Development of Fast Charging Station for Public Transport in Nakhon Ratchasima, Thailand

Terapong Boonraksa and Boonruang Marungsri*

Abstract— *Development of public transport systems is an essential component of the country and people, which involves proper economic analysis and the route planning. Electric vehicles (EV) become an option for internal combustion engine (IC) based on public transportation. Use of EV can reduce the consumption of fossil fuels by the internal combustion engines and can reduce air pollution as well. This paper proposes a direction of development of fast charging station for public transportation in Nakhon Ratchasima, Thailand. The feasibility study of the fast charging station comparing with conventional type is presented in this paper. The obstacles of fast charging stations in Nakhon Ratchasima, Thailand, the direction of development, are discussed in this paper. This paper also presents the type of EV charging, both conductive charging, and inductive charging. It also includes the DC fast charging station infrastructure. Finally, the fast charging station installation for each location is also discussed. The results show that the fast charging systems are suitable for urban installation due to the need for quick charging. The electrical power system in the area where the station installed is an essential part of the power supply, which must be capable of supporting the high-power demand of charging station and does not affect the electricity consumption of the area. It is necessary to consider that the power supply connected to a charging station requires a significant amount of electrical energy for charging. The EV charging affects voltage drop and power loss in a power distribution system, as a result, the quality of power and the stability of the power system is reduced.*

Keywords— **Electric vehicle, Electric public transportation, Fast charging station, Public charging stations.**

1. INTRODUCTION

Recently, the problem of air pollution and noise problems in the big cities are very significant. The main problem is caused by the excessive use of internal combustion engine. The Royal Thai government is encouraging research in electric vehicles, electrical systems to support the charging station for electric vehicles and electric vehicle technology for the public transport in Thailand.

Electric vehicles were first introduced in 1983 with battery power that could not be recharged. After that, the battery used for private cars and taxis. Fig. 1 shows the taxi using battery power. In 1901, the first electric vehicle could run at speeds exceeding 60 mph. During the 1920s, several hundred thousand of electric vehicles were produced, including cars, vans, taxis, and buses. Use of electric vehicles can reduce the consumption of fossil fuel [1].

Electric vehicle technology has been playing an essential role in the public transport system of Thailand and the use of electric vehicles in Thailand has increased in the past few years. Commonly used Electric vehicles are Hybrid electric vehicle (HEV), Plug-in hybrid electric vehicle (PHEV), Battery electric vehicle (BEV) or Electric vehicle (EV) [2]. Currently, electric vehicles are being imported into Thailand through major automotive companies. The Royal Thai government has launched a plan to provide Thailand's leading automotive companies with plans to invest in hybrid electric vehicles and electric vehicles. Toyota CH-R begins to play a role in the hybrid automotive market in Thailand. It has a 1.8-liter engine with a maximum power of 134 hp. The economics of the test is 30.2 km/l, and the reasonable price in Thailand is about 871,560 baht.

Fig. 1. Taxi in New York, about 1901, Battery-Powered EV [1].

There is also Toyota Prius with the same engine as the Toyota CH-R. The difference is that the power output of the engine is 121 hp [3]. Another vehicle in the market of

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electric vehicles in Thailand is Nissan Leaf, which is the next evolution of zero-emission electric vehicles and driven by the concept of intelligent driving. Fig. 2 the Nissan Leaf 2018 electrical propulsion system can drive up to 400 km of electricity with consuming 110 kW of electric power and 320 Nm of torque, which costs about 991,470 baht [4].

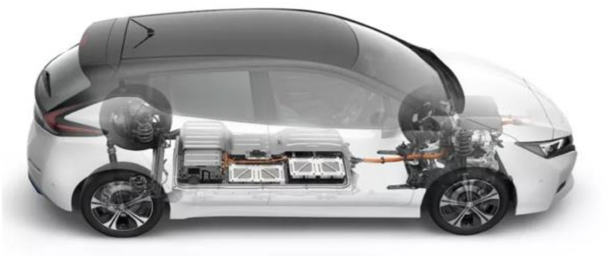

Fig. 2. Nissan Leaf electric vehicle [4].

This paper presents the possibilities of developing electric vehicles for public transport, a case study of Nakhon Ratchasima area. Types of the electric vehicles and various charging stations suitable for the electrical system in Thailand were studied. Furthermore, the number of EV fast-charging station and the situation of electric vehicle are also analyzed.

2. ANALYSIS OF THE SITUATION OF ELECTRIC VEHICLES IN THAILAND

Hybrid Electric Vehicle (HEV)

The hybrid electric vehicle consists of a piston engine acting as the main driving force [5]. It consumes fuel and works with electric motors to increase the vehicle's power; this makes the engine more efficient. It can be used to convert mechanical energy into electrical energy which is stored in batteries and supplied to electric motors. Therefore, it can reduce the demand of fuel than internal combustion engine.

Plug-in hybrid electric vehicle (PHEV)

The plug-in hybrid electric vehicle is an electric vehicle developed from a hybrid electric vehicle. It can be charged from the external source (Plug-in), allowing the car to power from two sources simultaneously. It can run to the long distance, and the speed increases directly to the electrical energy with energy directly to electricity. PHEV has two types of designs: Extended range EV (EREV) and Blended PHEV. The EREV focus on using electricity as the primary energy and the Blended PHEV is a combination of engine and electricity. Therefore, the EREV can run on electric power alone compared to the Blended PHEV, which makes it fuel-efficient.

Pure Electric Vehicle (EV)

Pure electric vehicle or battery electric vehicle is an electric vehicle that uses only battery power to drive an electric motor. So, the distance travelled by electric vehicles depends on the design, size, and type of the battery. When fossil fuels run out, electric vehicles are needed and become more demanding. Many researchers are interested in the technology of electric vehicles, batteries, etc. Fig. 3 shows the different types of electric vehicles.

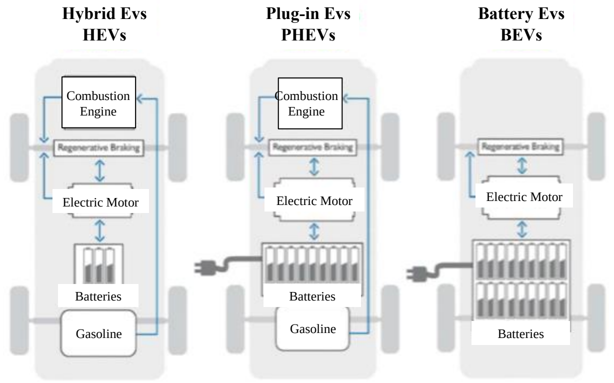

Fig. 3. Type of electric vehicles (EVs) [5].

3. CHARGING SYSTEM FOR ELECTRIC VEHICLES

Charging for electric vehicles is the connection of electric vehicles to the power supply to charge the battery. It is comparable to the refueling of internal combustion engine vehicles. The use of electric vehicles will reduce the amount of energy stored in the battery, and if the energy stored in the battery cease, the electric vehicle will not be able to drive. In the case of BEV will not be able to drive anymore. On the other hand, PHEV will still be able to use internal combustion engines to drive vehicles, but they will cost more fuel than electricity. Therefore, users of electric vehicles need to charge the battery by electricity periodically. Charging technology for electric vehicles can be divided into two types: conductive charging and inductive charging.

Conductive Charging

Conductive charging is the charging of batteries by connecting electric vehicles to the power supply directly through the cable (Or charging cable). This method is based on conduction of electricity through conductors. The electricity flowing from the power source through the of charging that widely used today. Electricity flows from the power source to the battery through charging cable and is widely used nowadays. It is easy to install highly efficient and can be used in both AC and DC system.

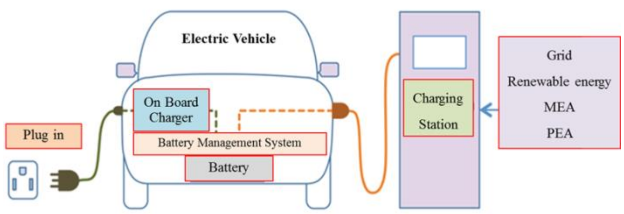

Fig. 4 Conductive charging of electric vehicles [6].

AC Charging is the electric charge from the AC to the electric vehicle. The onboard charger that is installed inside the electric vehicle converts the AC to DC into the battery. Fig. 4 shows the AC charging of electric vehicles. AC is charging as a standard charge system which converts AC to DC and vice-versa operates to its relatively low power consumption of 16-32 A. The AC charging is suitable for electrification in homes, office buildings and department stores, where electric vehicle can be parked for extended periods of time. The onboard charger is 3.3 kW and 6.6 kW for 1-phase charge system and up to 11 kW and 22 kW for 3-phase charge system.

DC Charging applied by supplying DC power to the electric vehicle. In this case, the charging station converts the AC power into direct current which is then supplied to the electric vehicle. The DC power supply to the EV can directly charge the battery. The Battery Management System (BMS) is responsible for the charging control, as shown in Fig. 4. DC charging is a fast charging, which can charge high power because there is no limit on Onboard Charger. The electric battery can be charged within 10-30 minutes. Because of its high-power consumption (around 50 kW), it requires a 3-phase power supply with high current ratings. The DC charging is often used in public areas where fast charging is required fast similar to the gas stations. It is suitable for electric vehicles that need to be charge several times during the day or for long distance travel such as trip between provinces.

Inductive Charging

Inductive charging or Wireless charging is shown in Fig. 5, is a charging technology based on electrical induction principle. When the power supply supplies an AC through the transmitter, which is mounted on the ground, the inductor coil in the transmitter generates an electromagnetic field. This induced electromagnetic field induces an alternating current in the inductor coil that is installed in the electric vehicle. Then the electric vehicle will feed the alternating current that will continue to charge the battery. Inductive charging has the advantage of being convenient and safe as it does not need to be plugged in and can reduce the risk of charging, such as short-circuits.

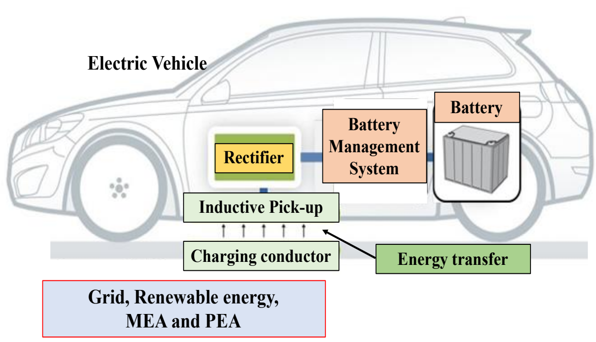

Fig. 5. Inductive Charging for Electric Vehicles [7].

However, there are disadvantages: low efficiency and heat, so it cannot support the charging with high power. Also, the induction charge is an alternating current, so it is necessary to use an onboard charger in an electric vehicle to convert the AC to DC before it charged to the battery. Induction charging has been introduced in some countries. It is installed on the street. It can charge electric vehicles while driving. However, it is not very popular because of the high cost and difficulty of installation. Unlike the conductive charging, it’s low cost and easy to install [7].

4. DEVELOPMENT OF CHARGING STATION IN NAKHON RATCHASIMA, THAILAND

The charging of electric vehicles depends on the level of electrical energy used. The National Electric Vehicle Infrastructure has set three levels of electric vehicles. In Table 1. show the characteristics of EV charging station with each level.

Charging Station Level 1

Level 1 (slow charging) uses a typical voltage to charge at 120 V. Use a Three-prong receptacle that can be found in your home or office. This charger can charge anywhere but has a limited power supply of approximately 12 A. Level 1 charging will take 8-14 hours or more. For complete charging, depending on the size of the battery.

Charging Station Level 2

Level 2 (standard charging) is the primary method of charging electric vehicles and requires the provision of specialized equipment for electric vehicles. Level 2 takes 1-3 hours to charge. The voltage is 240 V, the current is about 12-80 A. This reasonable level can be used to charge at both inside home and public service stations.

Charging Station Level 3

Level 3 (Fast Charging) Direct current is used to charge at this level, a high voltage of about 480 V is used, which can charge the battery within 20-30 minutes. Currently, several electric vehicles are using level 3 charging, such as Mitsubishi i-MiEV and Nissan Leaf. For Tesla electric cars, a unique charging system called Tesla Supercharger has been developed.

Table 1. Characteristics of EV Charging Station [14]

Charging Level	Level 1 AC	Level 2 AC	Level 3 DC Fast Charge
Voltage	120 V	240 V	480 V
Current	12-16 A	12-80 A	< 125 A
Charging Power	1.4-1.9 kW	2.5-19.2 kW	< 90 kW
Charging Time	8-14 hours	1-3 hours	20-30 minutes
Range per hour of charge	5 miles	10-20 miles	75 miles

Charging Station for Transportation

Electric vehicles for public transport or electric bus have been available recently. It can help to reduce air pollution in big cities. Fast charging systems are used to keep pace with the demand for electric vehicles. Fig. 6 show the wireless charging system for an electric bus and Fig. 7 shows a fast charging for an electric bus with a pantograph. It only takes 5 minutes to charge, and it makes electric vehicles to run for 1 hour [8], [9]. Another way is wireless charging. The wireless charging system charges at a rate of 400 kW which allow batteries to be charged in just 15 seconds every few stops [10].

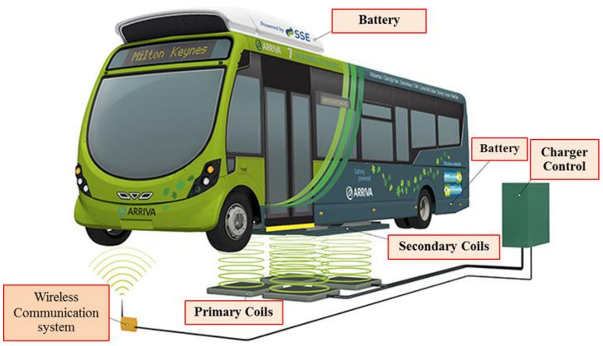

Fig. 6 Wireless charging system [9].

Fig. 7. Pantograph charging system [10].

5. THE PERSPECTIVE OF FAST CHARGING STATIONS IN NAKHON RATCHASIMA, THAILAND

Nakhon Ratchasima is one of the most populated provinces in Thailand. It is in the Northeast in Thailand. In Nakhon Ratchasima, the total area is 20,493,964 square kilometers with a population of 2,639,226 people [11]. Recently, the Provincial Electricity Authority (PEA) of Nakhon Ratchasima has opened a charging station for PHEV, which has an AC charging (normal charge) mode that takes about 30-45 minutes and DC charging (Quick charge) takes about 20 minutes [12]. In Fig 8 show PEA charging station in Nakhon Ratchasima.

The DC fast charging station infrastructure

Plug-in Electric vehicles (PEVs) and the electric bus has been more interest in Thailand. Therefore, there is an interest in analyzing the design and installation of fast charging stations in various forms such as charging stations for general electric vehicles, charging stations for mass transit electric vehicles, etc. The participation of various organizations was significant who took part in the development of systems and infrastructure for electric vehicles and charging stations. Fig. 9 shows the organizations involved in the development of electrification for electric vehicles in Thailand [13], [14].

Fig. 8. PEA Charging Station in Nakhon Ratchasima [12].

Fig. 9. The DC fast charging station infrastructure.

Government is a significant contributor to the fundamentals of electric vehicles. They plan the country's strategies and have funding policies, public location, and traffic planning. The general incentives of the government are in the form of refunds to reduce the cost of purchasing and installing charging stations.

Electric utility will analyze and plan the power delivery for the charging station to provide sufficient power to meet the need of the transportation system, businesses, and households. The load management systems are used to provide efficient power transmission. Including planning the electricity grid for charging stations installed in areas with the use of electric vehicles. The charging stations are essential to be located close to the distribution or the transmission system.

Private funders are co-investors with the government to build the charging stations for electric vehicles. It may be a manufacturer of motor vehicles or other businesses to design and manufacture parts of electric vehicles and the charging stations. It also analyzes the demand for electric vehicles in Thailand.

EVs customer is an electric vehicle user who can choose the nearest charging station and can pay for the charge using an RFID pay card or cash. Customers must be assured that their fast-charging stations are safe and meet the safety standards for their users. However, customers need to be careful when connecting the electrical system into electric vehicles.

Bidirectional Charging for Electric Vehicle

Over the years, electric vehicle technology has focused on the components of electric vehicle systems. Smart Grid and Electric Vehicle Concepts will play a new role by exchanging the power of electric vehicles with grid networks called gridable EVs (GEVs). Electric vehicles can charge their batteries from the grid and can also transfer energy back to the grid. The bidirectional charger has 3 new concepts for EV technology, vehicle-to-home (V2H), vehicle-to-vehicle (V2V), and vehicle-to-grid (V2G). These concepts have become more attractive and probably will turn into reality in the near future [15], [16].

Vehicle-to-Home (V2H) shows that when GEVs needs charging or discharging, a convenient way for users is to drive home. It can be connected to the home electrical system. V2H has a bi-directional on-board or offboard charger, so GEVs can charge the power from home or transfer power to the home as needed. This has the potential to make the household's daily load profile (DLP) smooth with energy exchanges, high performance during operation, easy to install without changing existing grid systems and compatible with V2V and V2G.

Vehicle-to-Vehicle (V2V) shows that GEVs can transfer energy using a bidirectional charger via a grid to transfer power between GEVs. The controller called an aggregator is responsible for compiling the GEVs to interact with the system. V2V is compatible with smart homes and indoor parking for energy sharing, with uncomplicated infrastructure and low power loss. V2V is compatible with renewable energy sources for the small community. But there is a need to use energy with the grid when electric vehicles charging.

Vehicle to Grid (V2G) shows that the GEVs can be connected to the grid to receive power and can transfer the power to the grid. V2G compatible with smart home parking and charging stations for power exchanges. The optimization strategies for V2G systems are possible and very flexible to use. Although the system is extremely flexible, it has complex controls. However, V2G can greatly improve the smart grid system. Fig. 10 shows the model power transfer of electric vehicles.

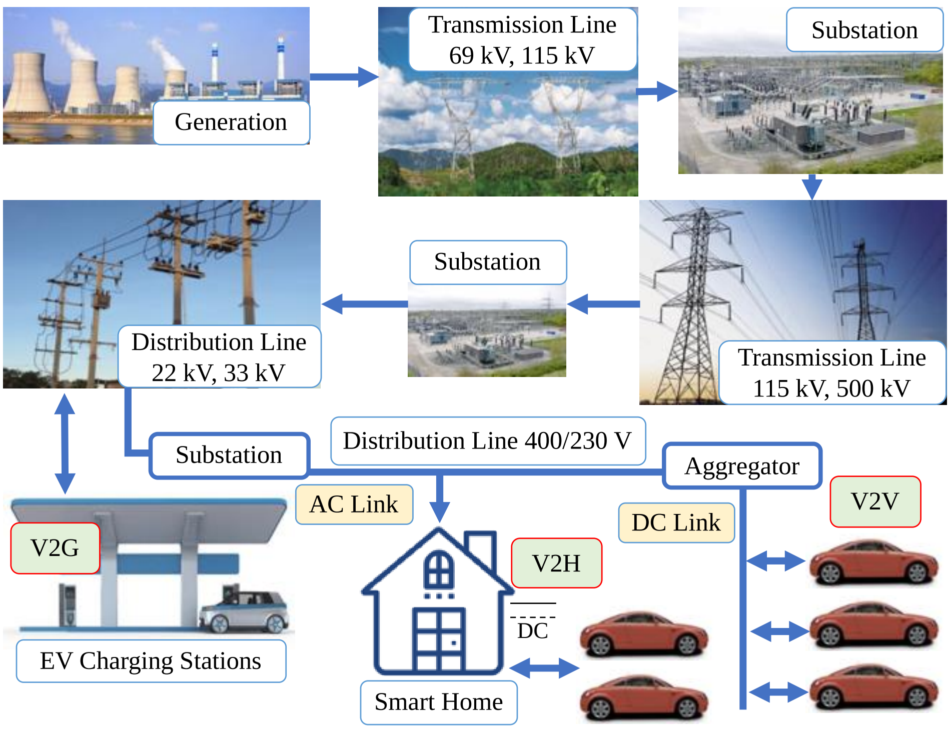

Fig. 10. The model power transfer of electric vehicles.

The concept of energy use or energy exchange of electric vehicles is more efficient and flexible today. GEVs will play an important role in future electric vehicle charging technologies, which will be developed in the system of Smart Grid, Smart Home and Smart City. Therefore, the proposed classification of V2H, V2V and V2G is the preferred framework for smart grid. It has simple, effective and controllable features.

6. THE METHOD TO DETERMINE THE NUMBER OF FAST CHARGING STATIONS IN THE AREA

The number of charging stations is essential for electric vehicle users. To keep the electric car continuously in use, there must be sufficient charging stations. There is also an electrical network accommodating the installation of a charging station. The methods for finding the number of fast charging stations are as follows equation (1) [17]. In this study, the sample case is based on the Phonrattanasak equation and uses the case study in Nakhon Ratchasima, Thailand.

$$N_{FCS} = \frac{A \times p_{density} \times p_{BEV}}{n_{sh} \times n_{cp} \times n_{sp}} \quad (1)$$

where

N_{FCS} : Number of fast charging stations

A : Size of area (km^2)

$p_{density}$: Population density (man/km^2)

p_{BEV} : Proportion of BEV owner per the number of the population in the area

n_{sh} : Number of service hour of a fast-charging station in the area

n_{cp} : Number of charging pump in a charging station

n_{sp} : The number of service in an hour of charging pump in a day

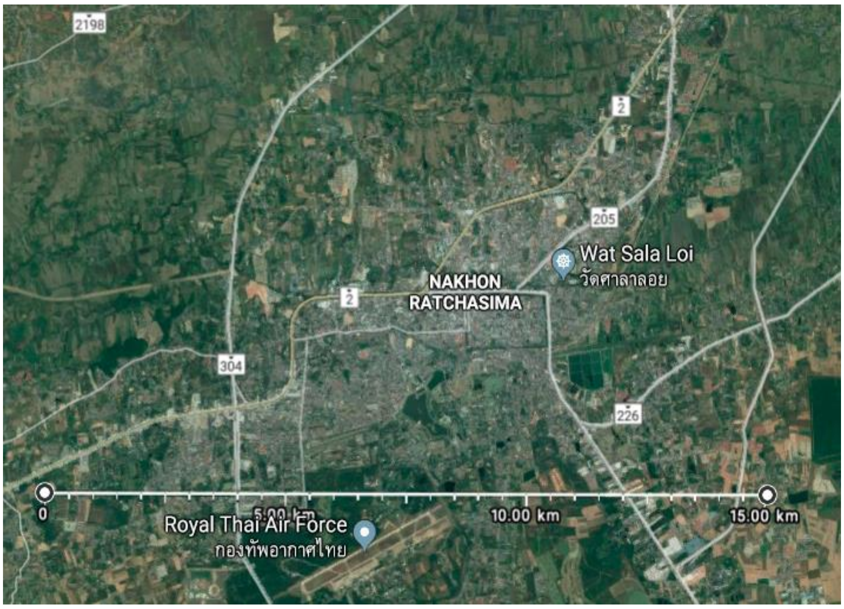

Fig. 11. Study area in Amphoe Mueang Nakhon Ratchasima.

Table 2. The Parameters for Determining the Amount of the Charging Station

Parameters	Value
Total area under this study (A)	15 km^2
The population of the total area	439,466 people
The population density ($p_{density}$)	582 people/km^2
The number of service hour of a fast-charging station in the area (n_{sh})	18 hour
Number of charging pump in a charging station (n_{cp})	4
Charging time of each electric vehicle.	15 min
The number of service in an hour of charging pump in a day (n_{sp})	4
Proportion of BEV owner per the number of the population in the area (p_{BEV})	10%

For example, in a case of Amphoe Mueang Nakhon Ratchasima area which has the population of the total area of 439,466 people. The total area is 755.596 km^2 [18]. In this case, only urban areas are used and Assume A = 15 km^2. So, the population density as 582 man/km^2, p_{BEV} = 10 %, n_{sh} = 18 hour, n_{cp} = 4, and BEVs will charge its battery in 15 minutes then n_{sp} = 4. Fig. 11 show the study area in Amphoe Mueang Nakhon Ratchasima and Table 2 show the parameters for determining the amount of the charging station.

In Nakhon Ratchasima Provence, there are private car registration of 445,475 people [19]. If the assumption is changed to 44547 electric vehicles or about 10% of car users. Therefore, the number of charging stations is calculated from the EV users of 10%, 20%, 30%, 40%, 50%, 60% and 70% respectively. This article is a case study of a sampling of the number of vehicles present in Nakhon Ratchasima, Thailand. To study and analyze the number of suitable charging stations in the area.

Therefore, enter the parameters into Equation (1) as follows:

$$N_{FCS} = (15 \times 582 \times 0.1)/(18 \times 4 \times 4) = 3$$

Therefore, the number of the fast charging station is 3 stations. There is the number of charging pump in a charging station = 4 pumps. The charges for fast charging stations = 3,647,574 baht per station, the voltage is 400 V, electric current 125 A and rated capacity 62.5 kW [20].

The case study has 7 cases. Determined the proportion of BEV owner per the number of the population in the area (p_{BEV}) of 10%, 20%, 30%, 40%, 50%, 60% and 70% respectively. The calculation results of the charging stations are shown in the Table 3.

Table 3. The Number of Charging Stations

p_{BEV}	10%	20%	30%	40%	50%	60%	70%
N_{FCS}	3	6	9	12	15	18	22

The calculation results in Table 3 show that the increase of the proportion of BEV owner per the number of the population in the area, as a result, the number of charging stations must be increased. When p_{BEV} increases by 10%, the number of charging stations increases by 3 stations.

Cost and benefit analysis for fast charging stations as discussed. Mostly, depending on the electrification rate of electric vehicles and the rate of use, it influences this analysis. It also includes the reduction of vehicle emission, the reduction of energy import and the reduction of travel cost of vehicle users. It is necessary to consider the power supply connected to a charging station that requires sufficient electrical energy for charging. There are an on-grid connection and an off-grid connection that could use an integrated renewable energy system to charging station [21].

The impact of electric vehicles charging on the distribution system

The rise of electric vehicles has contributed to reduce greenhouse gas emission and reduce fuel consumption. However, the charging of electric vehicles could have a significant impact on the grid or power distribution system. The electrical distribution system must have sufficient electrical power to support both the EV charging and the use in the public system [22]. If they can effectively integrate the EV charging system into the power distribution system, they will also play an important role in reducing the impact on other systems and becoming a useful resource for smart grid infrastructure [23]. Fig. 12 shows the basic structure of the EV charging station connected to the electrical distribution system of Thailand.

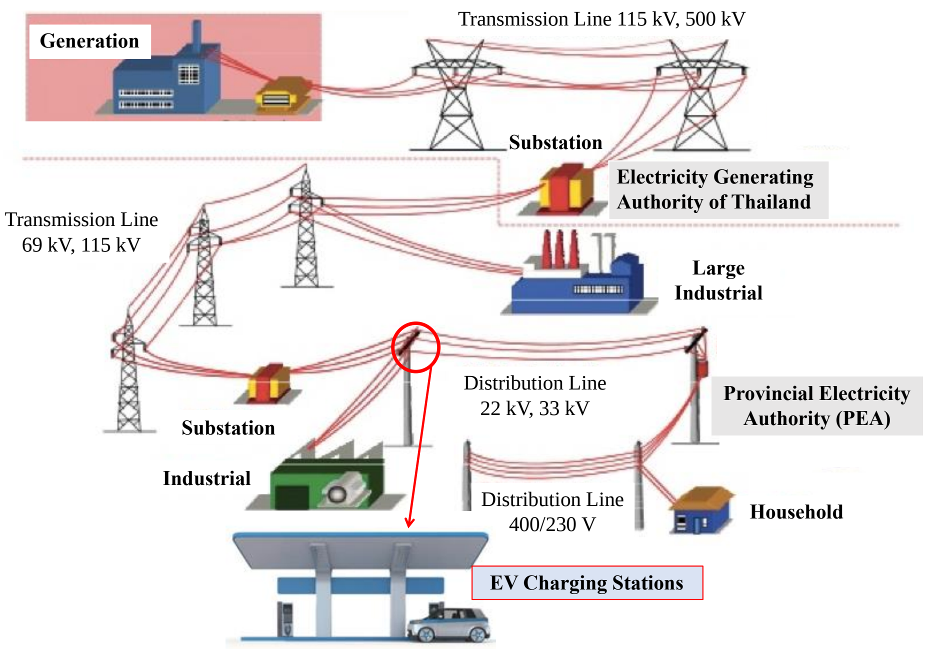

Fig. 12. Infrastructure of electric vehicles charging stations.

The impact of EV charging may change with the seasons. In Thailand, more demand of power will occur during summer season. One reason is that electric vehicle users turn on air conditioners more often to feel comfortable during driving. Another reason is that high heat can cause a drop-in performance of electric vehicle batteries. Fig. 13 shows the daily load curve for EV charging. The significant number of EV users start charging their vehicles at about 10.00 am and the maximum charging demand occurs during 9.00-10.00 pm. It may be due to the desire of EV user to fully charge their vehicle before returning to home. The EV charging affects voltage drop and power loss in power distribution systems [24]. As a result, the quality of power and the stability of the power system is reduced.

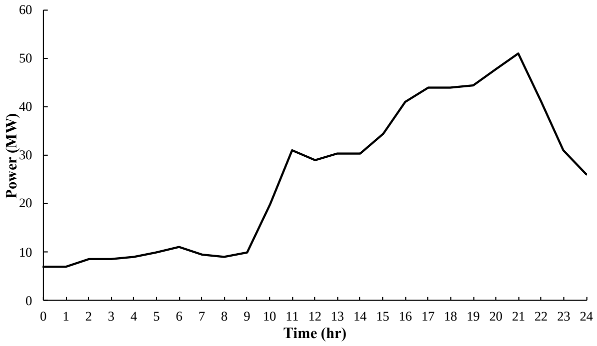

Fig. 13. Daily load curves for electric vehicles charging.

7. CONCLUSION

This paper presents the development of case studies for charging stations in urban areas, Nakhon Ratchasima, Thailand. Types of electric vehicles and charging systems for electric vehicles are presented in this paper. The charging stations calculated as per the requirement of the particular area. It also includes the DC fast charging station infrastructure and the impact of electric vehicles charging on the distribution system. The results show that the fast charging systems suitable for urban installation due to the need for quick charging. The electrical system in the area where the station installed is an essential part of the power supply, which is capable of supporting the high power and does not affect the electricity consumption of the area. It is necessary to consider the power supply connected to a charging station that requires sufficient electrical energy for charging. The EV charging affects voltage drop and power loss in power distribution systems. This results in lower the power quality and electrical system stability. This paper is the information for the development of electric vehicles and electric buses in the future.

REFERENCES

[1] Larminie, J. and Lowry, J. P. 2012. *Electric vehicle technology explained*. West Sussex, England: J. Wiley.

[2] Brand inside. Retrieved March 20, 2018, from the https://brandinside.asia/bev-in-thailand-research-krungsi/.

[3] Ridebuster. (n.d.). Retrieved March 20, 2018, from https://www.ridebuster.com/next-3-new-hybrid-toyota/.

[4] Grand Buffet. (2017, September 09). Retrieved March 20, 2018, from https://www.brandbuffet.in.th/2017/09/nissan-leaf-new-lauch-2017/.

[5] Shukla, A, DolceraWiki (2009). A Market Study on Hybrid Vehicles and the Concept of V2G. Retrieved March 20, 2018, from https://www.dolcera.com/wiki/index.php?title=A_market_study_on_Hybrid_vehicles_and_the_concept_of_V2G&redirect=no.

[6] Chen, H. L. (2016, February 04). Optocouplers Help Promote Safe, Efficient EV Charging Stations. Retrieved from http://www.electronicdesign.com/power/optocouplers-help-promote-safe-efficient-ev-charging-stations.

[7] Costello, M. (n.d.). News - Volvo. Retrieved March 20, 2018, from https://www.goauto.com.au/news/volvo/volvo-working-on-wireless-ev-charging/2011-05-25/9536.html.

[8] Charging stations and -systems. (n.d.). Retrieved March 20, 2018, from http://www.hybricon.se/en/products--services/charging-stations-and--systems.htm.

[9] Owano, N. (2014, January 11). Electric buses with wireless charging set for the UK run in Milton Keynes. Retrieved March 20, 2018, from https://techxplore.com/news/2014-01-electric-buses-wireless-UK-milton.html.

[10] Morris, C. (n.d.). ABB fast chargers support two different brands of e-buses in Trondheim. Retrieved March 20, 2018, from https://chargedevs.com/newswire/abb-fast-chargers-support-two-different-brands-of-e-buses-in-trondheim/.

[11] Nakhon Ratchasima Province. (2018, March 16). Retrieved March 20, 2018, from https://en.wikipedia.org/wiki/Nakhon_Ratchasima_ProvProv.

[12] Koratdaily. Retrieved March 20, 2018, from http://www.koratdaily.com/blog.php?id=5992&like=1.

[13] Business Case for Investing in Electric Vehicle Direct Current Fast Charge Station Infrastructure. (n.d.). Retrieved 2016, from https://www.ccme.ca/files/Resources/air/mobile_sources/Final%20DCFC%20Report.pdf.

[14] EV Charging Station Installation Guidebook. (n.d.). Retrieved March 17, 2018, from https://www.bing.com/cr?IG=DB4F36ED42934B8598A223FF87FDF959&CID=09F13597A68467A80EA73E22A72B6665&rd=1&h=w3Qg5au9n_LS7eCQuUQ-C80YKT7ySo9WPfkDGliybCw&v=1&r=https://www.driveelectricvt.com/Media/Default/docs/electric-vehicle-charging-station-guidebook.pdf&p=DevEx,5067.1.

[15] Liu, C., Chau, K. T., Wu, D., and Gao, S. (2013). Opportunities and Challenges of Vehicle-to-Home, Vehicle-to-Vehicle, and Vehicle-to-Grid Technologies. *Proceedings of the IEEE*, 101(11), 2409-2427.

[16] Tan, K. M., Ramachandaramurthy, V. K., and Yong, J. Y. (2014). Bidirectional battery charger for electric vehicle. *2014 IEEE Innovative Smart Grid Technologies - Asia (ISGT ASIA)*.

[17] Phonrattanasak, P.; and Leeprechanon N. 2012. Development of Fast Charging Station for Thailand. *International Journal of Innovation, Management and Technology*. 3(6): 668-674.

[18] Mueang Nakhon Ratchasima maps, Retrieved March 20, 2018, from https://www.google.com/maps/@14.9762271,102.090931,13605m/data=!3m1!1e3.

[19] Nakhon Ratchasima Provincial Land Transport. (n.d.). Retrieved from

http://www.dltkorat.go.th/index.php
[20] Colmenar-Santos, A., Palacio, C. D., Borge-Diez, D., and Monzón-Alejandro, O. (2014). Planning Minimum Interurban Fast Charging Infrastructure for Electric Vehicles: Methodology and Application to Spain. *Energies*, 7(3), 1207-1229.
[21] Schroeder, A., and Traber, T. (2012). The economics of fast charging infrastructure for electric vehicles. *Energy* Policy, 43, 136-144.
[22] Darabi, Z., and Ferdowsi, M. Aggregated impact of plug-in hybrid electric vehicles on electricity demand profile. *IEEE Transactions on Sustainable Energy*, vol.2, no. 4, 2011, pp. 501-508.
[23] Jiang, Z., Tian, H., Beshir, M. J., and Vohra, S. Analysis of Electric Vehicle Charging Impact on the Electric Power Grid. *2016 IEEE PES Transmission & Distribution Conference and Exposition - Latin America (PES T&D-LA)*, 2016.
[24] Boribun, B., Paolaor, P. and Kulworawanichpong, T. (2013). Impact of electric bus charging in power distribution systems. *Paper presented in Advances in Nano, Biomechanics, Robotics, and Energy Research*. Seoul, Korea. August 25-28, 2013.