CHAPTER 7

Conclusions

7.1 Summary of Work

This research proposed the modeling of renewable energy resources for generation reliability assessment. Renewable energy resources under consideration are solar (photovoltaic), wind, small hydro, biomass, and biogas. The contributions of this research are the impact of renewable generation on electricity demand characteristic, the effective capacity for generation reliability evaluation of renewable power plant, the reliability evaluation using conventional approach and modified approach.

It is important to assess the impact of renewable energy resources on electricity demand characteristics in response to the increasing penetration of renewable generation. Renewable generation was treated as negative load. Change in demand characteristics can be observed by considering change of LDC after integrating renewable energy resources. LDCs were obtained from hourly load data. It was found that, in case of Thailand, there is significant variation of renewable generation that can be observed from both seasonal and annual time frames. Renewable generation of photovoltaic and biomass powers highly affect demand characteristics because their generation capacities are much higher than other resources. The impact of renewable generation is minimal during July-October given that biomass generation is low in that time period. It was also found that renewable generation affects the shape of LDC and the division of load groups by means of changes of energy generation and duration of each load group. The impact on an annual basis is less obvious than the impact on a seasonal basis.

The equivalency between renewable and conventional capacities and their contributions on generation reliability are investigated by using the concept of effective

capacity. The operational behavior of renewable power plant is reflected by high FOR and low generation capacity. It can be observed that renewable power plant with either lower FOR or higher average power contributed to better generation reliability. Given identical renewable capacity; more renewable units (smaller in capacity size) yields better generation reliability.

The modeling of renewable energy resources was described for evaluating generation reliability. In the absence of operating characteristics of renewable unit, the EFOR was proposed to be a substitute for the FOR of conventional unit. Generation reliability under the presence of renewable energy resources was evaluated by using the LOLP as reliability index and the ELCC as capacity contribution. It is obvious that the penetration of renewable energy resources would have negative impact on generation reliability. The impact of renewable energy resources on generation reliability depends on generation capacity and loading condition. The contribution of renewable energy resources is important and deserves attention when they replace conventional (fossil-fuelled) resources

The modified approaches are proposed to evaluate generation reliability by the intermittent characteristics of renewable energy unit, identified from its generation profile. The LOLP is preferred as generation reliability index. There are five proper approaches to evaluate generation reliability. The reliability of the system decreases when the peak demand increases. As the capacity factor of the renewable energy unit increases, the reliability of the system increases. The approach IA gives the highest LOLP whereas the approach IIA and IIIA give the lowest LOLP. The approach IA proposes that the generation capacity of the renewable unit remains as its own but the FOR is modified by using EFOR with the total energy in EFOR calculation is defined as the total energy which the renewable unit can produce with the generation capacity in the time horizon. The Approach IIA and the Approach IIIA propose that the modified generation capacity is defined as an average power generation over 24 hours without modifying the FOR. The modified approach which is simple and intuitive is the approach IA which proposed that the generation capacity remains as its own and the FOR is modified as EFOR which is similar to 1-CF. Meanwhile, the approach which has the equivalent generation profile like the actual generation profile the most is the approach IIIC. The Approach IIIC proposes that the modified generation capacity is

defined as a maximum power generation at ON-state and an average power generation in a de-rated hour at de-rated state. The modified FOR is a probability at OFF state.

Finally, the proper reliability modeling of renewable energy resources is proposed for the purposes of generation reliability assessment and generation planning. The proper penetration level of renewable energy resources into generation system can be evaluated by using the concept of the effective capacity. The equivalency between the conventional unit and the renewable energy unit can be evaluated by using the effective capacity and the capacity credit.

7.2 Recommendations

For this research, the reliability modeling of renewable energy resources is proposed in order to evaluate the generation reliability which is focused on power system adequacy domain. The modeling is used in the generation reliability assessment for long-term evaluations. However, the power system reliability studies should also be developed for short-term reliability evaluation. The long-term evaluations are performed for the sake of planning while the short-term reliability evaluations are sought for daily operation, including system security assessment where the effects of sudden disturbances are evaluated. If the reliability is considered in security domain, the set of reliability indices will be changed.