

OPTIMAL CHARGING STRATEGY FOR
PLUG-IN HYBRID ELECTRIC VEHICLE
USING EVOLUTIONARY ALGORITHM

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OPTIMAL CHARGING STRATEGY FOR
PLUG-IN HYBRID ELECTRIC VEHICLE
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ABSTRAK

Plug in Kendaraan Elektrik Hibrid (PHEV) telah diramal meningkat di pasaran. Ini disebabkan pengguna menghargai manfaat yang PHEV memberikan. Setiap PHEV mempunyai simpanan bateri dan perlu dicas semula. Peningkatan mengecas Plug in Kendaraan Hybrid Electric pada sistem pengagihan telah menyebabkan peningkatan dalam system dan ini telah membebankan sistem. Dalam kajian ini, satu sistem mengecas kawalan baru telah dianjurkan untuk mengawal pengecasan supaya rangkaian pengedaran tidak menjadi beban. Strategi pengecasan optimum untuk plug-in kendaraan elektrik hibrid (PHEV) telah dicadangkan dan system ini diprogram dengan menggunakan algoritma evolusi untuk mendapatkan keadaan pengecasan yang paling sesuai bagi setiap pengecasan PHEV. Strategi mengecas mengawal masa pengecasan pada Profil Kendaraan Mengecas (VCLP). VCLP diprogram menggunakan MATLAB dari data perjalanan kendaraan sebenar daripada National Household Travel Survey (NHTS). Profil cas kendaraan tersebut diuji dengan IEEE bas-30 sistem. Hasil kajian menunjukkan bahawa strategi yang dihasilkan mencapai kapasiti bateri yang ditetapkan dan telah mengurangkan beban puncak dan faktor muatan meningkat sekali gus mengurangkan kesan di rangkaian sistem kuasa.

ABSTRACT

Plug in Hybrid Electric Vehicle (PHEV) is predicted to increase on the road as for users appreciate the benefits that a PHEV can provide. Every PHEV has a battery storage and needs to be recharged. The increase of charging Plug in Hybrid Electric Vehicle on the distribution system due to the increase in number of PHEV on the road will cause overload in the system. Upon this study, a control charging system is needed to control the charging so that the distribution network is not overloaded. An optimal charging strategy for plug-in hybrid electric vehicle (PHEV) is proposed and developed by using evolutionary algorithm to obtain the most suitable charging condition for each PHEV charging. The charging strategy controls the charging time on the vehicle charging load profile (VCLP). VCLP is developed using MATLAB from the real vehicle travel data from National Household Travel Survey (NHTS). The profile is test on IEEE bus-30 system. The results showed that the developed charging strategy achieved the required battery capacity and has reduced peak load and improved load factor thus reduces impacts on power system networks.

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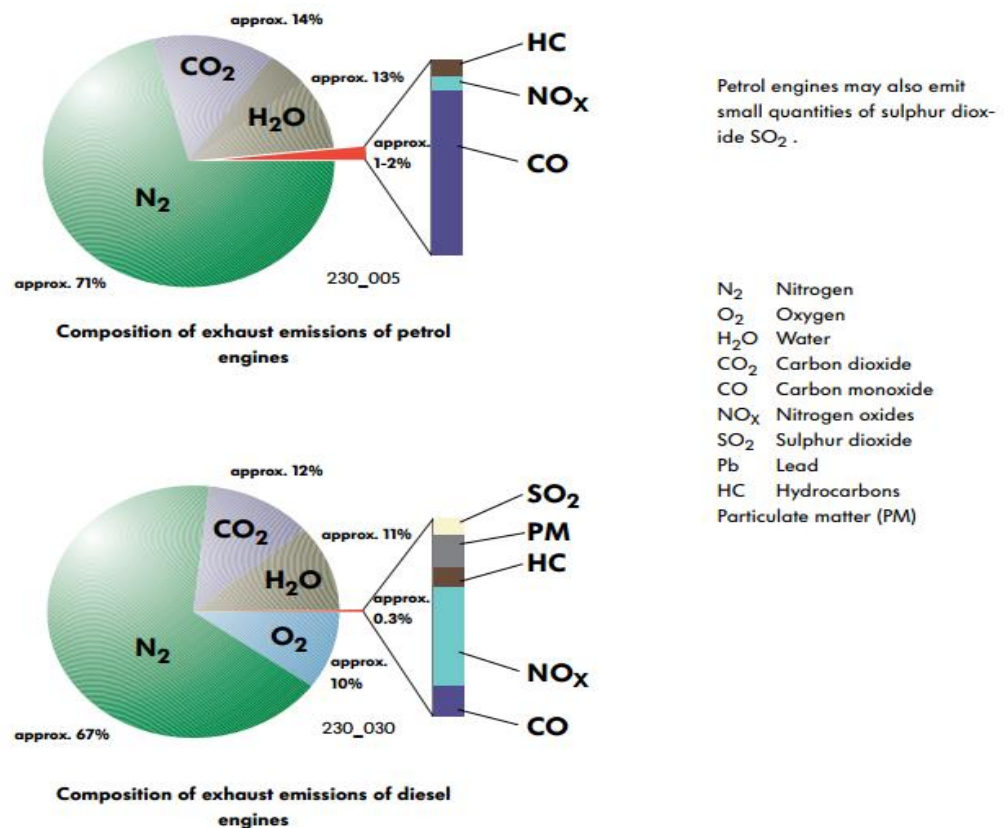
CHAPTER 1

INTRODUCTION

1.1 Project Background

Plug-in Hybrid Electric Vehicle (PHEV) is an electric vehicle which has two power sources. It has a rechargeable battery which can be recharge by plugging it into supply outlet. With a larger battery storage, and supported with gasoline makes PHEV more reliable than normal electric vehicles which solely depending on electric battery. Besides that, electric vehicle is well known for it reduced dramatically the emissions of harmful gasses after the combustion of gasoline such as carbon dioxide (CO_2) which cause greenhouse effect and global warming, carbon monoxide (CO) happens when incomplete burning, hydrocarbons (C_xH_y), nitrogen oxides (NO_x) and Particular Matter (PM) or known as soot[1].

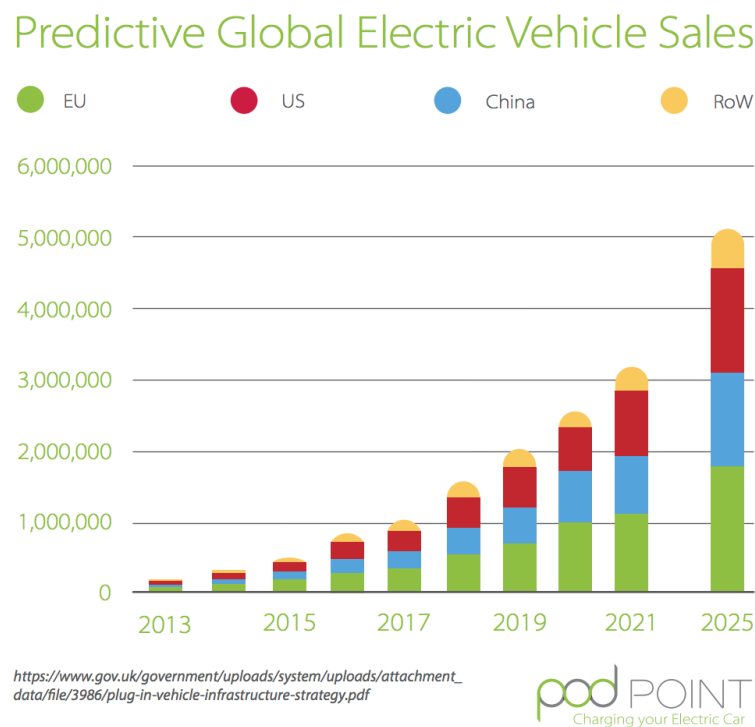
Figure 1.1 Composition of exhaust emissions of petrol and diesel engines



Moreover, PHEV reduce the dependency of country on foreign oil. The increase of EVs and PHEVs usage could result in a magnificent dent in foreign oil dependence. At present, the transportation sector is the dominant consumer of foreign oil, with the nation spending nearly \$1 billion per day on oil, sustaining this dependency. EVs and PHEVs could utilize idle electricity infrastructure to reduce foreign oil dependence by up to fifty percent, or 6.5 million barrels of oil per day.

According CEO and the founder of POD Point (UK top EV charging equipment supplier), Eric Fairbairn has present an info graphic while he was being interviewed. He did a prediction for the growth of Electric Vehicles and PHEV for the coming year base on the sales and the data collected over the past few years[2], [3].

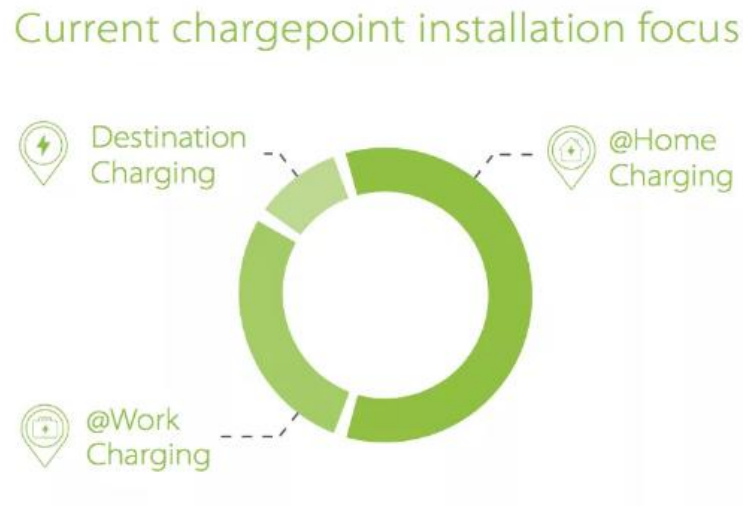
Figure 1.2 Predictive Global Electric Vehicle Sales



This clearly define that most user are being aware of the benefits that PHEV and EV can provide benefits for the user and as well as to the country. Along with the rapid increase of

purchasing PHEV and EV cars, the demand for electric supply will linearly increase. For this, the charging point for EV and PHEV should increase as well.

Figure 1.3 Current Charge point installation focus



Besides the advantages, when large amounts of PHEV are brought into the community, a serious question arises whether the power grid can handle the extra load created by charging of PHEVs in the near future. Studies have been involved to examine the effect of PHEV on power grid system and distribution systems [4]. These studies have their focus on particular power grid system network or distribution circuit. In fact, the system level impacts can be very different from one form of circuit to another; therefore, we must consider the uncertainty in PHEV charging patterns and the diversity of circuit characteristic. Regarding on the uncertainty are the absolute information such as penetration levels, charging characteristic and charging pattern both partially and temporarily that is required for a PHEV due to varying causes. Thus, multiple studies need to be applicable to any utility or country. The impacts on a power grid distribution system due to uncontrolled charging activities may result in transformers, and cables overloaded and caused infringement of early planning's limitation.

1.2 Problem Statement

Due to the increase of PHEV user in the future, charging PHEV will cause distribution system overloaded. This event is unwanted and may cause great disturbance. Power system operator must come out with strategies to overcome this problem. What are the strategies that can control the charging system for Plug-In Hybrid Electric Vehicle so that it will not cause negative impact to Power System Network?

1.3 Objective of Project

This study aims to develop an algorithm to overcome grid system overload when large numbers of PHEV are connected to the load while charging. For the said aim, three objectives are necessary.

- I. To develop an optimal charging strategy for PHEV
- II. To analyze the Vehicle Charging Load Profile (VCLP) of PHEV's
- III. To investigate the impact of VCLP to power system network

1.4 Scope of Project

- I. Form an Evolutionary Algorithm to control the charging to prevent over load
- II. Develop the Vehicle Charging Load Profile (VCLP)
- III. Test the system on IEEE 30 bus system
- IV. Use MATLAB to develop algorithm

1.5 Thesis Outlines

This thesis comprised of five chapters which are as follows; Introduction, Literature Review, Methodology, Result Analysis and Discussion, and Conclusion respectively.

Chapter 1 is the Introduction of the overall project on Optimal Charging Strategy for Plug-In Hybrid Electric Vehicle using Evolutionary Algorithm. In this chapter, Project Background, Problem Statement, Objective and Scope of the project will be discussed.

Chapter 2 will cover the discussion on the Literature Review of the project which includes various studies that are applicable in the design and development of the project. In this chapter, comparison of Plug in Hybrid with other vehicles are being discussed. Besides that, the impact of overload in distribution system and classification for control strategies will be brought out. Followed by Evolutionary algorithm and its pros and cons. By performing detail studies, the most suitable method is chosen to apply in the developing of the project.

Chapter 3 discusses about the Methodology of the project. In this chapter, the process and methods as well as data used that are employed to complete the project are discussed. Data obtain from NHTS are mentioned. Steps to calculate power consumed by each PHEV, develop electrical power system load curve based on 24hours system, develop of VCLP, develop of LFA, and develop of Algorithm which is tested on IEEE-30bus system will be discussed in detail in this section.

Chapter 4 describe the Result Analysis and Discussion of the Vehicle Charging Load Profile, Real-time load, uncontrolled load profile, IEEE 30 bus testing system, Load Flow Analysis and Optimal Charging Strategy for Plug-In Hybrid Electric Vehicle which result the controlled graph. The results are obtained from MATLAB by generating equations and programming. Details analysis and comparison are made on the data and collected results.

Chapter 5 concludes all the results, data, and findings of this project. The drawbacks and limitation of the proposed equation is discussed. Suggestions and recommendations are proposed to improve the project's reliability, and stability.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is important for every project to begin because it contains current knowledge which allows a researcher to study and understand about the applicable findings, as well as the theoretical and methodological aspects to current study. In this topic, comparison of Plug in Hybrid with other vehicles are being discussed. Besides, the impact of overload in distribution system and classification for control strategies will be brought out. Followed by Evolutionary algorithm and its pros and cons. By performing detail studies, the most suitable method is chosen to apply in the developing of the project.

2.2 Comparison of Plug in Hybrid with other vehicles

Most of all, we all acknowledge that Electric Vehicle is going to be the future of vehicle. The question is, why Plug in Hybrid Electric Vehicle, PHEV. According the Electric Vehicle World Sales Database[5], battery electric vehicles (BEV) and plug-in hybrids (PHEV) had move towards Plug-in Hybrids (PHEV) while previous years and different between the regions. China has a ratio of two EVs on one PHEV. Whereas in USA and Europe, the EV/PHEV has an approach of one PHEV to one EV. New model launches, mostly PHEV in Europe/US and mostly EVs in China play an important part in this. Europe shows diverse and interesting developments in the individual countries which depend largely on the tax & incentive structures and domestic product. Plug in hybrid electric vehicles (PHEVs) reduce fossil fuel dependence while allowing charging between vehicles and the electric grid. However, the performance and economics as well as environmental benefits of PHEVs are influenced by their charging patterns, power management strategies, and energy storage

system sizes. These three aspects are typically considered in isolation, as discussed next[6]. PHEV provides two alternatives source which will be able to switch among themselves when one source of supply is run flat. This provide great confidence for those that travelled far and to places where charging station are not common. PHEV has a larger battery capacity compare to the battery capacity in normal hybrid car. According to a survey by UCS [7], 54 percent of the responds listed that distance driven for most drivers are less than 40 miles a day. Most PHEV has a minimum battery capacity of 6.51kWh which is around 20 miles. In addition, run with electricity but not gasoline is cheaper and cleaner. Average cost for 100 miles with electricity cost \$3.45 compared to \$13.52 by driving 100 miles on gasoline. The benefits provided by PHEV promotes consumer to invest on it even after the emerged of battery electric vehicles. Even the competition is strong, but both Electric vehicles are standing strong in the car market. Because of this reason, study on PHEV charging is needed to control the penetration of PHEV in distribution networks.

2.3 Impact of Charging PHEV in distribution Networks

All PHEV needs to recharge the battery with an electrical source. Along the increase in charging of PHEV in distribution networks, the electricity demand will greatly increase, and overload in distribution networks will take place[8]. High charging load of PHEVs presence in distribution network will also lead to the increase of network losses and eventually worsen the buses voltage profile [9]. Power electronic based devices such as battery chargers are used in PHEVs. Therefore, harmonics are produced due to switching operation of power electronic elements are expected [10]. When PHEV penetration level increased, new peak loads will be created, may exceed the distribution transformer capacity result overload the transformer[4]. This is clear that without proper control of PHEV charging, large amount of charging load will be injected into the distribution system and cause negative impact to it.

2.4 Conventional Charging Strategies for PHEV

In 1989 the Impact electric vehicle (EV) for General Motors was developed by Aero Vironment Inc (AV). GM then converted the Impact from prototype to the first production-class electric vehicle, EV-1, and marketed it in 1996 and 1999. From the early days of the

Impact/EV-1 program, AV focused a great deal of attention on the charging paradigm. Issues included user safety, vehicle safety, battery chemistry, battery management systems, battery pack development, pack testing and validation, charger power electronics, vehicle/charger interface, inductive vs. conductive charging schemes, and DC delivery methods and connectors. While the first round of EVs proved unsuccessful for a variety of reasons, the movement provided many valuable lessons relative to the charging paradigm. For example, the question of inductive vs. conductive charging swung overwhelmingly toward conductive in the late-1990s, and has remained so for the new round of EVs[11].

2.4.1 Slow Charging

Slow charging will always be related to overnight charging. The charging usually last for six to eight-hour period. Slow charging used the PHEV charger, adjust according with the input voltage from the grid. A 120V, 15A (80%) service would supply a 1.4kW charger, while a 240V, 32A service would supply a 6.6kW charger [11]. A PHEV with a 5kWh battery pack, for example, would have a 1.4kW charger that allows complete recharge on the order of five hours [11].

2.4.2 Fast Charging

Fast charging is any charging rate other than slow charging. The real definition is much more complex. According Figure 2.1, which listed a few of the commonly used terms, that include fast charge, rapid charge, and quick charge. The California Air Resources Board (ARB), in their Zero Emissions Vehicle (ZEV) mandate program, lists a certification requirement for fast charging as a ten-minute charge that enables the vehicle to travel 100 miles[11].

Figure 2.1 Power Levels for DC Charging

| Type of Charge | Charger Power Level, kW | | |
|-----------------------------------|-------------------------|-----------|-------------|
| | Heavy Duty | SUV/Sedan | Small Sedan |
| Fast Charge, 10 minutes, 100% SOC | 500 | 250 | 125 |
| Rapid Charge, 15 minutes, 60% SOC | 250 | 125 | 60 |
| Quick Charge, 60 minutes, 70% SOC | 75 | 35 | 20 |
| Plug-In Hybrid, 30 Minutes | 40 | 20 | 10 |

2.5 Other Method on Smart Control Charging Strategies

Besides the conventional method being introduced at the same time with the PHEV, engineers also set their eyes on the effect of PHEV charging which overloads the distribution system. Some methods had been proposed such as Integrated Battery Charger and the help of algorithm.

2.5.1 Integrated Battery Charger

Integrated Battery Charger based on Split-winding Switched Reluctance Motor Drive was proposed [12]. The development of plug-in electric vehicle (PHEV)'s on-board battery charger received much attention. Compared with independent battery charger, the integrated battery charger can reduce the cost, the weight, the volume and so on. An integrated battery charger based on split-winding switched reluctance motor (SRM) system, the boost and buck inductances are limited by the phase winding of the motor, so the performance of the integrated battery charger is cut down [12]. In the proposed integrated motor drive, a novel converter topology and split-winding method are used to reduce the inductance and resistor of boost and buck inductances. Compared with conventional asymmetric converter, a relay and a diode are added in the proposed circuit. This topology can be rebuilt as a bridgeless buck-boost battery charger to satisfy the battery charging requirement [12].

2.5.2 Control Charging Algorithm

Controller based on fuzzy logic, which integrates an objective state-of-charge (SoC) is introduced. To fulfil these functionalities, two controllers are implemented to manage the energy flows. A first controller called home controller is turned ON when the vehicle is connected to the house and then a second controller named PHEV controller is switched ON when the vehicle is used. The goal of the home controller is to manage the remaining battery energy to help the grid to supply the household load during ON peak period and charges the battery at Off-peak period. The effect, to use an ON/OFF peak periods is to shift the battery charge from peak periods to the night and to reduce peaks using the remaining battery energy.

Therefore, the electricity price will indicate when Off-peak and ON-peak occur. Then, the home controller can use a predetermined electricity price [13].

2.6 Evolutionary Algorithm

The function of Evolutionary Algorithm (EA) is to optimize fitness which can be represented using mathematical equation. It can be used to minimize the fitness or it can be used to maximize fitness. Types of EA are classical EA, Meta EA and Adaptive EA. Mutation technique is said to be different from each type of EA. Evolutionary Algorithm must have specific operators to function which are initialization, fitness 1 computation, mutation, fitness 2 computation, combination, selection, new generation definition and lastly convergence test. Initialization is to generate random numbers. Fitness is the function or equation to be optimized. It can be single mathematical equation or a set of sub-program or subroutine. Mutation is to generate offspring or children. Combination is to combine parents and offspring. Lastly is selection which is to find the “survivors”, the optimized solution.

Evolutionary Algorithm is preferred in this project is due to its ability to use the decision variables and problem functions directly. When compare evolutionary algorithm with classical optimization methods, there are a few differences in several ways [14].

2.6.1 Random Versus Deterministic Operation

Knowing that EA relies in part on random sampling, this makes it a nondeterministic algorithm, which user may obtain different solutions on different runs; even if you haven't changed your model. In contrast, the linear, nonlinear and integer Solvers also included in the classical algorithm are deterministic methods -- it will always provide the same solution if user start with the same values in the variables.

2.6.2 Population Versus Single Best Solution

Where classical optimization methods keep a single best solution, an evolutionary algorithm maintains a population of candidate solutions. Only those that having equivalent objectives of

these is considered, but those other population are sample points in other regions of the search space, where a better solution may later be found. The practice of a population of solutions helps EA avoid staying at a local optimum, when an even better optimum might be found outside the current solution.

2.6.3 Creating New Solutions Through Mutation

An evolutionary algorithm always makes random changes or mutations in one or more members of the current population, yielding a new candidate solution which may be better or worse than present population members. There are many ways to perform a mutation, and the Evolutionary Algorithm employs three different mutation strategies. The result of a mutation may be an impracticable solution, and the Evolutionary Algorithm will attempt to repair the solution to make it convenient; but still, it is not always successful.

2.6.4 Combining Solutions Through Crossover

An evolutionary algorithm tries to create a new solution by combining elements of present solutions, with some features from each parent. The decision variable values of existing solutions are combined in a "crossover" operation. Same as mutation, there are many possible ways to perform a crossover operation, some are much better than others and some might not.

2.6.5 Selecting Solutions/ Optimized Solution

An evolutionary algorithm performs a selection to process in which the most suitable members of the population will be selected, and eliminate the least suitable members. In a constrained optimization problem, the condition for suitability depends on whether a solution is convenient or does it satisfies all the constraints, and partly on its objective function value. The selection process is the step that guides the evolutionary algorithm towards even better solutions.

2.6.6 Disadvantage of Evolutionary Algorithms

A disadvantage of any evolutionary algorithm is that a solution is considered only when it is in comparison to other or existing known solutions; this algorithm actually has no concept of a best fit solution, or any way to examine or to prove whether a solution is optimal. Therefore, evolutionary algorithms are best employed on problems where it is difficult or impossible to test for optimality. This also means that an evolutionary algorithm never stops, aside from the length of time, or the number of iterations or candidate solutions, which you wish to allow it to explore.

2.6.7 Summary

In short, from the studies and all the reviews we understand the effects and impact of overload in PHEV charging. Evolutionary Algorithm is chosen because of the ability to optimize the system by generating offspring and creating new population to achieve optimization. Therefore, Evolutionary Algorithm is chosen to fit in as the solver to optimize the charging of PHEV.

CHAPTER 3

METHODOLOGY

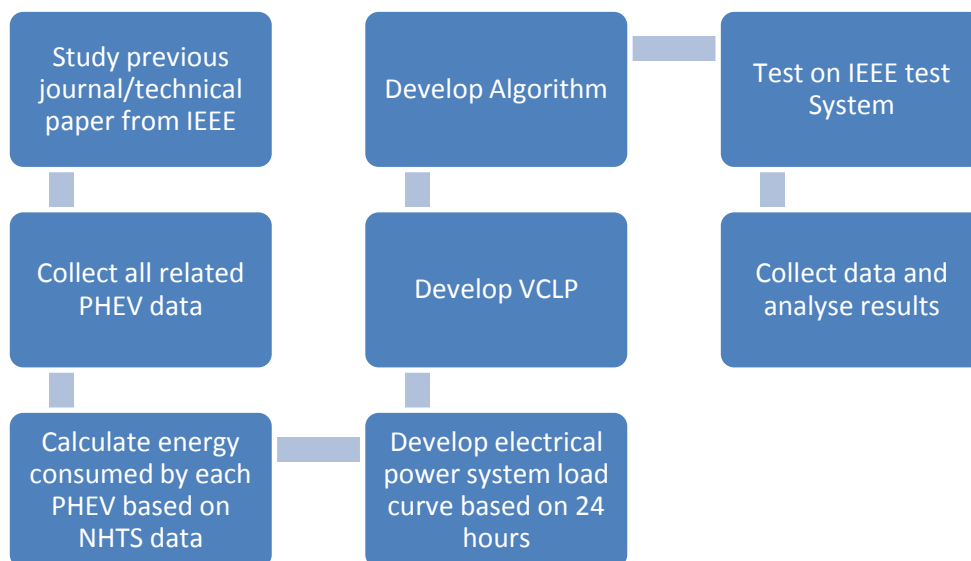
3.1 Introduction

This chapter describe about the procedure and steps that are implemented in the project. The project development process and system operation flow are discussed in flow chart. The

3.2 Project Flow Chart

The flow chart of the project is shown in Figure 3.1 to illustrate the process flow of the project.

Figure 3.1 Flow chart of the process of developing the project



3.3 Collection of Related Data

In order to create an actual Vehicle Charging Load Profile, actual data and patterns are required. NHTS data is used to develop this VCLP which is also being mentioned in the literature reveal. The total number of PHEV involve in this project is, $n=40,000$. The travel patterns, and driven distance are obtained from NHTS. There are another two parameters which are required such as the number of vehicle type used in NHTS and energy capacity of each types of PHEV.

Refer to table 3.1 and table 3.2, it shows the vehicle type which is labelled with numbers: type 1= Compact Sedan, type 2=Mid-size Sedan, type 3= Mid-size SUV and lastly type 4= Full Size SUV. From table 3.1, we noticed that most of the user in NHTS are using PHEV type 1, compact Sedan with a percentage of 60.85%.

Figure 3.1 and figure 3.2 shows the final arriving time and as well as the distance driven, miles. From the above figure data, we notice that from 15:20 till 20:20 have more than 1000 numbers of cars compare to any other period. Around 5520 vehicles driven 25-30 miles each day which is shown in figure 3.2.

3.4 Types of PHEV

Types of PHEV have different battery capacity and different energy per-mile. Four types of vehicles are chosen for examine under this study. Type 1: Compact Sedan, type 2: Mid-size Sedan, type 3: Mid-size SUV and lastly type 4: Full-size SUV. Table 3.1 showed the number and percentage of each type of PHEV and Table 3.2 showed the Energy capacity for type PHEV20

Table 3.1 Number and percentage of each type of vehicle obtain from HNTS

| PHEV Type | 1 | 2 | 3 | 4 |
|----------------------|----------|----------|----------|----------|
| Number | 24340 | 4776 | 5240 | 5644 |
| Percentage | 60.85% | 11.94% | 13.1% | 14.11% |

Table 3.2 Energy Capacity for Type PHEV-20

| Vehicle Type | Energy Capacity (kWh) PHEV-20 | kWh/mile |
|--------------|----------------------------------|----------|
| 1 | 6.51 | 0.3255 |
| 2 | 7.20 | 0.3605 |
| 3 | 8.75 | 0.4375 |
| 4 | 10.15 | 0.5075 |

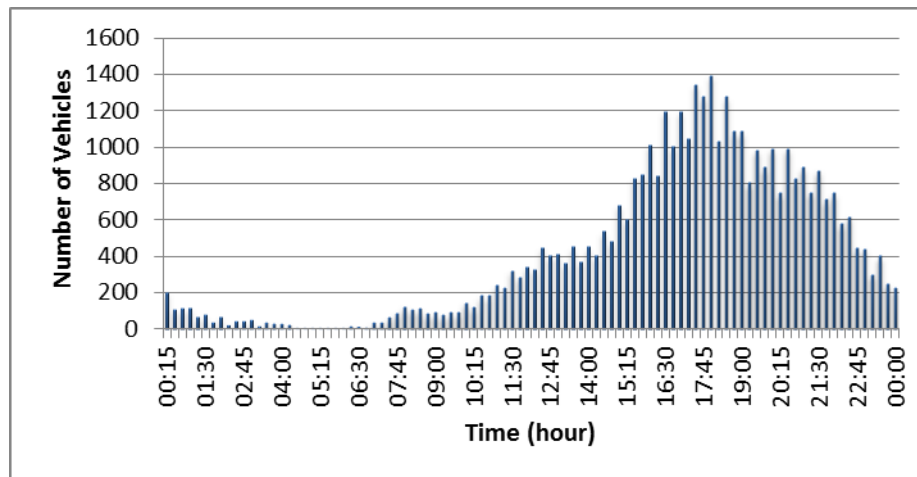
Table 3.1 show the number and percentage of each type of PHEV obtain from HNTS. Table 3.2 shows the energy capacity for type PHEV-20. Based on the tabulated data collected, we can generate and calculate for the energy consume by PHEV which is later use in developing Vehicle Charging Load Profile (VCLP).

3.5 Arriving Time and Distance Driven

3.5.1 Arriving Time

The final arriving time is mentioned and being used as the pattern of most user. User will charge their cars right after they are back from work place or other places to home. Charging take place and the time is recorded from the given data from NHTS. Once user start to charge their car, an amount of load is added into the power grid system, therefore it is important to study the arriving time.

Figure 3.2 Numbers of PHEV versus arriving time

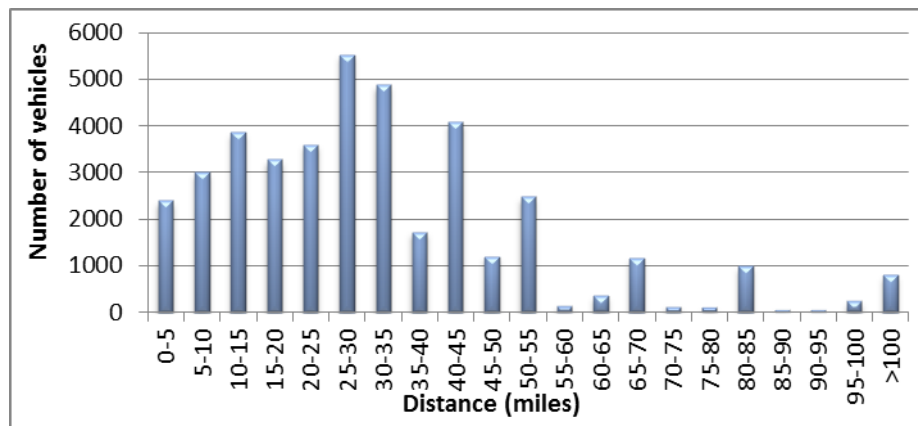


From figure 3.1, the time located for each segment is 15 minutes. From 16:30 till 19:00 is the peak numbers of PHEV return home. From 00:15 till 10:15 have only a few PHEV went back home.

3.5.2 Distance Driven

Distance Driven or also known as distance travelled will help us to know how far and how long does users travelled. With different driven miles, the energy consumption may differ. Some user did not run flat their battery for every use of PHEV. Therefore, by knowing the distance travel, we can estimate the electric energy used for the given mile driven. Calculation can be made.

Figure 3.3: Number of vehicles versus daily driven distance



Form the figure 3.2 we can notice 25-30 miles is the most driven distance compares to other distance range mentioned. Second comes 30-35 miles and followed by 40-45 miles. Distance driven average below 1000 user are 55-60 miles, 60-65 miles, 70-75 miles, 75-80 miles, 80-85 miles, 85-90 miles, and distance above 90 miles.

3.6 Charging Rate for Four types of PHEV-20

The charging rate is being set to 1.4kWh. It indicates the charging rate for each hour [11]. Slow charging such as 1.4kWh is typically link with overnight charging. This is easy to understand that we can translate it into an eight-hour period of charging for type 4 PHEV-20 with a charging rate of 1.4kWh. Table for charging rate and as well as the type section required are tabulated base on calculation and comparison can be made. The higher the charging rate, the lesser time it requires for charging to 100% state of charge.

Table 3.3 1.4kWh Hourly Charging rate for four types of PHEV-20

| Rate kWh | Hou r | 1 st | 2 nd | 3 rd | 4 th | 5 th | 6 th | 7 th | 8 th |
|-------------|----------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Type | | | | | | | | | |
| 1.4 | 1 | 1.4 | 1.4 | 1.4 | 1.4 | 0.91 | - | - | - |
| | 2 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 0.21 | - | - |
| | 3 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 0.35 | - |
| | 4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 0.35 |

3.7 PJM Hourly Integrated Real-Time LMP values for 2016 09 01

This data consists the value of Location Marginal Price (LMP) for PJM zone on 2016 September. The data used in this project is on 1st September 2016. This is not the latest data I can obtain but due to the weather and condition, it is chosen for it is more likely to obtain the normal power load flow graph as what is obtain in Malaysia. Base on the power load flow profile obtain in PJM, equation for normalize power is given as below:

$$\text{normalized load}(t) = \frac{\text{Load PJM}(t)}{\text{Average Load PJM}} \quad 3.1$$

00:15 < t < 24:00, the interval is 15 minutes

Base on the normalized load, we can change static power load obtained from IEEE 30 bus test system to create a 24 hours' load profile. This profile will later become a reference to develop real time load by the equation given:

$$\text{Real Time Load}(bus, t) = \text{IEEE30 Load}(bus) \times \frac{\text{Load PJM}(t)}{\text{Average Load PJM}} \quad 3.2$$
$$1 \leq \text{Bus} \leq 30; \quad 00:15 < t < 24:00(15 \text{ minutes interval})$$

3.8 IEEE 30-bus system

The MATLAB file for IEEE 30-bus test system was obtained from Matpower 6.1. The table shows the power for each bus in the system. The data is taken out and shown in table below, Bus Type Code [0=Load Bus; 1=Slack Bus; 2=Generation Bus]:

Table 3.4 IEEE 30-Bus Test System Simplified Power Table

| Number of Bus | Type of Bus | Power(MW) |
|---------------|-------------|-----------|
| 1 | 1 | 0 |
| 2 | 2 | 21.7 |
| 3 | 0 | 2.4 |
| 4 | 0 | 7.6 |
| 5 | 2 | 94.2 |
| 6 | 0 | 0 |
| 7 | 0 | 22.8 |
| 8 | 2 | 30 |
| 9 | 0 | 0 |
| 10 | 0 | 5.8 |
| 11 | 2 | 0 |
| 12 | 0 | 11.2 |
| 13 | 2 | 0 |
| 14 | 0 | 6.2 |
| 15 | 0 | 8.2 |
| 16 | 0 | 3.5 |
| 17 | 0 | 9 |
| 18 | 0 | 3.2 |
| 19 | 0 | 9.5 |
| 20 | 0 | 2.2 |
| 21 | 0 | 17.5 |
| 22 | 0 | 0 |
| 23 | 0 | 3.2 |
| 24 | 0 | 8.7 |
| 25 | 0 | 0 |
| 26 | 0 | 3.5 |
| 27 | 0 | 0 |
| 28 | 0 | 0 |
| 29 | 0 | 2.4 |
| 30 | 0 | 10.6 |

The data in IEEE30 bus test system is used to find the weight factor for each bus and distribute the load of PHEV among the 30 bus. The equation used is as shown below:

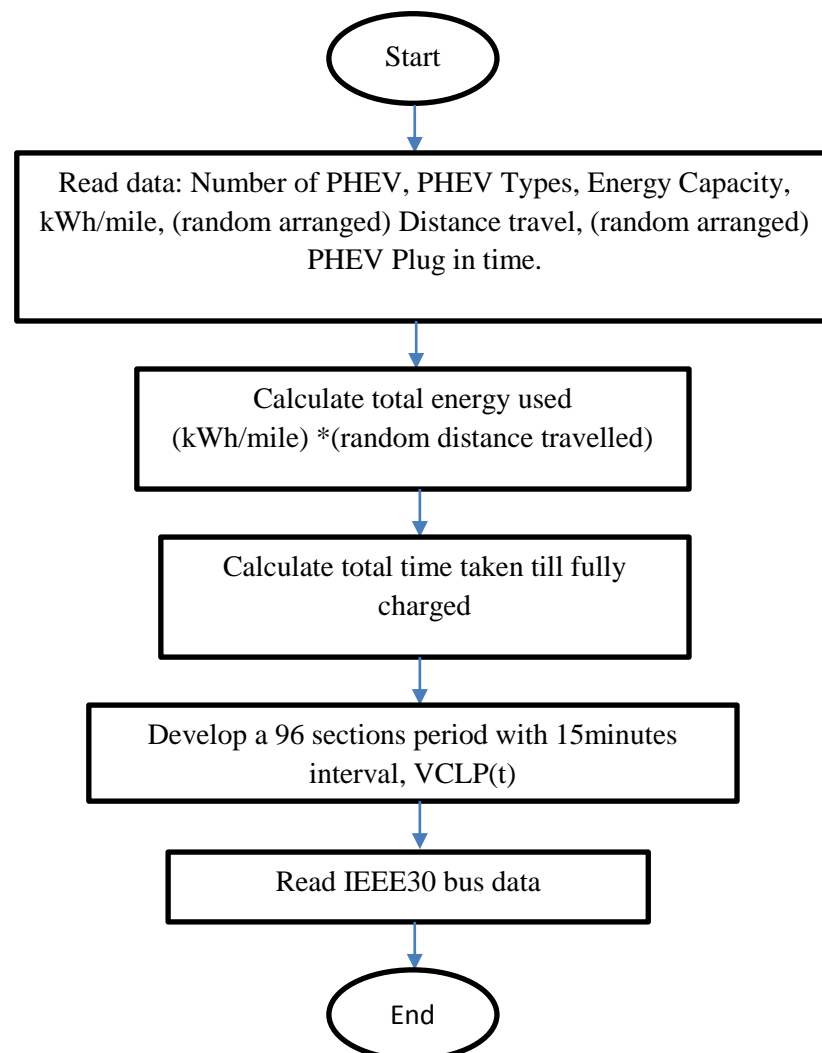
$$New\ Load(bus, t) = RealTime\ Load(bus, t) + VCLP(t) \frac{IEEE30(bus)}{Total\ Power\ of\ 30\ bus} \quad 3.3$$

$$1 \leq Bus \leq 30; \quad 00:15 < t < 24:00(15\ minutes\ interval)$$

3.9 Develop Vehicle Charging Load Profile

This section describes on the technique used to develop the VCLP base on the collected data.

Figure 3.4 Flow Chart for developing VLCP



First, key in the data obtain for Numbers of PHEV, the portion for types of PHEV, charging rate (1.4kWh due to charging at housing area), max energy capacity of each types of PHEV,

distance driven from NHTS (randomly assigned), and lastly the arrival time (randomly assigned).

Random data are obtained from this set of programming which is shown below:

```
randnumber1= randperm (40000);  
randnumber2=randnumber1(:);  
r_distance= [randnumber2 t_distance];  
s_distance=sortrows(r_distance);  
random_distance= s_distance(:,2);
```

The command randperm(a) will generate randomly assigned number for as much as “a”. Randomly assigned numbers will pair with the original data that is needed to randomize. The command sortrows will later sort the random assigned numbers back to ascending order while this results the original data being randomly sorted. Random data is created each time the run button is pressed.

For each PHEV, with random assigned distance, this generates different energy consumed by each PHEV. To calculate the energy consumed:

$$\text{Energy Consumed} = \text{Distance} \times \text{Energy Per Mile} \quad 3.4$$

We noticed that due to different energy per mile and randomly assigned distance driven, the energy consumed obtain from the equation above may differ from the max energy capacity for that energy consumed more than the max capacity will be set to its max energy capacity while those that are less than the rated energy capacity will maintain the calculated energy consumed.

After that, we need to calculate how much time needed to fully charge the batteries with charging rate of 1.4kWh. The equations to calculate the time taken is shown below:

$$Time\ to\ Fully\ Charged = \frac{Energy\ Consumed}{1.4} \quad 3.5$$

The values obtained will be in hours. To obtain an interval of 15 minutes, the obtained time will need to multiply by 4 due to every hour has four 15 minutes' intervals. We then obtain 96 intervals charging time and was stored in table1. To plot the VCLP, the charging rate for each interval are sum up. [n=numbers of PHEV; t=15 minutes interval]

$$Charge\ Load(n, t) = \sum_{n=1}^{40000} charge\ rate(n, t) \quad 3.6$$

$$1 \leq n \leq 40000 \quad ; \quad 1 \leq t \leq 96$$

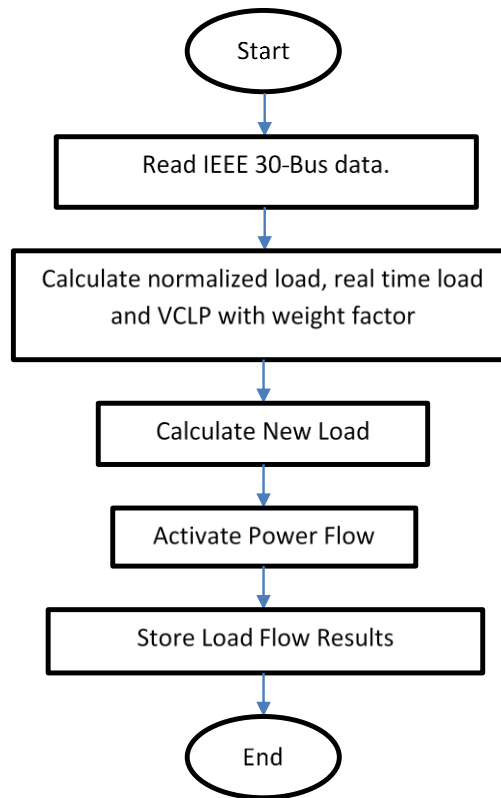
Figure 3.5 Arrange Charging load

| | 12 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 |
|----|----|----|--------|--------|--------|--------|--------|--------|--------|----|----|----|----|----|----|----|----|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 1.4000 | 1.4000 | 1.4000 | 1.4000 | 1.4000 | 1.4000 | 1.4000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

All the charging load for 40000 PHEVs are arranged in the table above. Column indicates the 15 minutes charging intervals and the row indicates the PHEV. The system is charged with 1.4kWh charging rate. The zero indicates no charging at that moment and the column is ranged from 15 to 143. This is because, column 1 till 12 are occupied with other values. 15 is the initial point and it undergo 96 intervals. Those that are charged at 2400 will have leftover time on charging and another 32 slots are reserved for the extra charge load. Total will be 15 plus 96 plus another 32 and gives you 143. The extra 32 will later be added on to the first 32 intervals. This will ensure that the leftover charging load are sum back to the system

3.10 Develop Load Flow Analysis

Figure 3.6 Flow Chart for develop Load Flow Analysis



To generate LFA, there are several steps needed to apply to obtain a real-time load from IEEE 30 bus test system and as well, to obtain the new load after the weight factor is applied on VCLP. While obtaining a Real-Time data from IEEE 30 bus test system which is given in static data from a random time, some steps are taken to obtain the real-time curve. Real-time data are obtained from PJM, regional transmission organization in North America on 1st of September 2016. By using the data from PJM, we can normalize the value obtained from PJM and multiply with the Load given in IEEE30 bus test system to generate a new load curve graph. The equation 3.1 for Normalize Load is used. This equation helps to generate the shape of a real-time load graph. By multiplying the load on each bus, we can obtain the Load Flow for each bus. Equation 3.2 for Real Time Load is used. When it comes to assign the Load of VCLP on each bus, the method being practice in this project is the weight factor. By understanding the load on each bus, we can generate an equation to divide the load according

the load in IEEE 30 bus system. The PHEV will only apply to the busses with load. The equation for weight factor is given as below:

$$weight\ factor(bus) = \frac{IEEE30(bus)}{Total\ Power\ of\ 30\ bus} \quad 3.7$$

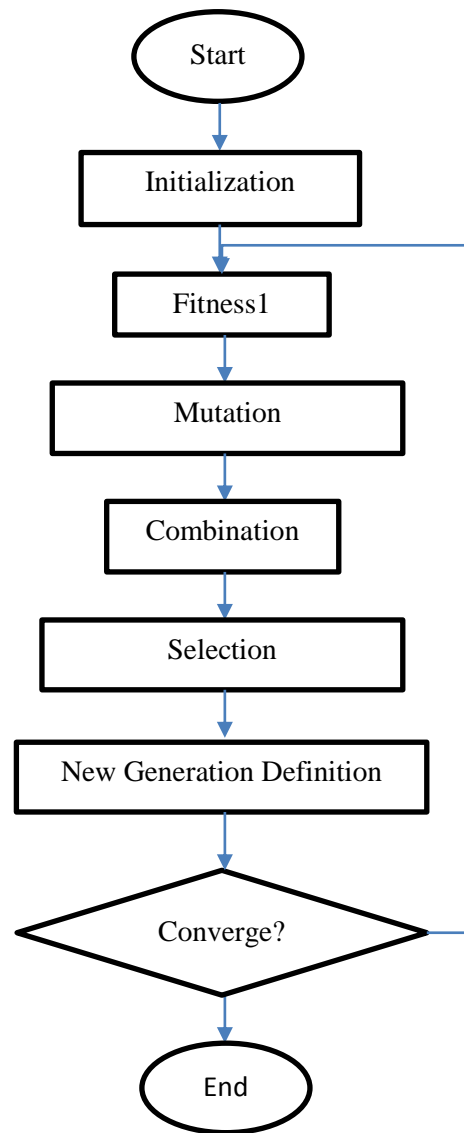
$$1 \leq bus \leq 30$$

This method is better than randomly assigned load on each bus. This is because larger load in IEEE30 simply means that it can sustain more loads than those that are lesser. If random load is assigned to the system, some of the busses might not be able to sustain the large amount of PHEV connected to it (in an actual situation). Therefore, it is wise to use weight factor method. The develop of Real Time New Load is based on the equation 3.3 for New Load. By adding the VCLP load assigned to each bus with the load presents in each bus we can obtain the new load for each bus. Load flow analysis is applied with original load from IEEE 30-bus test system being replaced by the New Load (bus, t). The Load Flow Analysis is conducted as common practice considering the VCLP attached to its load for 24 hours.

3.11 Optimize Charging Algorithm

The whole idea is to generate new charging time for each PHEV which did not satisfied the controlled charging peak load. The total load is set to be less than 500MW. As for the system, itself has a peak load of 400MW to 450MW.

Figure 3.7 Flow Chart For Evolutionary Programming Algorithm(EP)



To initialize the evolutionary programming, random numbers are generated. With the generated numbers, it is later on undergo fitness1 which is as below:

$$\text{Power of charging Load}(t) = \text{numbers of car}(t) \times (\text{charge rate}) + 3.8$$

$$IEEE30 \text{ bus load}(t)$$

The power of charging load must be less than 500MW to be accepted as acceptable population. 20 sets of populations are obtained. T is ranged from 1 to 96. From here, we can obtain the number of cars connected to the grid and charged at that interval. 20 population will

undergo mutation. Gaussian Distribution function, equation 3.9 is implemented to obtain a new set of data. Another 20 populations are generated and are called offspring.

$$X_{i+m,j} = X_{i,j} + N\left(0, B(X_{jmax} - X_{jmin})\left(\frac{f_i}{f_{max}}\right)\right) \quad 3.9$$

Combination will combine both parents and offspring together to form a 40 populations data. To select the survival of the fittest, the method used is elitism. This will minimize the fitness. We rearrange the arrangement of the population so that the minimum fitness will be on top and the maximum fitness will be at the bottom.

Convergence test is used to determine the stopping criterion. It is use to define the minimum fitness and the maximum fitness. X will be the same for all populations. Fitness1 will be the same for all populations. Fitness1=Fitness2 (mutation). With this, when fitness max minus fitness min will produce an accuracy of ϵ . ϵ is set by programmer and usually around 0.00001. Therefore, the answer you obtained will converge and become similar.

New values for charging time of PHEV is obtained and can be plot into a new graph. Values of new obtained data are stored. LFA is conducted to examine the controlled load.

3.12 Summary

This chapter successfully discuss on the data collected, equations and method used to develop VCLP, run LFA and to generate evolutionary algorithm.

CHAPTER 4

RESULTS AND DISCUSSION

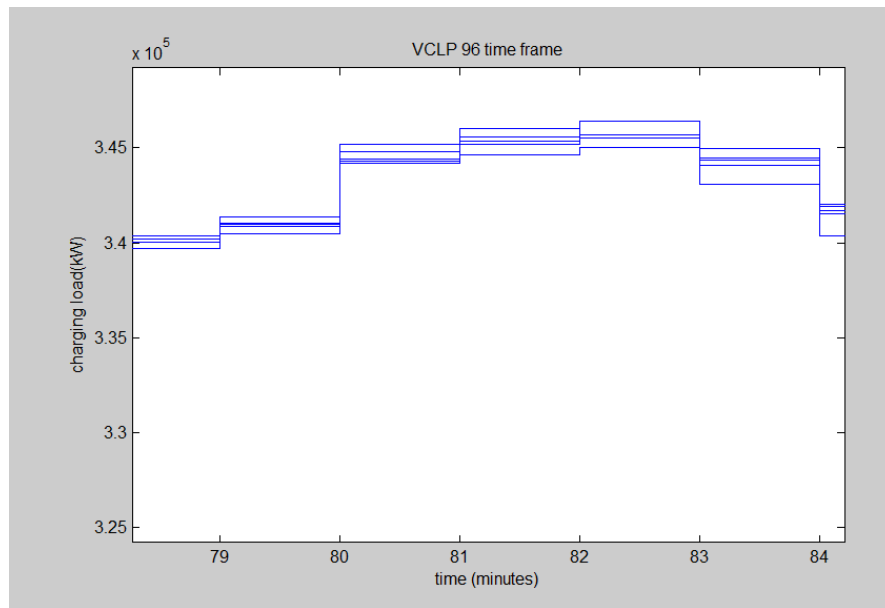
4.1 Introduction

This section will discuss all the results and findings from MATLAB. The analysis is made based on the programming and graph generated from given data. Comparison of the results with the uncontrolled load is made.

4.2 Results and Discussion on Vehicle Charging Load Profile

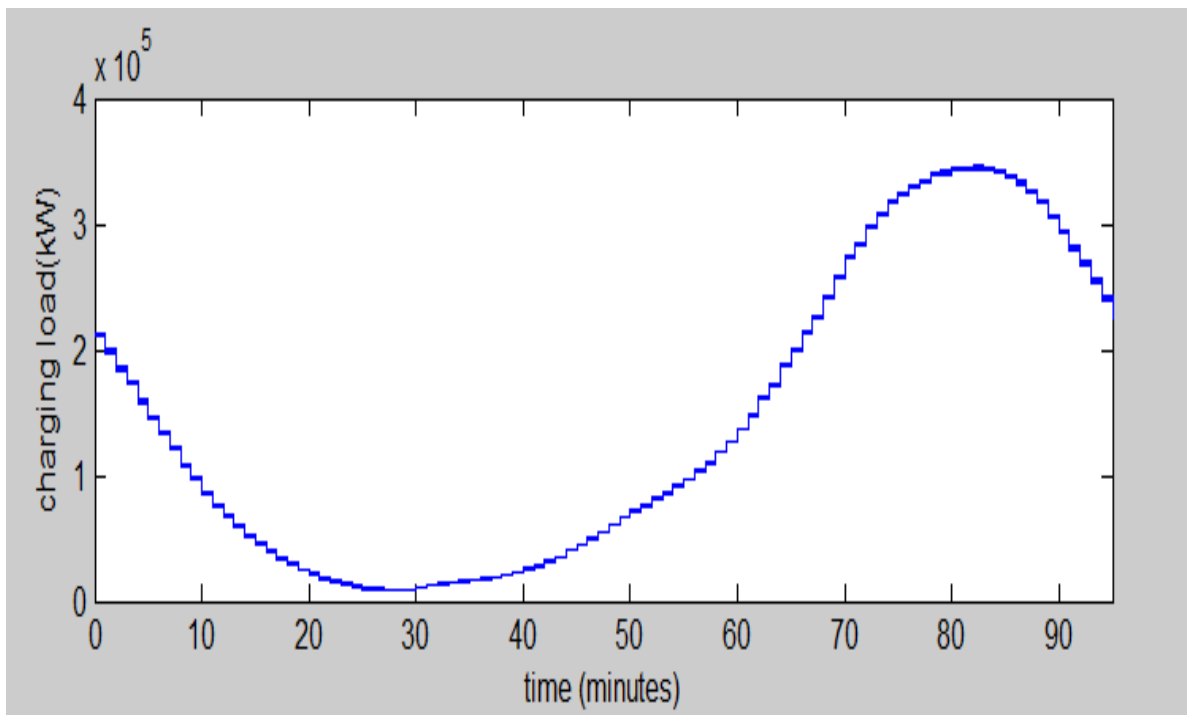
This is the first approach to start the whole project. Data from NHTS are interpret and applied to form VCLP. To have a data which is more real in nature, we try not to arrange the data to the types of vehicle manually and purposely. The best way is to randomly distributes the distance driven and as well as the start charging time. With this, we will constantly get different values each time we generate the profile. Figure 4.1 shows an enlarged section of the graph for VCLP.

Figure 4.1 Multiple data with each run in MATLAB



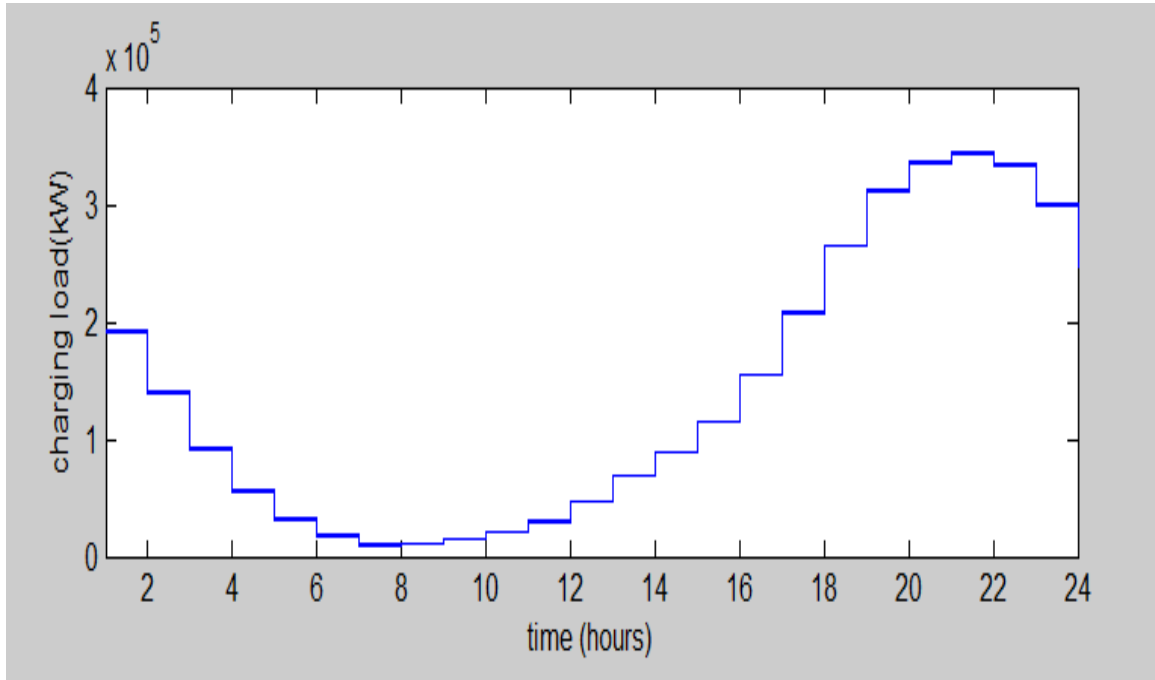
From figure 4.1, the step graph has multiple steps in one intervals due to the changes in distance driven and different start charging time. It is said to have a closer approach to the real-life data. A data of 40000 PHEVs are generated and the charging load contributed are summed together to obtain the charging load at each interval.

Figure 4.2 Vehicle Charging Load Profile in 15 minutes time frame



In figure 4.2, we manage to generate the 24 hours' vehicle charging load curve with 15 minutes' time frame. We break it into 15 minutes' time frame to have a more accurate result. The data on start charging time is given in every 15 minutes starting from 00 15. The end time is on 24 00. Besides the 15 minutes' time frame graph, we generate another 24 hours' vehicle charging load cure based on every hour.

Figure 4.3 Vehicle Charging Load Profile for every hour

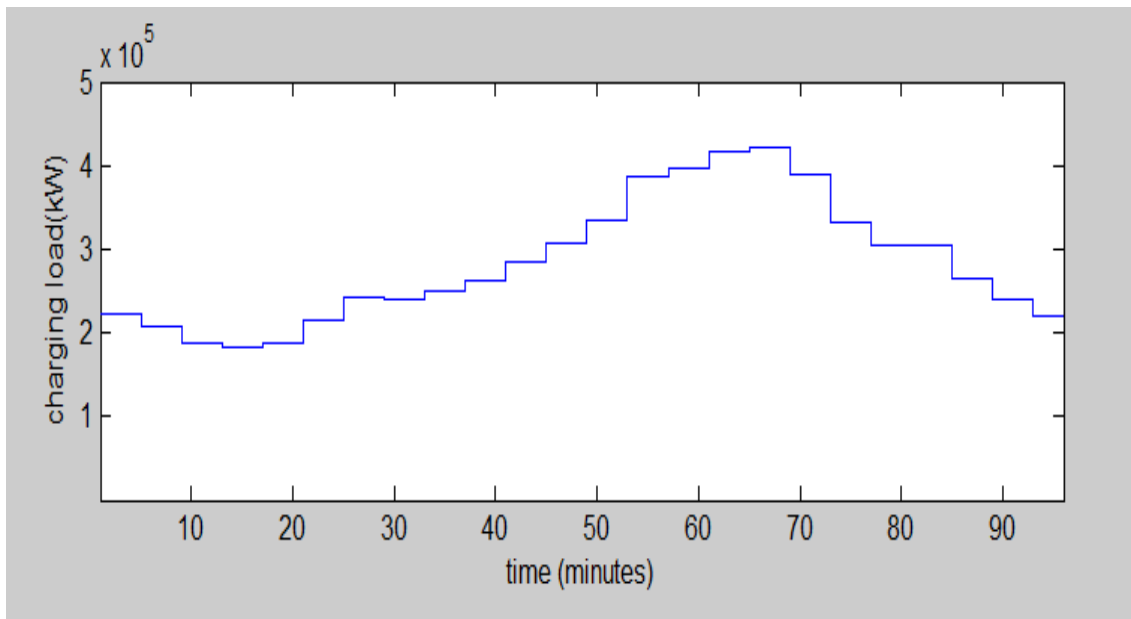


In Figure 4.3, we obtain it by sum up the four 15 minutes' intervals to find the average. 24 hourly VCLP is used to observe the profile in 24 hourly system. While generating the VCLP, we notice that 2100 till 2200 gives the highest charging load. Most of the users came back from work around that time range and causing massive charging on that time interval. We notice also the time from 0700 till 0800 has the lowest charging load. It is due to the working hours which people start their work around 0700 till 0800. Sending kids off to schools and goes to work. So, a few of them will charge their PHEV around that time.

4.3 Results and Discussion on Real Time Load Profile

As mentioned in the previous chapters, real time load is generated from a static load values from IEEE 30 bus test system and undergo normalization with a real load curve to obtain a Real-time IEEE 30 bus load profile.

Figure 4.4 Real-Time Load Profile



Static values are obtained from table 3.4. Normalized value from Location Marginal Price (LMP) for PJM zone on 2016 September is chosen. USA is having summer on September. The temperature and the condition is suitable to obtain as the normalize curve. In winter, cold temperatures increased the magnitude for internal resistance therefore affecting battery capacity [15]. Battery State of Charge, SoC will reduce and obtaining a 100% SoC is difficult. September will be the reasonable date to choose. While winter, heater load also contributes to the load profile and causes an increase in the load curve profile. In Figure 4.4, it shows that there is a peak of 422MW on 65 till 69 intervals (16 00 till 17 00) and a minimum dent of 189MW from 15 till 19 (04 00 till 05 00).

4.4 Results and Discussion on New Uncontrol Load Profile

With the VCLP and Real-time load profile, we now can generate a new uncontrol load profile. It is by equation 3.3 we manage to obtain the new load values. Sum of the VCLP and real-time load will give you a new uncontrol load.

Figure 4.5 New Uncontrol Load Profile

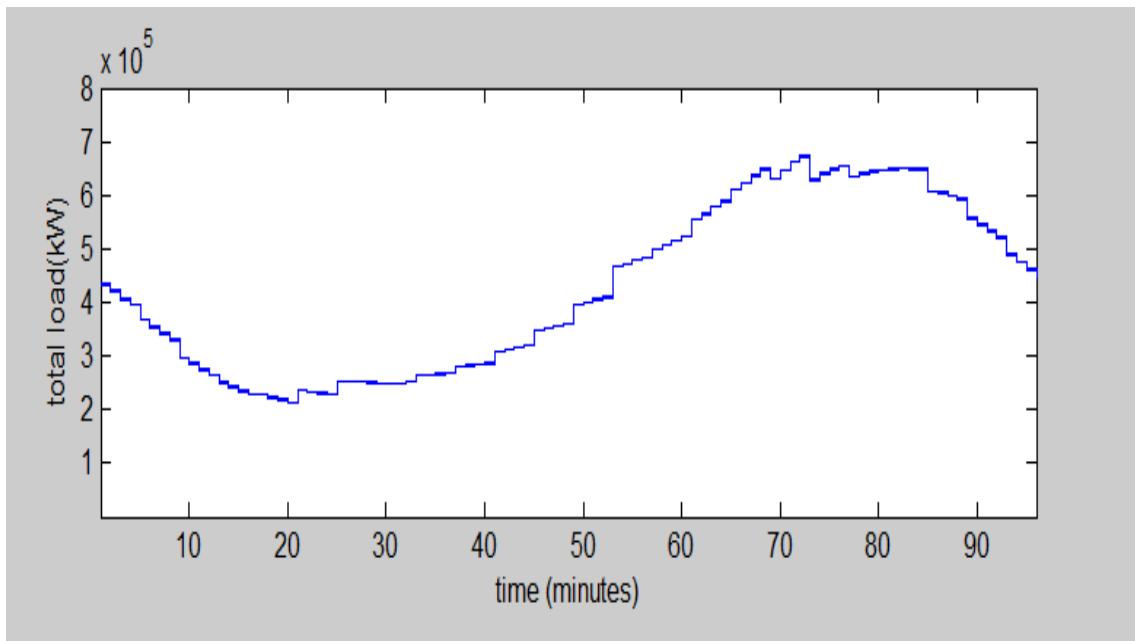
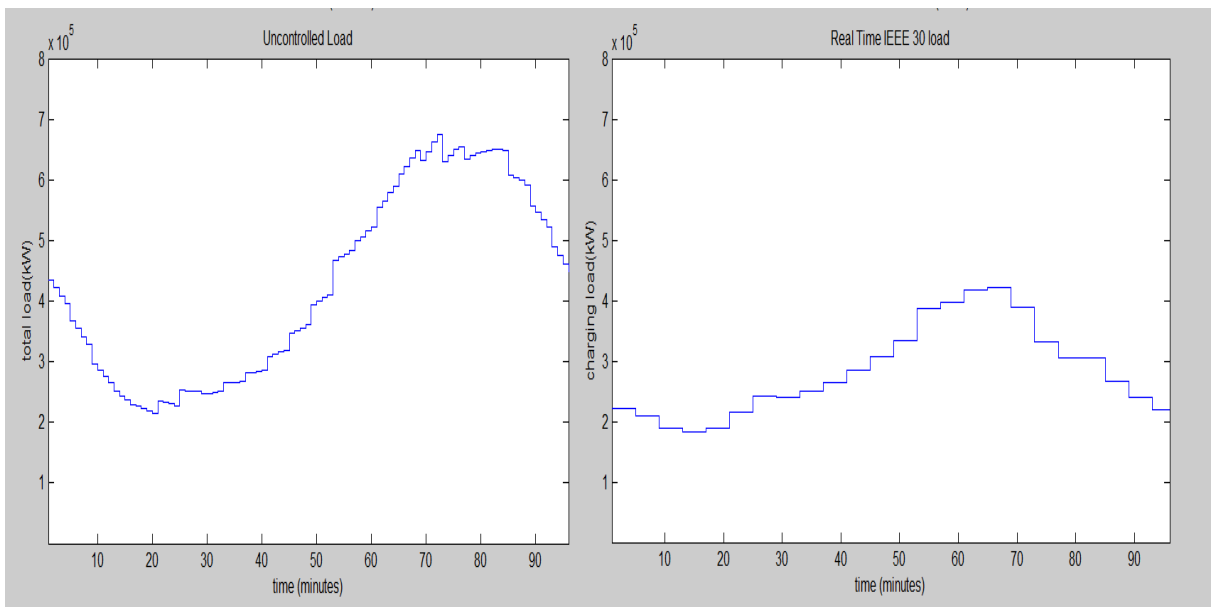


Figure 4.5 shows us the total load in the distribution system when charging load of VCLP is added into the system. This will contribute a peak load of 687MW and a minimum load of 213MW.

Figure 4.6 Comparison of New Uncontrol load with Real-Time IEEE 30 load



In Figure 4.6, we observe that a sharp increase at the peak load with a difference of 252MW. That is a massive increase of load contributed by the PHEV charging at that moment. The distribution network has a high peak load the same way as the VCLP, this is why the peak load

for the uncontrolled load has massive increase and therefore will result in overload for under designed distribution system. Load flow analysis is carried out.

Figure 4.7 Load Flow Analysis for New Uncontrol Load Profile at maximum

| | | | | | | |
|------------|----|---------|---------|---------|---------|--------|
| 24 | | -19.555 | -5.684 | 20.364 | | |
| | 22 | -12.950 | -5.270 | 13.982 | 0.293 | 0.456 |
| | 23 | -4.141 | -2.684 | 4.934 | 0.042 | 0.086 |
| | 25 | -2.464 | 2.269 | 3.349 | 0.028 | 0.048 |
| 25 | | 0.000 | 0.000 | 0.000 | | |
| | 24 | 2.491 | -2.221 | 3.337 | 0.028 | 0.048 |
| | 26 | 8.137 | 3.831 | 8.993 | 0.270 | 0.403 |
| | 27 | -10.628 | -1.610 | 10.749 | 0.166 | 0.316 |
| 26 | | -7.867 | -3.427 | 8.581 | | |
| | 25 | -7.867 | -3.427 | 8.581 | 0.270 | 0.403 |
| 27 | | 0.000 | 0.000 | 0.000 | | |
| | 25 | 10.794 | 1.926 | 10.964 | 0.166 | 0.316 |
| | 28 | -42.103 | -10.037 | 43.283 | 0.000 | 9.355 |
| | 29 | 14.559 | 3.895 | 15.071 | 0.630 | 1.189 |
| | 30 | 16.750 | 4.216 | 17.273 | 1.205 | 2.267 |
| 28 | | 0.000 | 0.000 | 0.000 | | |
| | 27 | 42.103 | 19.392 | 46.354 | 0.000 | 9.355 |
| | 8 | 0.539 | -18.945 | 18.953 | 0.219 | -3.108 |
| | 6 | -42.641 | -0.447 | 42.644 | 0.366 | -9.843 |
| 29 | | -5.394 | -1.341 | 5.559 | | |
| | 27 | -13.929 | -2.706 | 14.190 | 0.630 | 1.189 |
| | 30 | 8.535 | 1.365 | 8.643 | 0.255 | 0.482 |
| 30 | | -23.825 | -2.831 | 23.993 | | |
| | 27 | -15.546 | -1.948 | 15.667 | 1.205 | 2.267 |
| | 29 | -8.280 | -0.883 | 8.327 | 0.255 | 0.482 |
| Total loss | | | | 126.723 | 445.959 | |

From figure 4.7, the Load Flow Analysis, LFA is generated using MATLAB on IEEE 30 bus test system. The loads are being distributed according the weight factor, equation 3.7 and LFA is run for the uncontrol load profile. The above data shows the analysis from bus 1 to bus 30 but due to the space provided it was cut off from bus number 24 until bus number 30. The total

losses are 126.723MW and 445.959MVAR when it is at peak load period where most PHEVs are connected to the distribution network.

Figure 4.8 Load Flow Analysis for New Uncontrol Load Profile at minimum

| | | | | | | |
|------------|----|---------|--------|--------|---------|---------|
| 25 | | 0.000 | 0.000 | 0.000 | | |
| | 24 | 1.653 | -2.157 | 2.718 | 0.015 | 0.026 |
| | 26 | 5.039 | 2.843 | 5.786 | 0.091 | 0.136 |
| | 27 | -6.692 | -0.685 | 6.727 | 0.053 | 0.101 |
| 26 | | -4.948 | -2.707 | 5.640 | | |
| | 25 | -4.948 | -2.707 | 5.640 | 0.091 | 0.136 |
| 27 | | 0.000 | 0.000 | 0.000 | | |
| | 25 | 6.745 | 0.786 | 6.790 | 0.053 | 0.101 |
| | 28 | -25.755 | -5.270 | 26.288 | 0.000 | 2.865 |
| | 29 | 8.854 | 2.217 | 9.128 | 0.192 | 0.362 |
| | 30 | 10.156 | 2.267 | 10.406 | 0.363 | 0.683 |
| 28 | | 0.000 | 0.000 | 0.000 | | |
| | 27 | 25.755 | 8.135 | 27.009 | 0.000 | 2.865 |
| | 8 | 0.682 | -6.134 | 6.172 | 0.012 | -4.040 |
| | 6 | -26.437 | -2.001 | 26.513 | 0.128 | -11.855 |
| 29 | | -3.393 | -1.059 | 3.555 | | |
| | 27 | -8.663 | -1.855 | 8.859 | 0.192 | 0.362 |
| | 30 | 5.269 | 0.796 | 5.329 | 0.076 | 0.143 |
| 30 | | -14.987 | -2.236 | 15.152 | | |
| | 27 | -9.793 | -1.583 | 9.920 | 0.363 | 0.683 |
| | 29 | -5.194 | -0.653 | 5.234 | 0.076 | 0.143 |
| Total loss | | | | 39.985 | 111.735 | |

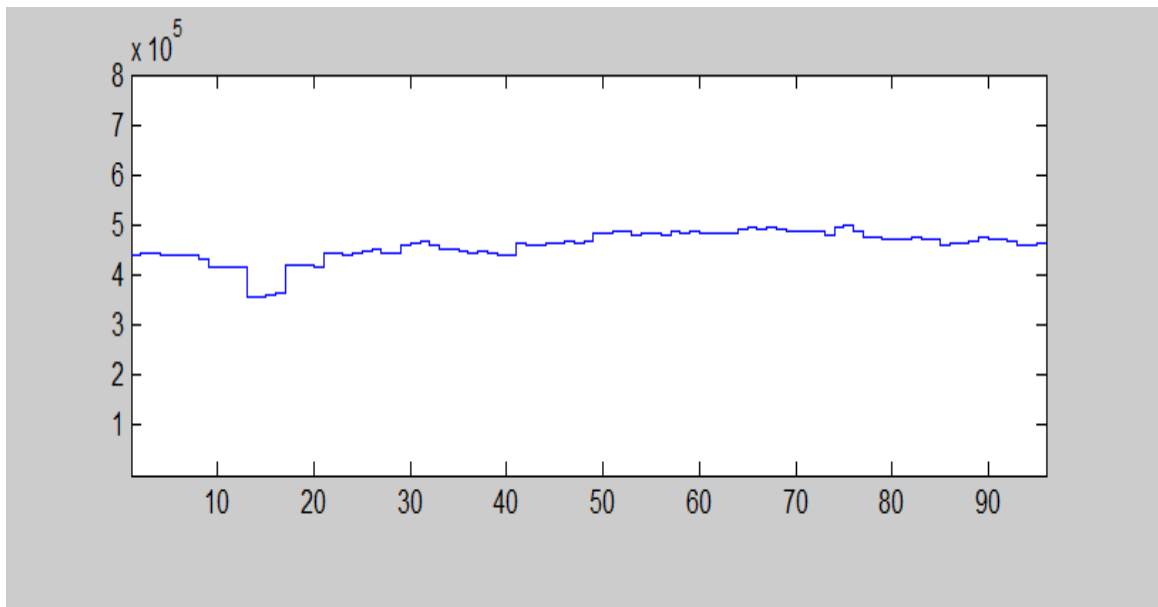
Figure 4.8 shows the total losses are 30.985MW and 111.735MVAR when it is at minimum load period where lesser PHEVs are connected to the distribution network. From both figure 4.7 and figure 4.8, it is also observed that both the real and reactive power loss exhibits an increase in the penetration of the PHEV charging [16]. This indicates that at the penetration when PHEV injection was low, the PHEV contributed positively to the network by contributing lesser losses to the system. However, as the penetration increases both the active and the reactive power loss began to increase which we can observe in Figure 4.7, meaning

that, at higher penetration of PHEV, the real and reactive power loss increase. This will cause the system to suffer from poor power factor. The figures also show that there is a penetration level at which the real and reactive power loss is minimum which is shown in Figure 4.8.

4.5 Results and Discussion on Controlled Load Profile

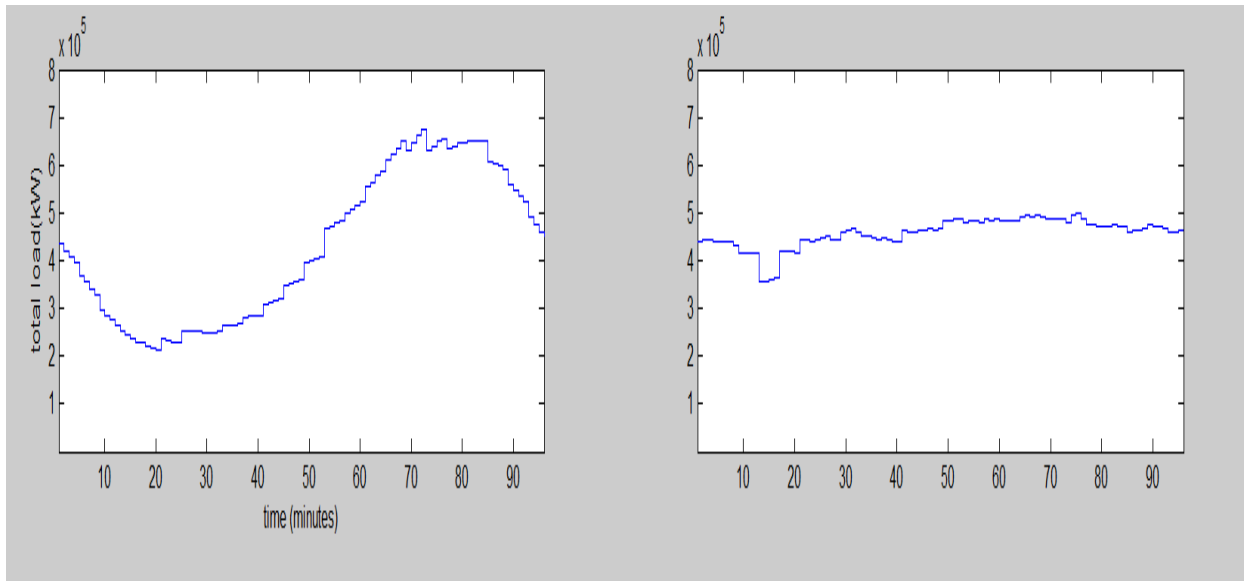
The suggested evolutionary algorithm was implemented and the new controlled load value was obtained. This is the final output graph and the objective of this project.

Figure 4.9 Controlled Load Profile



In Figure 4.9, implementation of optimization for charging using evolutionary algorithm provides a nearly ideal outcome which the utility is hoping to see in the distribution network curve. The total load is maintained at the level of more than 300MW and less than 500MW. The algorithm function in a way that the PHEV charging will be limited between 300MW and 500MW depending on the PHEV presence in the system. This will prevent the PHEV charging to overload the system. PHEV that is presence in the peak load period will be readjust the charging time. Most of the charging at peak load will be moved to the part where the distribution network is at minimum load. The excessive charging at peak load will be filling up the minimum load dent and therefore we can have a slightly flat and ideal curve load line.

Figure 4.10 Comparison of Uncontrolled Load profile with Controlled Load Profile



From Figure 4.10 we observed that the new generated load has a significant peak load drop compared to the uncontrolled load profile. The new controlled load curve has a maximum peak of 489MW and with a minimum load of 364MW. Load Flow Analysis is carried out and we obtained lesser overall losses compare to LFA generated for Uncontrolled Load Profile.

Figure 4.11 Load Flow Analysis on Controlled Load Profile

| | | | | | | |
|------------|----|---------|--------|--------|--------|---------|
| 25 | | 0.000 | 0.000 | 0.000 | | |
| | 24 | 1.245 | -1.746 | 2.145 | 0.008 | 0.014 |
| | 26 | 3.343 | 2.091 | 3.943 | 0.038 | 0.056 |
| | 27 | -4.588 | -0.345 | 4.601 | 0.022 | 0.042 |
| 26 | | -3.305 | -2.035 | 3.882 | | |
| | 25 | -3.305 | -2.035 | 3.882 | 0.038 | 0.056 |
| 27 | | 0.000 | 0.000 | 0.000 | | |
| | 25 | 4.610 | 0.387 | 4.627 | 0.022 | 0.042 |
| | 28 | -17.132 | -3.327 | 17.453 | 0.000 | 1.134 |
| | 29 | 5.837 | 1.473 | 6.020 | 0.075 | 0.142 |
| | 30 | 6.686 | 1.467 | 6.845 | 0.141 | 0.266 |
| 28 | | 0.000 | 0.000 | 0.000 | | |
| | 27 | 17.132 | 4.462 | 17.704 | 0.000 | 1.134 |
| | 8 | 0.576 | -1.090 | 1.233 | 0.001 | -4.374 |
| | 6 | -17.708 | -3.372 | 18.027 | 0.053 | -13.153 |
| 29 | | -2.267 | -0.796 | 2.402 | | |
| | 27 | -5.762 | -1.332 | 5.914 | 0.075 | 0.142 |
| | 30 | 3.495 | 0.535 | 3.536 | 0.029 | 0.055 |
| 30 | | -10.010 | -1.681 | 10.151 | | |
| | 27 | -6.545 | -1.201 | 6.654 | 0.141 | 0.266 |
| | 29 | -3.466 | -0.480 | 3.499 | 0.029 | 0.055 |
| Total loss | | | | 15.411 | 13.693 | |

Figure 4.11 shows the power flow and losses in all bus are 15.411MW and 13.693MVAR. From here we can say that the losses has reduced and this actually support our objectives and provide us with a better power factor for distribution and generation network [16]. Compare with Figure 4.8, the differences obtain are 111.312MW and 432.266MVAR. A load flow study should be performed during the planning design stages of a power system and when evaluating changes to an existing system. The system voltages remain within specified limits under operating conditions, and transformers and conductors will not overload.

4.6 Financial Report

The financial report to carry out this project is shown in Table 4.1. From the information in Table 4.5, it could be concluded that the total set up cost for the optimization charging algorithm is RM 0.00. The financial information is important to commercialize the product. By taking the expenses of the project as reference, the selling price of the product can be estimated with consideration of reasonable profit.

Table 4.1 Item cost

| Items | Cost (RM) |
|--------------|-----------------|
| Laptop | Own Properties |
| MATLAB 2010a | Student Version |

4.7 Conclusion

In short, the expected result is achieved but some policy while using this Algorithm will be introduced due to some limitation such as unable to fasten up the charging process and unable to have a SoC more than 80%. But overall, we manage to reduce the peak load and the controlled load profile is generated.

CHAPTER 5

CONCLUSION

5.1 Introduction

This study aims to develop an algorithm to overcome grid system overload when large numbers of PHEV are connected to the load while charging. The developed algorithm can generate VCLP, Real-time IEEE 30 bus load Profile, Uncontrolled Load Profile and lastly the controlled load profile with the given data. LFA is done and the result was satisfied. The load peak was controlled and the charging is maintained at a SoC of 80%.

5.2 Limitation of the Algorithm

As what has been mentioned throughout the project, the drawback of this algorithm is that user cannot achieve a SoC of 100%. To maximize the fitness, all SoC has been limited to 80%. This is however not user friendly. To allow other PHEV to have places to charge, when one battery is reached 80% SoC, the charge rate will become zero and stop charging the PHEV. Another PHEV that is not having an 80% SoC will replace the charging period and continue to charge until 80% State of Charge.

Besides that, the charging time will be prolonged when we implement this charging algorithm. This is due to the readjustment of start charging time and delay the actual charging period. When a person has a flat PHEV, and plug in the charger to charge the battery at peak load, the algorithm will stop the charging or may not stop depending on the condition of the distribution network load profile. The start charging time will be postponed even when the charger is plugged in. When there are empty slots, the charging will be able to take place.

5.3 Improvement of the Algorithm

The overcome the limitation, the algorithm must be able to adjust the charging rate for the PHEV. This will allow the PHEV to undergo fast charging at minimum load and slow charging at peak load. This will reduce the charging time and will be able to provide a State of Charge of over 90%.

An extra battery can be installed to the system, while the distribution network is at minimum load, the system can charge the battery. When the distribution network is at peak load, the battery will switch with the distribution network and charge the PHEV. This will assure the user to always have their PHEV charged up no matter what condition happened in the distribution system.

5.4 Conclusion

In a nut shell, the objective of the project has been achieved as the algorithm to optimize charging of PHEV has been developed successfully. Moreover, all the objective and scope of the project has been achieved successfully with the method proposed. Knowledge on MATLAB has been practice in this project.

Due to the limitation, the algorithm may not be able to provide a more than 85% SoC and the charging time has been prolonged. But overall, the algorithm need to be revised and better algorithm can be developed to optimized the charging system and as well as provide more than 90% SoC and reduce the charging time as well as provide a more reliable charging experience.

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APPENDIX A

MATLAB CODING FOR THE WHOLE PROJECT

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                %New Script%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%PCLP_PHEV Data formatted as below
% coloum
% 1      : vehicle_types (1,2,3,4)
% 2      : miles driven;
% 3      : battery capacity(phev-20);
% 4      : EPM;
% 5      : Arrival time(minutes);
% 6      : Energy consumed by each phev.
% 7      : Required charging time - Data in coloumb #7,8,9 not being
used
% 8      : round(charging time)
% 9      : ceil(charging time)
% 10     : Energy used / charging energy required
% 15-120: charging step allocation on 15 minutes time frame
% 126    : sum of the charging steps for every 15 minutes

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                %vehicle_types%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

type1= ones(24340,1);
type2= ones(4776,1)*2;
type3= ones(5240,1)*3;
type4= ones(5644,1)*4;

vehicletypes= [type1; type2; type3; type4];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                %battery capacity(phev-20)%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

EC_type1= ones(24340,1)*6.51;
EC_type2= ones(4776,1)*7.21;
EC_type3= ones(5240,1)*8.75;
EC_type4= ones(5644,1)*10.15;

EC_total= [EC_type1; EC_type2; EC_type3; EC_type4];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                %miles driven%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

m0_5= randi([1,5],2400,1);
m5_10= randi([6,10],3000,1);
m10_15= randi([11,15],3852,1);
m15_20= randi([16,20],3280,1);
m25_30= randi([26,30],5520,1);
m30_35= randi([31,35],4880,1);
```

```

m35_40= randi([36,40],1720,1);
m20_25= randi([21,25],3600,1);
m40_45= randi([41,45],4080,1);
m45_50= randi([46,50],1200,1);
m50_55= randi([51,55],2480,1);
m55_60= randi([56,60],132,1);
m60_65= randi([61,65],348,1);
m65_70= randi([66,70],1148,1);
m70_75= randi([71,75],120,1);
m75_80= randi([76,80],104,1);
m85_85= randi([81,85],988,1);
m80_85= randi([81,85],988,1);
m85_90= randi([86,90],56,1);
m90_95= randi([91,95],52,1);
m95_100= randi([96,100],240,1);
m100plus= randi([101,120],800,1);

t_distance=[m0_5;m5_10;m10_15;m15_20;m20_25;m25_30;m30_35;m35_40;m40_4
5;m45_50;m50_55;m55_60;m60_65;m65_70;m70_75;m75_80;m80_85;m85_90;m90_9
5;m95_100;m100plus];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                %EPM%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

EPM_type1= ones(24340,1)*0.3255;
EPM_type2= ones(4776,1)*0.3605;
EPM_type3= ones(5240,1)*0.4375;
EPM_type4= ones(5644,1)*0.5075;

EPM_total= [EPM_type1; EPM_type2; EPM_type3; EPM_type4];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                %Arrival time(minutes)%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

start10=ones(200,1)*10;
start11=ones(108,1)*11;
start12=ones(112,1)*12;
start13=ones(116,1)*13;
start14=ones(68,1)*14;
start15=ones(76,1)*15;
start16=ones(36,1)*16;
start17=ones(68,1)*17;
start18=ones(20,1)*18;
start19=ones(40,1)*19;
start20=ones(40,1)*20;
start21=ones(48,1)*21;
start22=ones(16,1)*22;
start23=ones(36,1)*23;
start24=ones(32,1)*24;
start25=ones(28,1)*25;
start26=ones(24,1)*26;
start27=ones(4,1)*27;
start28=ones(4,1)*28;
start29=ones(4,1)*29;
start30=ones(4,1)*30;
start31=ones(4,1)*31;
start32=ones(4,1)*32;

```



```

start33=ones(8,1)*33;
start34=ones(16,1)*34;
start35=ones(12,1)*35;
start36=ones(10,1)*36;
start37=ones(36,1)*37;
start38=ones(36,1)*38;
start39=ones(64,1)*39;
start40=ones(68,1)*40;
start41=ones(124,1)*41;
start42=ones(168,1)*42;
start43=ones(112,1)*43;
start44=ones(84,1)*44;
start45=ones(92,1)*45;
start46=ones(76,1)*46;
start47=ones(92,1)*47;
start48=ones(92,1)*48;
start49=ones(144,1)*49;
start50=ones(120,1)*50;
start51=ones(184,1)*51;
start52=ones(184,1)*52;
start53=ones(240,1)*53;
start54=ones(224,1)*54;
start55=ones(320,1)*55;
start56=ones(284,1)*56;
start57=ones(340,1)*57;
start58=ones(328,1)*58;
start59=ones(448,1)*59;
start60=ones(400,1)*60;
start61=ones(412,1)*61;
start62=ones(360,1)*62;
start63=ones(452,1)*63;
start64=ones(368,1)*64;
start65=ones(452,1)*65;
start66=ones(400,1)*66;
start67=ones(536,1)*67;
start68=ones(480,1)*68;
start69=ones(680,1)*69;
start70=ones(604,1)*70;
start71=ones(828,1)*71;
start72=ones(844,1)*72;
start73=ones(1012,1)*73;
start74=ones(842,1)*74;
start75=ones(1196,1)*75;
start76=ones(1000,1)*76;
start77=ones(1196,1)*77;
start78=ones(1044,1)*78;
start79=ones(1344,1)*79;
start80=ones(1276,1)*80;
start81=ones(1392,1)*81;
start82=ones(1028,1)*82;
start83=ones(1276,1)*83;
start84=ones(1084,1)*84;
start85=ones(1084,1)*85;
start86=ones(804,1)*86;
start87=ones(984,1)*87;
start88=ones(888,1)*88;
start89=ones(992,1)*89;
start90=ones(748,1)*90;
start91=ones(992,1)*91;
start92=ones(824,1)*92;
start93=ones(888,1)*93;

```

```

start94=ones(752,1)*94;
start95=ones(872,1)*95;
start96=ones(712,1)*96;
start97=ones(748,1)*97;
start98=ones(576,1)*98;
start99=ones(616,1)*99;
start100=ones(444,1)*100;
start101=ones(440,1)*101;
start102=ones(300,1)*102;
start103=ones(400,1)*103;
start104=ones(248,1)*104;
start105=ones(184,1)*105;

start_time_all=[start10; start11; start12; start13; start14; start15;
start16; start17; start18; start19; start20; start21; start22;
start23; start24; start25; start26; start27; start28; start29;
start30; start31; start32; start33; start34; start35; start36;
start37; start38; start39; start40; start41; start42; start43;
start44; start45; start46; start47; start48; start49; start50;
start51; start52; start53; start54; start55; start56; start57;
start58; start59; start60; start61; start62; start63; start64;
start65; start66; start67; start68; start69; start70; start71;
start72; start73; start74; start75; start76; start77; start78;
start79; start80; start81; start82; start83; start84; start85;
start86; start87; start88; start89; start90; start91; start92;
start93; start94; start95; start96; start97; start98; start99;
start100; start101; start102; start103; start104; start105];
randnumber3= randperm(40000);
randnumber4=randnumber3(:);
r_plug_in_time=[randnumber4 start_time_all];
s_p_i_t=sortrows(r_plug_in_time);
random_plug_time= s_p_i_t(:,2);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                %Energy consumed by each phev%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

randnumber1= randperm(40000);
randnumber2=randnumber1(:);
r_distance=[randnumber2 t_distance];
s_distance=sortrows(r_distance);
random_distance= s_distance(:,2);

o_kWh= EPM_total.*random_distance;

breakdown1=o_kWh(1:24340);
breakdown2=o_kWh(24341:29116);
breakdown3=o_kWh(29117:34356);
breakdown4=o_kWh(34357:40000);
breakdown1(breakdown1 >=6.51)=6.51;
breakdown2(breakdown2 >=7.21)=7.21;
breakdown3(breakdown3 >=8.75)=8.75;
breakdown4(breakdown4 >=10.15)=10.15;
t_breakdown=[breakdown1; breakdown2; breakdown3; breakdown4];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                %Required charging time    _hours_%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

```

charge_hours_1_4=ceil((t_breakdown/1.4)*4);

%not using the below 2%
charge_hours_2_9=ceil((t_breakdown/2.9)*4);
charge_hours_7_6=ceil((t_breakdown/7.6)*4);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Forming initial information table%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

table1=[vehicletypes EC_total EPM_total random_distance o_kWh
t_breakdown charge_hours_1_4 charge_hours_2_9 charge_hours_7_6
random_plug_time];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%develop charging load capacity table for PHEV%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

for n=1:40000 % Fix to 40000 %
    h = 5+table1(n,10); % Starting time (the table will be
shifted and starting on 15~110)%
    hh=h+table1(n,7); % charging end time %
    Lmin=h;
    Lmax=hh;

    for t=h:hh
        if t<=15
            table1(n,hh+1:143) = zeros(1);
            table1(n,15:hh) = ones(1)*1.4;

            elseif t>=110
                table1(n,15:109)=0;
                table1(n,h:hh)=1.4;

            else
                table1(n,15:h-1)=0;
                table1(n,h:hh)=1.4;
                table1(n,hh+1:143)=0;

            end
        end
    end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% max charging load base on 15minutes %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

x1=table1(:,15);
x2=table1(:,16);
x3=table1(:,17);
x4=table1(:,19);

```

```

x5=table1(:,20);
x6=table1(:,21);
x7=table1(:,22);
x8=table1(:,23);
x9=table1(:,24);
x10=table1(:,25);
x11=table1(:,26);
x12=table1(:,27);
x13=table1(:,28);
x14=table1(:,29);
x15=table1(:,30);
x16=table1(:,31);
x17=table1(:,32);
x18=table1(:,33);
x19=table1(:,34);
x20=table1(:,35);
x21=table1(:,36);
x22=table1(:,37);
x23=table1(:,38);
x24=table1(:,39);
x25=table1(:,40);
x26=table1(:,41);
x27=table1(:,42);
x28=table1(:,43);
x29=table1(:,44);
x30=table1(:,45);
x31=table1(:,46);
x32=table1(:,47);
x33=table1(:,48);
x34=table1(:,49);
x35=table1(:,50);
x36=table1(:,51);
x37=table1(:,52);
x38=table1(:,53);
x39=table1(:,54);
x40=table1(:,55);
x41=table1(:,56);
x42=table1(:,57);
x43=table1(:,58);
x44=table1(:,59);
x45=table1(:,60);
x46=table1(:,61);
x47=table1(:,62);
x48=table1(:,63);
x49=table1(:,64);
x50=table1(:,65);
x51=table1(:,66);
x52=table1(:,67);
x53=table1(:,68);
x54=table1(:,69);
x55=table1(:,70);
x56=table1(:,71);
x57=table1(:,72);
x58=table1(:,73);
x59=table1(:,74);
x60=table1(:,75);
x61=table1(:,76);
x62=table1(:,77);
x63=table1(:,78);
x64=table1(:,79);
x65=table1(:,80);

```

```

x66=table1(:,81);
x67=table1(:,82);
x68=table1(:,83);
x69=table1(:,84);
x70=table1(:,85);
x71=table1(:,86);
x72=table1(:,87);
x73=table1(:,88);
x74=table1(:,89);
x75=table1(:,90);
x76=table1(:,91);
x77=table1(:,92);
x78=table1(:,93);
x79=table1(:,94);
x80=table1(:,95);
x81=table1(:,96);
x82=table1(:,97);
x83=table1(:,98);
x84=table1(:,99);
x85=table1(:,100);
x86=table1(:,101);
x87=table1(:,102);
x88=table1(:,103);
x89=table1(:,104);
x90=table1(:,105);
x91=table1(:,106);
x92=table1(:,107);
x93=table1(:,108);
x94=table1(:,109);
x95=table1(:,110);
x96=table1(:,111);
x97=table1(:,112);
x98=table1(:,113);
x99=table1(:,114);
x100=table1(:,115);
x101=table1(:,116);
x102=table1(:,117);
x103=table1(:,118);
x104=table1(:,119);
x105=table1(:,120);
x106=table1(:,121);
x107=table1(:,122);
x108=table1(:,123);
x109=table1(:,124);
x110=table1(:,125);
x111=table1(:,126);
x112=table1(:,127);
x113=table1(:,128);
x114=table1(:,129);
x115=table1(:,130);
x116=table1(:,131);
x117=table1(:,132);
x118=table1(:,133);
x119=table1(:,134);
x120=table1(:,135);
x121=table1(:,136);
x122=table1(:,137);
x123=table1(:,138);
x124=table1(:,139);
x125=table1(:,140);
x126=table1(:,141);

```

```

x127=table1(:,142);
x128=table1(:,143);

table1(1,146)=sum(x1)+sum(x97);
table1(2,146)=sum(x2)+sum(x98);
table1(3,146)=sum(x3)+sum(x99);
table1(4,146)=sum(x4)+sum(x100);
table1(5,146)=sum(x5)+sum(x101);
table1(6,146)=sum(x6)+sum(x102);
table1(7,146)=sum(x7)+sum(x103);
table1(8,146)=sum(x8)+sum(x104);
table1(9,146)=sum(x9)+sum(x105);
table1(10,146)=sum(x10)+sum(x106);
table1(11,146)=sum(x11)+sum(x107);
table1(12,146)=sum(x12)+sum(x108);
table1(13,146)=sum(x13)+sum(x109);
table1(14,146)=sum(x14)+sum(x110);
table1(15,146)=sum(x15)+sum(x111);
table1(16,146)=sum(x16)+sum(x112);
table1(17,146)=sum(x17)+sum(x113);
table1(18,146)=sum(x18)+sum(x114);
table1(19,146)=sum(x19)+sum(x115);
table1(20,146)=sum(x20)+sum(x116);
table1(21,146)=sum(x21)+sum(x117);
table1(22,146)=sum(x22)+sum(x118);
table1(23,146)=sum(x23)+sum(x119);
table1(24,146)=sum(x24)+sum(x120);
table1(25,146)=sum(x25)+sum(x121);
table1(26,146)=sum(x26)+sum(x122);
table1(27,146)=sum(x27)+sum(x123);
table1(28,146)=sum(x28)+sum(x124);
table1(29,146)=sum(x29)+sum(x125);
table1(30,146)=sum(x30)+sum(x126);
table1(31,146)=sum(x31)+sum(x127);
table1(32,146)=sum(x32)+sum(x128);
table1(33,146)=sum(x33);
table1(34,146)=sum(x34);
table1(35,146)=sum(x35);
table1(36,146)=sum(x36);
table1(37,146)=sum(x37);
table1(38,146)=sum(x38);
table1(39,146)=sum(x39);
table1(40,146)=sum(x40);
table1(41,146)=sum(x41);
table1(42,146)=sum(x42);
table1(43,146)=sum(x43);
table1(44,146)=sum(x44);
table1(45,146)=sum(x45);
table1(46,146)=sum(x46);
table1(47,146)=sum(x47);
table1(48,146)=sum(x48);
table1(49,146)=sum(x49);
table1(50,146)=sum(x50);
table1(51,146)=sum(x51);
table1(52,146)=sum(x52);
table1(53,146)=sum(x53);
table1(54,146)=sum(x54);
table1(55,146)=sum(x55);
table1(56,146)=sum(x56);
table1(57,146)=sum(x57);
table1(58,146)=sum(x58);

```

```

table1(59,146)=sum(x59);
table1(60,146)=sum(x60);
table1(61,146)=sum(x61);
table1(62,146)=sum(x62);
table1(63,146)=sum(x63);
table1(64,146)=sum(x64);
table1(65,146)=sum(x65);
table1(66,146)=sum(x66);
table1(67,146)=sum(x67);
table1(68,146)=sum(x68);
table1(69,146)=sum(x69);
table1(70,146)=sum(x70);
table1(71,146)=sum(x71);
table1(72,146)=sum(x72);
table1(73,146)=sum(x73);
table1(74,146)=sum(x74);
table1(75,146)=sum(x75);
table1(76,146)=sum(x76);
table1(77,146)=sum(x77);
table1(78,146)=sum(x78);
table1(79,146)=sum(x79);
table1(80,146)=sum(x80);
table1(81,146)=sum(x81);
table1(82,146)=sum(x82);
table1(83,146)=sum(x83);
table1(84,146)=sum(x84);
table1(85,146)=sum(x85);
table1(86,146)=sum(x86);
table1(87,146)=sum(x87);
table1(88,146)=sum(x88);
table1(89,146)=sum(x89);
table1(90,146)=sum(x90);
table1(91,146)=sum(x91);
table1(92,146)=sum(x92);
table1(93,146)=sum(x93);
table1(94,146)=sum(x94);
table1(95,146)=sum(x95);
table1(96,146)=sum(x96);

o=1:96;
table1(o,148)=table1(o,146)*12.5;
%12.5=500K

subplot(3,2,1)
y=table1(1:96,148);
time=0:95;
stairs(time,y);
axis( [0 95 0 400000] );
xlabel( 'time (minutes)' );
ylabel('charging load(kW)');
title('VCLP 96 time frame');
hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% max charging load base on 24hours %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

table1(1,147)=sum(table1(1:4,146))/4;
table1(2,147)=sum(table1(5:8,146))/4;
table1(3,147)=sum(table1(9:12,146))/4;

```

```

table1(4,147)=sum(table1(13:16,146))/4;
table1(5,147)=sum(table1(17:20,146))/4;
table1(6,147)=sum(table1(21:24,146))/4;
table1(7,147)=sum(table1(25:28,146))/4;
table1(8,147)=sum(table1(29:32,146))/4;
table1(9,147)=sum(table1(33:36,146))/4;
table1(10,147)=sum(table1(37:40,146))/4;
table1(11,147)=sum(table1(41:44,146))/4;
table1(12,147)=sum(table1(45:48,146))/4;
table1(13,147)=sum(table1(49:52,146))/4;
table1(14,147)=sum(table1(53:56,146))/4;
table1(15,147)=sum(table1(57:60,146))/4;
table1(16,147)=sum(table1(61:64,146))/4;
table1(17,147)=sum(table1(65:68,146))/4;
table1(18,147)=sum(table1(69:72,146))/4;
table1(19,147)=sum(table1(73:76,146))/4;
table1(20,147)=sum(table1(77:80,146))/4;
table1(21,147)=sum(table1(81:84,146))/4;
table1(22,147)=sum(table1(85:88,146))/4;
table1(23,147)=sum(table1(89:92,146))/4;
table1(24,147)=sum(table1(93:96,146))/4;

p=1:24;
table1(p,149)=table1(p,147)*12.5;

subplot(3,2,2)
yy=table1(1:24,149);
timel=1:24;
stairs(timel,yy);
axis([1 24 1 400000]);
xlabel('time (hours)');
ylabel('charging load(kW)');
title('VCLP 24 time frame');
hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% PJM 2016 September 01 load data (24 hours)%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

pjm_data=[20.62 20.62 20.62 20.62    19.39 19.39 19.39 19.39 17.48
17.48 17.48 17.48 17.06 17.06 17.06 17.06 17.53 17.53 17.53 17.53
19.93 19.93 19.93 19.93 22.47 22.47 22.47 22.47 22.2 22.2 22.2 22.2
23.3 23.3 23.3 23.3 24.49 24.49 24.49 24.49 26.36 26.36 26.36 26.36
28.5 28.5 28.5 28.5 30.99 30.99 30.99 30.99 35.91 35.91 35.91 35.91
36.86 36.86 36.86 36.86 38.74 38.74 38.74 38.74 39.24 39.24 39.24
39.24 36.11 36.11 36.11 36.11 30.77 30.77 30.77 30.77 28.35 28.35
28.35 28.35 28.32 28.32 28.32 28.32 24.69 24.69 24.69 24.69 22.21
22.21 22.21 22.21 20.45 20.45 20.45 20.45
];
avg=mean(pjm_data);
new_wave=pjm_data./avg;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
30 bus load from IEEE30 bus test system
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

bus_load=[0 21.7 2.4 7.6 94.2 0 22.8 30 0 5.8 0 11.2 0 6.2 8.2 3.5 9
3.2 9.5 2.2 17.5 0 3.2 8.7 0 3.5 0 0 2.4 10.6];

```



```

t3=1:96;
bus1=bus_load(1,1)*new_wave(1,t3);
bus2=bus_load(1,2)*new_wave(1,t3);
bus3=bus_load(1,3)*new_wave(1,t3);
bus4=bus_load(1,4)*new_wave(1,t3);
bus5=bus_load(1,5)*new_wave(1,t3);
bus6=bus_load(1,6)*new_wave(1,t3);
bus7=bus_load(1,7)*new_wave(1,t3);
bus8=bus_load(1,8)*new_wave(1,t3);
bus9=bus_load(1,9)*new_wave(1,t3);
bus10=bus_load(1,10)*new_wave(1,t3);
bus11=bus_load(1,11)*new_wave(1,t3);
bus12=bus_load(1,12)*new_wave(1,t3);
bus13=bus_load(1,13)*new_wave(1,t3);
bus14=bus_load(1,14)*new_wave(1,t3);
bus15=bus_load(1,15)*new_wave(1,t3);
bus16=bus_load(1,16)*new_wave(1,t3);
bus17=bus_load(1,17)*new_wave(1,t3);
bus18=bus_load(1,18)*new_wave(1,t3);
bus19=bus_load(1,19)*new_wave(1,t3);
bus20=bus_load(1,20)*new_wave(1,t3);
bus21=bus_load(1,21)*new_wave(1,t3);
bus22=bus_load(1,22)*new_wave(1,t3);
bus23=bus_load(1,23)*new_wave(1,t3);
bus24=bus_load(1,24)*new_wave(1,t3);
bus25=bus_load(1,25)*new_wave(1,t3);
bus26=bus_load(1,26)*new_wave(1,t3);
bus27=bus_load(1,27)*new_wave(1,t3);
bus28=bus_load(1,28)*new_wave(1,t3);
bus29=bus_load(1,29)*new_wave(1,t3);
bus30=bus_load(1,30)*new_wave(1,t3);

table2=[bus1; bus2; bus3; bus4; bus5; bus6; bus7; bus8; bus9; bus10;
bus11; bus12; bus13; bus14; bus15; bus16; bus17; bus18; bus19; bus20;
bus21; bus22; bus23; bus24; bus25; bus26; bus27; bus28; bus29; bus30];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% VCLP load distribution (weight factor)%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

bus_load=[0; 21.7; 2.4; 7.6; 94.2; 0; 22.8; 30; 0; 5.8; 0; 11.2; 0;
6.2; 8.2; 3.5; 9; 3.2; 9.5; 2.2; 17.5; 0; 3.2; 8.7; 0; 3.5; 0; 0; 2.4;
10.6];
w=sum(bus_load);
s=1:30;
w_factor=bus_load(s,1)./w;
z1=table1(1,146)*w_factor;
z2=table1(2,146)*w_factor;
z3=table1(3,146)*w_factor;
z4=table1(4,146)*w_factor;
z5=table1(5,146)*w_factor;
z6=table1(6,146)*w_factor;
z7=table1(7,146)*w_factor;
z8=table1(8,146)*w_factor;
z9=table1(9,146)*w_factor;
z10=table1(10,146)*w_factor;
z11=table1(11,146)*w_factor;
z12=table1(12,146)*w_factor;
z13=table1(13,146)*w_factor;

```

```

z14=table1(14,146)*w_factor;
z15=table1(15,146)*w_factor;
z16=table1(16,146)*w_factor;
z17=table1(17,146)*w_factor;
z18=table1(18,146)*w_factor;
z19=table1(19,146)*w_factor;
z20=table1(20,146)*w_factor;
z21=table1(21,146)*w_factor;
z22=table1(22,146)*w_factor;
z23=table1(23,146)*w_factor;
z24=table1(24,146)*w_factor;
z25=table1(25,146)*w_factor;
z26=table1(26,146)*w_factor;
z27=table1(27,146)*w_factor;
z28=table1(28,146)*w_factor;
z29=table1(29,146)*w_factor;
z30=table1(30,146)*w_factor;
z31=table1(31,146)*w_factor;
z32=table1(32,146)*w_factor;
z33=table1(33,146)*w_factor;
z34=table1(34,146)*w_factor;
z35=table1(35,146)*w_factor;
z36=table1(36,146)*w_factor;
z37=table1(37,146)*w_factor;
z38=table1(38,146)*w_factor;
z39=table1(39,146)*w_factor;
z40=table1(40,146)*w_factor;
z41=table1(41,146)*w_factor;
z42=table1(42,146)*w_factor;
z43=table1(43,146)*w_factor;
z44=table1(44,146)*w_factor;
z45=table1(45,146)*w_factor;
z46=table1(46,146)*w_factor;
z47=table1(47,146)*w_factor;
z48=table1(48,146)*w_factor;
z49=table1(49,146)*w_factor;
z50=table1(50,146)*w_factor;
z51=table1(51,146)*w_factor;
z52=table1(52,146)*w_factor;
z53=table1(53,146)*w_factor;
z54=table1(54,146)*w_factor;
z55=table1(55,146)*w_factor;
z56=table1(56,146)*w_factor;
z57=table1(57,146)*w_factor;
z58=table1(58,146)*w_factor;
z59=table1(59,146)*w_factor;
z60=table1(60,146)*w_factor;
z61=table1(61,146)*w_factor;
z62=table1(62,146)*w_factor;
z63=table1(63,146)*w_factor;
z64=table1(64,146)*w_factor;
z65=table1(65,146)*w_factor;
z66=table1(66,146)*w_factor;
z67=table1(67,146)*w_factor;
z68=table1(68,146)*w_factor;
z69=table1(69,146)*w_factor;
z70=table1(70,146)*w_factor;
z71=table1(71,146)*w_factor;
z72=table1(72,146)*w_factor;
z73=table1(73,146)*w_factor;
z74=table1(74,146)*w_factor;

```

```

z75=table1(75,146)*w_factor;
z76=table1(76,146)*w_factor;
z77=table1(77,146)*w_factor;
z78=table1(78,146)*w_factor;
z79=table1(79,146)*w_factor;
z80=table1(80,146)*w_factor;
z81=table1(81,146)*w_factor;
z82=table1(82,146)*w_factor;
z83=table1(83,146)*w_factor;
z84=table1(84,146)*w_factor;
z85=table1(85,146)*w_factor;
z86=table1(86,146)*w_factor;
z87=table1(87,146)*w_factor;
z88=table1(88,146)*w_factor;
z89=table1(89,146)*w_factor;
z90=table1(90,146)*w_factor;
z91=table1(91,146)*w_factor;
z92=table1(92,146)*w_factor;
z93=table1(93,146)*w_factor;
z94=table1(94,146)*w_factor;
z95=table1(95,146)*w_factor;
z96=table1(96,146)*w_factor;

table3=[z1 z2 z3 z4 z5 z6 z7 z8 z9 z10 z11 z12 z13 z14 z15 z16 z17
z18 z19 z20 z21 z22 z23 z24 z25 z26 z27 z28 z29 z30 z31 z32 z33 z34
z35 z36 z37 z38 z39 z40 z41 z42 z43 z44 z45 z46 z47 z48 z49 z50 z51
z52 z53 z54 z55 z56 z57 z58 z59 z60 z61 z62 z63 z64 z65 z66 z67 z68
z69 z70 z71 z72 z73 z74 z75 z76 z77 z78 z79 z80 z81 z82 z83 z84 z85
z86 z87 z88 z89 z90 z91 z92 z93 z94 z95 z96];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% New Generated Load with combination of PJM and VCLP%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
c=1:96;
table4=sum(table2(:,c))*1000+sum(table3(:,c))*12.5;
%80k=2; 150k=3.75; 250k=6.25; 500k=12.5;

subplot(3,2,3)
io=table4(1,1:96);
time2=1:96;
stairs(time2,io);
axis([1 96 1 800000]);
xlabel('time (minutes)');
ylabel('total load(kW)');
title('Uncontrolled Load');
hold on;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% New Generated Load with PJM data%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

c=1:96;
real_time_load=sum(table2(:,c))*1000;
subplot(3,2,4)
stairs(real_time_load);
axis([1 96 1 800000]);
xlabel('time (minutes)');
ylabel('charging load(kW)');
title('Real Time IEEE 30 load');

```

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                % Load Flow Analysis%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

```

clc;
[busdata, linedata, basemva, accuracy, maxiter]=IEEE30_data; % Call
IEEE 30-bus test system data
minutes=1; % Set hour start at 1
phev_no=40000; % No of phevs
loading=[20.62 19.39 17.48 17.06 17.53 19.93 22.47 22.2
23.3 24.49 26.36 28.5 30.99 35.91 36.86 38.74 39.24
36.11 30.77 28.35 28.32 24.69 22.21 20.45];
loading_avg=sum(loading)/length(loading);
loading_factor=loading/loading_avg; % Calculate normalize factor to be
used in IEEE 30 bus system
VCLP_LOAD=table1(1:96,146)';

```

```

while minutes <= 96; % minutes = number of quarter in 24 hrs
    [busdata, linedata, basemva, accuracy, maxiter]=IEEE30_data;
    hour=ceil(minutes/4); % round up to upper number
    busdata(:,5:6)=busdata(:,5:6)*loading_factor(hour); % to represent
    24 hrs real time load
    IEEE_Realtime_Load(minutes)=sum(busdata(:,5));
    for n=1:30
        PCLP_Ratio(n) = busdata(n,5)/IEEE_Realtime_Load(minutes);
    %Represent the number of PHEV at load buses

    busdata(n,5)=busdata(n,5)+(PCLP_Ratio(1,n)*12.5*VCLP_LOAD(1,minutes)/1
    000); % /1000 to standardize to MW unit of energy.
    %80k=2; 150k=3.75; 250k=6.25; 500k=12.5;
    end
    busdata;
    LFYBUS;
    LFNEWTON_EP;
    LINEFLOW_EP;
    Total_Load(minutes)=sum(busdata(:,5));
    output(minutes,:)=[minutes IEEE_Realtime_Load(minutes)
    Total_Load(minutes) real(SLT)];
    minutes=minutes+1
end
n=1:30;
    table5=busdata(n,5);

```

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                                %Evolutionary Algorithm%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

```

% I later find out that there is no use of finf SOC cause it is so
hard to
% control and that is basically based on users' preference. So instead
of
% controlling the SOC , i rather design a system that assign the
charge

```

```
% quantity at each 15 minutes. With this, i propose this idea as in to
% control the
```

```
count=1;
count1=1;
while count<=100;
    while count1<=20;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% INITIALIZE
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        xx1=randi([14000,14500],1);
        xx2=randi([14000,14500],1);
        xx3=randi([14000,14500],1);
        xx4=randi([14000,14500],1);
        xx5=randi([14500,15100],1);
        xx6=randi([14500,15100],1);
        xx7=randi([14500,15100],1);
        xx8=randi([14500,15100],1);
        xx9=randi([14500,15100],1);
        xx10=randi([14500,15100],1);
        xx11=randi([14500,15100],1);
        xx12=randi([14500,15100],1);
        xx13=randi([11150,11650],1);
        xx14=randi([11150,11650],1);
        xx15=randi([11150,11650],1);
        xx16=randi([11150,11650],1);
        xx17=randi([14700,15100],1);
        xx18=randi([14700,15100],1);
        xx19=randi([14700,15100],1);
        xx20=randi([14700,15100],1);
        xx21=randi([14500,15000],1);
        xx22=randi([14500,15000],1);
        xx23=randi([14500,15000],1);
        xx24=randi([14500,15000],1);
        xx25=randi([13000,13500],1);
        xx26=randi([13000,13500],1);
        xx27=randi([13000,13500],1);
        xx28=randi([13000,13500],1);
        xx29=randi([14200,14700],1);
        xx30=randi([14200,14700],1);
        xx31=randi([14200,14700],1);
        xx32=randi([14200,14700],1);
        xx33=randi([12500,13000],1);
        xx34=randi([12500,13000],1);
        xx35=randi([12500,13000],1);
        xx36=randi([12500,13000],1);
        xx37=randi([11000,11900],1);
        xx38=randi([11000,11900],1);
        xx39=randi([11000,11900],1);
        xx40=randi([11000,11900],1);
        xx41=randi([11300,11800],1);
        xx42=randi([11300,11800],1);
        xx43=randi([11300,11800],1);
        xx44=randi([11300,11800],1);
        xx45=randi([10000,10700],1);
        xx46=randi([10000,10700],1);
        xx47=randi([10000,10700],1);
        xx48=randi([10000,10700],1);
        xx49=randi([9400,9900],1);
        xx50=randi([9400,9900],1);
```

```

xx51=randi([9400,9900],1);
xx52=randi([9400,9900],1);
xx53=randi([6000,6400],1);
xx54=randi([6000,6400],1);
xx55=randi([6000,6400],1);
xx56=randi([6000,6400],1);
xx57=randi([5600,6100],1);
xx58=randi([5600,6100],1);
xx59=randi([5600,6100],1);
xx60=randi([5600,6100],1);
xx61=randi([4200,4700],1);
xx62=randi([4200,4700],1);
xx63=randi([4200,4700],1);
xx64=randi([4200,4700],1);
xx65=randi([4400,4900],1);
xx66=randi([4400,4900],1);
xx67=randi([4400,4900],1);
xx68=randi([4400,4900],1);
xx69=randi([6200,6700],1);
xx70=randi([6200,6700],1);
xx71=randi([6200,6700],1);
xx72=randi([6200,6700],1);
xx73=randi([9600,11000],1);
xx74=randi([9600,11000],1);
xx75=randi([9600,11000],1);
xx76=randi([9600,11000],1);
xx77=randi([10500,11000],1);
xx78=randi([10500,11000],1);
xx79=randi([10500,11000],1);
xx80=randi([10500,11000],1);
xx81=randi([10500,11000],1);
xx82=randi([10500,11000],1);
xx83=randi([10500,11000],1);
xx84=randi([10500,11000],1);
xx85=randi([12500,13000],1);
xx86=randi([12500,13000],1);
xx87=randi([12500,13000],1);
xx88=randi([12500,13000],1);
xx89=randi([14700,15200],1);
xx90=randi([14700,15200],1);
xx91=randi([14700,15200],1);
xx92=randi([14700,15200],1);
xx93=randi([15000,15900],1);
xx94=randi([15000,15900],1);
xx95=randi([15000,15900],1);
xx96=randi([15000,15900],1);

```

```

%%%%%%%% FITNESS 1 %%%%%%%%%

```

```

y=(xx1*(17.5)-250000)+(xx2*(17.5)-250000)+(xx3*(17.5)-
250000)+(xx4*(17.5)-250000)+(xx5*(17.5)-260000)+(xx6*(17.5)-
260000)+(xx7*(17.5)-260000)+(xx8*(17.5)-260000)+(xx9*(17.5)-
260000)+(xx10*(17.5)-260000)+(xx11*(17.5)-260000)+(xx12*(17.5)-
260000)+(xx13*(17.5)-280000)+(xx14*(17.5)-280000)+(xx15*(17.5)-
280000)+(xx16*(17.5)-280000)+(xx17*(17.5)-260000)+(xx18*(17.5)-
260000)+(xx19*(17.5)-260000)+(xx20*(17.5)-260000)+(xx21*(17.5)-
250000)+(xx22*(17.5)-250000)+(xx23*(17.5)-250000)+(xx24*(17.5)-
250000)+(xx25*(17.5)-220000)+(xx26*(17.5)-220000)+(xx27*(17.5)-
220000)+(xx28*(17.5)-220000)+(xx29*(17.5)-240000)+(xx30*(17.5)-
240000)+(xx31*(17.5)-240000)+(xx32*(17.5)-240000)+(xx33*(17.5)-
220000)+(xx34*(17.5)-220000)+(xx35*(17.5)-220000)+(xx36*(17.5)-
220000)+(xx37*(17.5)-200000)+(xx38*(17.5)-200000)+(xx39*(17.5)-

```

```

200000)+(xx40*(17.5)-200000)+(xx41*(17.5)-190000)+(xx42*(17.5)-
190000)+(xx43*(17.5)-190000)+(xx44*(17.5)-190000)+(xx45*(17.5)-
180000)+(xx46*(17.5)-180000)+(xx47*(17.5)-180000)+(xx48*(17.5)-
180000)+(xx49*(17.5)-156000)+(xx50*(17.5)-156000)+(xx51*(17.5)-
156000)+(xx52*(17.5)-156000)+(xx53*(17.5)-103000)+(xx54*(17.5)-
103000)+(xx55*(17.5)-103000)+(xx56*(17.5)-103000)+(xx57*(17.5)-
90000)+(xx58*(17.5)-90000)+(xx59*(17.5)-90000)+(xx60*(17.5)-
90000)+(xx61*(17.5)-73000)+(xx62*(17.5)-73000)+(xx63*(17.5)-
73000)+(xx64*(17.5)-73000)+(xx65*(17.5)-68000)+(xx66*(17.5)-
68000)+(xx67*(17.5)-68000)+(xx68*(17.5)-68000)+(xx69*(17.5)-
100000)+(xx70*(17.5)-100000)+(xx71*(17.5)-100000)+(xx72*(17.5)-
100000)+(xx73*(17.5)-159000)+(xx74*(17.5)-159000)+(xx75*(17.5)-
159000)+(xx76*(17.5)-159000)+(xx77*(17.5)-185000)+(xx78*(17.5)-
185000)+(xx79*(17.5)-185000)+(xx80*(17.5)-185000)+(xx81*(17.5)-
185000)+(xx82*(17.5)-185000)+(xx83*(17.5)-185000)+(xx84*(17.5)-
185000)+(xx85*(17.5)-220000)+(xx86*(17.5)-220000)+(xx87*(17.5)-
220000)+(xx88*(17.5)-220000)+(xx89*(17.5)-250000)+(xx90*(17.5)-
250000)+(xx91*(17.5)-250000)+(xx92*(17.5)-250000)+(xx93*(17.5)-
270000)+(xx94*(17.5)-270000)+(xx95*(17.5)-270000)+(xx96*(17.5)-
270000);

    if y<0
        count=count+1;
    else
        output1(count1,:)= [count1 xx1 xx2 xx3 xx4 xx5 xx6 xx7 xx8
xx9 xx10 xx11 xx12 xx13 xx14 xx15 xx16 xx17 xx18 xx19 xx20 xx21 xx22
xx23 xx24 xx25 xx26 xx27 xx28 xx29 xx30 xx31 xx32 xx33 xx34 xx35 xx36
xx37 xx38 xx39 xx40 xx41 xx42 xx43 xx44 xx45 xx46 xx47 xx48 xx49 xx50
xx51 xx52 xx53 xx54 xx55 xx56 xx57 xx58 xx59 xx60 xx61 xx62 xx63 xx64
xx65 xx66 xx67 xx68 xx69 xx70 xx71 xx72 xx73 xx74 xx75 xx76 xx77 xx78
xx79 xx80 xx81 xx82 xx83 xx84 xx85 xx86 xx87 xx88 xx89 xx90 xx91 xx92
xx93 xx94 xx95 xx96 y]
        count1=count1+1
        if count1==21;
            return
        end
    end
end
end
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% MUTATION!!!!!!!!!!!!
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% After the above fitness we obtain 20 population for 96 period. It
must
% undergo mutation to obtain another set of slightly related value.
With
% this, i introduce my very own theory, which is everyvalue will be
% multiply with 0.95. With this, new sets of data is obtained %

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

y_max=max(output1(:,98));
y_min=min(output1(:,98));

mutation=output1(1:20,1:98)*0.95;

```

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% COMBINATION!!!!!!!!!!!!!!
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Combine parent with offspring

output_all=[output1;mutation];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% SELECTION!!!!!!!!!!!!!!
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

rank_optimum_charge=sortrows(output_all,98)

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% BEST OPTION
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

selected_values=output_all(1,2:97);

controlled_load=selected_values(1,1:96)*15.5+real_time_load(1,1:96)

stairs(controlled_load)
axis( [1 96 1 800000]);
xlabel( 'time (minutes)' );
ylabel('charging load(kW)');
title('Controlled Load');

```


APPENDIX B
START CHARGING TIME FOR PHEV FROM NHTS

| Time | | Percentage | Numbers of PHEV |
|-------------|----------|-------------------|------------------------|
| 00:15:00 | 0.107527 | 0.50 | 200 |
| 00:30:00 | 0.344086 | 0.27 | 108 |
| 00:45:00 | 0.602151 | 0.28 | 112 |
| 01:00:00 | 0.903226 | 0.29 | 116 |
| 01:15:00 | 1.11828 | 0.17 | 68 |
| 01:30:00 | 1.37634 | 0.19 | 76 |
| 01:45:00 | 1.6129 | 0.09 | 36 |
| 02:00:00 | 1.84946 | 0.17 | 68 |
| 02:15:00 | 2.08602 | 0.05 | 20 |
| 02:30:00 | 2.3871 | 0.10 | 40 |
| 02:45:00 | 2.58065 | 0.10 | 40 |
| 03:00:00 | 2.8172 | 0.12 | 48 |
| 03:15:00 | 3.11828 | 0.04 | 16 |
| 03:30:00 | 3.33333 | 0.09 | 36 |
| 03:45:00 | 3.54839 | 0.08 | 32 |
| 04:00:00 | 3.87097 | 0.07 | 28 |
| 04:15:00 | 4.08602 | 0.06 | 24 |
| 04:30:00 | 4.32258 | 0.01 | 4 |
| 04:45:00 | 4.60215 | 0.01 | 4 |
| 05:00:00 | 4.86022 | 0.01 | 4 |
| 05:15:00 | 5.09677 | 0.01 | 4 |
| 05:30:00 | 5.37634 | 0.01 | 4 |
| 05:45:00 | 5.6129 | 0.01 | 4 |
| 06:00:00 | 5.87097 | 0.02 | 8 |
| 06:15:00 | 6.08602 | 0.04 | 16 |
| 06:30:00 | 6.3871 | 0.03 | 12 |
| 06:45:00 | 6.58065 | 0.03 | 10 |
| 07:00:00 | 6.8172 | 0.09 | 36 |
| 07:15:00 | 7.07527 | 0.09 | 36 |
| 07:30:00 | 7.33333 | 0.16 | 64 |
| 07:45:00 | 7.54839 | 0.22 | 88 |
| 08:00:00 | 7.84946 | 0.31 | 124 |
| 08:15:00 | 8.06452 | 0.27 | 108 |
| 08:30:00 | 8.32258 | 0.28 | 112 |
| 08:45:00 | 8.60215 | 0.21 | 84 |

| | | | |
|----------|---------|------|------|
| 09:00:00 | 8.83871 | 0.23 | 92 |
| 09:15:00 | 9.05376 | 0.19 | 76 |
| 09:30:00 | 9.31183 | 0.23 | 92 |
| 09:45:00 | 9.56989 | 0.23 | 92 |
| 10:00:00 | 9.80645 | 0.36 | 144 |
| 10:15:00 | 10.0645 | 0.30 | 120 |
| 10:30:00 | 10.3226 | 0.46 | 184 |
| 10:45:00 | 10.5376 | 0.46 | 184 |
| 11:00:00 | 10.8172 | 0.60 | 240 |
| 11:15:00 | 11.0538 | 0.56 | 224 |
| 11:30:00 | 11.3333 | 0.80 | 320 |
| 11:45:00 | 11.5914 | 0.71 | 284 |
| 12:00:00 | 11.828 | 0.85 | 340 |
| 12:15:00 | 12.0645 | 0.82 | 328 |
| 12:30:00 | 12.3441 | 1.12 | 448 |
| 12:45:00 | 12.5806 | 1.00 | 400 |
| 13:00:00 | 12.7957 | 1.03 | 412 |
| 13:15:00 | 13.0538 | 0.90 | 360 |
| 13:30:00 | 13.3118 | 1.13 | 452 |
| 13:45:00 | 13.5054 | 0.92 | 368 |
| 14:00:00 | 13.7634 | 1.13 | 452 |
| 14:15:00 | 14.043 | 1.00 | 400 |
| 14:30:00 | 14.3011 | 1.34 | 536 |
| 14:45:00 | 14.5376 | 1.20 | 480 |
| 15:00:00 | 14.7957 | 1.70 | 680 |
| 15:15:00 | 15.0538 | 1.51 | 604 |
| 15:30:00 | 15.3118 | 2.07 | 828 |
| 15:45:00 | 15.5699 | 2.11 | 844 |
| 16:00:00 | 15.8065 | 2.53 | 1012 |
| 16:15:00 | 16.0215 | 2.11 | 842 |
| 16:30:00 | 16.2796 | 2.99 | 1196 |
| 16:45:00 | 16.5376 | 2.50 | 1000 |
| 17:00:00 | 16.7957 | 2.99 | 1196 |
| 17:15:00 | 17.0323 | 2.61 | 1044 |
| 17:30:00 | 17.2903 | 3.36 | 1344 |
| 17:45:00 | 17.5054 | 3.19 | 1276 |
| 18:00:00 | 17.828 | 3.48 | 1392 |
| 18:15:00 | 18.043 | 2.57 | 1028 |
| 18:30:00 | 18.2796 | 3.19 | 1276 |
| 18:45:00 | 18.5591 | 2.71 | 1084 |
| 19:00:00 | 18.7957 | 2.71 | 1084 |
| 19:15:00 | 19.0323 | 2.01 | 804 |
| 19:30:00 | 19.3118 | 2.46 | 984 |
| 19:45:00 | 19.5699 | 2.22 | 888 |
| 20:00:00 | 19.7849 | 2.48 | 992 |
| 20:15:00 | 20.0645 | 1.87 | 748 |
| 20:30:00 | 20.2796 | 2.48 | 992 |

| | | | |
|----------|---------|------|-----|
| 20:45:00 | 20.4946 | 2.06 | 824 |
| 21:00:00 | 20.7742 | 2.22 | 888 |
| 21:15:00 | 21.0538 | 1.88 | 752 |
| 21:30:00 | 21.2473 | 2.18 | 872 |
| 21:45:00 | 21.5269 | 1.78 | 712 |
| 22:00:00 | 21.8065 | 1.87 | 748 |
| 22:15:00 | 22 | 1.44 | 576 |
| 22:30:00 | 22.2366 | 1.54 | 616 |
| 22:45:00 | 22.5376 | 1.11 | 444 |
| 23:00:00 | 22.7527 | 1.10 | 440 |
| 23:15:00 | 23.0108 | 0.75 | 300 |
| 23:30:00 | 23.2903 | 1.00 | 400 |
| 23:45:00 | 23.5054 | 0.62 | 248 |
| 24:00:00 | 23.7419 | 0.56 | 224 |

APPENDIX C
HOURLY INTEGRATED DAY-AHEAD LMP VALUES FOR
201609

| Start of Day Ahead | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 | 2100 | 2200 | 2300 | 2400 |
|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|-------|-------|
| 20160901 | 20.62 | 19.39 | 17.48 | 17.06 | 17.53 | 19.93 | 22.47 | 22.2 | 23.3 | 24.49 | 26.36 | 28.5 | 30.99 | 35.91 | 36.86 | 38.74 | 39.24 | 36.11 | 30.77 | 28.35 | 28.32 | 24.69 | 22.21 | 20.45 |
| 20160902 | 18.22 | 17.99 | 14.86 | 13.27 | 13.47 | 18 | 20.9 | 21.25 | 22.48 | 23.88 | 25.47 | 27.33 | 28.77 | 31.62 | 33.11 | 34.32 | 34.86 | 32.39 | 28.12 | 26.35 | 26.89 | 23.78 | 21.76 | 19.33 |
| 20160903 | 13.85 | 13.05 | 11.81 | 10.44 | 9.62 | 10.45 | 11.43 | 13.26 | 17.78 | 20.41 | 21.8 | 22.85 | 23.61 | 23.86 | 23.91 | 23.86 | 24.12 | 24.02 | 23.75 | 23.66 | 23.33 | 22.4 | 19.48 | 15.75 |
| 20160904 | 12.92 | 12.05 | 10.94 | 7.81 | 3.39 | 3.15 | 2.27 | 7.96 | 13.05 | 16.6 | 19.93 | 20.88 | 22.25 | 22.51 | 22.76 | 22.76 | 23.07 | 23.35 | 23.56 | 23.68 | 23.69 | 22.16 | 19.85 | 14.29 |
| 20160905 | 13.69 | 12.22 | 10.58 | 9.32 | 9.2 | 9.13 | 10.35 | 13.29 | 18.2 | 20.27 | 22.08 | 23.37 | 25.69 | 28.61 | 33.11 | 34.47 | 39.01 | 39.16 | 34.75 | 34.08 | 32.61 | 24.38 | 21.89 | 19.74 |
| 20160906 | 19.39 | 17.51 | 13.56 | 11.99 | 12.48 | 17.4 | 21.14 | 21.63 | 22.75 | 25.51 | 29.89 | 35.87 | 39.73 | 46.19 | 49.06 | 57.07 | 64.43 | 53.4 | 45.11 | 43.13 | 43.67 | 32.78 | 25.68 | 22.82 |
| 20160907 | 22.07 | 21.08 | 18.8 | 16.15 | 16.77 | 21.03 | 23.61 | 23.84 | 25.1 | 28.64 | 34.28 | 44.27 | 49.15 | 56.55 | 65.55 | 62.43 | 68.12 | 54.65 | 44.44 | 43.82 | 41.84 | 34.76 | 27.33 | 23.7 |
| 20160908 | 22.83 | 21.65 | 19.65 | 18.37 | 18.76 | 21.64 | 24.61 | 24.31 | 25.53 | 29.51 | 36.17 | 41.1 | 49.67 | 62.23 | 87.82 | 103.99 | 109.5 | 84.26 | 54.04 | 46.43 | 43.55 | 36.85 | 28.15 | 24.41 |
| 20160909 | 23.03 | 22.25 | 21.44 | 20.37 | 20.69 | 22 | 24.23 | 24.93 | 25.92 | 29.85 | 33.74 | 37.94 | 43.58 | 53.44 | 63.73 | 71.6 | 73.57 | 59.23 | 42.33 | 37.45 | 35.6 | 32.18 | 26.79 | 24.09 |
| 20160910 | 23.28 | 22.24 | 21.27 | 19.76 | 19.05 | 19.64 | 20.95 | 21.47 | 22.91 | 25.17 | 28.74 | 34.47 | 37.97 | 44.04 | 51.11 | 54.37 | 56.62 | 50.74 | 36.62 | 33.22 | 32.72 | 26.98 | 24.18 | 22.65 |
| 20160911 | 22.24 | 21.24 | 19.64 | 18.57 | 17.31 | 17.82 | 18.14 | 18.97 | 21.06 | 23.08 | 24.23 | 25.26 | 26.37 | 30.26 | 29.75 | 31.3 | 32.14 | 31.32 | 26.44 | 27.86 | 26.35 | 23.51 | 22.27 | 20.93 |
| 20160912 | 18.72 | 16.93 | 15.55 | 13.57 | 14.96 | 19.06 | 23.31 | 22.4 | 23.09 | 24.75 | 26.47 | 29.56 | 31.53 | 34.62 | 34.99 | 38.7 | 42.18 | 39.62 | 34.85 | 35.8 | 36.07 | 26.53 | 22.41 | 20.85 |
| 20160913 | 18.37 | 16.07 | 13.47 | 12.8 | 14.23 | 18.85 | 23.12 | 22.56 | 23.27 | 25.7 | 28.05 | 32.14 | 36.72 | 39.49 | 45.82 | 50.23 | 57.91 | 50.01 | 40.55 | 41.47 | 39.04 | 29.67 | 24.94 | 21.91 |
| 20160914 | 21.68 | 19.74 | 18.11 | 17.01 | 17.68 | 21.13 | 24.89 | 24.54 | 25.37 | 27.91 | 31.86 | 35.54 | 44.51 | 53.07 | 59.85 | 70.98 | 75.83 | 63.2 | 45.62 | 43.29 | 39.74 | 31.27 | 25.53 | 22.97 |
| 20160915 | 20.02 | 18.28 | 16.61 | 14.37 | 16.28 | 19.43 | 23.24 | 23.03 | 23.78 | 25.37 | 27.25 | 30.23 | 32.52 | 35.7 | 37.32 | 44.83 | 47.6 | 43.47 | 32.46 | 32.79 | 31.99 | 25.31 | 22.49 | 20.47 |
| 20160916 | 19.42 | 18.27 | 17.16 | 15.77 | 17.6 | 20.05 | 22.94 | 23.04 | 23.66 | 25.18 | 26.79 | 31.45 | 34.67 | 36.93 | 37.11 | 43.11 | 45.03 | 40.97 | 34.06 | 34.09 | 34.4 | 26.09 | 23.23 | 21.89 |
| 20160917 | 19.61 | 19.25 | 18.12 | 16.69 | 16.07 | 17.25 | 18.51 | 18.75 | 20.32 | 22.98 | 24.57 | 26.43 | 29.42 | 32.34 | 34.04 | 35.78 | 37.39 | 34.72 | 30.45 | 33.38 | 31.69 | 26.02 | 22.13 | 20.16 |
| 20160918 | 20.72 | 20.56 | 18.68 | 17.56 | 16.26 | 17.22 | 17.88 | 18.96 | 21.49 | 23.52 | 24.59 | 27.83 | 32.89 | 36.94 | 39.33 | 44.66 | 47.98 | 44.2 | 37.4 | 44.15 | 40.84 | 30.05 | 24.03 | 22.34 |
| 20160919 | 22.18 | 21.02 | 19.81 | 19.12 | 19.39 | 21.24 | 25.33 | 24.59 | 26.74 | 30.4 | 34.41 | 38.12 | 43.72 | 45.87 | 47.14 | 56.83 | 62.03 | 54.28 | 42.12 | 44.05 | 42.18 | 31.81 | 24.83 | 22.99 |
| 20160920 | 22.63 | 21.61 | 20.14 | 19.22 | 19.39 | 22.78 | 31.38 | 28.14 | 30.65 | 36.8 | 40.77 | 45.11 | 50.59 | 55.89 | 64.48 | 81.04 | 91.63 | 78.56 | 52.59 | 54.87 | 48.31 | 39.58 | 29.38 | 24.09 |
| 20160921 | 21.48 | 19.55 | 18.38 | 16.76 | 17.93 | 20.67 | 25.32 | 24.98 | 25.15 | 28.06 | 31.18 | 37.14 | 41.74 | 48.88 | 51.74 | 59.7 | 67.01 | 57.65 | 47.85 | 47.85 | 43.63 | 32.2 | 24.89 | 22.88 |
| 20160922 | 21.3 | 19.76 | 18.81 | 17.65 | 18.46 | 21.03 | 26.09 | 25.15 | 26.24 | 28.19 | 31.74 | 38.1 | 45.69 | 50.53 | 54.88 | 64.1 | 70.1 | 59.52 | 47.96 | 48.13 | 43.94 | 34.6 | 26.55 | 23.75 |
| 20160923 | 20.51 | 19.32 | 18.24 | 17.45 | 18.06 | 20.03 | 25.08 | 24.53 | 24.89 | 26.82 | 30.66 | 37.73 | 41.89 | 46.9 | 52.72 | 65.21 | 69.49 | 51.89 | 41.81 | 41.34 | 38.4 | 31.06 | 24.83 | 23.75 |
| 20160924 | 21.94 | 20.65 | 19.51 | 18.54 | 18.49 | 19.21 | 20.39 | 20.85 | 22.02 | 23.77 | 25.92 | 28.65 | 31.7 | 33.96 | 35.82 | 41.39 | 44.15 | 37.94 | 31.2 | 35.87 | 31.01 | 25.01 | 21.9 | 21.16 |
| 20160925 | 18.64 | 18.21 | 16.17 | 13.09 | 12.74 | 13.63 | 15.12 | 16.93 | 18.87 | 21.31 | 22.34 | 23.82 | 24.59 | 25.39 | 24.95 | 26.99 | 31.03 | 32.78 | 27.4 | 33.29 | 30.87 | 25.08 | 21.82 | 20.27 |
| 20160926 | 18.12 | 17.75 | 15.12 | 13.45 | 17.02 | 19.85 | 24.74 | 24.2 | 24.71 | 26.12 | 27.33 | 31.27 | 31.87 | 34.21 | 34.28 | 34.62 | 35.96 | 34.69 | 31.04 | 38.79 | 33.81 | 26.07 | 22.26 | 20.76 |
| 20160927 | 18.57 | 18.09 | 17.24 | 17.26 | 17.7 | 20.75 | 26.77 | 25.23 | 25.33 | 26.55 | 27.61 | 29.44 | 28.97 | 29.62 | 28.71 | 29.45 | 29.42 | 28.91 | 27.51 | 33.89 | 29.75 | 25.37 | 22.19 | 20.76 |
| 20160928 | 18.82 | 18.53 | 17.52 | 16.52 | 17.75 | 20.63 | 25.52 | 25.15 | 25.33 | 25.98 | 26.58 | 27.87 | 28.7 | 30.24 | 29.68 | 30.52 | 30.38 | 29.33 | 28.32 | 35.35 | 31.32 | 26.74 | 22.13 | 20.7 |
| 20160929 | 18.52 | 17.74 | 16.6 | 16.18 | 16.85 | 19.86 | 25.21 | 25.75 | 26.33 | 27.11 | 28.25 | 29.22 | 29.04 | 28.96 | 29.74 | 29.59 | 28.8 | 28.63 | 26.16 | 30.53 | 28.34 | 24.94 | 21.91 | 20.31 |
| 20160930 | 17.28 | 16.93 | 16.04 | 15.5 | 16.45 | 19.31 | 23.84 | 25.05 | 25.11 | 26.78 | 27.43 | 27.69 | 27.87 | 28.18 | 27.73 | 27.06 | 27.97 | 27.34 | 26.38 | 28.43 | 27.2 | 24.61 | 21.79 | 20.57 |