STABILIZATION OF ISLANDING PEA MICRO GRID BY PEVS CHARGING CONTROL

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ABSTRACT

This paper presents a charging control strategy of plug-in electric vehicles (PEVs) in a smart grid including network communication and information systems. The proposed strategy aims at reducing impact of Micro Grid (MG) stability problem during islanding mode, no power support from the main grid. The islanding situation may lead to a problem of insufficient power supply and eventually cause power outages. PEV is a type of load that is expected to increase in the future. Anticipated advantages are controllability of battery charging, and the communication system linked to smart grid control system. MG model in this simulation study imitates the 22 kV 50 Hz electric power distribution system of Provincial Electricity Authority (PEA). The simulation results based on DIgSILENT PowerFactory program illustrate the MG with PEVs charging control could fast reduce the power demand in MG effectively; as a result, this control strategy mitigates the frequency deviation in the MG and maintains the stability of the system.

INTRODUCTION

Within 2022, Thailand sets policy to gain the proportion of renewable energy up to 20 % of the total energy consumption. Accordingly the Provincial Electricity Authority of Thailand (PEA) has been developing electricity distribution systems into Smart Grid environment. For instance, MG which has renewable energy sources, including smart electric devices such as PEVs connected to Grid, since those devices are more likely to be popular in the future. MG is one of the most important components in Smart Grid. The control system will be installed in the future and connected to the intelligent device in MG, which can be monitored from the control center. This ability decreases the risk of a wide-area power outage. Therefore, MG is appropriate for the important city that requires the electricity stability, or has a problem of connection to main system, including the city that needs to ensure continuity of the power supply into the system. However, energy partially comes from local renewable energy sources, which may not be stable. It may spark a problem of insufficient power supply, especially, when more uncontrolled charging of PEVs is penetrating in the system. PEV is superior to other electric devices because PEVs have intelligent communication and energy storage system, i.e. battery. Reducing power or pause charging of PEVs, a new method of load shedding will not affect customers and also prevent system from a blackout. Therefore, PEVs charging control is reasonable to maintain stability of MG during islanding mode.

PEVS AND POWER SYSTEM STABILITY

Frequency Deviation Control

Power system stability requires a balance of power in the system, in other words electric power produced at any one time should be equal to the electric power consumed at that time. Also constant of frequency and voltage are important factors in determining the quality of power supply [1]. In general, the frequency control of power system is to keep synchronous frequency of the power system within the acceptable range, when there is an imbalance between the electric power generated from the generator and demand of the load. Imbalance of electric power causes system frequency to deviate from the synchronous frequency i.e., frequency deviations [2]. When the frequency deviation exceeds acceptable tolerances, it will cause problems to the system. The overall frequency-dependent characteristic of a composite load may be expressed as

$$\Delta P_e = \Delta P_L + D\Delta\omega_r \qquad (1)$$

Where ΔP_e is electrical power deviations, ΔP_L is power demand of load changes, $\Delta\omega_r$ is rotor speed deviation, Δf is frequency deviations and D is load damping constant.

The nominal frequency of PEA system is 50Hz. The Electricity Supply Regulations require the system frequency to be maintained at 50Hz $\pm$ 1%. That means the minimum acceptable of system frequency is 49.5Hz.

PEVs charging control strategy

The implementation of smart grid to support the power distribution system of PEA is reveals the infrastructure suitable for the use of PEVs. Therefore, it has been predicted that there will be a dramatic increase in the future. The increasing number of PEVs is the increasing load in the electric power system. The more connected PEVs to the system simultaneously without proper management controls would cause problems to the system. The results of the investigation presented in [3] showed that large deployment of EVs could results in violation of supply/demand matching and statutory voltage limits. Under certain operating conditions, they may also lead to power quality problems and voltage imbalance.

Each vehicle must have three required elements: a connection to the grid for electrical energy flow, control or logical connection necessary for communication with the grid operators and controls and metering on-board the vehicle [4]. These elements make PEVs as the controllable load in power system. With a large number of electric vehicles connected to the grid, they can not only be load to regulate power system load characteristics, but also be participated in low frequency response services mainly in two ways. Easiest approach would be to switch off all PEVs that are charging. This will introduce a proportional reduction in load, thus reducing the frequency excursion. In an event of a high frequency all the PEVs that are in stand-by mode with the state of charge of battery is less than 100% could be charged thus adding an additional load to the grid [5].

The previous PEVs charging control strategies use on-off control characteristics, to stabilize the power system. However, there are various approaches or strategies such as PEVs can provide the electric power from the battery to compensate the power system shortage (Vehicle to Grid, V2G) [4], [6]. Currently, there are limitations in the design the battery utilization. Therefore, the power system compensation by power from the battery is not guaranteed by PEV manufacturer including the regulations that need to be approved by the administrator and PEV owners. There is also need for the further research.

The proposed control strategy of PEVs charging in this paper is using the frequency deviation to determine the quantity of PEVs charging power in the system. This is an uncomplicated process along with no complex calculations.

The frequency levels to determine the PEVs charging power is divided into 3 levels, first level is the frequency that lower than 49.5Hz. The charging power will be reduced by 20% in order to decrease the total energy consumption and enhance the functionality of the control devices to balance the power in micro grid. The frequency level that below 49.3Hz, the PEVs charging power will be reduced by 50% and the last group is the frequency level of the system less than 49Hz, all of the connected PEVs are temporarily paused charging until the system be recovered to normal state. If total power from PEVs paused charging is not enough, load shedding scheme will be employed as the next step. The proposed algorithm is shown in Fig. 1.

SIMULATION MODEL OF MICRO GRID

Micro Grid is a controllable component of the smart grid defined as a part of distribution network capable of supplying its own local load even in the case of disconnection from the upstream network [7]. The MG is centrally controlled and managed by a Micro Grid Central Controller (MGCC) installed at the MV/LV substation. The MGCC includes several key functions (such as economic managing and control functionalities) and heads the hierarchical control system [8].

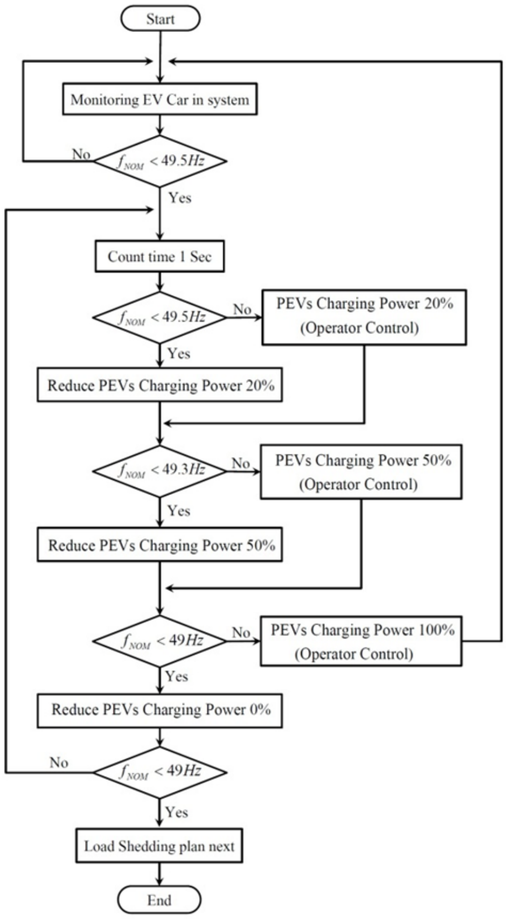

Fig. 1. PEVs Charging Control Algorithm

PEA Micro Grid Model

The MG infrastructure in this paper is supposed to completely support for modern technology in the future. The Utility was able to connect and exchanged the system information, power generator and modern electrical equipment such as electric cars via communication system. The main components of the micro grid system include Micro Grid Central Controller (MGCC), power plant or a traditional power plant, renewable energy source (RES), energy storage system (ESS) and common electrical equipment in the system. This includes PEVs which may be additional smart equipments in the future.

The specification of the MG simulation employs data from the PEA Power System Development Project of Micro Grid System at Mae Saraing, Mae Hong Son (a project in an area of the Northern Thailand) to study the behaviour of the system in case of with and without the implementation of PEVs charging control which are shown in Fig. 2.

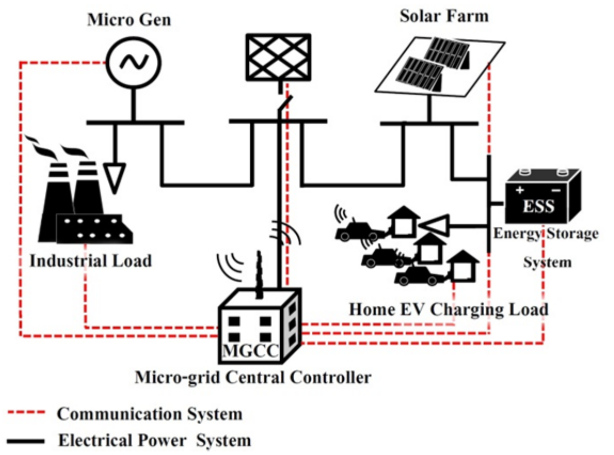

Fig. 2. Sample of PEA Micro Grid Model

Here, the simulation model is assumed that MG is connected to the distribution system of PEA (22kV 50 Hz) The electricity generator in the model assumed to be consisting of 4MW Micro Source, responsible for control the balance of the generation and load in the system. The 2MW renewable energy sources (such as solar farm, wind farm and micro dam). The 1MW energy storage system has 2 functions. First, the energy storage will serve as MG power compensation when the system is separated from the main grid. And another duty is maintaining the system frequency within an acceptable range.

The amounts of loads in the MG simulation have to take into account the expected increasing load in the future. The framework plan of PEA electrical system development Vol. 11 is predicted that within 2021, the northern region of Thailand will have the highest electricity demand about 3,669 MW which is increasing from 2012 about 1,106 MW (43% increasing) approximately. In 2012 the maximum power demand of Mae Sariang district is 5 MW. Thus, the maximum power demand of Mae Sariang district in 2021 is about 7 MW. The simple model to study behavior of micro grid is developed in the DIgSILENT Power Factory as shown in Appendix 1.

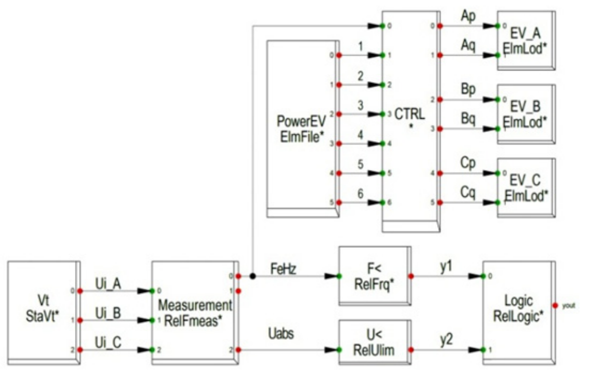

Fig. 3. PEVs charging controller

The MGCC has to examine the frequency of the system, which will be sent to the charging controller that is connected to all of the PEVs in the system. The controller is able to know the charging power of the entire connected PEVs and determine the frequency deviation to operate the functionality of the charging equipment to increase or decrease the PEVs charging power. The controller unit is shown in Fig. 3.

Simulation Study

When MG operates in islanding mode, the power deviations will be supported by battery energy storage for maintaining the nominal frequency. The distributed generation controller will keep the stability of voltage. In this phenomenon, all of power in MG is used to compensate the power which loss from main grid. In this operation each generation produces the maximum power capacity. If disturbance occurred, MG is unstable. This paper demonstrates a comparative analysis of MG simulations with and without PEVs charging control. Setting ups the scenario in MG, when the system encounters an extremely high-increasing load scenario.

The model of high-increasing load used data from daily load profile of feeder 6 Banglamung substation of PEA. The daily load profile shows an extremely high-increasing load in the power distribution system. If this situation occurs in MG during islanding mode, may lead to the MG instability problem. The daily load profile is shown in Fig. 4.

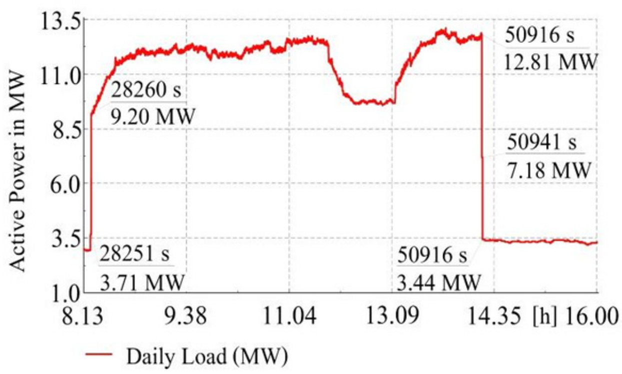

Fig. 4. The power deviation of daily load profile

RESULTS

When the problem occurs at the main grid, the protection of MG will open the circuit connecting to the main system for MG to maintain the power to the load connected to the system. The frequency of MG system during islanding mode is shown in Fig. 5. The frequency deviation is detected by under frequency relay, ESS receives the signal from relay and provide MG power compensation. The power generations in MG are shown in Fig. 6.

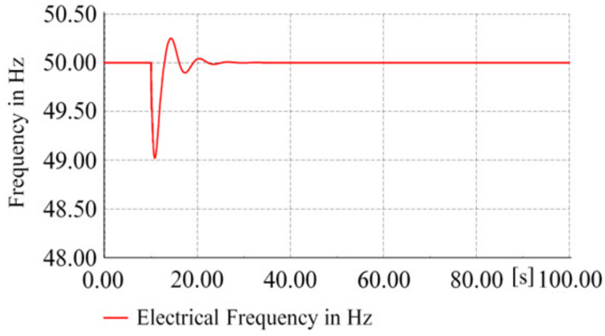

Fig. 5. The frequency of Micro Grid

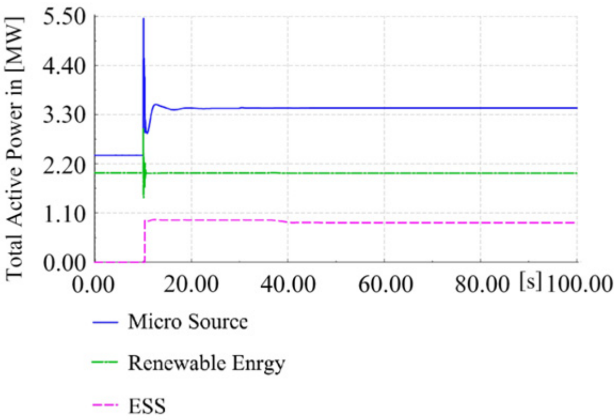

Fig. 6. The electric power generated in Micro Grid

If a rapid increasing load occurs in the MG. In case of the period is a high energy demand and insufficient reserved energy, the system will be affected with low stability. Additional load in the system is causes loss of stability and lead to system collapse. This simulation is set base load increasing from 5MW to 7MW; the consequence is the reduction of the system frequency lower than acceptable range, which may adversely affect to the connected generator in the MG. The frequency deviation and the electric power generated in MG while increasing load is shown in Fig. 7 and Fig. 8, respectively.

The experiment of control charging strategy is simulated by adjusting the proportion of PEVs charging power to the total electric demand of the system. First step is increasing the eliminated charging power consumption to be 5% of the total power in the system. Then, the simulation will increase the proportion of pause charging power to 15% and 20% compared with the total power system respectively.

The results have the same trend, more PEVs charging power, the more advantage to the system with control charging strategy. The system frequency will be in nominal state faster than usual as shown in Fig. 9.

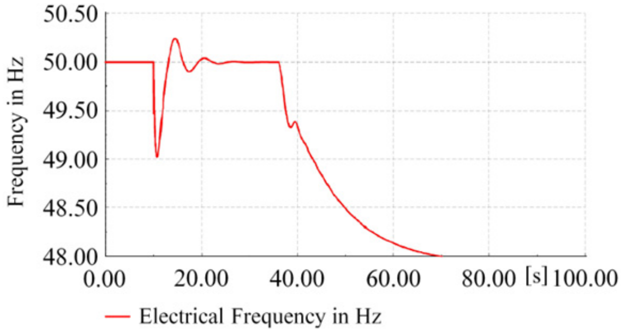

Fig. 7. The frequency of Micro Grid

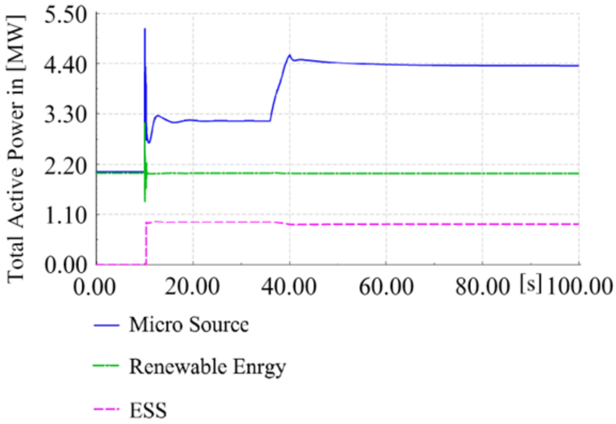

Fig. 8. the electric power generated in Micro Grid

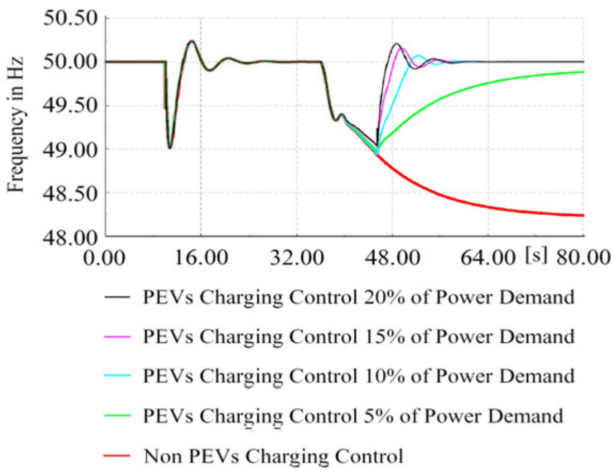

Fig. 9. The frequency of Micro Grid with different PEVs charging control strategies

In addition, the PEVs charging control strategy is also reduced power which is generated from the MG system supply, this yields the MG system to have more generating reserve capacity and avoid a risk of power shortage. The electric power generated in MG with PEVs charging control strategy is shown in Fig. 10.

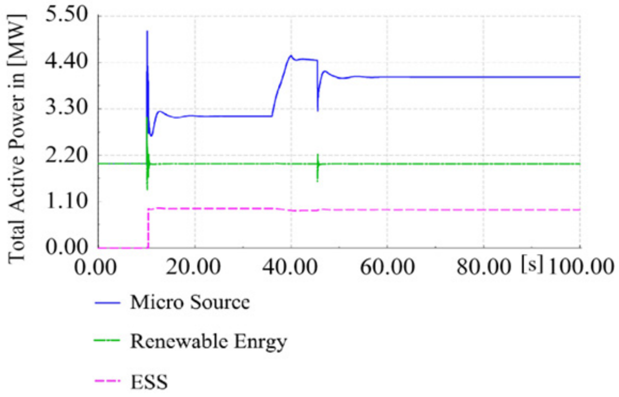

Fig. 10. The electric power generated in Micro Grid with PEVs charging control strategy

CONCLUSION

This paper presents a dynamic simulation on DIgSILENT PowerFactory to control PEVs charging for minimizing power demand instantaneously in MG as a new method of load shedding. Customers will have less effect on this method because the customers can continuously use other electric appliances while the PEVs charging are reduced charging power or temporarily paused.

This method can also enhance the system stability especially in MG during islanding mode. Moreover, the increasing of PEVs in the future will make this strategy more efficient.

It also increases the flexibility in power management and is able to reduce the capacity of the energy storage system in part which supports the increasing of PEVs load as well. However, the optimal charging plan and the effect of communication delay will be presented in the future work.

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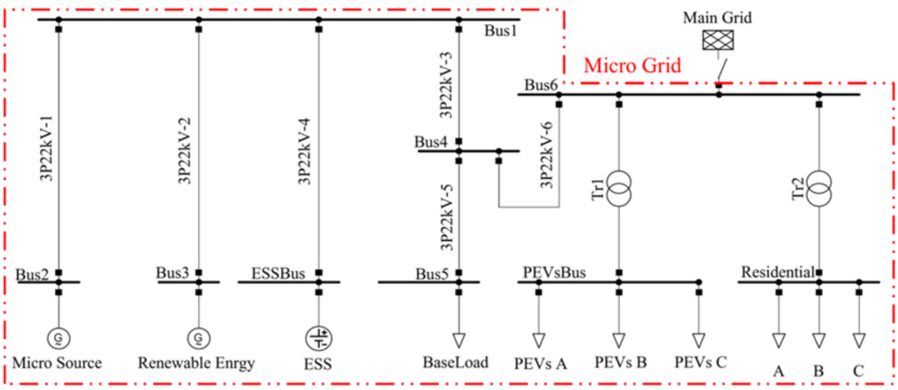

Appendix 1. PEA Micro Grid Model in DIgSILENT Power Factory program