Optimization of Electrical Charging Station Capacity

ABDULGADER H. ABDULGADER ALSHARIF

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Supervisor:

Prof.Dr.Osman Ucan

osman.ucan@altinbas.edu.tr

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Optimization of Electrical Charging Station Capacity

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[Abdulgader H. Abdulgader ALSHARIF]

[Signature]

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ABSTRACT

Optimization of Electrical Charging Station Capacity

ALSHARIF, ABDULGADER.

[M.S],[Department of Electric and Computer Engineering], Altınbaş Üniversitesi-Turkey

Supervisor:

Prof.Dr. Osman N. UCAN.

Electrical vehicle charging Station (EVCS) is not a new that used as a petrol station to feed the vehicles by the fuel, that prepared to get the optimization method for the Electric Vehicle Charge Station by finding the capacity of using mathematical models for as the topic has mentioned that using a designed system that consist from some of tools that using to count the costs such as PVs, Battery Banks, Transmission lines and Electric vehicles (EVs) those stopped in public parking that using the main grid and Photovoltaic to charge different types of cars those have stopped in the various number of tracking depends on some of international standard critical points.

Keyword: Mathematical Model, PVs model, EVs, Battery Bank, Electricity grid, MATLAB, Optimization.

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Chapter: 1 Introduction to Electric Vehicle Charge Stations (EVCS)

1.6 Introduction

The uses of electric vehicles have been started since decades ago, that used to reduce the cost of charge, the emission that emitting from car pipe CO2, using a new technique for drivers by using Electric Vehicles which using electricity instead of using either Petrol or Gas, according to the social of living needs a car to carry and move on, electric vehicle can do all as normal cars do.

Vehicles needs some main material to work such as wheels, engine and batteries and so on, the main part that we are concentrating is batteries that will be in in details later in chapter 2 in section 2.5.

The electrical power system which we are using to find the capacity for the Electric Vehicle Charge Station (EVCS) that will be considered and customize the cost for different types of cars that connected to the designed system which will be presented later, there are some important terminologies the definition of the electric power system terms will be presented as (load profile) in this work will present the calculation for the capacity cost of Electrical Vehicle Charge Stations (EVCS) with some different types of electrical cars with their own various charging power levels, batteries and the hours for driver by some mathematical modeling equations also the data sheet for solar panels.

One of the most important programs that using to solve the mathematical equations and other types of equation is MATLAB, which we are using to optimize the cost and obtaining the capacity of the (EVCS) which will be presented the result in chapter 5, that is defined as a high-performance language for technical computing that using in most of fields such as engineering, chemistry and so on. It integrates computation, visualization and can make a code programming in an easy approach also easy-to-use environment where problems and solutions are expressed in familiar mathematical notation which that listed in MATLAB library, furthermore is used in typical uses that includes the list below:

- Math and computation.
- Algorithm development.
- Modelling, simulation and prototyping.
- Data analysis, exploration and visualization.

- Scientific and engineering graphics as we have used in this thesis in chapter 5.
- Application development, including Graphical User Interface building (what is MATLAB? n.d.)

According to our designed system which used smart grid network that use PV & PEV...ect. that using electricity which means that electricity is the best-known form of available energy that can be harnessed to meet and provide a human need for an equilibrated, with the list of prices will be illustrated later ("U.S. Department of Energy," n.d.)

As the techniques in the world has rising and getting developed, that make at every moment created or in another term is invested a new method of living and solving problems which means that will make people's life easier and easier in some parts and in the other regions will be harder because of the modern techniques.

In the electricity world and transportation side, scientists have invested a new type of cars in last decides that using electricity to be moved or driver that reduces the emission pollution from the traditional cars which using the petroleum fuel, the main purpose of using Electric Vehicles (EVs) is to reduce the emission of cars that caused many problems to humans such as diseases and pollution for the environment and global warming.

In addition, instead of using traditional station for providing the fuel to cars, in this work will use another type of stations which named Electrical Vehicle Charge Station (EVCS) to charge vehicles, which will be depends on so many factors such as the type of battery bank or battery pack which is one of the car parts and types of Electric Vehicles (EVs) connecting to the main electric grid that will be as main supplier to the station and it is not that matter of the type of car (PHEV,BEV, EV), this work has proposed a new idea by connecting some PVs to the system and finding the cost by some methodologies with an optimization approaches

The methods and tools which will be used in this thesis are a MATLAB program to obtain the plotting result and mathematical models that will find the cost for each part of the work mathematically, then finding the total cost for whole system using some previous studies as references using multi mathematical modeling equations for each function.

Consequently, we would like to obtain the benefit from the sun light to customizes the cost of using general electricity network which increasing year by year that will reduce the electricity bills as this work will be present for each part with more details later in chapter2.

In this thesis, we will present different section and definitions, first is the abstract and acknowledgment then chapter 1 presented the background and introduction to the system of Eclectic Vehicles and history with some definitions included the literature review and mathematical modeling, chapter 2 presented the full details for the system by using the description, definitions, tables, graphs to all solar panels, solar irradiance, batteries, power level of charging and smart grid details, chapter 3 is presented the costs of each part in our system, chapter 4 is the main part of this thesis that figured out the result using the technical program (MATLAB) to obtain the result, chapter 5 is summarized the whole result those obtained in this work, chapter 6 is the last chapter in this thesis that having the recommendation and future work then the codes using MATLAB last a few papers presented the references.

1.7 Definition of Optimization

The best way to get enhancement for something and working or behavior well is called (optimization) or in another term it is an act, process or methodology of making something to be in better way such as (a design, system or decision) that is working in fully perfect way, functional or effective as possible.

Specifically, the mathematical procedures (as finding the maximum of a function) or minimum of the function.

1.8 What is a Load Profile?

Load Profile is an abroad term or it is not a common word which we used in electric power engineering that can refers to a number of different forms of data. It can refer to demand and consumption data, also it can be a reference to derived data types, such as Regression and Profile Coefficients (Elexon, 2013).

1.9 Literature review

The last decades, scientists have invested a new type of transportation that use to move or deliver goods is to drive cars around and carry a lot of stuff such as the normal car does. Furthermore, that 100% using electricity as a fuel, these types named as an Electric Vehicle (EV) which completely depends on the electricity as main fuel, therefore the main supplier to move it instead of using petrol which is making so many problems for our environment, health and cost so much money.

The begging of the electric vehicles was in 1832-1839 by Scottish inventor that named Robert Anderson ("History of the Electric Car," 2010) and continued developing the invitation by so many experts in many other countries till today with the new generation and different types of modern electric vehicles such as PHEV, BEV and EV.

Manufacturing are making vehicles with the international standard details such as Toyota, Mazda and Nissan and so on, each one of those have a level power of charging according to some criteria's and polices depends on the battery type or engine.

According to the previous studies that related to the work in electric vehicles charge stations papers and researches those have been published in either local or international journals for the batteries such as in ("The electric car places heavy demands on its batteries," 2011) (Mary Fitzpatrick & Legislative Analyst, 2016) ("What is LiFePO4 battery? BESTGO POWER GROUP," 2015) (Neagoe-Stefana, Eremia, Toma, & Neagoe, 2015) and for the electric vehicles in (Ustun, Ozansoy, & Zayegh, n.d.) (Ccadmin, 2012) (Hydro Quebec, 2015) and the electric grid, for the types of photovoltaic system which consists the types of solar panels in ("What are the different types of solar photovoltaic cells?: Types of Solar Photovoltaic Cell, n.d)," n.d.) ("What are the different types of solar photovoltaic cells?: Types of Solar Photovoltaic Cell, n.d)," n.d.) for the main part of the sun irradiance which reflected the sun light to the earth that presented in (Rahimi-Eichi, Ojha, Baronti, & Chow, 2013).

The diagram that illustrated below in fig.1 is explain the assumption system which we have designed.

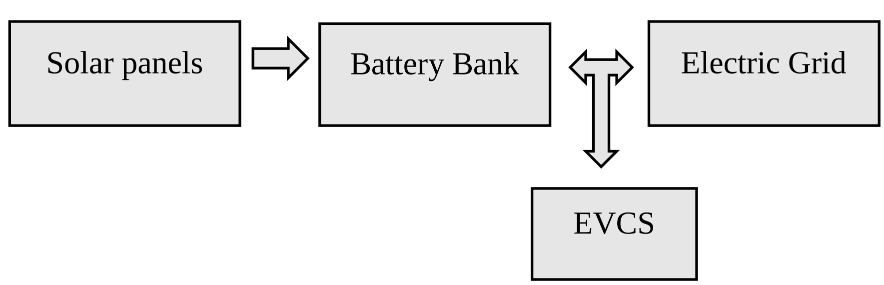

Figure.1 Diagram of EVCS System Design.

1.10 Methodology

The methodology that we will use in this thesis is MATLAB Program (what is matlab?,n.d) that using to figure out the result for cost and the capacity of the Electric Vehicle Charge Station (EVCS) that we will see later in the last section with the result and discussion with some mathematical modeling result those listed in table those found in (Shao-yun, Liang, Hong, & Long, 2012) for the presented flowchart or the diagram that illustrated in figure 1 of the designed system which consists of 4 boxes, the Solar panels, Battery Bank, Electric Grid and Electric Vehicle Charge Station (EVCS), respectively that can figure out the full idea of this thesis.

1.6 Size of the station:

According to the sun irradiance for the UV (Ultra-voltaic) that measure in unit of nm and the relationship between the solar cell and the irradiance is , the equation below is using for the number and types of car in the park, there are some nations which meaning as presented in the matrix (l row) that stands for the types of cars for example ($l_1 = 2{,}4{,}6\ kw$) and (n column) for number of vehicles those stop in the park such as n=(1,2,3….n).

$$x = \begin{bmatrix} l_{1,1} & l_{1,2} \cdots & l_{1,n} \\ l_{2,1} & l_{2,2} \cdots & l_{2,n} \\ l_{3,1} & l_{3,2} \cdots & l_{3,n} \end{bmatrix} \qquad (1)$$

The entry for each matrix that presented below for A, B, C for solar panels with irradiance for the locations, batteries, generator for the electricity, respectively. To obtain the results for each part in the main equation that will be presented in a specific graph that implemented in MATLAB.

$$EVCS = [A + B + C]\begin{bmatrix} U_S \\ U_B \\ U_G \end{bmatrix} \qquad (2)$$

When A, B and C equal to the mentioned equations below (3), (4), (5).

$$A = IRRP_S \qquad (3)$$

When A stands for the obtained result for the sun irradiances and solar panels considering to the specific location and season which obviously is not constant for all years.

$$B = \frac{N.P_B}{level.power.charging} = \frac{P_B}{kw} \qquad (4)$$

When B stands for the obtained result for the battery size that measured in $w/h which multiplied with the N number of battery that divided with the values of the level power of charging of vehicles in kw.

$$C = Electricity - rate \qquad (5)$$

When C stands for the electricity rate which will be in $kw/h depends on the location and Table 6 in chapter 3 listed the prices of the electricity in various countries.

Chapter 2 The main design system for Electric Vehicle Charge Station (EVCS)

2.1 Electric Vehicle Charge Station (EVCS)

Electric Vehicles (EVs) are becoming center of attractions as the substitute of conventional fossil fuel vehicles as the formers are less liable to Green House Gases (GHG) emission (Islam & Mithulananthan, 2016) which represented in different countries around the world such as (U.S, UK, Canada….etc.) that needs a charge stations to supply vehicles which means give the ability or power to the car to move, depends on the type of battery and the level of power, the most of cars are used level 2 to charge, because of the volt and current of the battery and the electricity output for the homes and public charge station' output in kwh.

The main objective for using this system which we have designed to minimize the cost of charging that using either suppliers (Electricity or Solar panels) that minimize the cost of bills, the mathematical equation (6) which found in (Shao-yun et al., 2012) that could find the total capacity of electric vehicles for all cars those stopping in the park and obtained the result later in chapter 4.

$$EVCS(P_{car_{total}}) = \sum_{i}^{m}\sum_{j}^{m} P_{car_{i,j}} \qquad (6)$$

When $EVCS(P_{car_{total}})$ refers to the total cost of number of electric vehicle ($P_{car.total}$) in the park with different types of cars as they have listed in the track as those illustrated in the matrix, The double sum nation ($\sum_{i}^{m}\sum_{j}^{m} P_{car_{i,j}}$) with number of rows and columns (i, j) that refers to the loss cost of charge station and (m) refers to the number of cars in charging stations or in another term is the tracking.

$$P_{car} = u_S P_S + u_B P_B + u_G P_G \qquad (7)$$

The above equation (7) is translated to equation (6) that take us deeply and give more specific explanation for the main one.

$$u_S + u_B + u_G = 1 \qquad (8)$$

Equation (8) presented the balances for solar panels, battery bank and electricity grid, respectively or in another expression is the losses for the charge station that should be normalized and equal to one which will be counted depends on the balances or losses for each part in the system mathematically.

When P_{car} responses to the total number of cars in the park and explain the summation operation for the equation (6) to combine the idea with equation (7), u_S responses for the balance or losses of charge station for solar panels, P_S solar panels power that present the type and size which prepared from the manufactures within the ability of the sun irradiance for the solar panel which presented in the back of the solar panel piece in small sticker, using math to find the value of the equation as a vector for solar panels and its balance.

$$u_S P_S = [IRR] \lfloor LK.P_{solarpieces} \rfloor \quad (9)$$

$$P_S = \begin{bmatrix} LK & LK \cdots & \begin{matrix} LK \\ \vdots \end{matrix} \\ LK & LK \cdots & \begin{matrix} LK \\ \vdots \\ \ddots \end{matrix} \\ LK & LK \cdots & LK \end{bmatrix} \quad (10)$$

To be in more mathematical details, as presented earlier in equation (7) will count the run result separated for each part to obtain the total cost for the Electric Vehicle Charge Station (EVCS) will use equation (9) when the vector [IRR] responses for the irradiance and L & k are the size of solar panel dimension.

Which we can define the solar irradiance as the sun delivers energy to the earth by means of electromagnetic radiation. For our purposes we can assume that the radiation flows evenly distributed from a surface which is close to spherical. The sunlight covers a broad range of wavelengths from roughly 250 nm (UV) over the visible range (400-700 nm) as presented in figure 2 below up to several thousands of nm (IR). The radiation density is decreasing with the square of the distance. At the average distance of the earth from the sun the flux of energy amounts to 1366 W/m^2 which is called the solar constant ((Rahimi-Eichi et al., 2013).

In addition, we could define the Ultraviolet (UV) as the electromagnetic radiation with a wavelength from 10-400 nm which is not visible to human eyes, that can measure in nm, which is shorter than that of visible light but longer than X-rays (Ultraviolet (UV),n.d).

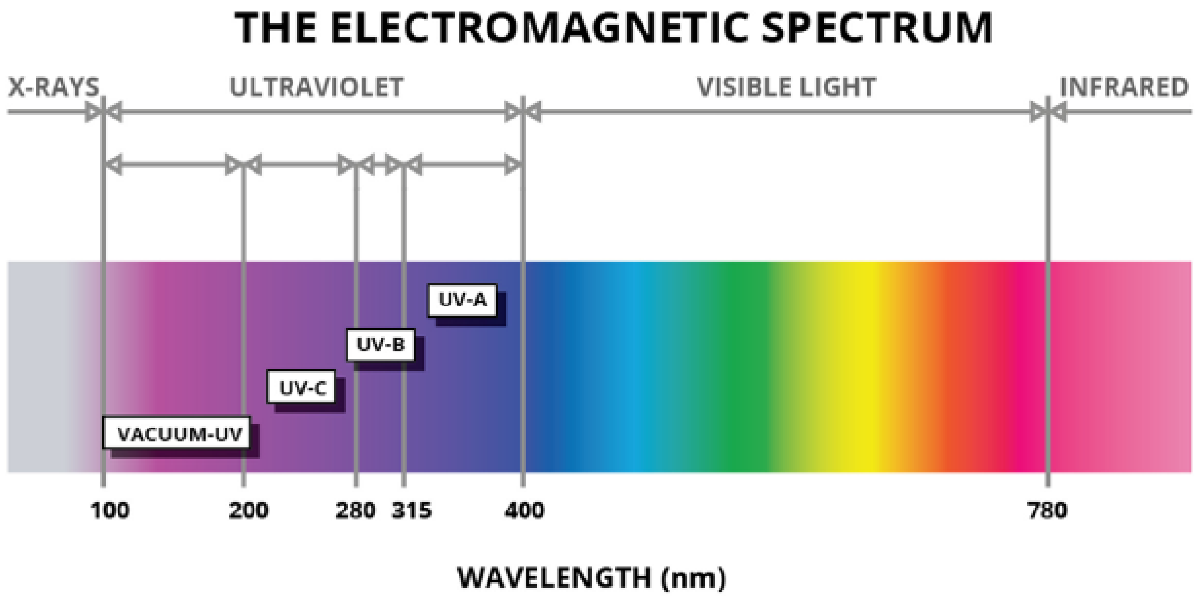

Figure.2 Color Spectrum Highlighting UV-A, UV-B, and UV-C ("Applications of Ultra-Violet LEDs and Safety Considerations," 2016)

The total irradiated energy per year, including seasonal changes, times of overcast sky, and night time, amounts to about 1000 kWh/m^2 year in Central Europe (corresponding to 2 to 3 hours of ideal sunshine each day). The map below illustrates the worldwide distribution of the irradiation density.

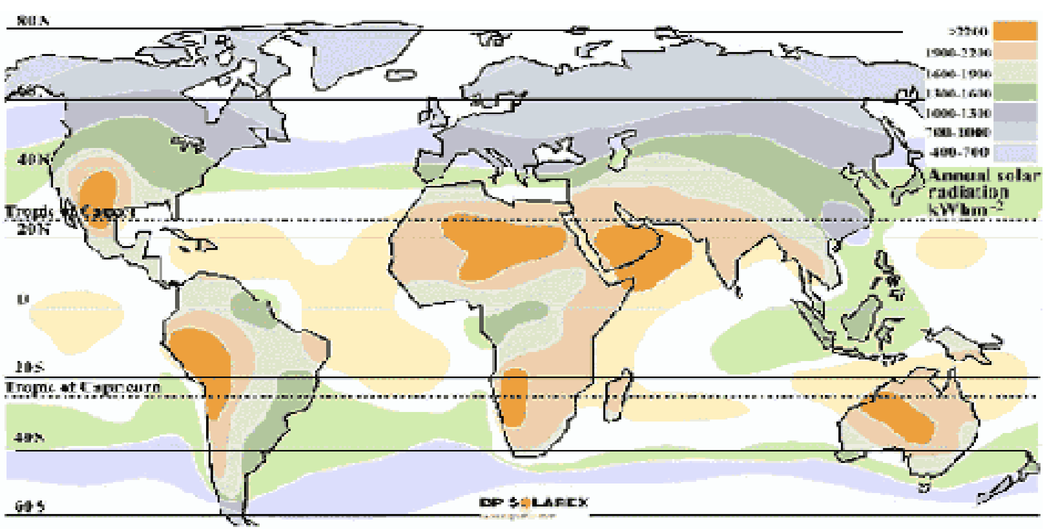

Figure.3 Solar Irradiation Map (Rahimi-Eichi et al., 2013)

2.1.1 Solar Irradiance Variation

The overall aim of the study of the solar irradiance variations is to understand that:

- How the solar irradiance is changing, because of its importance on the earth's climate,
- What are the physical mechanisms that influence upon it in order to forecast future changes.
- To learn from its changes about the structure of the solar interior, particularly its convection zone and its atmosphere (Rahimi-Eichi et al., 2013)

There are so many types of charging station which are depends on the location or the time that we are charging our cars, such as the home charging ("Home charging, Electric vehicle charging guide," 2017) work place charging ("work place charging, Electric vehicle charging guide," 2017) and public charging ("work place charging, Electric vehicle charging guide," 2017) respectively. that is an obvious for the electric vehicle runs on a motor using electricity from an external charging supply as a power source ("EV Electric Vehicle," 2017) that produce zero emission CO2.

Moreover, the time for charging is an important for drivers to be considered so much to the drivers according to the kind of trip or type of vehicle, figure 4 illustrated the time charging range for each type (home(residential)–public-workplace).

Figure.4 Charging Infrastructure For Home, workplace and public Electric Vehicles (A. Penticoff, 2014)

In addition, for the various number of Electric Vehicles (EVs) among us those are using in the countries such as (UK, Canada, Australia and USA) which are using this technique as illustrated below in table 1 with the number of size of batteries and the driving range that may expected to be driven.

Table 1 Types of Electrical Vehicle and Its Designed (Ustun et al., n.d.)

Company	Model	EV Types	Driving Rang (Km)	Battery size (kWh)	Designated Charging Level
Toyota	Prius	PHEV	8	4	1
Buick		PHEV	16	8	1
Chevrolet	Volt	EREV	64	16	2a
Fisker	Karma	PHEV	80	22	2a
Nissan	LEAF	EV	160	24	2a
Toyota	RAV4	EV	190	27	2a
Cooper	Mini E	EV	251	28	2a
Tesla	Roadster	EV	354	53	2b

The mathematical equation in (Ccadmin, 2012)that have used to count the time of charging is as presented below equation (11) according to the main 3 factors to compute the charge time for Electric Vehicle (EV) are:

1. Vehicle Acceptance Rate (aka the car's charger, in kW)
2. Vehicle Battery Capacity (in kWh)
3. Charging Station Delivery Rate (aka the stations' max output capacity, in kW).

$$Charge\ Time\ Demand = \frac{Vehicle\ Battery\ Capacity}{Charging\ Station\ Delivery\ Rate} \tag{11}$$

For the mathematical modeling that count the number of cars we would express it as the matrix

$$Car_{total} = \begin{bmatrix} LQ_{1,1} \cdots\cdots LQ_{1,2} \cdots & LQ_{1,n} \\ LQ_{2,1} \quad LQ_{2,2} \cdots & LQ_{2,n} \\ LQ_{3,1} \quad LQ_{3,2} \cdots & LQ_{3,n} \\ LQ_{4,1} \quad LQ_{4,2} \cdots & LQ_{4,n} \\ & \vdots \\ LQ_{n,n} \cdots\cdots LQ_{n,n} \cdots & LQ_{n,n} \end{bmatrix} \tag{12}$$

When Car_{total} is responses for the total number of cars those are parked in the Electric Vehicle Charge Station (EVCS) those will be charged, without carrying on the type of vehicle.

2.2.1Charging Station Benefit

There are so many benefits that using for the Charge Stations (CS) for many applications, at different locations such as (a premium retail center, grocery store, parking garage, entertainment venue and airport), for the benefit of charging for the utilities and some applications as listed below.

2.2.1.1 Boost Branding, Customer Attraction & Retention

To provide a charge station to drivers are such an awesome work and a great way to attract and keep customers who drive plug-in Electric Vehicles (PEVs) because locating a charging station is not always the easiest task, from that station will power our PEV instead of using petrol fuel. Electric Vehicle charging stations (EVCS) also give businesses a unique way to differentiate from competitors and enhance and promote a positive, environmentally friendly brand image.

2.2.1.2 Digital or Static Advertising Opportunities

Content options are nearly endless and all depend on the location of the charging station. Each time an EV owner charges their car, it becomes a perfect opportunity to advertise to that driver. For example, if a charging station is in front of a premium retail center, it is the perfect time to reach a highly valued demographic with paid advertising from store locations inside the retail center.

2.2.1.3 Reduce Environmental Footprint and Save Energy:

According to Portland General Electric (PGE), about one-third (13%) of the country’s greenhouse gas emissions come from transportation, and 60 % of that is from vehicle use. Charging stations significantly aid in reducing carbon emissions (CO2) and the more public stations installed, the more interested non-EV drivers will be to join the movement by using the EVs to reduce the emission and be friendly with the environment that make them protected from the pollution and from different dioecies (Hydro Quebec, 2015)

2.2.2 Types of Level Power Charging

Firstly, Electric vehicles, we can be plugged right into a standard household or workplace such (hospitals, universities, public cars parking) outlet that will charge the electric vehicles as figure 5 below figured the types of outlet those using to charge vehicles as used in 3 regions in North America, Europe, China, in addition.

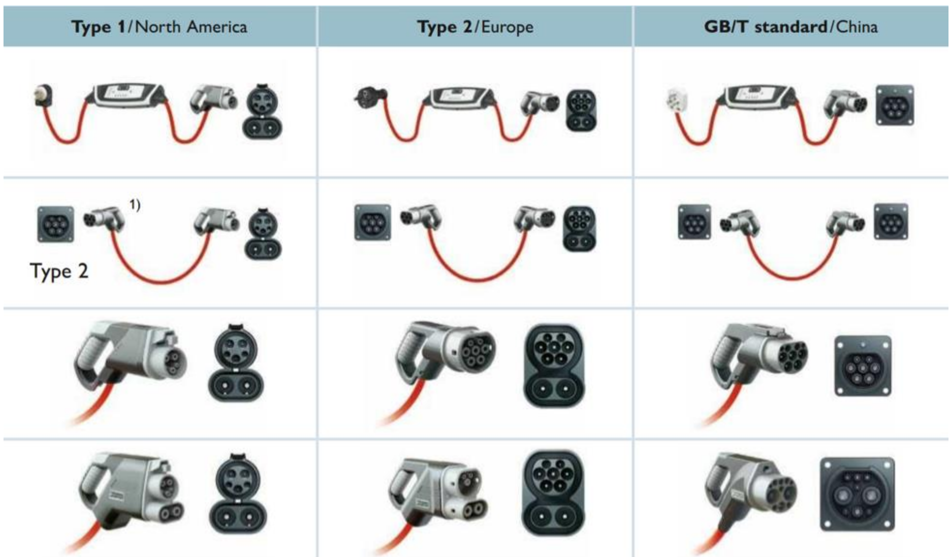

Figure.5 The CCS Type 1, which complies with SAE J1772 and IEC 62196-3, is used for fast DC charging in the USA (Schweber, n.d.)

There are three types of power charging levels, which are using in different places, one of them that will use for the previous authorities in (Ustun et al., n.d.) such as (workplaces, household…etc.) which is use Level 1 that could produce (110V, 15amps) charging, also the rest of levels will be presented later in table 2. For each level would take some hours to be partly or fully charged as level 1 will take between 8-20 hours to fully charge an EV at Level 1.

Secondly, for the second kind of power level charging, Level 2 charging stations as presented in table 2 which use a (240-volt/30A) and can fully charge a vehicle from 0 %-100% charge in about 4-6 hours.

Thirdly, the last level of charging is known as level 3 or in in another word fast DC charge in short or (also known as Direct Current Fast Chargers (DCFC) that use (480-volt/167A) that can charge a vehicle that reach to 80% in about 30 minutes. We could say that for these stations allow

EV drivers to charge their vehicles about 8 times faster than Level 2 charging stations, making longer trips more feasible for EV drivers without facing troubles (Ustun et al., n.d.)

Each one of the above charging types has limited time to charge cars and common power levels of charging as presented in table 2 below.

Table 2 Charging Power Levels (Ustun et al., n.d.)**.**

Charging level	Rated Voltage/Current	Type	Charging Power (KW)
1	110V/15A	Opportunity	1.4
2a	220V/15A	Home	3.3
2b	220V/30A	Home/Public	6.6
3	480V/167A	Public/Private	50-70

A kilowatt is a metric that equals 1,000 watts of power that measure the power rate and we use the terms *watt-hours (Wh)* or *kilowatt-hours (kWh)* to describe energy use ("kW and kWh Explained," 2017).

2.2.3 Travel Distance Per Charge

For the distances that could go for the kilometers without caring about the fuel that would use to move cars whenever we wanted, EVs can typically travel at least 100 kilometers on a single charge in general. Some batteries for EVs can go up to 160 kilometers on one charge, while plug-in hybrid electrics (PHEV) may travel more than 500 kilometers using a combination of battery and gasoline engine technology. The distance for an EV can travel depends on the vehicle technology (battery electric or plug-in hybrid) and that also depends on some other critical caring points for the batteries such as the points those listed below.

- Battery size.
- Weight carried.
- Temperature.
- Accessories in use.
- An individual's driving style.

EVs don't run out of charge unexpectedly. As with gasoline-powered vehicles, the dashboard display will indicate your level of charge so you can plan your trips accordingly ("Charging Electric Vehicles," 2009)

2.6 PV Solar Panels Classification

Solar panel is the main part of the solar system that convert energy from one form to another which is convert it from the sun light into the electricity that we are using in our homes and other locations to power the lights on our streets and the machinery in our industries, using this solar panels to reduce the cost between electricity and solar system, in addition, calculating the capacity of the EVCS. They can be seen on an industrial scale in solar farms and more discretely on the top or roofs of our own houses (Ccadmin, 2012)

The main types of solar panel as known are 3 types as listed below, in this work will not be concentrating as types and installation:

- Monocrystalline silicon solar panels.
- Polycrystalline (or multi-crystalline) solar panels.
- Amorphous/thin film solar panels ("What are the different types of solar photovoltaic cells?: Types of Solar Photovoltaic Cell", n.d.)

In the earlier part that presented in the equation (7) as the main equation for the system that will count the summation for all system and produce the total power for all vehicles those are in EVCS.

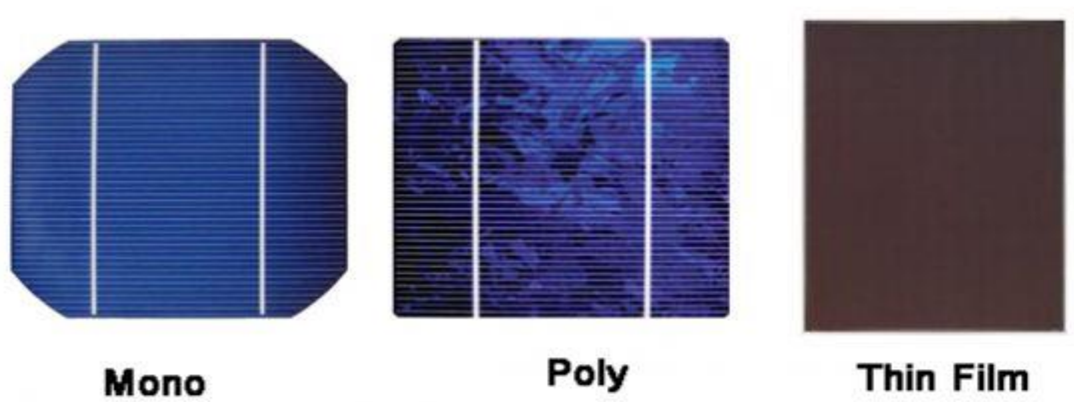

Figure.6 Types of Solar Panels (O'Neill, 2017)

To be considered in this system is the first and second one, Monocrystalline and Polycrystalline those have the highest efficiency, for the mono is having the highest efficiency compared to the all types which is 15%, and its disadvantages are the cost and can impact by the high temperature, and the second one is the polycrystalline that can work in any weather and its disadvantage s need to install more panels and the efficiency is 13%.

For the more details which has explaining the amount produced for each one of the solar panels in mathematical forms presented in (Alsharif, Othman, Alsgear, Kura, & Mahariq, 2017) that have taken place in section XII

2.6.1 The Cost of Solar Panels

Residential solar systems are typically sized from 3 to 8kW the same as expected in the MATLAB code with the result that obtained in chapter 4 and end up costing between $15,000 and $40,000. The cost per watt (price inclusive of parts, labor, permitting fees, overhead and profit) has decreased significantly over the last decade and is now between 6 and 8 ($/W) in many parts of the U.S. Generally, the bigger the system, the lower the cost per watt (Mathias Aarre Maehlum, 2015).

For each solar panel system has its own details according to the deigned system, that obviously needs some standard and critical points such as (area, the total output for power, the efficiency, Solar irradiance) that have mentioned in (Haugh, 2015) according to the main formula to obtain the total output for power.

$$Total\ Power\ Output = Total\ Area\ x\ Solar\ Irradiance\ x\ Conversion\ Efficiency \qquad (13)$$

In this work we have assumed that, the total power output is 1000 kw that will define the total area which I need to install the panels when solar irradiance is 1000 Watt/m2 as mentioned which means it’s known for a surface perpendicular to the sun’s rays at sea level on a clear day and conversion Efficiency is 18%=0.18 (“How to Calculate the Surface Area Required by Solar Panels Fundamentals,” 2013)

2.4 Transmission Line (Electricity Grid)

The prices in the world has been increasing as listed in the table 6 later, in MATLAB CODE and the result that obtained has taken 10 $kwh as a price for the system for the U.S and can be vary, for the electricity according to the changing that occurred in the world for the global warming and the environment changes, the measuring unit of the electricity is kwh, also we can calculate the cost of electricity per kwh depends on some critical points as presented below:

1. Where you live.
2. How much you use.
3. The time of year (summer rates are usually higher than winter).
4. Possibly when you use it (some utilities have lower rates in the evenings).
5. **Who your provider is** (every utility has different rates) which have taken from (Michael Bluejay's, 2015)

Mathematically, equation (7) is presented the calculation for all solar panels, batteries bank, electricity grid and counting the capacity of EVCS, respectively.

Widely classification since power stations type is depend (i.e. voltage & frequency), therefore we will be depending on the energy (kw/h) in this thesis.

A kilowatt is a metric that equals 1,000 watts of power that measure the power rate and we use the terms *watt-hours (Wh)* or *kilowatt-hours (kWh)* to describe energy use ("kW and kWh Explained," 2017)

2.5 Battery Bank

As the main definition of the battery and its own principle as defined, Batteries are electrochemical devices which convert chemical energy into electrical energy or vice versa by means of controlled chemical reactions between a set of active chemicals The battery bank is not that important for the system that we are going to design which illustrated in figure 1, install it either in the begging of the system or at the end before the Electric Vehicle Charge Station (EVCS) which means that can work under two systems either On-Grid or Off-Grid but for the vehicles its an important part to charge it and deal whit it when discharged.

Furthermore, for the various types of batteries for the car, such as illustrated in the table 3 which installed in BEV types that figured in figure 7. that uses chemical energy stored in rechargeable battery packs ("Battery Electric Vehicle," 2010) battery pack is presented that provide DC current.

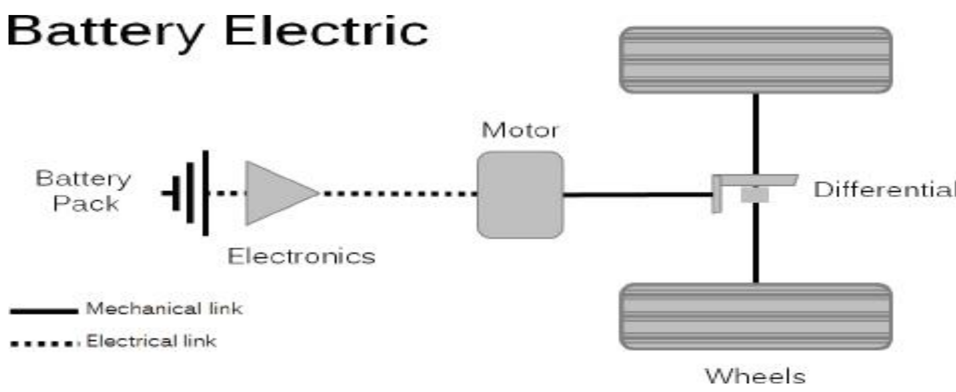

Figure.7 Design of BEV Type Battery Electric Vehicle ("Battery Electric Vehicle," 2010)

In table 1, listed the battery size in (kwh) with the types of the EVs, that presented in the chart below, figure 8.

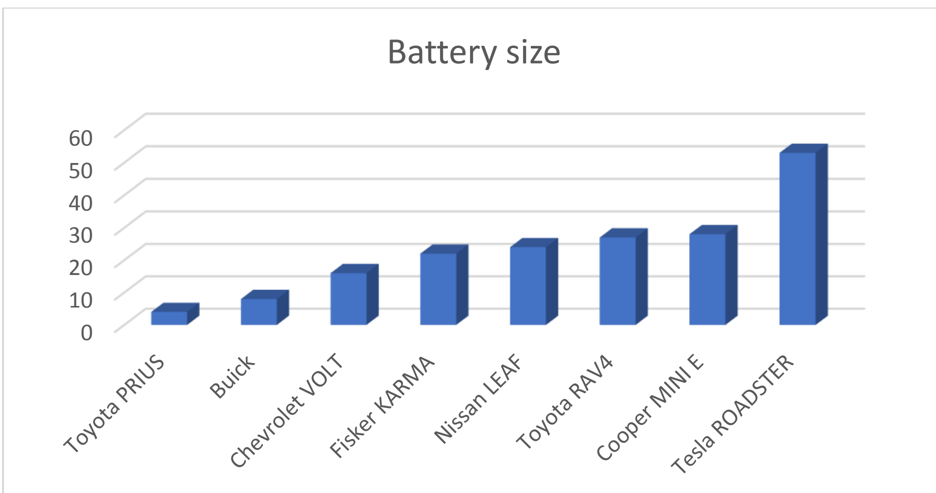

Figure.8 Chart for The Battery Size.

Table 3 has presented the types of the batteries those used in the Electric Vehicles (EVs), Each type of car has used a type of the illustrated batteries in table below, depends on the cost, weigh (kg) for the different car are using Lithium Ion battery for each accuracy.

Table 3 Batteries Types Comparisons ("The electric car places heavy demands on its batteries," 2011)

Battery Type	Energy/weight watt-hours/kg	Energy / volume watt-hours/L	Power/weight watt/kg	Energy /US $ watt-hours/$
Lead acid	30-40	60-75	180	4-10
Nickel-Zinc	60-70	170	900	2-3
Lithium Ion	160	270	1800	3-5
Lithium Polymer	130-200	300	To 2800	3-5

One of the most important components of electric vehicle is the battery, which has more than 4 types of the batteries with their details, those have illustrated in table3 above, which must perform well and must be reliable as it could if not surly will face trouble. The main reason that should we have a battery are:

- To provide a high power during strong acceleration.
- Sudden large capacity for high autonomy.
- Long life to reduce costs.
- Extend the longevity of the vehicle.

Field of batteries have a high interest to researchers for a long time, especially since it blocks the spread of electric cars on the market (Mary Fitzpatrick & Legislative Analyst, 2016)

Traditionally, most electric vehicles have used lead-acid batteries due to mature technology, high availability and low cost, but they have a major negative impact on the environment through their construction use, disposal or recycling. Another disadvantage of this type of battery is the short lifetime (battery should be changed every three years), a period much shorter than the life of an EV, as a case for all batteries, these have a much lower energy density than fossil fuels, in this case, 30-40 Wh/kg.

The cost per unit of energy is 200- 250 euro. The efficiency (70-75%) and the current generation capacity of the battery in deep cycle lead-acid decreases as the temperature is lower, so that its performance and reduce the autonomy of up to 40% (Arancibia & Strunz, 2012)

Currently, the majority of EVs mass-produces use Li-Ion batteries with the anode composed of LiFePO4, which means lithium iron phosphate battery that use for which belongs to one kind of rechargeable lithium batteries, battery takes LiFePO4 as cathode materials ("What is LiFePO4 battery? BESTGO POWER GROUP," 2015), because they have a good energy density (100 Wh/kg) is not harmful to the environment and long life (at least 10 years or 7,000 charge / discharge cycles).

Because they have a high cost per unit of energy (500-1000 euro / kWh), battery electric vehicles are the most expensive part of it, depending on capacity can be up to 50% of the final price of the car (Neagoe-Stefana et al., 2015)

The average energy cost for the electricity that listed in table 3 which illustrated in ref. ("The electric car places heavy demands on its batteries," 2011) that cost in between 2-10 $w/h that may vary from 7 to 18 cents per kilowatt-hour, this may cost between 2.10$ to 5.40$.

2.5.1 General Model for EV Charging Loads

2.5.1.1 Charging Characteristics of EV Batteries

Lead-acid, lithium-ion and Nickel Metal Hydride (NiMH) have been the top three contending technologies for EV batteries due to a combination of performance capability, safety, life and cost (Linden, D., & Reddy, 2002)

2.5.2 EVs Battery Charging Scenarios

The EV load demand can be dictated to some extent by the electricity tariff structure (Qian, Zhou, Allan, & Yuan, 2011)

2.5.2.1 Battery Management System

Besides the growth of the battery technology, the BMS is a key element to make the utilization of the battery in the smart grid and EVs safe, reliable and efficient. The BMS not only controls the operational conditions of the battery to prolong its life and guarantee its safety but also provides accurate estimation of the SOC and SOH for the energy management modules in the smart grid and EVs.

To fulfill these tasks, a BMS has several features to control and monitor the operational state of the battery at different battery cell, battery module and battery pack levels.

2.5.2.2 The Need for BMS in Smart Grids and EVs

The growing that occurred in battery technology that seems to be growing very fast to provide practical solutions for the EVs and the smart grid industry, the progress in technology and materials alone cannot guarantee a solution that will overcome all the concerns. Some of the concerns regarding the integration of the battery storage into the smart grid are as follows.

- **Cost**: includes manufacturing, maintenance, labor, operation and replacement costs.
- **Lifetime**: measured by the charge, discharge cycles and calendar life of the battery.

- **Power delivery**: measured in terms of charge, discharge rate, energy storage level, ramp rate and charge discharge efficiency.
- **Environmental impact and safety**: measured in terms of the safety/ risk factors due to the chemical composition of the battery, operating temperature, etc.(Rahimi-Eichi et al., 2013).

2.5.4 **Battery Capacity**

It is important for drivers and manufacturing to consider on the accrued, flexible, strongest and the time for the battery to take a driver to a specific point, using the electric vehicles as a modern technology seems to make our live to be easier, the following table is presented the type of vehicles with the battery capacity for each one.

Table.4 Battery Capacity for Some Electric Vehicles (“Electric Vehicles Battery,” n.d.)

EV Type	Battery capacity
Citroen C-Zero / Peugeot iOn (i.MIEV)	14 kWh (2011) / 16 kWh (2012-)
BMW i3	22–33 kWh
Kia Soul EV	(2016) 27 kWh
Honda Clarity (2018)	25.5 kWh
Ford Focus Electric (2018)	33.5 kWh
Ford Focus Electric (2012)	23 kWh
Fiat 500e	24 kWh
Chevrolet Bolt / Opel Ampera-e	60 kWh

2.6 Smart Grid

The Smart grid (SG) also known as Intelligent Grid (IG), Grid-Wise (GW) or Intragrain which is an approach or method to the next generation power grid that uses information and communication technologies to transfer power from central generating stations to consumers in a two-way manner and also from Distributed Energy Resources (DERs) to other consumers and controls all the processes in an intelligent and pervasive manner (Brown & Freeman, 2001) and Electric vehicles (EVs) are considered as an important player in SG that uses the electric general grid and system (Clairand, Rodriguez Garcia, & Alvarez Bel, 2017).

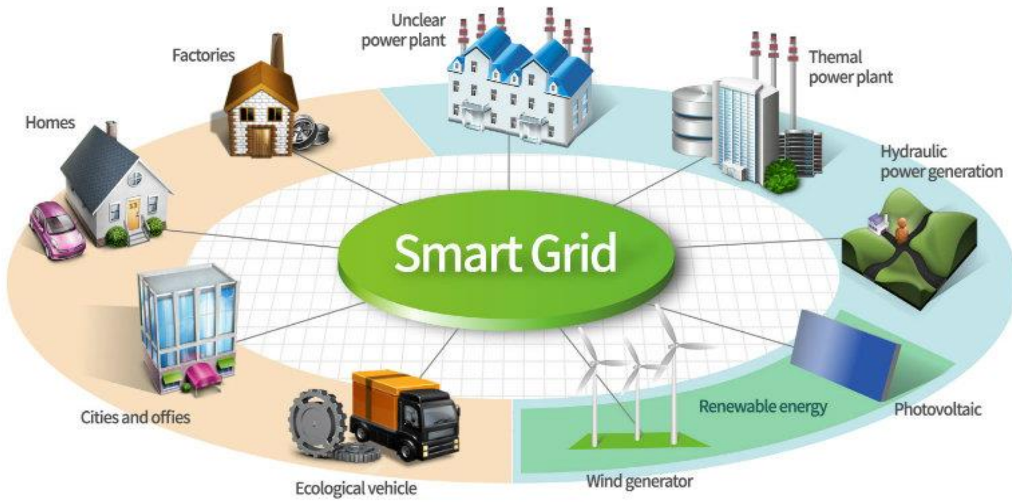

Figure 9 International Symposium on Smart Grid Technologies (CT BUREAU, 2017)

The EV may be the solution for particulars world. EVs are nonpolluting vehicles and they almost do not produce noise and emission from its tailpipe.

Chapter 3: Advanced Explanations to Cost Function For EVCS.

3.1 Cost Function for The Electric Vehicles Charging Stations (EVCS)

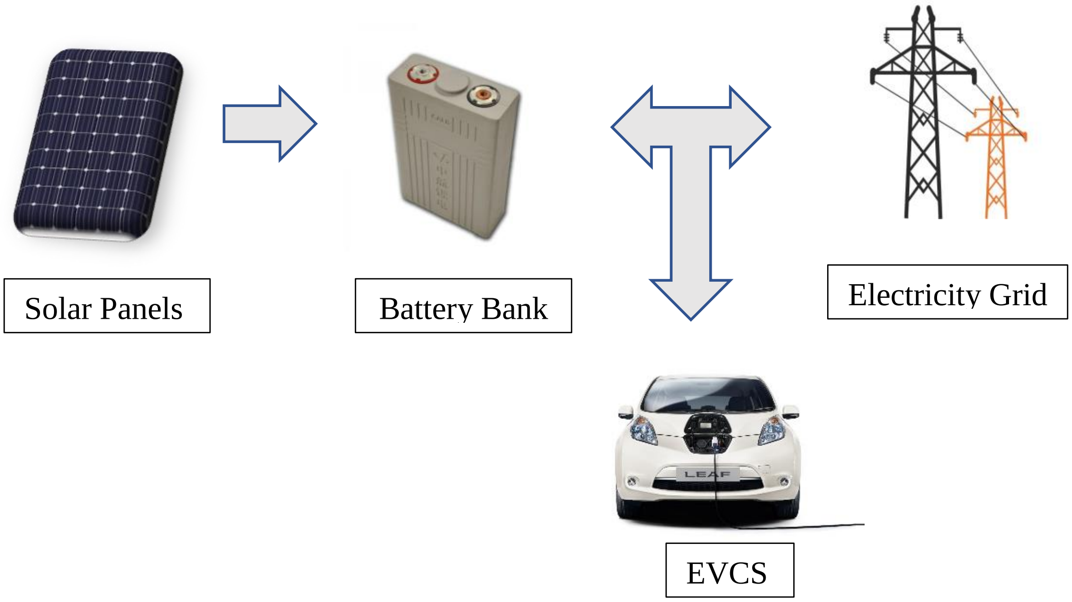

Figure.10 Diagram for EVCS System Design

According to the equations from (1) to (13) for the above system in mathematical expression that could counted the capacity and costs for each part after the summation operation we will obtain the total cost for all vehicles depends on the number of electric vehicles which found in the park which presented in figure 10 as EVCS term.

3.2 Performance of Vehicle Battery Systems with the cost

The performance of each battery has its characteristics which make it either more or less desirable to use in a specific application such as the type of electric vehicle, the table below is presented the extra types in more details for batteries more than those had been presented in table 3.

Table 4 presented the same types of vehicles batteries with the cost that scaled from 1-10

Table.5 Types of Batteries with Scale Cost (R. Bailey, 2012)

Battery Type	Energy Density Whr/kg	Power Density W/kg	Life Cycles Per Battery	Cost on scale of 1 to 10
Current Lead Acid	35	150	500	1
Advanced Lead Acid	48	150	800	3
GM Ovonic NiMH	70	220	>600	8
SAFT NiMH	70	150	1,500	8
SAFT lithium ion	120	230	600	9
Lithium polymer	150	350	<600	10
Zebra sodium-nickel chloride	86	150	<1000	4
Impact on Vehicle performance	Range	Acceleration	Life Cycle Cost, Replacement Cost	Initial Cost, Replacement Cost

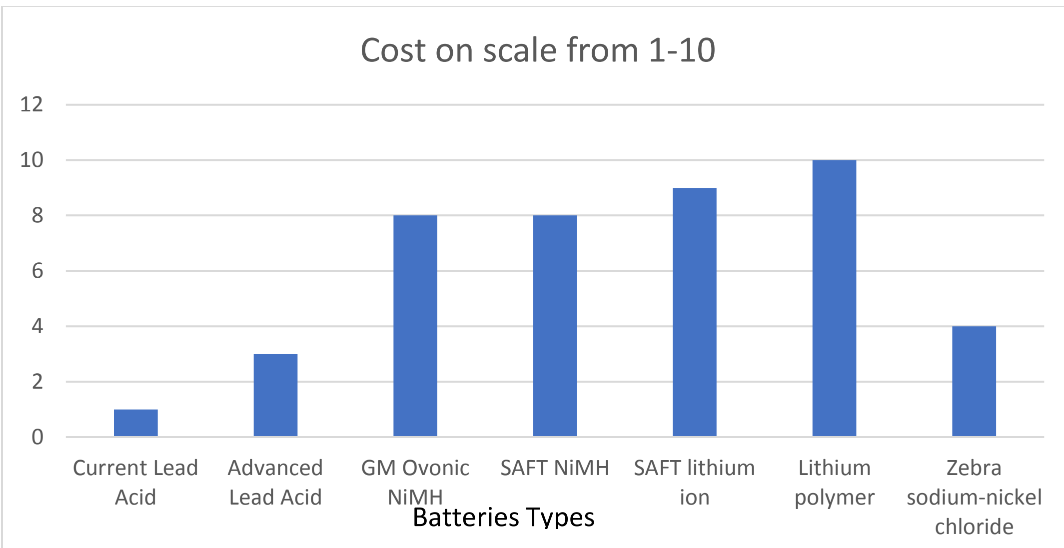

Figure. 11 Chart of The Cost on Scaled on Various Types of Batteries

The chart above illustrated the average or range cost or scaled for the most used batteries such as (current Lead Acid, SAFT lithium ion and Zebra sodium-nickel chloride), to be in more details, the proper use for batteries according to the life time cycle, strongest ideal with temperature.

3.3 Cost of The Electricity in Different Countries

The average price for the electricity in $kw/h as presented in the table 5 below for the most of countries in the world (Dillinger, 2017)

Table.6 Average for The Cost of Electricity

Rank	Country	$Kw/h
1	Italy	21.01
2	Germany	19.21
3	UK	15.40
4	Portugal	13.84
5	Spain	13.64
6	Belgium	12.68
7	Slovakia	12.55
8	France	10.74
9	Czech Republic	10.47
10	Poland	10.46
11	Austria	10.44
12	Netherlands	10.08
13	U.S.	10.00
14	Australia	9.71
15	South Africa	8.97
16	Finland	8.59
17	Canada	8.11
18	Sweden	7.87

The chart that presented in figure 12 is named under the Cost of Electricity by Country, that seeking to show the various prices and decreased cost in different countries in $kw/h which have taken from the table above to present them in average form.

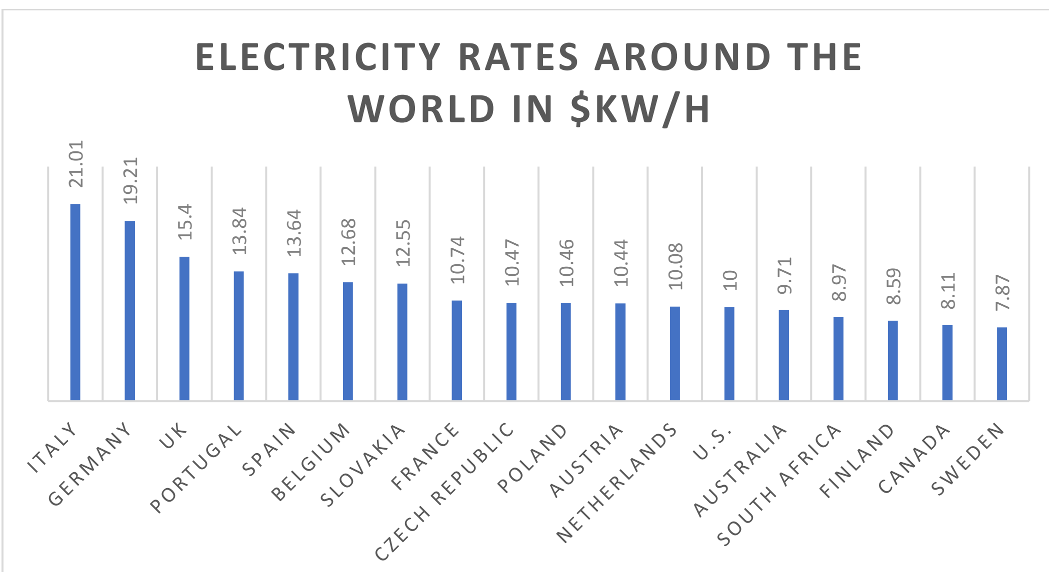

Figure.12 Cost of Electricity by Country (Dillinger, 2017)

3.4 Size of the station

To find the optimization for the cost and size of the station, firstly we need to find the cost of the solar panels that measured in (kw), and know the irradiance for the sun light for various locations In addition for getting to know the Power level of charging for different types of cars as presented and some additional types are listed in table 6 below in kw, for Toyota Rav4 EV is 9.6 kW, for Audi A3 E-Tron is 3.3 kw, for BMW Active is 7 kw acceptance rate (Ccadmin, 2012).

Table 6 listed the types of cars with their power level of charging depends on the level type, which we could say the range is between 3.3-20 kw.

Table.7 Power Levels for Various Cars

No.	Vehicle's Type	Power Levels in kw
1	Audi A3 e-Tron	3.3 Kw
2	BMW i3	7.4 Kw
3	Cadillac ELR	3.3 Kw
4	Chevy Spark EV	3.3 Kw
5	Chevy Volt	3.3 Kw
6	Fiat 500e	6.6 Kw
7	Ford C-Max Energi	3.3 Kw
8	Ford Fusion Energi	3.3 Kw
9	Ford Focus Electric	6.6 Kw
10	Honda Accord Plug-In Hybrid	6.6 Kw
11	Hyundai Sonata Plug-in Hybrid	3.3 Kw
12	Kia Soul EV	6.6 Kw
13	Mercedes B-Class Electric	10 Kw
14	Mercedes S550 Plug-in Hybrid	3.3 Kw
15	Mercedes C350 Plug-in Hybrid	3.3 Kw
16	Mitsubishi i-MiEV	3.3 Kw
17	Nissan LEAF	3.3 kW / 6.6 Kw
18	Porsche Cayenne S E-Hybrid	3.6 kW / 7.2 Kw
19	Porsche Panamera S E-Hybrid	3 Kw
20	Smart Electric Drive	3.3 Kw
21	Tesla Model S	10 kW / 20 Kw
22	Tesla Model X	10 kW / 20 Kw
23	Toyota Prius Plug-In	3.3 Kw
24	Volkswagen e-Golf	3.6 kW / 7.2 Kw

Chapter 4 The Result and Discussion

Result and Discussion

To obtain the value of solar panels in kw needs to know the solar irradiance, in this work we have assumed the values of sun irradiance from 0.1 to 1, we can also define the solar irradiance as the amount of light energy from one thing hitting a square meter of another each second. Photons that carry this energy have wavelengths from energetic X-rays and gamma rays to visible light to the infrared and radio (Rob Garner, 2008), moreover, needs to install the solar panels in specific location to obtain the proper result, in this work we have considered the result as an average for all irradiance which we may expected for the whole countries.

We can say that all of the manufactures are putting on the back of panels a piece of paper as a sticker which called specification sheet or data sheet that presented the details of the user panel such as presented in the figure 14 below, the below graph 13 is figured out the dimension ratio between the solar irradiance with number of solar panels those installed in the system.

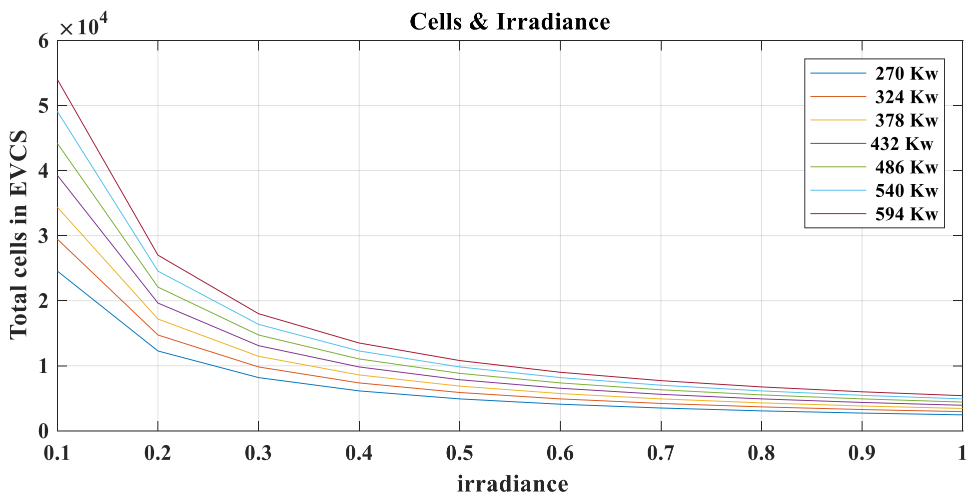

Figure.13 The Number of Cells Required for Different Power Utilities with Respect to Sun Irradiance Range.

The input data for the solar irradiance as presented in the MATLAB code between 0.1-1 and the expected outcome of solar is P_c_T = 270 324 378 432 486 540 594 in kw for the three tracking of car park and the output is 110 w for the solar panel with the power level charge of cars 2 4 6 kw also can be vary, this detail is written in the back of each solar panel from the manufacture as figure14 shows them in the begging as the power max in watt.

Figure.14 Data Sheet for Real Solar Panels

Case 1

The next graph has present the ratio between the number of solar panels and number of vehicles in the park in 3 tracking as assumed in this work also can be vary, which has considered when solar panel cell equal to 110 W, irradiance (0.1 0.3 0.5 0.7 0.9), which has increased

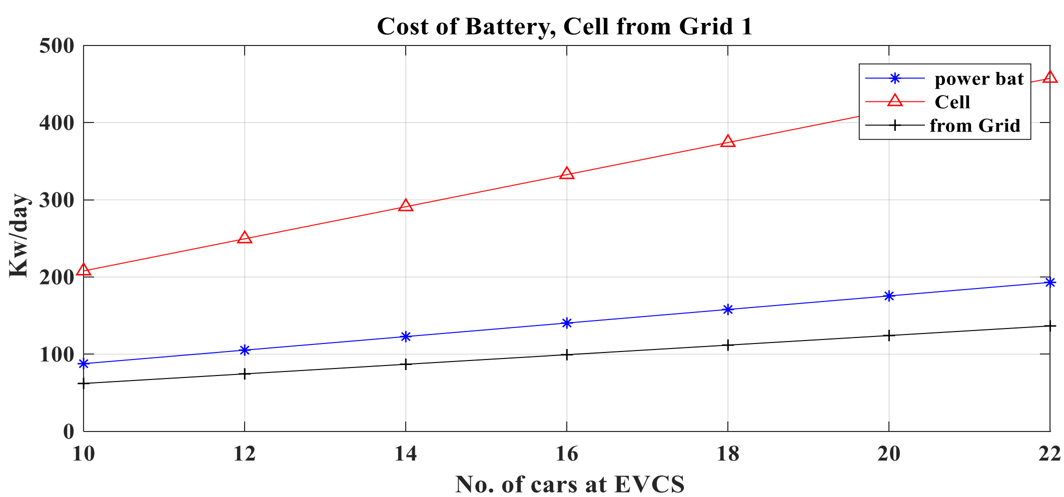

Figure.15 Cost of Battery & Cell from Grid 1 (Case 1)

Case 2

Base on the price of electricity grid in 10$ kw/h for the specific location that located in U.S that taken from the table 5, we obtained the below graph 16 which has illustrated the 2 lines those seemed to be liner which means that, according to the minimum cost of the electricity cost we can justify our result which means can be vary from the above table that presented in table 5, in this work we obtained the three results such as the power of battery, solar panels and the line that presented the electricity that came from the electricity grid, respectively.

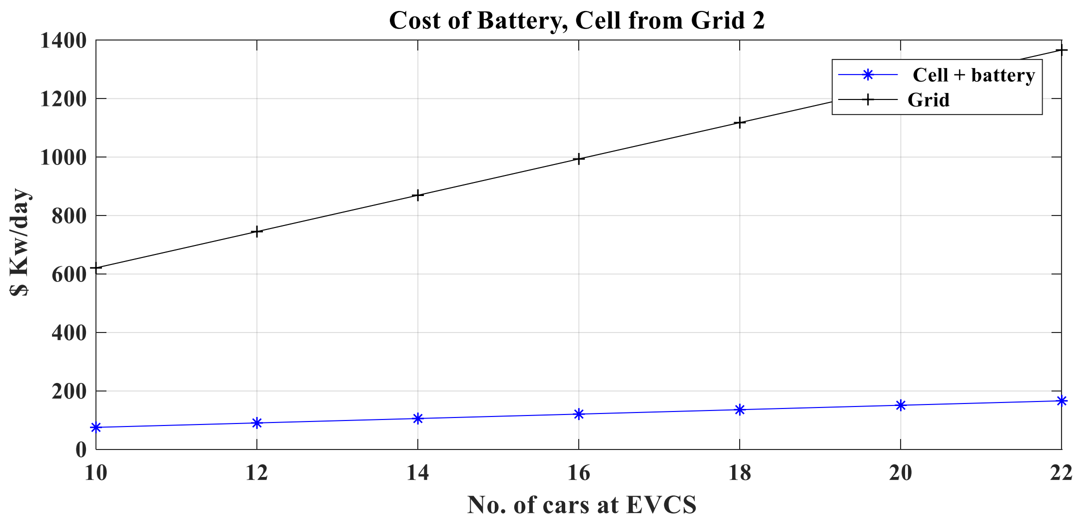

Figure.16 Cost Battery & Cell from Grid 2 (Case2)

The chart bar 17 below is obtained by considering the distribution of the peak load of the electric vehicle charge station (EVCS) for only one day for 24 hours which shows that the peak load time at 3 pm for that vehicles need to charge which is changeable, that means when will change the values depends on the price of solar panels and the run hours that need vehicles to be charged.

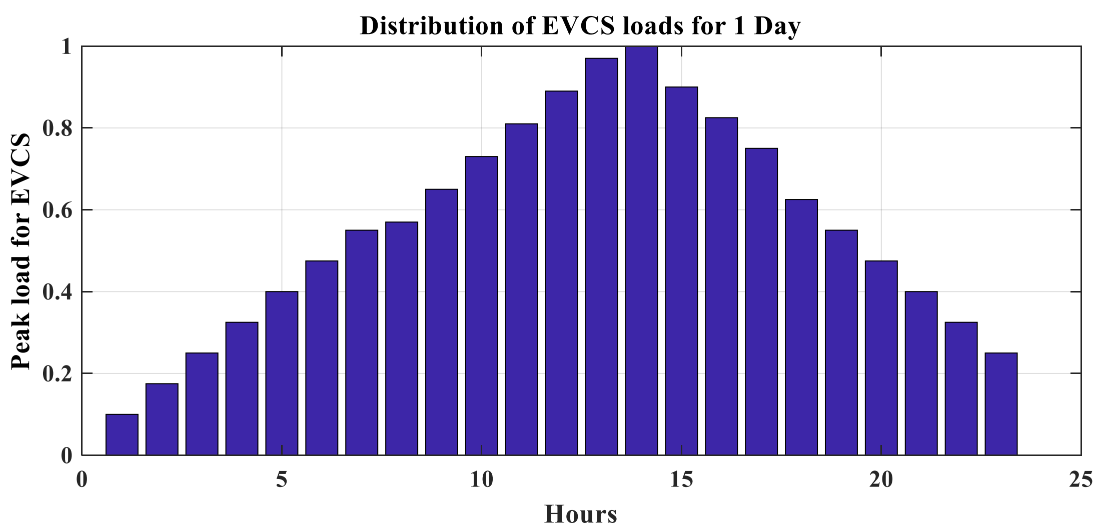

Figure.17 Char Bar for The Distribution of EVCS Load for 1 Day.

Chapter 5 Conclusion

Conclusion

To summaries that, Solar irradiance is not constant, figure3 figured out the world solar irradiance map, which depends on the location and season, in our system we have concentrating on the them as an average for all which was between 0.1-1, the result that presented in figure 13 is presented the value of solar panel output which is 110 w and the range that assumed to be for irradiance as they presented in series 270 324 378 432 486 540 594 in kw with power level of charging in kw for different number of vehicles which can be vary nit constant.

The obtained result as in figure 8 is presented the average of the battery sizes, consequently we reach to this result in EV that types under Tesla ROAD STEER is the biggest size of the vehicles types which has got from the chart.

In chart 12 & table 6 has listed the prices of the countries, respectively. According to the price in U.S which defined as 10 $kwh obtained the result

Figures 15,16 the two case1,2 respectively are the cost of battery with solar panels cell

Figure 17 the chart bar presented the distribution peak load for EVCS for one day only, which seems to be presented the peak load that electric vehicles needs to be charged that consider a battery cost in 250 $ for the one piece of NIK cadomin type which can be vary with other types and the main time of charging is almost 2 hours and the main time of discharging is 1 hour by default.

Chapter 6 Future work

Future work

Related to the result for optimization that we have obtained would recommend researches and scientists to continue working on the same topic which talking about the **Optimization of Electrical Charging Station Capacity,** by using alternative Algorithms and methods to solve this kind of issue.

The most proppare method to customize the bill’s costs is to use some alternative forms of energy such as we have use in this work solar system to produce the electricity.

APPENDIX A

EVCS	**Electric Vehicle Charge Station**
MATLAB	**Mathematical Laboratory.**
PV	**Photovoltaic.**
PEV	**Plug-in Electric Vehicles.**
EV	**Electric Vehicle.**
PHEV	**Plug-in Hybrid Electric Vehicle**
BEV	**Battery Electric Vehicles**
GHG	**Green House Gases**
UV	**ULTRA-VIOLET RADIATION**
CS	**Charge Station.**
PGE	**Portland General Electric**
CO2	**Carbon dioxide**
DC	**Direct Current**
DCFC	**Direct Current Fast Charging**
BMS	**Battery Management System**
SOC	**State of Charge.**
SG	**Smart Grid**
IG	**Intelligent Grid**

GW	**Grid-Wise**
DERs	**Distributed Energy Resources**

APPENDIX B

MATLAB CODE

```
clc ; clear all; close all

% % %%SOLAR IRRIADIANCE
l= 10:2:22 ; % l=20;          % No. of cars at each track {can be vary}
TRC = 3 ;               % no. of tracks of station  {can be vary}
P_level =[ 3 6 18] ;   kw=10^3;%kw
P_c_T= (l.*sum (P_level))

Pan_des =  .110 ; % watt
irr= 0.1:0.1:1 ;

P_S = irr* Pan_des ;

for i= 1:length (P_S)

    N_cell(i,:)= ceil(P_c_T./ P_S(i)) ;
end
No_cell= min (N_cell);
 %%%%%%%%%%
 max_Req = P_c_T; % wk
 figure; plot( irr,N_cell)
    ylabel (' Total cells in EVCS'); xlabel (' irradiance')
    legend (' 270 Kw', ' 324 Kw ',' 378 Kw',  '432 Kw ', ' 486 Kw', ' 540
Kw', ' 594 Kw') % should be put values of P_c_T
    grid on
    axis auto
    title('Cells & Irradiance')
==============================================================================
l= 10:2:22 ; % l=20;          % No. of cars at each track {can be vary}
TRC = 3 ;               % no. of tracks of station  {can be vary}
P_level =[ 3 6 18] ;   kw=10^3;%kw
P_c_T= (l.*sum (P_level))

Pan_des =  .110 ; % kw
irr= 0.1:0.1:1 ;

P_S = irr* Pan_des ;

for i= 1:length (P_S)

    N_cell(i,:)=  ceil(P_c_T./ P_S(i)) ;
end
No_cell= min (N_cell);
 %%%%%%%%%%
 max_Req = P_c_T; % kw

==============================================================================
```

```
%% cell
 cel =  0.1 ; % kw
 dute_life_cell = 25; % year ... put 12 years ..based irradiance (12 h/ day)
 cost_cell = 100 ; % price for cell in $
 mantance = 0.1 ;% from price
 cost_A = No_cell * cost_cell/( dute_life_cell *365*24);
 Real_cost_A= 12*  cost_A;
================================================================================
 %% Grid
 cost_G = 10 ; % for a minimam ocation in kwh use a country

 y_c = cost_G* max_Req.^1   ;
 %y_A= cost_A* max_Req.^1;

================================================================================
    %% case_1  with Battery

    cost_Bat = 250 ;% $ / one peace NIK cadom which can be changed

    Power_Bat = 0.5 ; % kw ....put 0.4   80% based life cycle
    dis_charge = 1;  % hour
    charge =2 ;% hours
    dutcycale = 4 ;% life cycle for battery which a year = 365 day

    cost_kwh_Bat = cost_Bat/ (dutcycale*Power_Bat *365 );
    Real_cost_B=  8 *  cost_kwh_Bat ;      % 1 dis_char + 2 charge =3 /24 = 8

================================================================================
%% Optimize part
    %% Load
 lod_dist1 = 0.1 :.075: 0.55  ;
 lod_dist2 = 0.57:.08 : .99 ;
 lod_dist3 =1;
 lod_dist4 = abs(-.9 :.075:- 0.68) ;
  lod_dist5 = abs(-0.625 :.075:-  0.25 ) ;

 load_1= max_Req.*sum( lod_dist1)/7  ;  % from 12 AM - 7 AM
  load_2= max_Req.*sum( lod_dist2)/6;  % from 7 AM - 1 PM..sun rise at 7 AM
  load_3= max_Req.* sum(abs(1))/1;             % 1 - 2 PM
  load_4= max_Req.* sum(lod_dist4)/4;  % from  2 AM to 6 PM  sun set
    load_5= max_Req.* sum(lod_dist5)/6;  % from  6 PM to 12 AM

    set_P_B = load_1  ;
    set_P_Cell =  load_2 ;
    Set_P_Grad = load_3 - set_P_Cell  ;
    set_charge =3*( set_P_Cell - load_4 );

    % check time required for charging
    if max (load_5 ) < max(set_charge )
         Yes= 1
       else No= 1
    end
```

==

```
    %% cost project $/kw
       %  1
    Cos_Grid_day = Set_P_Grid*  cost_G     ;               % K $
    Cos_cell = ((set_P_Cell /cel) * cost_cell )/1000 ;  % K $
     Cos_Bat = ((set_P_B /Power_Bat)*cost_Bat )/1000 ;    % K $

     %% cost $ kwday
   cost_cell_day = (Cos_cell/ ( 25 *(1/2) * 365))*1000 ;  % $ KWd

     cost_Bat_day = (Cos_Bat /(4*365))*1000 ;

     Total_Cost_Cell_Bat_day = cost_cell_day + cost_Bat_day; % day
     Total_Cost_Cell_Bat_Kwh = Total_Cost_Cell_Bat_day./(set_P_Cell +
set_P_B);
      Cos_Grid_Kwh = Cos_Grid_day/Set_P_Grid; % this cost based on Utility.
     Total_Power_Cell_Bat =set_P_Cell + set_P_B


    %% Plot 1
    plot (l, set_P_B, 'b-*'); hold on
    plot (l, set_P_Cell, 'r-^')
      plot (l, Set_P_Grad, 'k-+')
    ylabel ('Kw/day'); xlabel (' No. of cars at ECV')
    legend ('power bat ', ' Cell ', 'from Grid')
    grid on

    %% plot 2
     plot (l, Total_Cost_Cell_Bat_day, 'b-*'); hold on
   % plot (l, cost_Bat_day, 'r-^')
      plot (l, Set_P_Grad *10, 'k-+')
    ylabel (' $ Kw/day'); xlabel (' No. of cars at ECV')
    legend ('Cell + battery ', ' Grid')
    grid on
```

==

```
     %% case_2 minimize Battery

     POWE_com=set_P_Cell +Set_P_Grid

     set_P_B2 =set_P_B; Set_P_Grid2= Set_P_Grid;
     for i= 1:10
        set = 10
         set_P_B2 = set_P_B2 - set;
        Set_P_Grid2 = Set_P_Grid2 + set;
     End
```

==

```
%%      bar for Distribution of EVCS loads for 1 Day
      figure; bar ([ lod_dist1 lod_dist2 lod_dist3 lod_dist4 lod_dist5])
     ok=1;
     axis auto
    title ('Distribution of EVCS loads for 1 Day')
    xlabel ('Hours')
```

```
ylabel ('Peak load for EVCS')
grid on
```

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