done in Chapters 3 and 4. Deterministic criterion was employed in determining spinning reserve requirement. By assuming that some part of the original system units is spin-off to become GENCO units, the original system has an obligation to provide spinning reserve to BC demand. Based on this assumption, determination of best strategy and its associated total cost was done using the proposed method in Chapter 3. The impact of providing reserve to BC demand was included in the proposed method. Based on the obtained total cost, spinning reserve price was calculated by balancing the increase of cost by providing reserve to BC firm demand and the benefit from reserve selling. The increase of cost was calculated by subtracting the produced total cost by providing reserve with the cost without providing reserve. Based on the results of all test systems, it was found that the reserve price is highly depending on the size of the considered test system and the reliability of the system units. At small system size, risk cost plays a dominant role in total cost. As a consequence, by providing additional reserve to back-up BC firm demand, the original system would also get benefit in term of reducing the risk cost as well as the total cost.

On contrary, the contribution of risk cost tends to decrease at larger system size, in which the reliability of the system units plays an important factor in determining reserve price. The higher contracted demand, the more expensive reserve price is. Meanwhile, at the same contracted demand, the variation of number of GENCOs shows that the trend of reserve price was depend on how good the reliability level of the original system units is. At a better reliability of original system units, reserve price tends to increase at higher number of GENCOs. Otherwise, reserve price tends to decrease by increasing the number of GENCOs if the original system utilizes units which have worse reliable data.

6.2 Key Contributions

This section summarizes the finding and the contribution of the proposed method to answer the impact of system uncertainty to the obtained best strategy and spinning reserve price.

1. An operating strategy model based on deterministic spinning reserve criterion is proposed in Chapter 3 investigate the impact of system uncertainty to the short-term operating strategy of a power system. The proposed method was able to handle the problem of demand uncertainty and unit unavailability. Based on the presented results, it can be concluded that by considering system uncertainty, the determination of the best strategy is sensitive to the change of several factors, e.g. standard deviation, probability of load level, and value of loss load. In addition, the degree of sensitivity of each parameter varies depending on the system size. One of the consequences of considering higher model of demand uncertainty is regarding with the highly increase of computation time due to the increases of developed scenarios. It can be solved by implementing parallel computation of

each developed scenario. Meanwhile, by adopting more sophisticated model of unit unavailability, the utilities have able to provide a detail of reliability data including start-up failure rate, etc. A typical sophisticated model of unit unavailability can be found in [25].

2. In the same direction with the proposed method, the best strategy taking into account system uncertainty based on probabilistic criterion can be determined. By using a predefined reliability index (EUE_{max}) as a stopping criterion to determine the spinning reserve requirement, the best strategy which yields a minimum total cost can be obtained. Application of the proposed method to a modified IEEE-24 test system which has been replicated close to an actual system size shows that the best strategy was sensitive with respect to utilized parameters, i.e. EUE_{max}, probability of load level, and EUE price. The proposed method in Chapter 4 can also be applied to an actual system taking into account more complex model of both demand and generating unit uncertainty with a consequence of longer computation time which can be solved by parallel computation method.
3. The proposed method in Chapter 3 which utilizes the combination of decision analysis and three spinning reserve strategies to determine the best operating strategy by considering system uncertainty is also applied in Chapter 5. By using the proposed method in Chapter 5, any utilities under partially deregulated structure can determine a suitable spinning reserve price by taking into account both system uncertainty and bilateral transactions. Generally, the demand uncertainty causes the increase of total cost, hence if the reserve price is calculated based on the assumption of a fix of the future demand, the obtained reserve price will be less than the one by taking into account demand uncertainty. Furthermore, the unit cost of the utilities will be higher than what should be. By considering system uncertainty, it is expected that the obtained reserve price will be close to the actual value.

6.3 Recommendations for Further Research

Some recommendations for the future research are as follows:

1. In practice, there is a probability that a starting-up of generating units would fails. If the record data is available for each generating units, it is very interesting to investigate the effect of considering detail reliability model of generating units instead of a simple two-state Markov model which has been utilized in this

research. By considering detail model of unit including the failure probability of start-up unit, the obtained risk cost might be closer to the practical system.

2. As presented in Chapter 4, spinning reserve is determined based on a predefined reliability index, i.e. maximum allowed Expected Unserved Energy (EUE_{max}). By using the aggregate of EUE to evaluate spinning reserve requirement, the spinning reserve has to be updated entirely for the whole interval although it is not actually needed at some intervals. Accordingly, the obtained spinning reserve at last iteration which is met the reliability index would be excessively high. It is interesting to investigate the impact of using other index which should be evaluated in each time interval such as LOLP and unit commitment risk index. By using this reliability index, the spinning reserve might be obtained at close to the margin of the predefined reliability index.

3. According to the impact of bilateral contracts, since in this work it is assumed that the GENCOs do not have enough capacity to provide spinning reserve for their BC firms demand hence all back-up power is assumed might be provided by original system. In the case that the GENCOs still have a certain amount of spinning reserve capacity but it does not enough to cover all BC firm demand, it is interesting to investigate what is the impact to the reserve price. It is also interesting to apply the model to a more practical power system by considering another source of power generations in the system, e.g. the combination of hydro-thermal generation, renewable energy generation, and imported power from neighboring system.