Feasibility Study of Potential of Hybrid Renewable Energy Generation Sources for Rural Community; A Case of Nongplathao Park Community, Chaiphaphum Provincial Administration Organization, Thailand.

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Abstract

Renewable energy utilization is widely concerned all over the world. They are increasingly utilized in Thailand due to the Royal Thai government policy and subsidize that emphasize their utilization in potential areas. Chaiphaphum Province, located in northeastern part of Thailand, is a high potential area for renewable energy utilization. This paper presents the feasibility study of the potential of hybrid renewable energy sources, i.e. solar and wind energies, for the rural community under Chaiphaphum Provincial Organization. In this study, annual data of wind speed, wind direction, wind gust speed and solar irradiation taken from the meteorological department of Chaiphaphum provincial area, Thailand were used in the study. Optimum hybrid renewable energy generation sources, i.e. wind turbine and PV, were designed for Nongplathao Park Community, Muang District, Chaiphaphum province. Results showed the annual average wind speed of 7.02 m/s, and annual average solar energy of 4.6722 kWh/m². Furthermore, the design of On-Grid hybrid renewable generation system was seen to be practical. Initial investment cost was analyzed by Homer Version 3.6.3.0. From the results, the total capacity for generation of electricity from hybrid renewable energy sources of 52 kW was obtained. By considering the community location and its potential, small wind turbines with a capacity of 3 kW/tower, 4 units and PV system of 40 kW were chosen for design in this study.

Keywords: Solar Energy, Wind Energy, Hybrid Renewable Generation, On-Grid Generation.

1. Introduction

Basically, energy is very important and necessary to human life. The world is driven by the energy with power consumption in various categories. However, some energy are limited and not cost effective. The effort to bring renewable energy sources to generate the electricity increases all over the world. Renewable energy sources are natural energy sources including wind, solar, hydropower, biomass, biogas and geothermal energies, that can be recycled, which have been very popular as an alternative energy for electric power generation sources. Renewable energies are known as green energy to reduce pollution and global warming problems.

The hybrid renewable energy system is the electric generation system which combines two or more renewable energy resources with off-grid or on-grid in order to fulfill the demand of a selected area. An energy storage system can also be included or excluded in the hybrid renewable energy system. An example of on-grid PV-wind turbine hybrid renewable energy system is shown in Fig.1.

For renewable energy sources utilization, the feasibility studies of potential and optimal of the hybrid renewable

energy generation system were conducted all over the world.

Fig. 1. On-grid PV-wind turbine hybrid renewable energy system.

The economic feasibility analyses of biogas, biomass, PV wind-based stand-alone and grid-connected hybrid renewable energy source for dairy farm-based energy generation was conducted in South-Africa⁽¹⁾. Their systems were designed to not only cater for the energy needs of the farm but also for the local community. They found an optimum solution to apply in South Africa. The simulation and economic analysis of hybrid renewable energy system consisting of photovoltaic arrays, along with wind turbines and battery systems were conducted in India⁽²⁾. They found that the combination of solar and wind energy resources with the battery as a backup source brings to the optimal configuration of the hybrid renewable energy system with 5% of surplus energy and can be used as an off-grid system in Pithoragarh, Uttarakhand. The isolated hybrid renewable energy system including PV, wind turbine, and ocean renewable energy storage was studied in Iran based on a real case study by using weather data from Kish Island⁽³⁾. They found that regarding weather conditions of island and load changes, the best hybrid system consisted of 4 wind turbines, a solar system with a capacity of 2MW and 9 ORES storage sphere was most economical structure.

Thailand's government has a policy directly on the electricity market for generated power from renewable energy as an alternative energy development plan (AEDP) 2015. The goal of renewable energy source was set to supply 25% of the total demand within 2021⁽⁴⁾. Chaiyaphum is located in the northeastern area of Thailand, about 342 kilometers from Bangkok. Its area is approximately 12,778.3 squared kilometers or 7,986,429 hectares, representing 7.6 percent of the northeastern area and 2.5 percent of the entire country. Location of Chaiyaphum

province is shown in Fig. 2. Currently, 14 renewable energy power plants are located in Chaiyaphum province including 8 solar power plants, 2 biogas power plants, 3 biomass power plants and 1 wind turbine power plant. Their total power generation capacity is 126.7 MW⁽⁵⁾.

Fig. 2: Location of Chaiyaphum province.

In this study, the feasibility study to design the optimum on-grid renewable energy system combining PV and wind turbine systems having a power capacity not less than 52 kW to supply electricity to the offices of Chaiyaphum Province and Nongplathao park. The selected area needs the energy of 1,148.90 kWh/ d.

2. Methodology

The studied on-grid hybrid renewable energy system consists of the wind turbine and solar photovoltaic panels. Before designing the optimal system, selected location, load profile, and potential of renewable energy resources should be evaluated and they are summarized as below.

2.1 Location of Study Area

The selected area for hybrid renewable energy system is located in Nongplathao Park, Muang district, Chaiyaphum province, Northeastern of Thailand having latitude 15° 48' 08.81"N and longitude 102 ° 00' 37.50"E, as shown in Fig 3.

2.2 Load profile

In this study, the electrical load profile of selected area was considered according to the seasonal variations i.e.

during summer, rainy, and winter seasons. The average energy consumption per month is 187.18 kWh or equivalent to 162,660.30 Baht/month. Monthly electrical load of the study area is shown in Fig 4.

Fig. 3. Location of the study area.

Fig. 4. Monthly average load for a complete year.

2.3 Solar Energy Potential

The global solar radiation incident on the area of Thailand is shown in Fig. 5. As illustrated in Fig. 5, highest solar irradiation, 19-20 MJ/m²-day, was measured in the northeastern area of Thailand, i.e. Nakhon Ratchasima, Chaiyaphum, Khon Khean, Mahasarakham, Buriram, Surin, Srisaket, Roi Et, Yasothon and Ubon Ratchathani provinces, due to their dry plateau⁽⁶⁾. Annual average global radiation of Thailand during 1964-2008 is 6.82 MJ or 4.672 kWh/m²/d, as shown in Fig.6.

The proper location has the highest potential to utilize solar energy for electric power generation. The selected study area located at 15° 48' 08.81"N, 102 ° 00' 37.50"E has the high potential for generating electricity from solar energy, as shown in Fig. 5. In such area, the highest average energy in April of each year is 5.458 kWh/ day and the

lowest in September, with the average energy 4.161 kWh/day.

Fig. 5 Average annual solar irradiation map of Thailand.

Fig. 6. The annual average of global and diffuse solar.

2.4 The Wind Energy Potential

In order to utilize wind energy to generate electricity, annual monsoon characteristic of selected location is very important. Annual monsoon characteristic of Thailand is illustrated in Fig. 7. Direction and speed of the wind at selected location must continuously measured to obtain correct wind data for analyzing the potential of wind energy to generate electricity.

Fig. 7 Season monsoon in Thailand.

Wind data of study area was measured and collected by the department of meteorology in Chaiyaphum Measuring

Station. Wind data of 2015 is shown in Fig. 8. The monthly average wind speed in the minimum is 5.293 m/s and the maximum is 8.844 m/s. The annual average wind speed is 7.019 m/s, which is sufficient for utilizing the wind energy in the selected area. As illustrated in Fig. 8, annual average wind speed measured was seen to be suitable for designing on-grid hybrid renewable energy generation system. From wind speed data, due to the cold season under northeast monsoon and tropical cyclone during November-January resulting average wind speed at 6.264 m/s was measured. In March –April, hot weather in summer under southwest monsoon and tropical cyclone resulting average wind speed at 6.563 m/s was measured. From May-October under rainy season with the effect of tropical cyclone and southwest monsoon, average wind speed at 7.675 m/s. was measured and was recorded as the highest wind speed of the measuring year.

Fig. 8 Daily wind speed for each month of 2015.

2.5 Simulation Model of Hybrid Renewable Energy System

Recently, HOMER (Hybrid Optimization Model for Electric Renewables) is a micropower optimization computer model software developed by the U.S. National

Renewable Energy Laboratory (NREL) to use in the design and the planning of renewable energy generation based microgrids. HOMER is used worldwide as a tool to utilize renewable energy sources^(1-3,7-13). Three mainly tasks, i.e. simulation, optimization, and sensitivity analysis are performed in HOMER to analyze behavior or renewable

energy supply system and its lifecycle cost. This study, the renewable hybrid system model consists of PV and WG, as shown in Fig 9. Homer version 3.6.3.0 was used to simulate the study system. In regular operation, PV and wind turbine feed the load demand to associate energy from the power grid.

Fig. 9. Simulation Model of the PV-Wind system.

Fig. 10. Obtained average hourly demand for each month.

Fig. 11. Obtained monthly power ratio of renewable energies and power of grid.

3. Simulation Results

By using all collected data, i.e. load demand, solar energy, and wind energy potentials, average hourly hybrid renewable energy output for each month are shown in Fig. 10. The average load demand at 1,177.22 kW/day was obtained from the simulation results. Furthermore, the average renewable energy output of 173.342 kW/day which represents 14.93% of the total energy demand was obtained. The average ratio of each energy sources to supply the load demand for every month is illustrated in Fig. 11. The ratio of total hybrid renewable power generation and power load demand from is shown in Fig. 12.

Fig. 12. Obtained ratio of total hybrid renewable power generation and supplied power from the grid.

The simulation results showed that the total capacity for the generation of electricity from hybrid renewable energy sources was 52 kW. By considering the selected area location, for wind energy utilization, slow speed small wind turbines with capacity 3 kW/tower 4 units were chosen to design for installation in the study. For the potential of solar energy, the suitable capacity of PV system for design and installation in the study area is 40 kW.

The results showed that the initial cost for wind turbine installation is 1,199,940 Thai Baht and the initial cost for PV system installation is 2,650,200 Thai Baht. Furthermore, the maintenance cost of 5.312 Baht/kWh, generation capacity of the designed system 63,270 kWh/yr. and selling cost of generated energy of 3.85 Bath/kWh were obtained.

4. Conclusions

This paper presented the feasibility study of hybrid renewable energy system for a rural community in Thailand by using Homer version 3.6.3.0 to simulate and optimize on-grid PV and wind turbine renewable sources. The study considered the selected location data such as global solar radiation, wind speed, and daily load demand. The optimal system was obtained from the simulation results.

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