Adaptable Energy Management of Home Energy Storage to Support EV Quick Charging

Praphun Pikultong[1], Nuttawut Intaboot[2], Thanet Vilasmongkolchai[3], Poothep Donthuam[4], and Sirichai Dangeam[5]
[1]Faculty of Engineering,
Suranaree University of Technology, Thailand
[2, 4]Faculty of Engineering,
Rajamangala University of Technology Suvarnabhumi, Thailand
[3]Faculty of Technology,
Siam Technology College, Thailand
[5]Faculty of Engineering,
Rajamangala University of Technology Thanyaburi, Thailand
[3]zl.thanet@gmail.com

Abstract **- EV quick charging technology was aim to support hasty life. Unfortunately, the EV charging at home cannot be installed regularly because the high power-demand can break the home's transmission system. Energy storage system has been used to improve electricity efficient of the house that doesn't designed for support EV quick charging. This research presents the control system of electricity supply for EV quick charging in household. The logical based control system has been designed to control the operation of energy storage system. Moreover, the developed mobile application will take the advantages on the energy usage planning and make EV user make a quick charge at home without redesigned the home's transmission system. On the cost benefit, the energy storage system can reduce the energy cost up to 71% compared to the plain building. Moreover, the EV energy planning application has been developed for customize energy management plan and make 16% and 71% energy cost reduction per EV charging in case of 5 hr. and 10 hr. pre-scheduled respectively.**

Keywords **- Energy Storage, Electric Vehicle, Planning, Quick Charge**

I. INTRODUCTION

Electrical Vehicle (EV) technology has challenges the limitation of traveling distance due to battery's capacity in the car. Therefore, electrical charging is really important to make it efficient for real use in the present days by focusing on the time of charging which should be as quick as filling fuel or in a few minutes. Energy storage system becomes a significant role in energy management at the moment, especially for quick charge for EV which will increase the electricity demands of the country [1-2]. Researchers have estimated the demand of charging 200 EVs in a day with the 2.2 MWh energy storage that can support the high electrical power while charging [1]. D. Sbordone and his team have reviewed and observed EV charging station for EV in different procedures following EU standards in order to design EV charging station by using the concept of energy storage with quick charge. Also, the prototype was tested and installed with smart grid by using Smart Metering System which can access the data of energy usage for

appropriate service [2]. For energy measuring equipment or Smart Meter, Tiong Meng Chung and Hamdan Daniyal had developed a meter for measuring one phase of electricity which can measure the electricity power by using electric appliances connected with circuit. The mentioned measuring equipment could measure highest electrical power of 13A with accuracy of 96.54% [3]. According to the mentioned research, the results showed that data, control system, and communication have importance to energy management to reduce the electricity demands. However, installing measuring equipment storage might not be accurate due to use of energy has been changed depending on users, especially when using lots of electrical power like charging to EV.

When considering the use of energy storage system and supplying electrical power from solar power by focusing on reducing cost for energy. J. Neubauer and M. Simpson had experimented small energy storage system that help supplying electricity when high electricity demand in short period which really benefits the cost without concerning energy from solar power and reduce the electricity demand to 2.5% [4]. Solar power system could be easy for houses which is suitable as energy sources to reduce demand of grid power. However, renewable energy sources like solar power which directly affect from the changing of weather as well as affecting energy combination. F.A.T. Al-Saedi has brought information from Yahoo Weather Forecast to analyze data and trends by using statistics through weather information. The analyzed information was used to evaluate by main control system of energy storage system. So, this research has shown the sample uses of smart home by having electrical system in houses, such as on-off lighting system to reducing energy usage [5].

For electrical backup system or battery has developed along with control system with the type of battery that has high efficient supply of power battery and suitable for quick charge which is known as lithium ion (li-ion) [6] which is the battery with high capacity and popular in using for energy storage. Also, European Commission Joint Research Centre in cooperation with frontier Economics has tested li-ion batteries for using in energy industries and found the efficiency is raised to 85% [7] which was related to the experiment from S.M. Schoenung and W.V. Hassenzahl [7]. For the self discharge test from L. Beurskens, the results showed that li-ion batteries have low self discharge ratio (0.03-0.1% per day) [8]. However, in the meantime, this type of batteries still having disadvantages, for example, easily depreciates and temperature could affect performance as well as high price. This could also lead to fire explosion when high temperature or electrolyte leaks. While designing, it is important to prevent and support all mentioned situations. For system development on field, Ishii Yuko and team had proposed the research that responds the demands of electricity to several electric vehicles make quick charging at the same time by using li-ion batteries as energy storage and control system to evaluate energy for Yokohama Smart City Project. This can conclude that the project could make energy balanced generally in the city [9].

Moreover, in the study of energy management for charging electric vehicles in sub-unit, it showed that in Thailand, there is still no research related to the policy to encourage using electric vehicles in the near future. Comparing to less number of charging stations, it is unavoidable to use home electricity for charging instead. However, limitation is that home's electric system is not designed for this charging purpose.

However, quick charge in the present days is not widespread for household because of high cost in equipments and installation to support household level. However, the rush of routine activities causes technology to be real-time. Quick charge is able to charge to electric vehicles for 80% of battery's capacity within 30 minutes. The electric vehicles' owners are able to relax more in the evening after work more flexible and encourage people to use electric vehicle to be widespread. In terms of economic study, J. Eyer and G. Corey had

calculated cost while charging and discharging concluded that energy cost is 4¢/kWh when charge batteries with the efficiency of 75% and discharge at 9.33¢/kWh. So, it's the significant information for considering and selecting the best timing for compresses and demand charge [10]. This application development helps energy management which is important to manage energy related to the demands of users and reduces the effects to household electrical system.

II. MATERIALS AND METHODS

This research is to develop household by using electrical energy storage and control system to increase stability and flexibility for electrical energy management as shown in Fig. 1, including energy management system (EMS) acting as the center of the system in order to observe building load and solar PV as well as energy management from solar PV and electricity demand which might need rapid change as well as using energy from power grid when high power is needed. Moreover, every data will be uploaded on clouds in order to monitor energy management through mobile application as well as setting plan for electric vehicle for appropriate management.

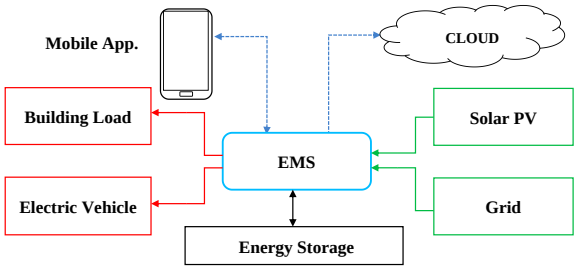

Fig. 1 System Overview

For the general process, control system was designed to work according to constraints by giving importance to efficiency and validity by energy storage system will work as electricity provider for electric vehicles and households. When there is an instruction from users to define plan for electric vehicle, the control system will manage each instruction differently by evaluating timing before quick charge to electric vehicle and store energy for support appropriately. The parameters configured for the system simulating was set the solar panels with the power of 10kW, energy storage system or battery in household with the capacity of 50kWh, electric vehicle battery capacity of 36kWh, and electric power of quick charge at 60kW. So, the comparison in terms of time length for pre-scheduling charge should be used to prepare energy storage system to supply electrical power to electric vehicles.

TABLE I
CONTROLLING CONDITION OF HOME ENERGY STORAGE SYSTEM

Conditions	Energy Storage	Priority	Remark
Solar radiance <100 W/m^2	n/a	5	use grid power
High battery temperature (>55^{o}C)	Not operate	0	force ventilation
Low battery (<10%SOC)	Not discharge	0	
On peak	Discharge	3	
EV plug-in (standard charge)	n/a	4	
EV plug-in (quick charge)	Discharge	2	
EV pre-scheduled	Force charge	1	use grid power

As the form of household electricity, the electricity will be used mainly at night (19:00pm - 24:00pm). It showed that the period that meet high electricity demand (on peak) is from 9:00am - 22:00pm. Therefore, reducing the electricity usage in the specific period of time will help reducing the electricity cost. Energy storage system is used to reduce electricity on peak in the specific time which will help reducing electricity cost and reducing load on transmission system as well as problems in increasing electrical power generating. So, control system will refer mainly to the period of time by the conditions of energy storage system for different situations according to Table I.

So, when the system receives the instruction to plan for electric vehicle, the control system will get the electrical energy from the power grid to support energy storage system (in case of not enough energy in the storage) under the condition of the formula below:

$$T_{store} = |T_{plan} - T_{plug}| \quad (1)$$

$$\frac{C_{home} - C_{EV}}{T_{store}} \begin{cases} \leq -2 : P_{charge} = 15kW \\ > -2 : P_{charge} = 8kW \end{cases} \quad (2)$$

When T_{store} is the No. of hour in the day for energy storing time before EV plugin required (hr), T_{plan} is the No. of hour in the day that of received EV pre-schedule (hr), T_{plug} is the No. of hour in the day that EV needed plug-in (hr), C_{home} is current capacity of home storage (kWh), C_{EV} is EV battery capacity (kWh), P_{charge} is grid required charging power (kW).

The condition in formula 2 will divide by storage preparing time which will make 8kW charging power from power grid to home's energy storage, when there is an electrical energy in home's energy storage in high level or has longer period for preparation. Also, 15kW power charging to energy storage in low level or shorter period of time preparing which will use high energy for storing in limited time.

III. RESULTS AND DISCUSSION

According to Fig. 2, it shows the system working for the whole day as well as the demands of electricity, electrical power generated by solar panels, power in and out of batteries, power from grid, battery capacity respectively. Fig. 2a shows the plan received (dotted line) before charging electric vehicle (dashed line) for 3 hours. Also, Fig. 2b shows the plan ahead for 2 hours. In Fig. 2b, the energy from the grid has been used in really high amount as the energy level in battery is not enough to provide for electrical demand for electric vehicle. From the simulated experiment with mentioned conditions, it shows that the plan of quick charge for electric vehicles should be not shorter than 2 hours, if not the electrical demand will affect the household electricity. However, the specific period of time also depends on the battery's capacity.

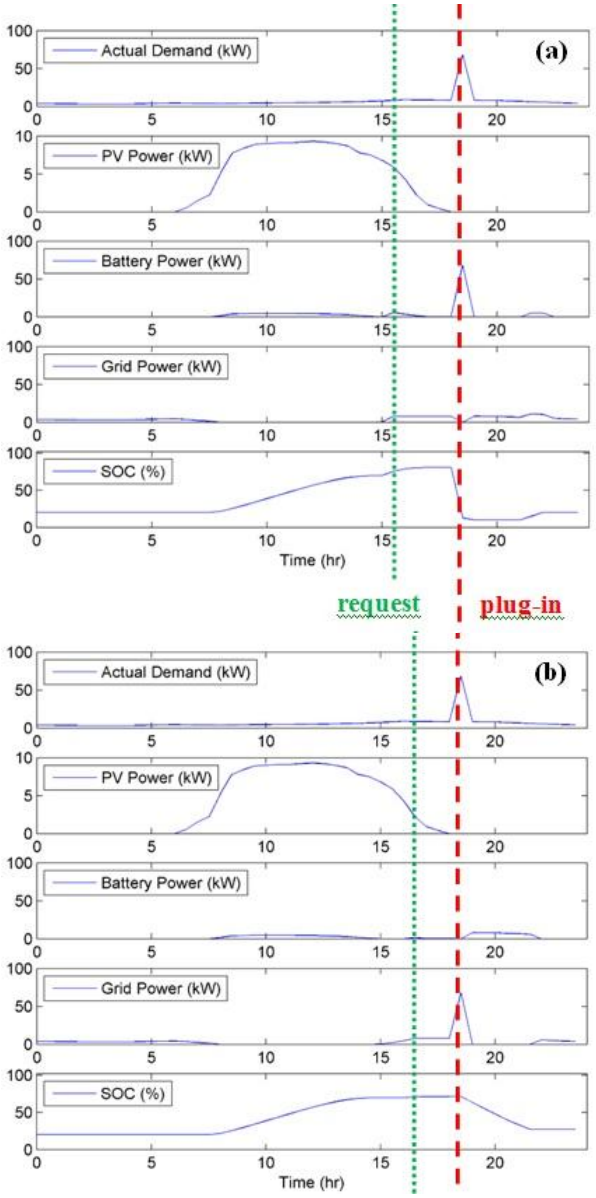

Fig. 2 System's Power Profile when Request for Quick Charge 3 hr. in Advance (a) and 2 hr. (b)

However, setting plan ahead for electric vehicles could help energy management and reduce destruction in electrical system. If there is sooner time of planning, it will be more efficient in energy management as well as reducing energy cost and reduce electricity peak demand in the view of national demand. Considering the potential of energy cost reduction comparing to the system while not installing energy storage system and while installing energy storage system, it showed that installation of energy storage system helps reducing of electrical system failure in household when high electrical power is needed for quick charge as well as reducing

electricity cost for electric vehicle up to 71% by shifting energy use to off-peak hours of the day. Also, when software is needed for planning electric vehicles, it reduces cost of electrical power for quick charge at least 16% and up to 71% when there is a plan ahead for at least 5 hours and 10 hours respectively.

IV. CONCLUSIONS

This research is to develop household with old electrical system to support EV quick charging at home. The using electrical energy storage and control system to increase stability and flexibility for electrical energy management, but it was not sufficient for individual lifestyle causes of nowadays working hours are more flexible. EV planning schedule application has presented as a tool for energy management and also prevented the home's electrical system break down due to high power demand. From the simulation, the longer setting plan ahead for EV presented more efficient in energy management as well as reducing energy cost and reduce electricity peak demand in the view of national demand. On the view of economy, up to 71% of energy cost can be reduced by shifting energy use to off-peak hours of the day. Also, when software is needed for planning electric vehicles, it reduces cost of electrical power for quick charge at least 16% and up to 71% when there is a plan ahead for at least 5 hours and 10 hours respectively. So, when solar panels generated electrical power along with the household system, it's not just increased the flexibility of energy usage, but also reduced energy cost depending on the demands of household's electricity.

V. ACKNOWLEDGMENT

This research was supported by the NSTDA Energy Storage Systems grant to the Development of Energy Balancing Management for Sub-Units Electric Cars Charging (FDA-CO-2560-4227-TH).

REFERENCES

(Arranged in the order of citation in the same fashion as the case of Footnotes.)

[1] Morris, C. (2016). "Stationary storage system enables a quick charge without straining the grid". <https://chargedevs.com/newswire/stationary-storage-system-enables-a-quick-charge-without-straining-the-grid/>.

[2] Sbordonea, D. and et al. (2015). "EV fast charging stations and energy storage technologies: A real implementation in the smart micro grid paradigm". Electric Power Systems Research, Vol. 120, pp. 96-108.

[3] Chung, T.M. and Daniyal, H. (2015). "Arduino Based Power Meter Using Instantaneous Power Calculation Method". ARPN Journal of Engineering and Applied Sciences, Vol. 10(21).

[4] Al-Saedi, F.A.T. (2013). "Peak Shaving Energy Management System for Smart House". International Journal of Computer Science Engineering and Technology (IJCSET), Vol. 3(10), pp. 359-366.

[5] Battery University. (2016). "Fast and Ultra-fast Chargers". <http://batteryuniversity.com/learn/article/ultra_fast_chargers>.

[6] European Commission Joint Research Centre in cooperation with frontier Economics. (2009). "Electricity storage in the power sector".

[7] Schoenung, S.M. and Hassenzahl, W.V. (2003). "SANDIA national laboratory: Long- vs. Short-Term Energy storage Technologies Analysis - A Life-Cycle Study". A study for the DoE Energy storage Systems Programme, Report reference: SAND2003-2783.

[8] Beurskens, L. (2003). "Analysis in the Framework of the Investire network - Economic performance of storage technologies". ECN-C--03-132.

[9] Yuko, I. and et al. (2012). "Development of Battery and Charger Integration System (BCIS)". Special Issue on Smart Energy Solution, NEC Technical Journal, Vol. 7(1).

[10] Eyer, J. and Corey, G. (2010). "SANDIA national laboratory: Energy Storage for the Electricity Grid - Benefits and Market Potential Assessment Guide A Study for the DOE Energy Storage Systems Program". Report reference: SAND2010-0815.