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The study and analysis of the impact on the power distribution system of the battery charger stations at Sakon Nakhon Rajabhat University

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Abstract

This article is presenting the study and analysis of the impact on the power distribution system of the battery charger stations at Sakon Nakhon Rajabhat University according to the problem of the difference between the plugs of electric car battery chargers at the battery charger station and the electrical receptacle of various types of electric vehicles which respond to the needs electric vehicles users that are currently in use. The proposed paper is introducing the electric vehicle battery charger principle, the design standard selection of the fast charge with various standard battery charger. Results are shown in simulation with the Power Simulation (PSIM) and the implementation of battery charger with various standard fast charge type which installed at Sakon Nakhon Rajabhat University. The results show that CHAdeMO and Type 2 can accommodate most of the electric vehicles currently in use. In addition, the operation of a fast-charge electric car battery charger can also help to prevent the deterioration of the battery. Due to the fast charging operation with voltage, current or unappropriated temperature, the charging process will not affect the power stability of the utility system and the system efficiency can be evaluated from the simulation and implementation results.

Keywords: EV quick charge station; CHAdeMO standard; Type 2 standard

1. Introduction

Recently, many countries around the world have a policy to promote and drive the use of electric vehicles (EV) instead of cars that use internal combustion engines. Since the electric cars do not emit carbon dioxide which causes greenhouse effect and does not release polluted smoke, thus, making it more environmentally friendly [1]. In addition, electric cars also have higher energy conversion efficiency than cars that use conventional internal combustion engines. Electric cars have a conversion efficiency of approximately around 80%, which is lost in the battery electric power conversion system and electric motors compared to the energy conversion efficiency of cars using internal combustion engines, only 35% to 40%, which has a conversion efficiency less than half of the electric car. Most of the lost energy is in the form of heat and friction of the piston [2, 3].

By considering the peak demand of Thailand until the current year (2018), the maximum power consumption is 29,618.80 megawatts, which occurred on 11 May 2016 at 22.28 hrs [4]. If within the next 10 years, Thailand has used 1 million electric cars, which the average power of each electric vehicle battery is about 40 kilowatts, that means Thailand will have a mobile battery power accumulation system in the form Electric cars up to 40,000 megawatts. Which is higher than the maximum power consumption of the country. It can supply power up to 80,000 megawatts because the batteries used in electric cars are lithium batteries, which can increase the stability of the electrical system and support the electrical system failure [5, 6]. This can also delay the construction of a power plant with high construction costs. [7].

Although electric cars have many advantages, but the use of electric cars is still limited in terms of distances. Charging the battery takes a long period of time and more importantly, the number of electric vehicle battery charging stations is relatively low. Therefore, the increasing the amount of electric vehicle battery charging stations is one way to promote the use of electric cars. But adding an electric vehicle battery charging station is necessary to choose a standard that is suitable and able to support most current electric vehicle. Therefore, this paper is studying and analysing the impact on the power distribution system of a multi standard battery charging station of Sakon Nakhon Rajabhat University. The article presents the principle of electric vehicle battery charging, design and implementation of the electric vehicle fast charger. Power Simulation (PSIM) program is used for simulation. The actual test results of several standard electric vehicle battery charging stations installed at Sakon Nakhon Rajabhat University will be presented and discussed in the next session.

2. Materials and Methods

The basic principles of charging batteries that need to be known is the standard of electric vehicle battery charging system. Since the rated current, rated voltage and rated power of the battery need to be considered. Furthermore, different standard type of plug and outlet cannot be used together. In order to understand the principle of charging the battery and can be able to choose the standard of charging the battery to suit the electric vehicle battery charging station that is currently in use. Therefore, this section will explain the principles of battery charging topology and the standard of electric vehicle battery charging system, which can be shown as follows.

Principle of battery charge

Battery charge is to deliver the dc power to the battery. The voltage of the power source must be higher than the voltage at the battery terminal. The magnitude of the current flowing into the battery can be described as equation 1 and equation 2 by V is the voltage of the power supply, I stands for the current that flows into the battery, R is The internal resistance of the battery and E is the voltage at the battery terminal. Which the equivalent circuit basic to charge the battery can be shown as shown in Fig. 1.

$$V = E + IR \tag{1}$$

$$I = \frac{V - E}{R} \tag{2}$$

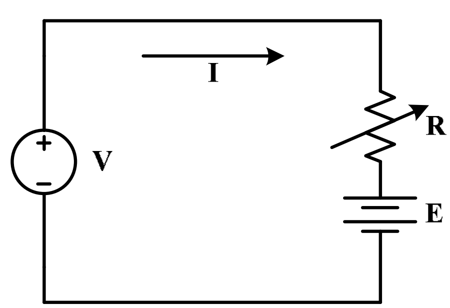


Fig. 1 The equivalent circuit is the basis for charging the battery.

Normally, the principle of charging the battery can be divided into 3 different ways: charging the battery with a constant current (CC), charging the battery with constant voltage: CV and charging with a constant current and constant voltage (CC-CV) [8].

Constant current battery charging is a constant charge with single constant value within a time period. The value of the current must not exceed the rated current of the battery. Which can be calculated from Capacity Rate (C-Rate). This method requires a maximum voltage limit, since when charging the battery for a certain period, the voltage at the battery terminal will gradually increase until the voltage exceeds the voltage of the battery. This will result the battery deterioration.

Battery charging is a constant voltage, which is charged with constant voltage. Since the voltage of the power source used to charge the battery is the voltage at the battery's rated power and when it fully charged, the voltage at the terminal of the battery is equal to the voltage of the power supply. Causing the current to flow into the battery is zero and stop working. At the beginning of the charge, the current that flows into the battery is very high. Therefore, it is necessary to set the maximum current that can be charged in order to prevent the maximum current for the battery. Charging batteries with constant current and constant voltage is a combination of a constant current charge and constant voltage charge together. During the initial charge, the battery will be charged with a constant current. By the voltage of the battery terminal will increase steadily until the specified value. After that, it will change from constant current to be charged with the constant voltage. Which the current will gradually decrease until the current reaches zero or the specified value. This method is most suitable for use because it can charge quickly and can fully charge the battery capacity.

Electric vehicle battery charging standards

Nevertheless, if considering the overall working principle according to the voltage level and charging Level, IEC 62196 standard can be divided into 3 levels as follows: [9 – 11]

1) Charging level 1 is charged with 1-phase AC at a voltage level of not more than 120 V. Charging at this voltage level will be used only in America. and Japan, this charge level 1 will take longer than other levels

2) Charging level 2 is a 1-phase AC charge, the voltage does not exceed more than 240 volts and the voltage is not more than 400 volts in 3-phase. For charging at level 2, a charger or charge controller must be installed in the vehicle.

3) Charging level 3 is charged with direct current of voltage not more than 500 Vdc. For charge level 1 and level 2, the AC current is charged by supplying power to power converter which is installed in the vehicle.

But for charging with this DC power, the power is supplied directly from the charger to the battery inside the electric car. Making it possible to charge the battery quicker which takes about only 30 minutes. This fast charge feature causing the power rating of the charger to be quite high. Therefore, this type of charger is suitable for installation in an electric charge station to facilitate users of electric vehicles that must travel far or travel between cities.

3. Results and Discussion

The design of multi-standard electric vehicle fast chargers is considered as a very important issue. Because the standard of the charger has so many standards. Therefore, the selection of charging standards is necessary to cover the use of most electric cars. The electrical outlet standards of various electric car manufacturers should be considered, which can be shown in Table 1 [12].

Based on the results of the study of the fast charge standards of the world's leading electric cars produced from various companies, there are three standards: the CHAdeMO standard of Japan, SAE

Combo (CCS) standards of Europe and America and the Tesla Supercharger standard. The Supercharger standard will only be used with electric cars produced by Tesla. But Tesla's electric car still has the special ability to support the CHAdeMO charge standard. Among the 11 electric cars that are popular in widespread use, there are 5 models that support the standard CHAdeMO. There are 3 models that support SAE Combo standards. There are 2 models that support the Supercharger standard and there are 3 models that are not officially disclosed. Therefore, in this research, this research is choosing to use the CHAdeMO standard because the CHAdeMO standard can support the use of most electric car users.

In general, electric cars produced from every company will have 2 standard receptacle sockets, one outlet will be charged at level 1 or slow charge by using a domestic home power 1-phase for charging. The second outlet is for the fast charging. Which may be DC fast charge or IEC Standard, Type 2 which uses 3-phase AC power, high current for charging. Therefore, many standard electric car battery chargers for electric vehicle battery charging stations should consist of 2 main standards, which are CHAdeMO and Type 2, as shown in Fig. 2, to cover the use of most electric vehicles with currently in use.

Table 1 Comparison of standards used in the charging of electric vehicles.

Model	DC Fast charge type	Standard/ As an option	Miles of charge in 30 min.
BMW i3	SAE Combo	Standard	75 – 100
Chevy S spark EV	SAE Combo	Option	75 – 100
Flat 500e	-	-	-
Kia Soul EV	CHAdeMO	Standard	75 – 100
Mercedes B-Class Electric	-	-	-
Mitsubishi i-MiEV	CHAdeMO	Standard	75 – 100
Nissan LEAF	CHAdeMO	Option	75 – 100
Smart Electric Drive	-	-	-
Tesla Model 5	Supercharger/CHAdeMO	Standard/ Option	170
Tesla Model x	Supercharger/CHAdeMO	Standard/ Option	170
Volkswagen e-Golf	SAE Combo	Standard	75 – 100

Simulation of multi-standard fast electric vehicle battery charger with computer program

As mentioned in the previous section, fast chargers with multi-standard used in research. It consists of 2 standards including CHAdeMO and Type 2. The battery of the CHAdeMO standards is charged with direct current and the power rating of 25 kW. Which will cover the usage of most electric vehicle. The Type 2 standard will be charged with 3-phase ac current with a rated power of 43 kW. It can be used with all electric cars because it is the common standard that electric cars of all companies are currently in use.

The multi-standard charger will receive power from the electricity distribution system of the Provincial Electricity Authority (PEA), which is a three-phase ac current through the transformer to reduce the voltage level from 22 kV to 380 V before entering the MDB and to the charger. Inside the battery charger, the electric vehicle will be installed with a PLC as the controller. To control the voltage level to be constant and control the amount of current to meet the requirements of electric vehicle.

Simulation of a fast electric vehicle battery charger based on the CHAdeMO standard

The CHAdeMO charging system will receive a three-phase ac power, rated voltage 380 V for the input of the AC-DC converter to convert ac power to direct current at a voltage of 500 V. The PLC controller is used as a feedback controller. Which uses current sensor and voltage sensor to measure current and voltage, respectively. The value will be sent to the PLC as well as the %SOC (State of charge) and the battery temperature of the electric vehicle for processing. When the PLC has processed, the on-off switch signal will be sent to the 6 power converters of the converter to control the output voltage level at 500 V and properly control the amount of charge current. Which the charge current used must not exceed the rated current of the electric vehicle battery as well as the temperature must not exceed the working conditions of the battery as well. For example, if the %SOC of the battery is greater than 80%, the controller should reduce the current to charge and when % SOC is 100%, the system will stop working or if the battery temperature is too high, the system must order to reduce the amount of current to charge. And if the temperature of the battery is so high that it cannot continue to work, the system must stop charging or working. Which the working principle and simulation results with PSIM (Power Simulation) program of fast charger according to CHAdeMO standard can be shown as in Fig. 2 (a) and Fig. 3 (a) respectively.

Simulation of a fast electric vehicle battery charger based on the Type 2 standard

For controlling the operation of the battery fast charger for an electric vehicle, the Type 2 can be shown in Fig. 2 (b). The integration of this system is not as complicated as the CHAdeMO standard. This system uses a PLC controller as a processor. The controller is used to turn on and off the magnetic contactor to control the electric power of the electric vehicle battery charger. The feedback controller is using the voltage sensor and current sensor to measure the voltage and current to be sent to the controller. If the output power is greater than the reference rated power, the controller will send a signal to the magnetic contactor for reducing the output current and output power. But if the output power is less than the reference rated power, the controller will increase the work cycle to allow the magnetic contactor to work longer. Resulting in increased power output which the simulation results with PSIM program can be shown in Fig. 3 (b).

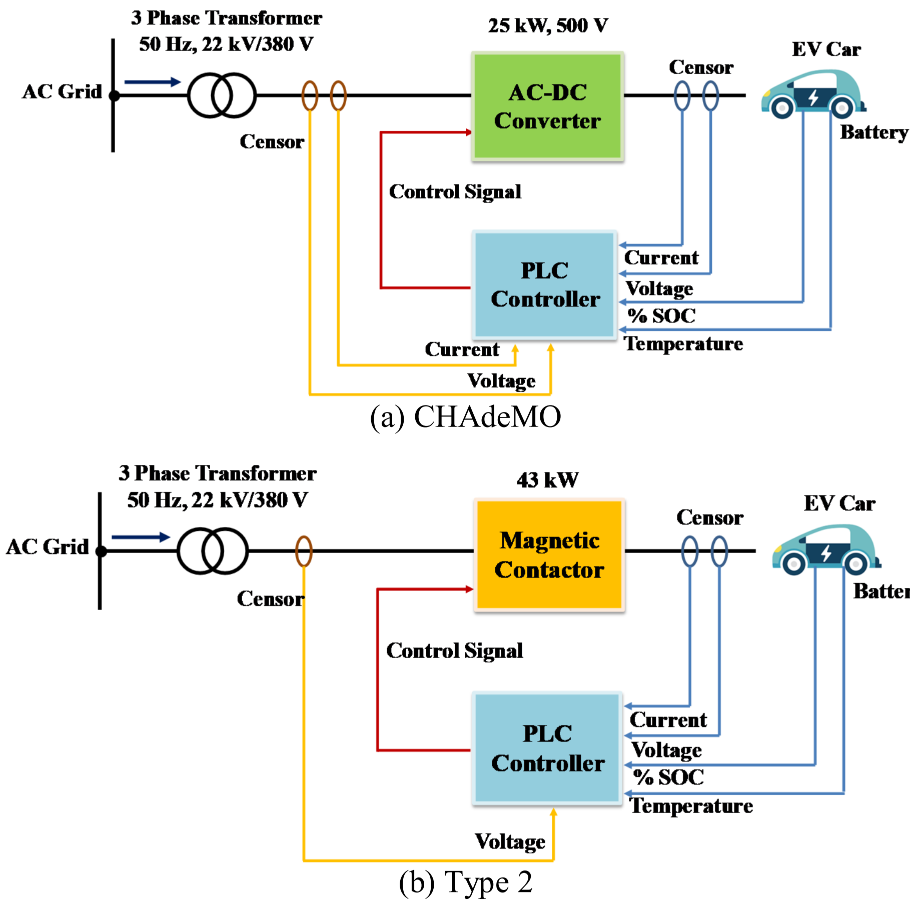


Fig. 2 The operation of a fast electric vehicle battery charger (a) CHAdeMO (b) Type 2.

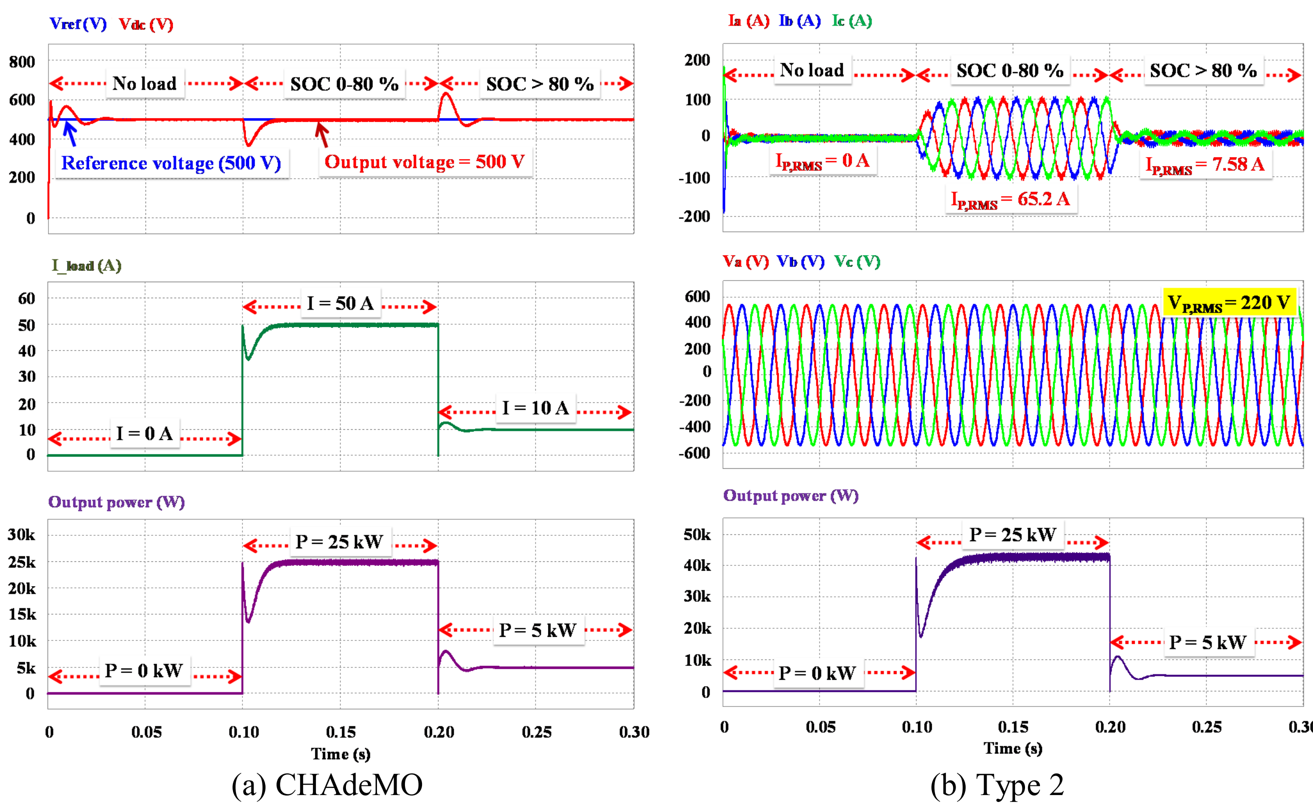


Fig. 3 The simulation result of a fast electric vehicle battery charger (a) CHAdeMO (b) Type 2.

The test results and the impact on the electrical system of a electric vehicle charging station

In the previous topic, the computer simulation of the electric vehicle battery with multi-standard charger has been mentioned. Which found that the system can properly operate. Next, the results of the test and the impact on the utility grid system of a multi-speed electric vehicle battery charger installed at Sakon Nakhon Rajabhat University will be described as shown in Fig. 4. By measuring the current, voltage, power, SOC of the battery inside the electric vehicle. The power quality of the system, the power factor of electrical system, frequency and distortion values of waveforms are also measured. The various test results can be shown as follows:

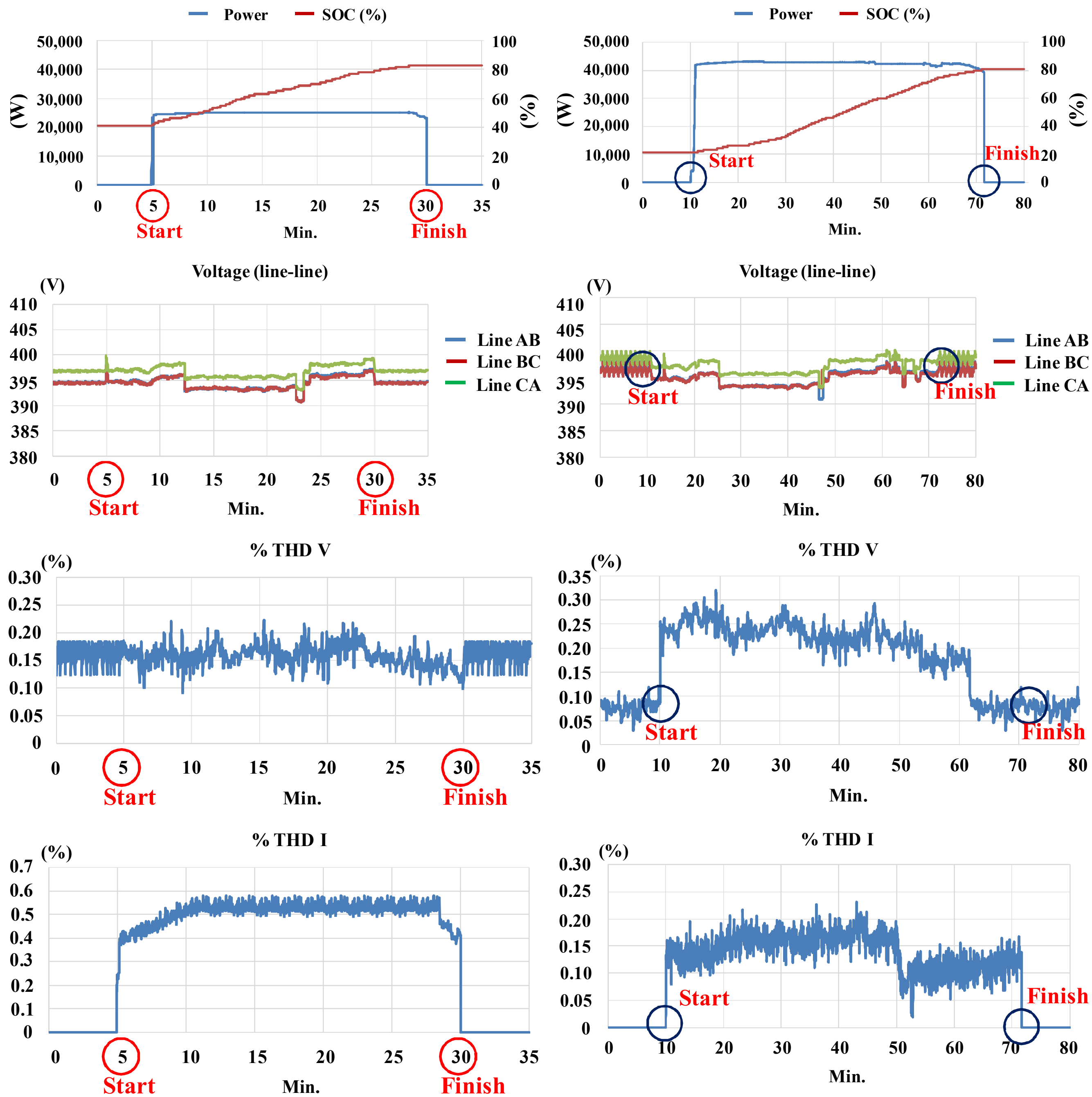
CHAdeMO standard

The electric cars that are used to test the performance of a fast electric vehicle battery charger with the CHAdeMO standard is a Nissan Leaf electric vehicle which uses a 24 kWh lithium-ion battery electric accumulator system that supports fast charge coordinates. 50 kW power (Rapid Charging Capability) and support for normal charge, rated power of 3.6 kW (On-board charger).

Type 2 standard

The BYD model e6 electric car is used for testing the performance of the Type 2 fast electric vehicle battery charger, which uses 80 kWh lithium-ion battery-powered current accumulator system. 43 kW AC power (On-board charger).

According to the tests, it was found that the performance of many fast chargers, both CHAdeMO and Type 2 standards, did not affect the electricity system of the Provincial Electricity Authority (PEA) and other power users in the vicinity. By the amount of current in accordance with the standards of utility system such as voltage during use is greater than 220 V in the case of a phase voltage and is greater than 380 V in case of line voltage. The power factor value is close to 1, which is greater than the 0.80 standard value of the PEA. The CHAdeMO standard has %THDV and % THDI, approximately around 0.20% and 0.60%, respectively. Type 2 standard has %THDV and % THDI, approximately 0.25% and 0.20%, respectively, which is considered to have very little distortion compared to the standard set by the PEA.



(a) CHAdeMO (b) Type 2

Fig. 4 The experimental result of the prototype electric vehicle charging station.

4. Conclusion

This article presents the study and analysis of the impact on the power distribution system of a standard multi-speed electric vehicle battery charging station of Sakon Nakhon Rajabhat University. In order to solve the difference between the plug of an electric vehicle battery charger at the battery charge station and the outlet of a various types of car standards. And answer to the needs of users of various electric car models that are currently in use. Based on simulation results and actual tests, it was found that many standard electric vehicle battery chargers that consists of CHAdeMO standards and Type 2 standards can work efficiently and does not affect the utility grid system and other power users in the vicinity.

5. Suggestions

The development of an electric vehicle quick charging station in the future could install a solar rooftop and battery energy storage system for maintaining voltage stability while charging the battery. The development of the EV rapid charging station that can provide two-way power transmission has been presented for supporting the power supply of the EV internal battery energy storage system in case of the returning power during the peak power demand.

6. Acknowledgements

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