Development of Fast Charging Station for Thailand

Prakornchai Phonrattanasak, *Member, IACSIT,* and Nopbhorn Leeprechanon

***Abstract*—Fast charging station is one type of charging method which can charge battery of electric vehicle (EV) in not over an hour. It can supply rapidly electric power to charge EV like gasoline pump station for internal combustion engine car. So it will be most popular charging station for EV customer in the future. This paper proposes direction of development of fast charging station for Thailand. Review of EV type in Thailand is presented in this paper. Benefit of fast charging station is compared with other type of charging station. Service model for fast charging station in Thailand is proposed in this paper. Barrier of fast charging station in Thailand is discussed in order to find out direction of development. Finally, method to determine the number of fast charging for each area is proposed in mathematic equation as well as calculation example of some area.**

***Index Terms*—Battery electric vehicle (BEV), plug in hybrid electric vehicle (PHEV), fast charging station.**

I. Introduction

During the last few decades, environmental impact of the petroleum-based transportation vehicle [1], along with the peak oil price, has led to renewed interest in an EV. Consequently, EVs will be most popular vehicle in the future because of low impact on environment and noise compared to conventional vehicle or internal combustion engine car.

These EVs have batteries to be electrified by charging stations where they can be at home or public areas. An electric vehicle charging station is an important element of using EVs in urban area and other area. Power distribution will be another important element to supply electric power to charging station toward EVs. Smart grid will control electric power supplying to EV population for recharging battery in order to impact on power distribution system.

Within the various standards for charging stations, charging method has been grouped into three basic levels:

Level I refer to single phase alternating current (AC) using grounded receptacles at home. Level II refers to single or triple phase AC. Level III refers to DC quick charging or fast charging. To achieve a very short charging period of time, fast charging station will supply DC voltages at high currents.

Fast charging therefore makes people so convenient to use it because EV customer can charge battery not over 15 minutes to get full charge [2]. So fast charging stations can then be installed along the street like gas or petrol station while connected to the electric power distribution grid. However, it needs high power and must be controlled by smart grid to ensure the availability of supply for EVs consumption.

This direction of development fast charging station for Thailand is presented in this paper. The benefit of fast charging station is discussed in section III and IV. Smart grid for power distribution system of Thailand is proposed in section V. Prospective service of fast charging station in Thailand is discussed in section VI. Method of determine the number of fast charging station is proposed in section VII. Service model for fast charging station is proposed in section VIII. Finally, Barrier of fast charging station is discussed in section IX.

II. Review EV Situation in Thailand

A. Plug in Hybrid Electric Vehicle (PHEV)

A PHEV [3] have the characteristics of both a hybrid electric vehicle (HEV) which has an electric motor and an internal combustion engine (ICE) and an all-electric vehicle having a plug to connect to the electrical grid. It is shown in Fig. 1. PHEV could get more than 100 miles per gallon while the vehicle runs primarily on the battery compared to the 30 to 55 miles per gallon that most of hybrid electric vehicle achieves at a charging.

A plug-in hybrid's all-electric range is designated by PHEV-[miles] or PHEV [kilometers] km in which the number represents the distance of the vehicle which can travel on battery power alone. For instance, a PHEV-20 can travel twenty miles (32 km) without using its combustion engine, so it may also be designated as a PHEV 32 km. EV Charging station for PHEV may be Level I and 2 which will recharge its battery at low electric current.

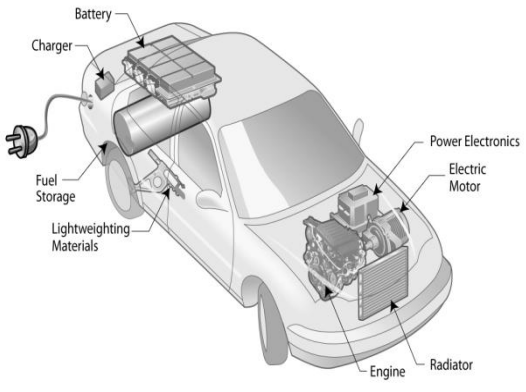

Fig. 1. Inner driving equipment of PHEV [4]

In Thailand, Volvo debuts Volvo V60 PHEV [5] to sell in next year and it have both a battery with size 11.2 kW-hr and a turbo-diesel. For Japan car, Toyota still not plans to sell PHEV in Thailand but the PX-MiEV II from Mitsubishi [6] which have electric vehicle engine 70 kW with a

Manuscript received September 10, 2012; revised October 30, 2012.

Prakornchai Phonrattanasak is with Thammasat University, Thailand while holding an academic staff member at the North Eastern University ,Thailand (e-mail: tumneu@live.com).

Nopbhorn Leeprechanon is with the Department of Electrical and Computer Engineering, Thammasat University, Thailand (e-mail: nopbhorn@ tu.ac.th).

conventional 2.0 litre MIVEC four cylinder unit is planned to sell for Thailand car customer.

B. Battery Electric Vehicle

Battery electric vehicle (BEV) or pure EV is a type of electric vehicle that uses only rechargeable battery. BEVs use electric motors and motor controllers instead of internal combustion engines (ICEs) for propulsion. A battery-only electric vehicle or all-electric vehicle derives all its power from its battery and has no internal combustion engine. Battery electric vehicles differ from fossil fuel-powered vehicles in that the electricity must be supported by electricity grid such as power distribution system. It is shown in Fig. 2.

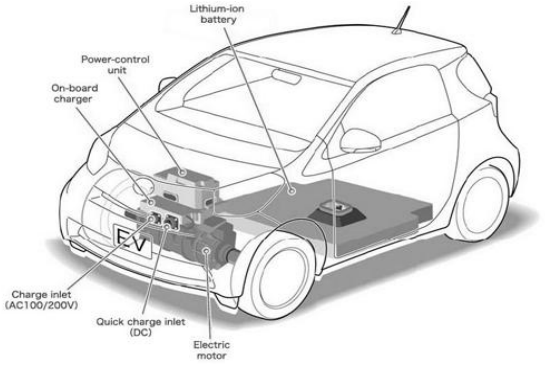

Fig. 2. Inner driving equipment of BEV [19]

HEV, PHEV and BEV are classified by fuel type in Fig. 3.

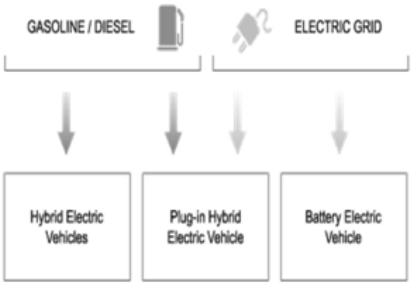

Fig. 3. Show fuel type of HEV, PHEV and BEV [7]

BEVs need more electric power to recharge battery or wants to consume electric power from EV charging station Level I, II or DC fast charging station. As the number of BEV increases, the number of charging points will have to increase as well. A trip of 1 km of BEV would consume electrical energy at the rate of 0.15 kWh/km [8]. This is economy fuel benefit of BEVs if electric charge per kWh is cheap. Another of benefit from BEVs with operating in all-electric mode is to produces less noise than traditional combustion engine vehicles. Consequently, low noise along the street of Thailand is from BEVs when it is increasingly used.

At the residential level, the PHEVs are planned to charge using Level I chargers, while BEVs are expected to charge at Level II or III. Charging BEVs will have more impact on the power distribution system due to their higher-power charging and higher energy capacity than PHEVs.

The Nissan Leaf is a full electric car, meaning 100% running on electricity. It runs about 200 km and it is currently sold in Thailand. Mitsubishi Motors Thailand [9] has agreed to start the testing i-MiEV with the Metropolitan Electricity Authority (MEA) and PEA ENCOM International Company and will bring recently it to sell in Thailand. Chinese car maker BYD also has plans to sell EVs in Thailand.

TABLE I: ANNOUNCED NATIONAL EV SALES TARGETS [10]

Country	Market share	Charging station	Incentive
Japan	15-20% in 2020	5,000 rapid charging station and 2 million regular charging station by 2020	Current incentive is up to $7,000 for EV
Korea	10% in 2020	150,000 charging station before 2016	Current incentive up to $2,470 for EV
China	540,000 unit in 2015	10 million EV charging stations by 2020	Incentives of $600-$9,000 for EV
Europe	480,000 unit in 2015	The approximate about €5bn for building EV infrastructure investment over the next seven years	**German**: Electric vehicles are exempt from the annual circulation tax for a period of five years **UK**: No Road tax for EV
USA	610,000 unit in 2015	more than 11,000 charging stations in 11 major cities	$7,500 federal tax credit with the purchase of EV
World	10% in 2020	-	-

Nowadays, Thailand don't have sale target of EV. Table I show announced national EV sales targets of some country and region in the world. Therefore EV in Thailand should be sold or driven by Thailand people at least 10% of all passenger cars in 2020 following direction of world.

From Table II, BEV will reduce CO_2 emission from vehicle when it is used by city people because it has zero emission.

TABLE II: COMPARISON OF CO2EMISSION OF EACH VEHICLE TYPE

No.	Vehicle	Litre/km	g CO_2/km
1.	Mid-size ICE car [11]	0.0898	208.3
2.	Small-size ICE car [11]	0.0714	165.6
3.	Eco car [11]	0.0710	164.7
4.	Hybrid car [11]	0.0501	116.2
5.	BEV	0	0

** 0.01 Litre/km = 23.20 g CO_2/km [12]

III. DEVELOPMENT OF CHARGING STATION IN THAILAND

A. Charging Station Level I

Level I charging station can be plugged in a household socket which takes approximately 8 to 10 hours to charge the vehicle. Level I is typically used for charging when there is only a home electric outlet available. Based on the battery type and vehicle, Level I charging add about 2 to 5 miles per hour of charging time. Slow charging, time consuming; unable to meet the need of emergency charging. The Society of Automotive Engineers has established charging standards (in Standard J1772) that cover the following two charging power levels: Level I up to 1.92 kW

In Thailand, charging station Level I will have level of voltage as 220 V and can plug into standard outlet of Engineering Institute of Thailand at home.

B. Charging Station Level II

Level II requires installation of home charging or public charging equipment and a dedicated circuit of up to 80 amps, depending on the BEVs or PHEVs requirements. However, most residential Level II will operate at lower power because

Level II can easily charge a typical EV battery overnight. The Society of Automotive Engineers has established charging standards (in Standard J1772) that cover the following two charging power levels: Level II up to 19.2 Kw.

Level II equipment also uses the same connector on the vehicle as Level I equipment. Based on the battery type and circuit capacity, Level II adds about 10 to 20 miles of range per hour of charging time, depending on the vehicle. In addition, electric vehicles are required to have an interlock deactivating the ignition while anything happens to disrupt the connection, such as a user releasing the connector latch, the power flow to the vehicle will immediately stop. Disadvantage of Level II is low range for using battery of PHEV or BEV.

In Thailand, charging station Level II will have level of voltage 220 VAC or 380 VAC (3 phase) with protection equipment.

C. Charging Station Level III or Fast Charging Station

Level III [13] fast charging stations will charge EV in less than one hour. Level III stations rely on an off-board charger that converts AC to DC, using three-phase electric service. Level III refers to direct current (DC), or "fast charging". To achieve a very short charging period of time, Level III chargers can supply very high voltages (300-500VDC) at very high currents (125-250 A). It needs more electric power and more complex control circuits. It is designed about 60 to 80 miles of range in 20 minutes of charging. DC Fast Charging will be more suitable than Level II in such locations because EVs customer will expect the shortest recharge time available to minimize travel time [20].

Fast charging stations should then be installed along the street like gas or petrol station while connected to the electric power distribution grid in Fig. 4. However, it must ensure the availability of supply for EVs consumption. Advantage of fast charging is large occupation area for BEVs but it need high investment cost for many fast charging stations to cover service area. The overcost of installation for fast chargers is compensated by the larger number of BEV charged and the larger charging capacity.

Charging station Level III will connect to power distribution system of Thailand as Metropolitan Electricity Authority (MEA) for Bangkok, Nonthaburi and Sumuthprakarn province and Provincial Electricity Authority (PEA) for remaining provinces.

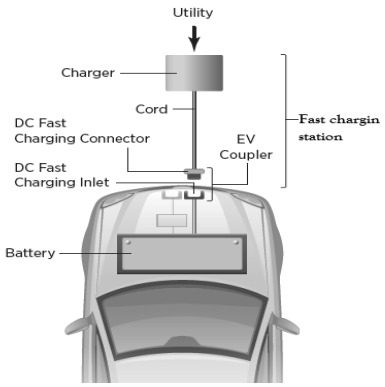

Fig. 4. Fast charging station connects to charge EV battery

The MEA [14] opened its first pilot EV station at its headquarters on Pleonchit Road at no charge until next year. The nine other stations will be in Bangkok, Samut Prakan, and Nonthaburi, with the construction cost of each at Bath 600,000. Services will include a quick charge at 20-30 minutes and a home charging system to fully charge a vehicle in 6-8 hours.

The MEA plans to develop quick-charge stations that will offer 360-volt charges allowing an EV to travel 100-140 km. fully charged. It wants to develop another 20 EV charging stations over the next two years for its internal use and public showcasing and nine charging stations next year at its service areas in Bangkok, Nonthaburi and Samut Prakan.

Nowadays, PTT just open its first PTT Pilot EV charging station (Second pilot project of charging station in Thailand) in Ayutthaya's Wang Noi district with more five stations to be launched by 2013. It can simultaneously serve three EVs at a time, with three kinds of charger; a DC Quick charger in 30 minutes; an AC Normal Charger in three hours and a Normal Charger in eight hours

In the future with more wide EVs, effect of high power consumption from many fast charging stations on residential transformer can degrade life time of transformer if total power supplying is over its maximum capacity in long time. Therefore fast charging should have the transformer separated from other load in order to avoid this problem.

D. Battery Switch Station

Battery switch station [15] is a place to swap a discharged battery and recharged battery. It is called as "Better Place". The spent battery is taken out and replaced with one that is fully charged. Automated battery-switching station can complete a battery swap in less than one minute. The switch process may takes less time than a stop to recharge battery at the charging station while driver may remain in the car throughout process. The entire process takes less than five minutes. Battery swapping is common in warehouses using electric forklift trucks to exchange battery. In a battery switch station, the driver can wait in the car while the battery is swapped.

Electric vehicle manufacturers that are working on battery switch technology have not standardized on battery access, attachment, dimension, location, or type for today. Smart system of battery switch station is programmed to speed up or slow down recharging automatically for optimum charging process to extend battery life span and performance. Moreover, the spare batteries at swap stations could participate in vehicle to grid.

The driver does not own the battery in the car. Thus driver don't worry with battery life, maintenance cost but the battery switch station company must be responsible or warranty especially for taxis and buses. The price of electric vehicle comes down.

For Thailand, battery switch station disappears because it's new technology and has very high investment cost.

IV. Comparison between Fast Charging Station and Other Type Charging Station in Case of Thailand

The fast charging station is compared with other type of charging station in Table III. Outstanding point of fast charging station is low electric energy charge per kW, wide service area and short time in period of charging process.

Electricity charge per kW is estimated based on electricity rate of MEA and PEA.

From Table III, electricity charge per kW of fast charging station is lower than other charge rate Moreover; Thailand government will help it popular if they support opening EV fast charging stations as well as subsidizing free services. It's easier than subsidizing charging station 1 and 2 because it serve EV customer in public area.

TABLE III: COMPARISON BETWEEN FAST CHARGING STATION AND OTHER TYPE OF CHARGING STATION

Type	Investment cost (Approximate) (Bath)	Period of Charging process	Service area	Electricity charge/kW
Battery switch stations	15,000,000 ($500,000) [15]	5 minute	Public	Depend on EV service company
Fast charging station	600,000 – 1,500,000 ($20,000 to $50,000) [16]	10 - 30 minute	Public	2.464 Bath/ kW*** [17]
Level II charging station	30,000 to 210,000 ($1,000 to $7,000)	1 – 8 Hour	Private	2.978 Bath/ kW ** [17]
Level I charging station	-	8 Hour up	Private	2.978 Bath/ kW ** [17]

** 2.978 Bath/ kW from electricity rates of consumption exceeding 400 kWh per month of residential rate.

*** 2.464 Bath/ kW from electricity rates of small general service at 22-33 KV.

Average vehicle kilometer traveling of sedan car in Bangkok area and Provincial area is 42.83 km/day and 38.55 km/day respectively [18]. So fast charging station about 96.56 to 128.74 km of range can serve EV in those ranges with one charging time per day.

V. FAST CHARGING AND SMART GRID OF THAILAND

Fast charging station should be constructed in urban area before other area because high price of BEV and purchasing power of BEV customer. However the government should support the use of electric cars as Japan, Europe and USA, for instance, by offering Incentives for purchasing BEV or tax reductions for such imported vehicles. Many fast charging stations is expected to be installed in urban area of Thailand in the near future. It's shown in Fig. 5.

Fast charging station will serve BEVs like gasoline pump station but it needs more electric power from distribution system of MEA or PEA. Smart grid of distribution substation must be therefore developed to control electric power supplying for many fast charging stations. It will play a role to manage and optimize load curve every day especially in summer season of Thailand.

The impact of fast charging station on the connected distribution grid is an important point for power distribution planning. Reducing the impact on the grid can be accomplished in many ways, including increasing consumer knowledge of the utility's operational issues, developing an effective advanced Metering Infrastructure (AMI) strategy and developing charging location networks. AMI technologies enable load leveling to the point of shutting off the vehicle charger during peak emergency times. It can be controlled by MEA or PEA control center.

Level III charging can also be incorporated in charging-network strategies and located in commuting traffic patterns. Careful planning of the charging networks will help utilities encourage market development electric transportation and lower the risk of unpredicted consequences.

Fig. 5. Proposed smart grid for fast charging station in Thailand

Because of need more power from distribution system, it should be installed close to main power distribution line of MEA or PEA.

VI. PROSPECTIVE SERVICE OF FAST CHARGING STATION IN EACH AREA OF THAILAND

A. Fast Charging Station in Urban Area

Fast charging station should be widely installed in urban area which wants reduce CO_2 emission form internal combustion engine car. Urban area is area which traffic flow encounter problem of congestion and CO_2 emission diffuses so much especially in big city of Thailand such as Bangkok. People will be happy with clean air if fast charging station will release this problem. It should be constructed to recharge EV every day before other area.

B. Fast Charging Station in Suburban Area

Suburban area is area which around urban area and want fast charging station when EV customer travel outside urban area. It support BEV customer in both suburban area and other area. It should be installed along main road or highway of Thailand in big city like gasoline pump station. It will eliminate range anxiety of service.

C. Fast Charging Station in Provincial Area

According to data of average vehicle kilometer traveling of sedan car in provincial area is 42.83 km/day, BEV customer in provincial area drive car a day more than urban area. So they want the number of fast charging more than urban area. However it depends on density of BEV customer per area too. Big provincial area near Bangkok in Thailand such as Ayutthaya should install fast charging station before other

provincial area.

D. Fast Charging Station in Rural Area

Rural areas have a low population density and typically much of the land is devoted to agriculture. There may be less air and water pollution than in an urban area. So it is not appropriately to install widely fast charging station but it may be constructed in small city for travelling in short distance within its area. PHEV should be used by PHEV customer more than BEV because people can drive car in mode of internal combustion engine with long range distance if battery is empty.

VII. Proposed Method to Determine the Number of Fast Charging in Area

The method for finding the number of fast charging station ($nfstation$) in area is proposed as follows.

$$nfstation \geq \frac{A \times pdensity \times pBEV}{sh \times ncp \times nst} \quad (1)$$

where

A = size of area (sq.km^2)

$pdensity$ = population density (man/km^2)

$pBEV$ = Proportion of BEV owner per the number of population in area

ncp = number of charging pump in a charging station

nst = the number of service in a hour of charging pump

sh = the number of service hour of fast charging station in a day

For example, in case of urban area which have population density as 400 man/km^2. Assume A = 10 km^2, $pBEV$ = 30%, ncp = 4, sh = 18 hour and BEVs will charge its battery in 15 minute then nst = 4.

$$nfstation \geq \frac{10 \times 400 \times 0.3}{18 \times 4 \times 4} = 4.16$$

Therefore the number of fast charging station is 5 stations.

In case of rural area which have population density as 10 man/km^2. Assume A = 80 km^2, $pBEV$ = 10%, ncp = 4, sh = 12 hour and BEVs will charge its battery in 15 minute then nst = 4.

$$nfstation \geq \frac{80 \times 10 \times 0.1}{12 \times 4 \times 4} = 0.41$$

Therefore the number of fast charging station is 1 station or is at center of rural community.

VIII. Proposed Business Model for Fast Charging Station

In order to promote fast charging station for EVs in Thailand, service model should be proposed to identify all concern organization. The service model for fast charging station in Thailand is shown in Fig. 6. This model comprise of 5 stakeholders as follow.

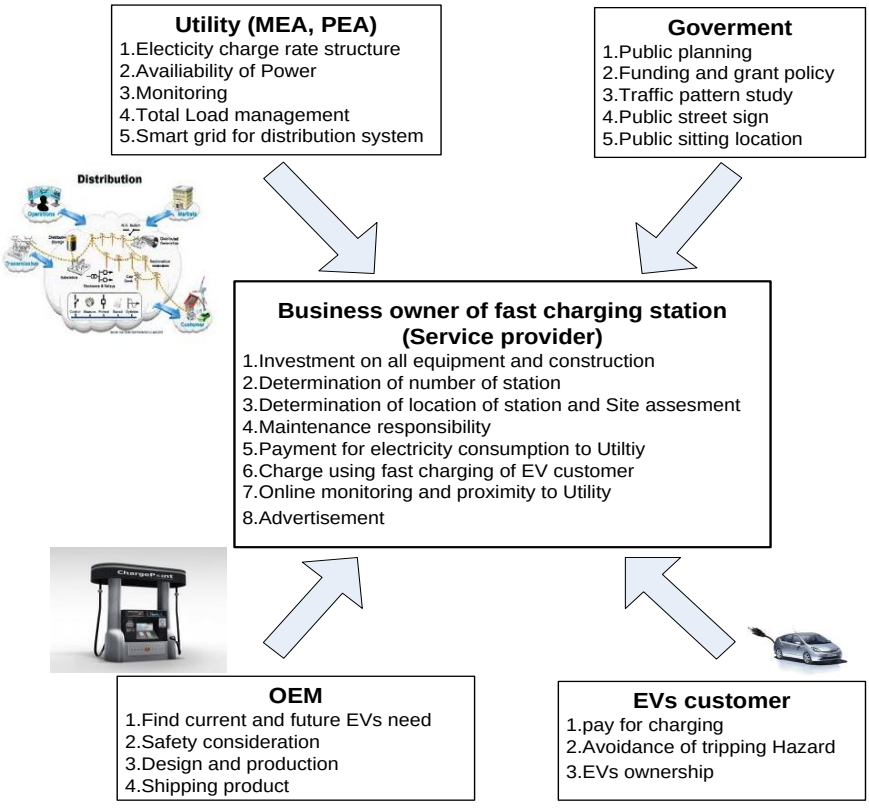

Fig. 6. Proposed service model for fast charging station in Thailand

A. EVs Customer

PHEVs or BEVs customer can use service fast charging station to charge battery. They will pay for charging to service provider through RFID pay card or other method. However, EVs customer should be careful to use fast charging to avoid danger from tripping hazard.

B. Original Equipment Manufacturer (OEM)

OEM will find need of current and future EVs customer to produce fast charging station. They have responsibility to design and produce about safety consideration. Then, they will send it to service provider.

C. Utility

Utility will determine electricity charge structure for service provider. They can control and manage smart distribution system for fast charging station. Load curve will be monitored in real time about load management function to reduce impact of more power consumption from more charging.

D. Government

Government will be important stakeholder to promote EVs for Thailand. They can grant fund for EVs customer to buy EVs in low price and fast charging station service. Moreover, they can support fast charging station in other way such as installation public street sign. Traffic pattern and public location planning should be studied by them before release policy for fast charging station.

E. Business Owner or Service Provider

They have duty in cooperation all stakeholders to construct fast charging station and service EVs for charging. Planning to determine number of station and location is responsibility before installation fast charging station. They receive service charge from EVs customer but they must invest on construction cost and maintenance expenditure. Moreover, they must operate and monitor using fast charging stations of EVs customer proximity to utility so that electric power energy from distribution system is efficiently supplied. In order to get more profit, they must promote using fast charging with EVs customer too.

IX. Barrier of Development Fast Charging Station in Thailand

A. Lack of Incentive Policy

Rate of electricity charge per kW is important factor for supporting using fast charging station. It should be supported or granted by government of Thailand. If EV customer can recharge EV battery everyday with low cost, then they will have economy fuel on travelling cost.

B. Anxiety of Battery Performance with Fast Charging

For problem of owner car, fast charging will decrease the life time of batteries. The life expectancy of the EV's battery is about 70-80 percent of capacity after 10 years of normal use. Frequent fast chargers--more than once per day--can bring to reduced performance of recharging and battery life time. The battery management systems (BMS) have to be built for protection systems to prevent the user from doing any real damage when a user is trying to fast charge the battery for a lot of times per day, the BMS could automatically slow down the charge rate. Development on BMS of MEA or PEA (In case, MEA and PEA are owner of fast charging station and service provider) will help to solve this problem.

C. Cost of BEV

Nowadays, BEVs are priced at a high level compared to similar ICE, which is caused by expensive components such as the battery or specific electric motor not being produced in large numbers yet. The government policy therefore should offer something additional to the owner to get them to buy it. In many countries financial incentives are granted in order to bring the prices of the two types of vehicles closer to each other. This incentive should be supported by Thailand government policy. Fast charging station will be installed widely if BEV is selected by most people to use it for travelling in the city.

X. Conclusion

This paper proposes direction of development of fast charging station for Thailand. Smart grid for power distribution system in Thailand is proposed to control and supply electric power to fast charging station toward EVs. Service model for fast charging station is proposed in this paper to promote it to be constructed for EVs in the future. Calculation formulation of proposed method can use to find the number of fast charging station in each area. Result from analysis benefit of fast charging in this paper will use as information for development them in the future.

References

[1] Automotive. [Online]. Available: http://blogs.automotive.com/vehicle-types/electric-vehicles/

[2] Nytimes. [Online]. Available: http://green.blogs.nytimes.com/2010/01/28/plans-for-fast-charging-stations-raise-concerns-among-california-utilities/

[3] E. Knipping and M. Duvall, "Environmental Assessment of Plug-In Hybrid Electric Vehicles: Nationwide Greenhouse Gas Emissions," *Electric Power Research Institute and Natural Resources Defense Council*, vol. 1, 2007.

[4] PHEV. [Online]. Available: http://commons.wikimedia.org/wiki/File:Plug-in_hybrid_electric_vehicle_(PHEV)_diagram.jpg

[5] Thaicarlover. [Online]. Available: http://www.thaicarlover.com/

[6] Ibtimes. [Online]. Available: http://www.ibtimes.co.uk/articles/20110718/mitsubishi-to-test-electric-vehicles-in-thailand.htm

[7] Mto. [Online]. Available: http://www.mto.gov.on.ca/english/dandv/vehicle/electric/plan-greener-ontario/buying-and-driving.shtml

[8] Aps. [Online]. Available: http://www.aps.org/units/fps/newsletters/2007/october/hafemeister.html

[9] Thaivisa. [Online]. Available: http://www.thaivisa.com/forum/topic/574498-thailands-first-ev-charging-station-opens-in-bangkok/

[10] EV PHEV Roadmap. [Online]. Available: www.iea.org/papers/EV_PHEV_Roadmap

[11] P. Jakapong and S. Chumnong, "Greenhouse Gas Emissions from Thailand's Transport Sector: Trends and Mitigation Options," *Applied Energy*, 2011.

[12] Unitjuggler. [Online]. Available: http://www.unitjuggler.com/convert-fuelconsumption-from-gperkmgasoline-to-lper100km.html

[13] Evworld. [Online]. Available: http://evworld.com/news.cfm?newsid=22591

[14] Thaivisa. [Online]. Available: http://www.thaivisa.com/forum/topic/574498-thailands-first-ev-charging-station-opens-in-bangkok/
[15] Better Place Expands Tokyo Battery Swap Trials Taxis Have Chang. [Online]. Available: http://green.autoblog.com/2010/08/27/better-place-expands-tokyo-battery-swap-trials-taxis-have-chang/
[16] Local Business in Rural Wisconsin Installs Free Ev Charging Location. [Online]. Available: http://insideevs.com/local-business-in-rural-wisconsin-installs-free-ev-charging-location/
[17] Utility Costs. [Online]. Available: http://www.boi.go.th/index.php?page=utility_costs&language=en
[18] P. Jakapong, S. Chumnong, and L. Bundit, "Land Transport Demand Analysis and Energy Saving Potentials in Thailand," *Asian Journal on Energy and Environment*, vol. 8, pp. 556-565, 2007
[19] Toyota Iq Electric Vehicle Release Next Year. [Online]. Available: http://winarco.com/toyota-iq-electric-vehicle-release-next-year/
[20] Greenhoustontx. [Online]. Available: http://www.greenhoustontx.gov/ev/pdf/longrangeevplan.pdf

Prakornchai Phonrattanasak was born in 1974 and received his B.Eng. and M.Eng. both in Engineering from Khonkaen university, Thailand in 1996 and 2002 respectively. He became a member of IACSIT in 2012. Currently, he is a lecturer at North Eastern University, Khonkaen, Thailand while pursuing his PhD in Engineering at the Department of Electrical and Computer Engineering, Thammasat university. His research interests are in the area of power system economics, optimization modelling, renewable energy and smart grid development issues.

Nopporn Leeprechanon was born in 1969 and obtained his B.Eng.(Hons) and M.Eng., both in Electrical Power Engineering from the King Mongkut Institute of Technology Ladkrabang, Thailand in 1991 and 1996 respectively, and received his PhD from Royal Melbourne Institute of Technology (RMIT University), Australia in 2003. He experienced in the power industries for several years before joining Thammasat University in 1996, He is currently an Assistant Professor within the Department of Electrical and Computer Engineering, Thammasat University. His research interests are in the area of power system economics, optimization modelling, power system planning, pricing and energy policy issues including smart grid and renewable energy development.