CHAPTER 7

CONCLUSION AND SUGGESTION

7.1 Conclusions

In this study, the mathematical models of evacuated tube solar water heater system are developed and validated in order to predict the effect of number of evacuated tube and dimensional thermosyphon using the thermal resistance method and Explicit Finite Difference Method (EFDM). The mathematical models are developed first and then validated with the experimental data under the identical weather data of Chiang Mai province, Thailand. After that, the mathematical models are completed, the EFDM model is developed to predict the optimal number of evacuated tube and dimensional thermosyphon on the net saving. Moreover, the optimal parameters of the evacuated tube solar water heater system are constructed and tested to validate the models. The conclusions of this research are as follows.

7.1.1 The single evacuated tube solar water heater

The single evacuated tube solar water heater is tested based on the climate of Chiang Mai province, Thailand. The solar intensity and ambient temperature are also recorded for the input data of the mathematical modeling program. The mathematical models of single evacuated tube solar water heater with thermosyphon are validated accurate by the experiment results. The conclusions are as followings:

- Thermal efficiency of the mathematical models is validated by the experimental result. It shows that the mathematical models are in good agreement with the experimental result. Thus, the EFDM is more accurate rather than the thermal resistance method about 16.73%.
- The instantaneous thermal efficiency of single evacuated tube in the experiment, thermal resistance method, and EFDM are 22.47%, 29.39%, and 23.47%, respectively.

- The maximum temperature of hot water in the experiment, thermal resistance method, and EFDM are 58.30^{o}C, 78.32^{o}C, and 68.51^{o}C, respectively. It should be noted that these temperatures occurred at the final time of the day.

7.1.2 The optimization of solar water heater system

The mathematical model of EFMD is to be accurate about 4.45% for the single evacuated tube solar water heater. Thus, the EFDM is suitable for the prediction more than the thermal resistant method. The EFDM is used for the optimization of the solar water heater system in order to study the effects of dimensional thermosyphon as well as a number of the evacuated tube on the net saving. Following is the conclusion.

- The evacuated tube solar water heater system can produce over 65^{o}C of hot water and the maximum value of water heat rate is obtained at 8 evacuated tubes, 15.88 mm (1/2 inch) of evaporator diameter, and 22.22 mm (3/4 inch) of condenser diameter. Moreover, the solar water heater system is obtained the maximum net saving at 98,078 Baht. These appropriate conditions are studied at Chiang Mai province, Thailand.

7.1.3 Validations of the mathematical models of evacuated tube solar water system

The validations of the mathematical models of evacuated tube solar water heater system are performed with the experiment results under the climatic conditions of Chiang Mai province. The solar water heater system consists of 8 evacuated tubes and volume of the water storage tank is 100 liters. Thus, the mathematical models of evacuated tube solar water heater system with thermosyphon are validated accurate by the experimental results. The conclusions are as followings:

- The mathematical models show a good agreement with temperature prediction of the solar water heater and thermal efficiency compared to the experimental results and the previous research.
- The thermal efficiency of the experiment is 58.28%, which is about 3.14% lower than the EFDM model at 60.11% and lower than the thermal

resistance method about 4.10% at 60.67%. The standard deviations on a partly cloudy day condition are higher than a clear sky day while a coefficient of determination is less than a clear sky day.

- The maximum temperature of hot water of the two weather conditions is occurred in the early evening period around 4:00 p.m. For a partly cloudy day condition, the maximum temperatures of hot water are 52.45^{o}C, 58.00^{o}C, and 55.04^{o}C for the experiment, the thermal resistance method, and the EFDM, respectively. For a clear sky day condition, the maximum temperatures of hot water are 65.25^{o}C, 75.85^{o}C, and 71.66^{o}C for the experiment, the thermal resistance method and EFDM, respectively.

7.1.4 Economics analysis

For the economics analysis, the water temperature of storage tank of experimental result is used for calculating the water heat rate by converting the heat energy compared to the electricity consumption of electric hot water heater. The conclusions are as followings:

- The simple payback period of the evacuated tube solar water heater system is 3 years and 11 months and the annual electrical consumption saving is 5,990.70 Baht/years.
- Net Present Value (NPV) is positive at 23,312.13 Baht which indicates the solar water heater system earnings generated by investment exceed the anticipated costs. The discount rate for zero NPV is 22.35%.

7.2 Suggestion for future work

7.2.1 The mathematical model

- The present mathematical models have been developed to predict the thermal efficiency of evacuated tube solar water heater using R141b thermosyphon. However, it can be modified for thermosyphon with other kinds of working fluid by substituting the properties of working fluid in the mathematical models.

- The mathematical model should be considered the heat loss of the water pipe between the manifold and storage tank. Moreover, the heat loss of the water pump should be considered as well.
- The thermal efficiency of the solar water heater system is affected by other parameters such as water flow rate, center distance of evacuated tube and shapes of collector fin. These parameters should be modified also. Furthermore, the appropriate boundary conditions are significant.

7.2.2 The experiment

- To enhance the efficiency of heat transfer rate, the condenser section should be considered to enhance the area and decrease the affect to water volume in manifold. Moreover, thermal conductivity should be added, for example; silver coated at the condenser section.
- The adiabatic section of thermosyphon should be short while the insulate should be thicker.