Optimal Design of Charging Station for Electric Vehicles Integrated with Renewable DG

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Abstract—**Electric vehicles (EVs) began to play an essential role in the public transportation system. It is a necessary part of developing and driving the economies of many countries in the future. EVs uses electric power to drive the mechanisms and other systems which must be stored electrical energy for use to drive the car move from one place to another one. However, the batteries of electric vehicles must be recharged, which requires the charging station to follow the distance traveled. Charging station and power sources for charging are an essential factor for the use of electric vehicles. This article is the study of the charging station for electric vehicles that use power sources from distribution systems and hybrid renewable energy system. In this study, photovoltaic (PV) and wind energy were the renewable energy sources to generate the electricity for charging the electric vehicles. The IEEE 33 bus system was modified and was used to simulate, and the Artificial Bee Colony (ABC) algorithm is an artificial intelligence technique to solve the problem. The simulation results show that the connection of hybrid renewable energy system to the distribution system for recharge electric vehicles provide electrical systems more reliable while being used during peak load times.**

Keywords—Electric Vehicle (EV); charging station; renewable DG; optimal design

I. INTRODUCTION

Electric vehicles (EVs) are increasingly used all over the world due to global warming problem and the cost of fossil fuel for an internal combustion engine. EVs were used for various purposes such as a private car and a public transport vehicle. Increasing in electrical power demand is cannot avoidable. In Thailand, electric vehicles have been growing developed resulting in the demand for electrical power. Due to Thailand import a significant amount of fossil fuel per year, it is necessary to find other alternative energy sources for generating electricity to reduce the cost of import fuel [1]. For alternative energy sources, Solar PV and low-speed wind turbines are widely used in Thailand. Many researchers interested hybrid renewable energy to generating electricity for reduce energy costs and develop the power distribution systems become more stable.

Also, currently, there are many researchers study on the charging station with electric power generation from hybrid renewable energy sources. They have purposed a techno-economic analysis of hybrid system comprising of solar and wind energy for powering a remote mobile transceiver station and investigation to find the effects of probable variation in solar radiation, wind speed, and diesel price in the optimal

system configurations [2]. Particle swarm optimization algorithm is used to determine the optimal position of the charging station in the distribution system [3]. The method for optimal allocation and sizing of renewable energy sources (RES) and electric vehicles (EV) charging stations presented by [4]. The Genetic Algorithm and Particle Swarm Optimization (GA-PSO) is used to solve the optimization problem. The voltage profile fluctuations for Plug-in-hybrid electric vehicle (PHEV) due to power variations of wind generation applied to the IEEE 34 bus test system presented by [5]. The optimization tool was applied to model the expansion of the electric power system. Wind farms were built in the region and evaluate the possibility of using a fleet of plug-in hybrid electric vehicles (PHEVs) to regularize energy imbalances [6]. The optimization algorithm was developed to coordinate the charging of EVs using a Genetic Algorithm (GA). It is a method used with low voltage systems in residential and prevention of the aging of power system elements [7].

This article presents simulation results for the optimal design of electric vehicle charging station integrated with renewable DG including solar PV and wind power generators to help generate electricity for the distribution system. The simulation performed on IEEE 34 bus using Artificial Bee Colony (ABC) algorithm to solve the optimization problem.

II. METHODOLOGY

A. Charging Station

Electric vehicles have been used in many countries around the world. However, the most critical infrastructure for using electric vehicles is the charging station. Therefore, the need to manage charging stations for electric vehicles is the high priority. Charging system for electric vehicles can be divided into AC charging and DC charging. AC charging can be easily charged at various locations or home. DC charging divided into three levels. At level 3, the Charging Stations is fast speed charging. Table I shows the details of a charging system for EV.

TABLE I. CHARGING SYSTEM FOR EV [8]

Charging type	Typical Voltage	Maximum current	Continuous power	Charging time
AC Level 1 with 1 phase	120 V	20 A	1.92 kW	~ 17 hrs.
AC Level 2 with 1 phase	240 V	80 A	19.2 kW	~ 8 hrs.
AC Level 3 with 3 phase	480 V and 600 V	400 A	Up to 100 kW	~ 30 min.
DC Level 1	450 V	80 A	< 36 kW	8-12 hrs.
DC Level 2	450 V	200 A	< 90 kW	4-6 hrs.
DC Level 3	600 V	400 A	< 240 kW	~ 30 min.

B. Solar PV and Wind Power in Thailand

Due to Thailand is a tropical country with enough sunlight to produce electricity. Solar PV is used extensively for generating electricity for homes and power systems. It can save cost on fossil fuels and can make electrical systems more reliable. Thailand can generate the electricity from PV up to 3000 MW per year [9]. The electrical specifications of the PV panels in this study included a power rated 150 W, a voltage of 17.8 V and a current of 7.87 A. For wind power in Thailand, low-speed wind turbines are used to generating the electricity. The average wind speed of 8 m/s at the height of 100 m is the requirement for a 10 MW wind turbine to produce electricity [10]. Fig. I show the typical hybrid PV and wind turbine configuration for charging station.
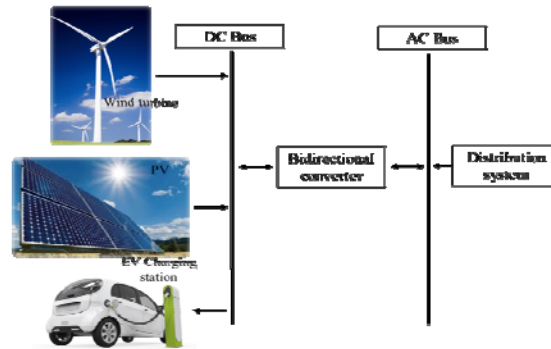

FIGURE I. TYPICAL HYBRID PV AND WIND TURBINE CONFIGURATION FOR CHARGING STATION

C. A Distribution System for Charging Station

The distribution system is an essential part of the electricity transmission to the charging station. In Thailand, the 22 kV distribution system is used to deliver power to the load. In this study, the IEEE 33-bus radial distribution system was modified for the simulation [13]. The modification system integrated with renewable DG operated at solar PV and wind power mode.

The modification radial distribution system for simulation is shown in Fig. II. There are 6 charging stations and 4 points renewable DG connected to the network. In this paper, each point has a designated renewable DG real power (P_{gen}) and reactive power (Q_{gen}) = 0.012 MVAR and 0.002 MW respectively. The load of EV charging station, P_{LOAD} = 1.2 MW and Q_{LOAD} = 0.554 MVAR.
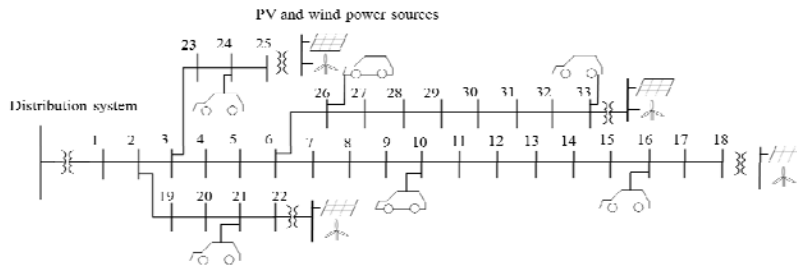

FIGURE II. THE IEEE 33-BUS RADIAL DISTRIBUTION SYSTEM INTEGRATED WITH RENEWABLE DG

D. Artificial Bee Colony (ABC) Algorithms

The ABC algorithm proposed by Karaboga, it uses to optimizing mathematical problems. Artificial bee colony or just known as the ABC optimization is one of the new optimization introduced by Karaboga in 2005.The ABC algorithms are a way of solving problems by using the honey bee's behavior. There is a division of work by the type of bee: employed bees, onlooker bees, and scout bees [11]. The onlooker and scout bee considered as an unemployed bee. The employed bees' searches and exploits a food location while the onlooker bees

wait in the hive. Therefore, the employed bee shared the information with the onlooker bees regarding a food location. In this paper, the ABC algorithms applied to the optimization problem.

III. PROBLEM FORMULATION

A. Objective Function

(1) The total real power loss (PLoss) in the power distribution system is formulated as follows.

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n}[\alpha_{ij}(P_iP_j + Q_iQ_j) + \beta_{ij}(P_iQ_j + Q_iP_j)] \tag{1}$$

Where P_i, P_j, Q_i, and Q_j are the injected active and reactive power in the bus i and j respectively.

(2) Power balance constraint is formulated as follows.

$$\sum_{i=1}^{k} P_{DG} + P_{System} = P_{Load} + P_{loss} \tag{2}$$

Total power generated in the network which is from renewable DG and substation must be equal to the summation of total load and the total power loss.

(3) Voltage constraint for all bus in the distribution system must operate within the acceptable limit which is between ±5% of the rated value, after the renewable DG output adjustment. Therefore, the acceptable voltage range in this analysis shows in Eq. 3 where m is the number of the bus in the system.

$$0.95 \text{ p.u.} \le V_m \le 1.05 \text{ p.u.} \tag{3}$$

(4) An optimization algorithm for Artificial Bee Colony (ABC). The constraints for ABC algorithm as follows: Colony size = 100; Onlookers and Employed bee = 50; Scout = 50; Limits = 100; Dimension = 1; Maximum cycle = 50.

Step 1: The food source area Xi (solutions population), The Xi form is as follows:

$$X_{i,j} = x_{min,j} + rand(0,1)(x_{max,j} - x_{min,j}) \tag{4}$$

Step 2: Calculate the nectar amount of the population using their fitness values using

$$Fitness = \frac{1}{1 + total\_losses} \tag{5}$$

Total Losses = Active Power Losses + Reactive Power Loss

Step 3: Produce neighbor solutions for the employed bees by using Eq. 6 and evaluate them as indicated by Step 2.

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}) \tag{6}$$

Step 4: Apply the acquisitive selection process between Xij and Vij. If all onlooker bees distributed, go to Step 5 Otherwise, go to the next step.

Step 5: Determine the probability values P(Xij) for the solutions Xij using Eq.7

$$P(X_{ij}) = \frac{F(X_i)}{\sum_{i=1}^{n} F(X_i)} \tag{7}$$

Step 6: Produce the new solutions Vi for the onlookers from the solutions xi, depending on Pi apply the greedy selection process between Xij and Vij.

Step 7: Determine the abandoned solution for the scout bees, if it exists, and replace it with an entirely new solution using equation and evaluate them as indicated in Step 2.

$$X^{new}_{i,j} = x_{min,j} + rand(0,1)(x_{max,j} - x_{min,j}) \tag{8}$$

Step 8: If cycle = MCN, stop and print result.
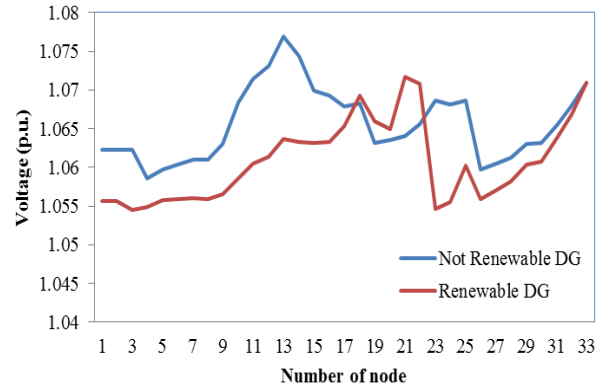
IV. SIMULATION RESULTS

FIGURE III. VOLTAGE PROFILE IN IEEE 33 NODES TEST SYSTEM
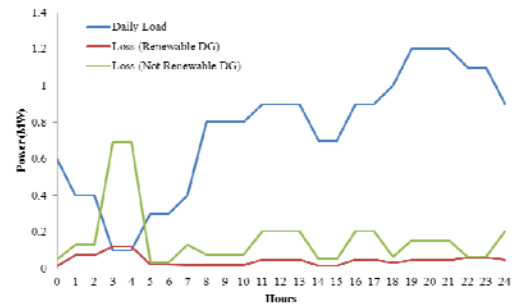

FIGURE IV. DAILY LOAD CURVE AND PLOSS WITH RENEWABLE DG

In Fig. 3, the voltage profile is comparisons of the voltage between the connection of renewable DG and not the connection of renewable DG. The maximum voltage =1.0769 p.u. and the minimum voltage = 1.0545 p.u. The results show

that when connected to the renewable DG, the voltage can be approximated to the acceptable voltage range. Figure 4 shows the daily load curve of charging station for simulation test system. The peak load is at the time 07:00-09:00 pm. decreasing the power loss of test system can be obtained when connected to the renewable DG.

V. Conclusion

The optimal design of charging station electric vehicles integrated with renewable DG include wind power, and solar PV was studied. The results show a potential of hybrid renewable energy sources. Using renewable energy integrated with electricity distribution systems can provide the system more reliable and suitable for rural areas. The proposed idea can be applied to optimize the charging stations for electric vehicles in rural areas, and it would be a good topic for future studies.

Acknowledgments

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