PALESTINE POLYTECHNIC UNIVERSITY

College of Engineering

Title

The Future Performance Of Distribution Networks With The Increasing Demand For The Use Of Electric Vehicles

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الإهداء

نهدي هذا العمل المتواضع إلى والدينا الكرام اللذان لم يدخرا جهداً في توفير كل الظروف المناسبة لإنجاح عملنا هذا ونهديه ايضاً إلى أعضاء هيئة التدريس وموظفي جامعة البوليتكنك ونخص بالذكر الدكتور نسيم قطيط

كما نهدي هذا العمل المتواضع لوطننا الغالي وعاصمة بلادنا القدس الشريف وإلى كل من احب العلم والتعلم

شكر وتقدير

الحمد الله الذي جعل التربية مشتقة من اسمه، وجعل أشرف الأعمال عمل المربين والصلاة والسلام على سيد المرسلين محمد

وعلى من اهتدى بهديه الى يوم الدين وبعد :

في نهاية عملنا المتواضع نحمد الله العظيم ونشكره كثيرا بجزيل شكرنا وعظيم امتناننا الى جامعة

بوليتكنك فلسطين ممثلة في رئيسها الدكتور عماد الخطيب .

وإن واجب العرفان يدعونا أن نتقدم بالشكر الوفير والتقدير الكبير لأستاذنا الجليل الدكتور نسيم قطيط

الذي كان له فضل الاشراف على هذا المشروع فكان نعم المرشد والموجه .

ولا ننسى كثير الشكر والاحترام والتقدير الى شركة كهرباء الخليل

وإن واجب العرفان يدعونا ان نتقدم بالشكر الوفير والتقدير الكبير الى موظفين شركة كهرباء الخليل

الذين افادونا بآرائهم العلمية القيمة واعطونا المعلومات الكافية عن شركة كهرباء الخليل لإتمام هذا المشروع

كما نتقدم بجزيل الشكر لعضوي

لجنة المناقشة: الدكتور سمير حنا والدكتور فؤاد الزرو .

في الختام نتقدم بخالص شكرنا وتقديرنا وعرفانا لكل من ساهم وانصح وارشد من اجل إتمام هذه الدراسة .

الملخص

مستقبل أداء شبكات التوزيع مع زيادة الطلب على استخدام السيارات الكهربائية

في الآونة الأخيرة، أصبح اتجاه استخدام المركبات الكهربائية في النقل أكثر من أي وقت مضى. يتم تشغيل السيارات الكهربائية بواسطة محرك كهربائي يتم تغذيته بواسطة البطارية، حيث يتم إعادة شحنها باستخدام شاحن كهربائي، وبالتالي فإنها تحتاج إلى محطات شحن كهربائية ليتم شحنها.

يدرس هذا المشروع شبكة الطاقة الكهربائية في مدينة الخليل نتيجة إضافة سبع محطات لشحن السيارات الكهربائية موزعة في الشبكة باستخدام برنامج محلل الكهرباء (Etap)، ويهدف الى عمل تخطيط استراتيجي على الشبكة واجراء التطورات والتحسينات ودراسة التأثيرات الناتجة على الشبكة من اجل وضع الحلول المناسبة.

يتمثل جوهر هذا المشروع في استخدام (Etap) الذي يحتوي على خاصية المحاكاة التي تسمح لنا بتحليل ودراسة حالة الشبكة بشكل أكثر دقة.

في هذا المشروع، تم استخدام أنواع مختلفة من المركبات الكهربائية التي تحتوي على بطاريات ذات قدرات مختفلة قابلة لعملية الشحن باستخدام تكنولوجيا الشحن ومستويات الشحن وفقا للمعايير الدولية المعتمدة التي يتم استخدامها في المحطات التي تم اضافتها على الشبكة من خلال اقتراح سناريوهات لمحاكاة الاحمال على الشبكة في أوقات مختلفة على مدار اليوم وعدد مختلف من المركبات الكهربائية.

تعاني هذه الشبكة من خسائر كبيرة، حيث تبين ان مقدار الطاقة الضائعة في شبكة الجهد المتوسط قبل إضافة المحطات هي 3.198% وهي قيمة مقبولة وفقا لمعايير اللجنة الكهرو تقنية الدولية (IEC).

في هذا المشروع، تم تطبيق سناريوهات مختلفة للأحمال على الشبكة لتحليل تدفق الطاقة وعرض الخسائر في الحالات المختلفة حيث تبين ان مقدار الطاقة الضائعة في الشبكة عند اعلى حمل تم اقتراحه 3.694% إضافة الى وجود زيادة احمال على بعض الكوابل ومحولات التوزيع والمحولات المغذية لمحطات شحن السيارات وبالتالي تم اقتراح سناريو لحل المشاكل التي ظهرت على الشبكة من خلال إعادة توزيع الاحمال على المحطات الفرعية واضافة محطة جديدة على الشبكة من اجل تقليل الخسائر.

أظهرت النتائج انه يمكن تخفيض اجمالي خسائر الطاقة عند اعلى حمل مقترح على الشبكة نتيجة إضافة محطات شحن السارات الكهربائية من 3.694% الى 3.0009 %.

Abstract

The future performance of distribution networks with the increasing demand for the use of electric vehicles

In recent times, the trend of using electric vehicles in transportation has become more than ever. Electric cars are powered by an electric motor that is powered by a battery, where they are recharged using an electric charger, and thus they need electric charging stations to be charged.

This project studies the electric power network in the city of Hebron as a result of adding seven electric vehicle charging stations distributed in the network using the Electricity Analyzer (Etap), and aims to make strategic planning on the network and make developments and improvements and study the resulting effects on the network in order to develop appropriate solutions.

The essence of this project is to use etap which has a simulation feature that allows us to analyze and study the state of the network more accurately.

In this project, different types of electric vehicles were used that contain batteries of different capacities that can be charged using charging technology and charging levels according to the approved international standards that are used in the stations that have been added to the network by proposing scenarios to simulate the loads on the network at times Different throughout the day and a different number of electric vehicles.

This network suffers from large losses, as it was found that the amount of wasted energy in the medium voltage network before adding the stations is 3.198%, which is an acceptable value according to the standards of the International Electrotechnical Commission (IEC).

In this project, different scenarios for loads on the network were applied to analyze the energy flow and display losses in different cases. It was found that the amount of wasted energy in the network at the highest load was 3.694% in addition to the presence Increasing loads on some cables, distribution transformers and feeding transformers for EV charging stations, and thus a scenario was proposed to solve the problems that appeared on the network by redistributing the loads to the substations and adding a new station to the network in order to reduce losses.

The results showed that the total energy losses could be reduced at the highest proposed load on the grid as a result of adding electric vehicle charging stations from 3.694% to 3.0009%.

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List of Abbreviations

AC	Alternative Current
AER	All-electric range
BEVs	Battery Electric Vehicles
BMS	Battery Management System
BS	Battery Storage
CHAdeMO	Charge de Move
CO2	Carbon Dioxide
DC	Direct Current
DoD	Depth of Discharge
EVs	Electric Vehicles
EVSE	Electric Vehicle Supply Equipment's
FCEV	Fuel cell electric vehicles
G2V	Grid to vehicle
HEVs	Hybrid Electric Vehicles
ICE	Internal Combustion Engine
IEC	International Electro technical Commission
km/h	Kilometers per hour
kV	Kilovolt
kWh	Kilowatt-hour
LI-ION	Lithium ion
LV	Low voltage network
MVA	Megavolt-ampere
MVar	Mega volt amps
MW	Megawatt
PEVs	Plug-in electric vehicles

PHEVs	Plug-in Hybrid Electric Vehicles
SAE	Society for Automotive Engineers
SOC	State-of-charge
THD	Total Harmonic Distortion
V2G	Vehicle to Grid
V2H	Vehicle to Home
V2V	Vehicle to Vehicle
Wh	Watt-hours
ZEVs	Zero-Emissions Vehicles
HEPCo	Hebron Electrical Power Company
ETAP	Electrical Transient Analyzer Program
NIS	New Israeli Shekel

Chapter1

Introduction

1.1 Overview

This project studies the effects that occur on the electric power grid in the city of Hebron as a result of adding charging stations for electric cars on it, where we will do a simulation of the distribution network when adding stations using the ETAP program to show the real effects that can occur on the network and create scenarios to reduce them.

1.2 The future of electric vehicles

The world is witnessing a huge demand for electric cars, as most forecasts indicate that the era of electric cars may begin soon. It is true that it is here today and there, but it is uncommon. "New Energy Finance" company predicts affiliated with Bloomberg's that this will change soon, and that some electric cars will become less expensive than petrol cars by 2025.

It is expected that 500 million electric vehicles will be on the roads by 2030. The technology and infrastructure for the charging of electric vehicles will be the key enabler for this mobility transition. EV charging facilities will be required at homes, workplaces, shops, recreational locations and along highways. The EV charging power has to be provided by the distribution network at low cost, with minimal reinforcement and at maximum reliability [44].

The impacts of EV penetration into LV networks can be considered as fundamental in terms of providing an insight of the system changes that are likely to happen in the short term. This in turn, implies for the need of communication infrastructure through power line carriers, internet connection or mobile phone networks [1] and possibly protocol standardization. Consumers will require information regarding the availability and pricing of charging and the benefits they can obtain from V2G. On the other side, operators will need to know the recharging intentions and State of Charge (SOC) for V2G services from the customers. Smart metering application may assist to the scope of providing easiness and immediacy to the consumers while in parallel, provide to the grid operators information regarding the behavior of the prosumers (since the owner of the EV has the ability to be a consumer or producer of power in the case of charging or discharging respectively) [21].

The following Figure 1.1 shows the general charging process for electric vehicles on a distribution station:

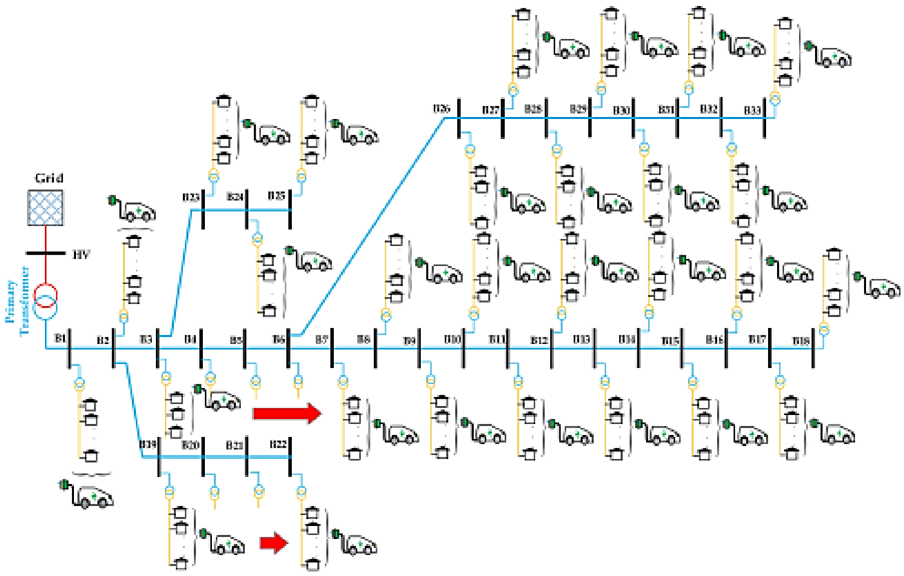

Figure 1.1: Plug-in electric vehicles (PEVs) connected in a radial distribution system [21].

1.3 Motivation

Most car manufacturers have tended to produce electric cars, which have increased demand in the recent period, because they reduce the consumption of petroleum materials and their dependence on electricity consumption and less maintenance compared to petroleum cars. For this reason, Palestinian cities have tended to install and operate electrical charging stations of all kinds, in addition to developing The appropriate infrastructure to construct and install these stations.

Where the Hebron municipality installed a charging station for electric cars in the Ein Sarah area opposite the Hebron municipality building.

1.4 Objectives

This project aims to study the effects resulting from adding charging stations for EVs on the electricity distribution network.

1) Adding charging stations for EV to the HEPCo network.

2) Implementation of the design using ETAP.

3) Analyze the effect of the electric vehicle charging station on the distribution network.

4) Proposing scenarios for charging electric vehicles on a distribution network at different times.

5) Proposing a scenario to solve the problems which could result from adding charging stations to the HEPCo network.

1.5 Problems

1) Voltage Drop: EV penetration is going to affect the voltage profile of distribution networks.
2) Distribution Transformer Thermal Limits: Currently, distribution transformers are rated according to the load that the LV networks are designed to withstand. The addition of EVs might generate the need for upgrade even though the distribution transformers are able to withstand 160% loading [2].
3) LV Cable Thermal Limits: The increase of load that the penetration of EVs entails, begets larger amounts of current that need to be fed through the distribution substation. This is mainly the case for the extreme operating conditions, maximum load and minimum EV penetration and minimum load and maximum EV penetration.
4) Network losses.
5) Voltage Unbalance: Geographically dispersed EVs, single phase connected, are likely to raise voltage unbalance issues.
6) Under-frequency: The load increase in LV networks is likely to affect the system frequency.
7) Current Harmonics: The battery chargers of EVs are likely to introduce harmonics in the network, according to [3].

1.6 Literature Review

The world is moving towards using electric vehicles as being environmentally friendly, as it becomes the transportation sector has become one of the main areas of energy consumption and has had a high impact on electrical power source sectors. Moreover, there have been several studies of new load characteristics that exist in electrical power systems. The plug-in electric vehicle (PEV) is a new electrical load type that is considered an emerging load in the focus area. Electric vehicles (EVs), either Plug-in Hybrids or Battery ones, rely on the electricity grid for charging in order to provide them with functionality .The usage of PEVs has increased due to their low carbon emissions and to decrease in petroleum derivatives consumption, promotion by governments, or privileges into certain special areas. The advantage of a PEV is that it utilizes both a fuel cell and battery as the energy source. The AC-DC converter has been used to convert electricity from the electrical power system to the battery as the charging state when the battery has a low level state-of-charge [2].

Interestingly, the recharging condition of the PEV battery has been taking place on the grids simultaneously, that serious problems can arise under uncoordinated opportunistic charging scenarios. Several recent studies show that the distribution grid could be significantly impacted by high penetration levels of uncoordinated PHEV charging, so the power system will be impacted.

Fast charging station in urban dwelling areas can be impacted by the electrical power system under conditions of voltage drop, transmission line loading, transformer loading, peak demand, and increase of total power loss. Therefore, the electrical power system needs to be managed to reduce the factors that limit its capacity to provide sufficient energy. Interestingly, the electric vehicle integration in demand response (DR) programs can manage energy consumption at the customer side of the meter which can reduce peak demand and price volatility by utilizing smart grid enabling technologies [3].

Chapter 2

ELECTRIC VEHICLES AND BATTERIES IN EV

2.1: TYPES OF ELECTRIC VEHICLES

There are three main types of electric vehicles (EVs), classed by the degree that electricity is used as their energy source. BEVs, or battery electric vehicles, PHEVs of plug-in hybrid electric vehicles, and HEVs, or hybrid electric vehicles [5,6].

2.1.1 Battery Electric Vehicles (BEVs)

Battery Electric Vehicles, also called BEVs, and more frequently called EVs, are fully-electric vehicles with rechargeable batteries and no gasoline engine. Battery electric vehicles store electricity onboard with high-capacity battery packs. Their battery power is used to run the electric motor and all onboard electronics. BEVs do not emit any harmful emissions and hazards caused by traditional gasoline-powered vehicles. BEVs are charged by electricity from an external source [6].

The following Table 2.1 shows some types of BEV.

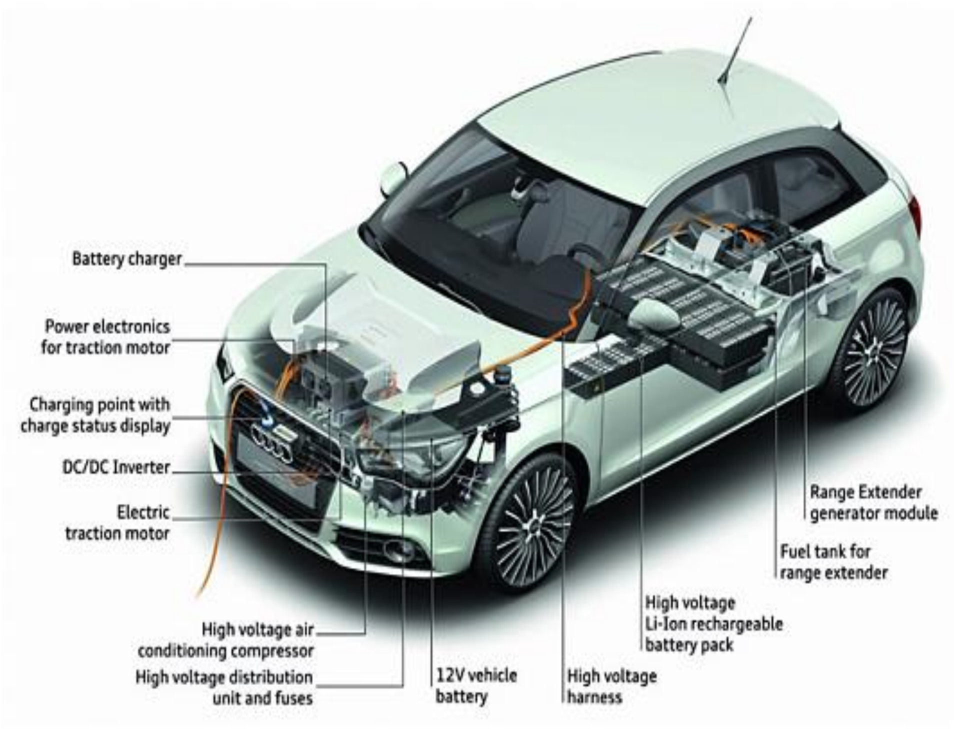

Figure 2.1: Battery Electric Vehicles (BEVs) [40].

2.1.2 Plug-in Hybrid Electric Vehicle (PHEVs)

Plug-in Hybrid Electric Vehicles or PHEVs can recharge the battery through both regenerative braking and "plugging in" to an external source of electrical power. While "standard" hybrids can (at low speed) go about 1-2 miles before the gasoline engine turns on, PHEV models can go anywhere from 10-40 miles before their gas engines provide assistance [6].

The following Table 2.1 shows some types of PHEVs.

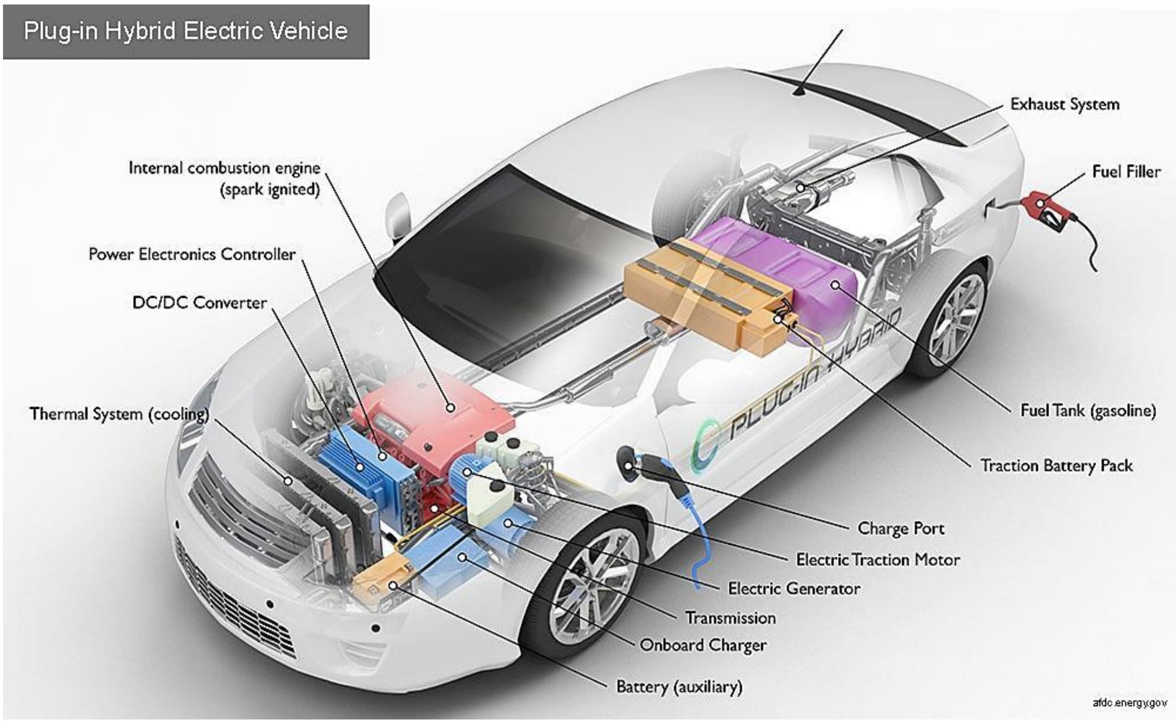

Figure 2.2: Plug-in Hybrid Electric Vehicle (PHEVs) [41].

Table 2.1: Comparison of the PEV types and technologies [7].

Manufacturer/Model	Type	Battery Size (kWh)	Electric Motor (kW)/Engine (L)	Range Electric (Miles)	Charging Rate (kW) [30,31]
Audi/A3 e-Tron	PHEV	8.8	75/1.4	16	3.3+
BMW/330e iPerformance	PHEV	7.6	65/2.0	22	1.4 */3.5+
BMW/i8 Coupe	PHEV	11.6	105.2/1.5	15	1.2 */3.7+
Chevrolet/Volt	PHEV	18.4	111/1.5	53	1.2 */3.6+
Ford/Fusion Energi SE	PHEV	7.6	88/2.0	21	*/3.3+
Honda/Clarity Plug-In Hybrid	PHEV	17	135.2/1.5	48	*/3.3+
Hyundai/Sonata	PHEV	9.8	50/2.0	27	*/3.3+
Mercedes/C350e	PHEV	6.2	60/2.0	20	3.3+
Toyota/Prius Prime	PHEV	8.8	60/1.8	25	*/3.3+
Porsche/Panamera S E-Hybrid	PHEV	14	101.45/4.0	16	3.3+
Volvo/XC90 T8	PHEV	10.4	65/2.0	19	3.3+
BMW/i3, i3s	BEV	33	126.82/135	114/107	1.2 */7.4+/DC
Chevrolet/Bolt	BEV	60	150	238	7.2+/DC
Fiat/500e	BEV	24	83	84	6.6+/DC
Honda/Clarity Electric	BEV	25.5	120	89	6.6+/DC
Hyundai/Ioniq Electric	BEV	28	88	124	6.6+/DC+
Nissan/Leaf	BEV	40	110	151	6.6+/DC
Smart ED	BEV	17.6	55	68	7.2+
Tesla/Model 3 Standard, Long Range	BEV	50,70	192.46, 202	220,310	*/+/DC+
Tesla/Model S 75D,100D and P100D	BEV	75,100,100	N/A	259,335,315	*/+/DC+
Tesla/Model X, 75D, 100D and P100D	BEV	75,100,100	N/A	237,295,289	*/11.5-17.2+/DC+
Kia/Soul EV	BEV	30	81.4	111	*/+/DC

Remark: * = AC level 1, + = AC level 2, DC = DC level 2, DC+ = DC level 3.

2.1.3 Hybrid Electric Vehicles (HEVs)

HEVs are powered by both gasoline and electricity. The electric energy is generated by the car's own braking system to recharge the battery. This is called 'regenerative braking', a process where the electric motor helps to slow the vehicle and uses some of the energy normally converted to heat by the brakes.

HEVs start off using the electric motor, then the gasoline engine cuts in as load or speed rises. The two motors are controlled by an internal computer, which ensures the best economy for the driving conditions [6].

HEV Examples:

- Toyota Prius Hybrid
- Honda Civic Hybrid
- Toyota Camry Hybrid

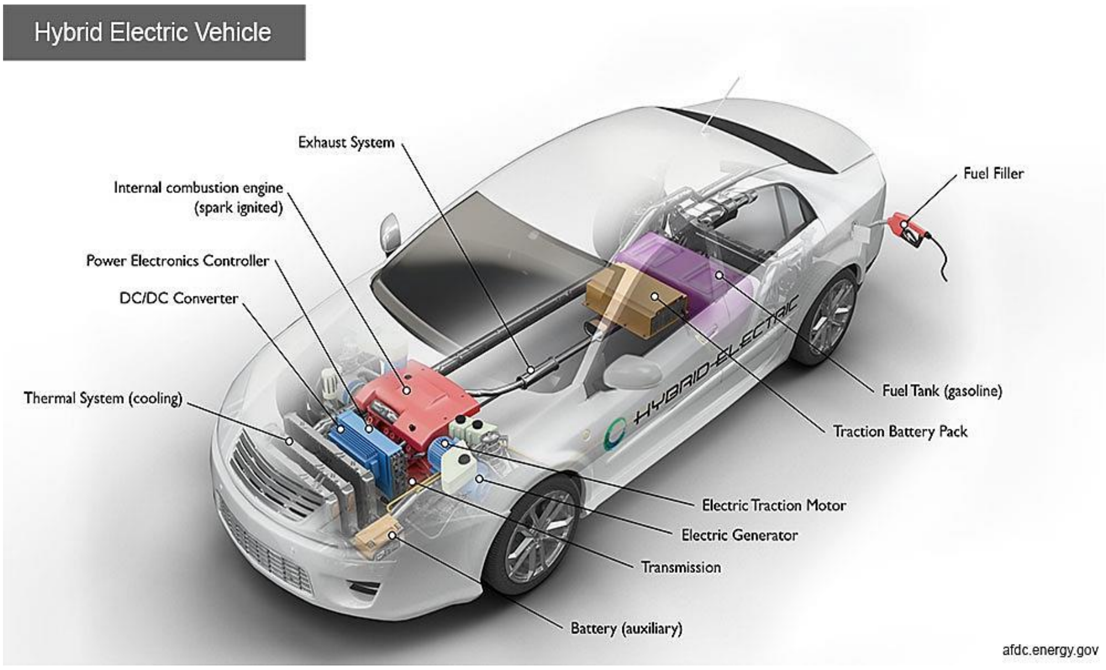

Figure 2.3: Hybrid Electric Vehicles (HEVs) [6].

2.2 TYPES OF Range IN ELECTRIC VEHICLES

The PEVs that are the focus of the present are often divided into two categories: battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) that include an ICE and an electric motor. This chapter uses vehicle AER to distinguish four classes of PEVs. The reason is that the obstacles to consumer adoption and the charging infrastructure requirements differ for the four classes of PEVs. BEVs are separated into long-range BEVs and limited-range BEVs, and PHEVs are separated into range-extended PHEVs and minimal PHEVs [4-5].

2.2.1 Type 1: Long-Range Battery Electric Vehicles

Today's drivers are accustomed to ICE and HEV vehicles that are able to drive for hundreds of miles and then be refueled at any gasoline station in several minutes. Extended trips are practical insofar as the refueling time is much shorter than the additional driving time that refueling provides. The full-size Tesla Model S is a demonstration that hundreds of miles are also possible with a BEV that gets its energy entirely from the electric grid. Half of the charge of a depleted battery can be replenished in 20 minutes.

2.2.2 Type 2: Limited-Range Battery Electric Vehicles

A limited-range BEV is more affordable simply because a smaller high-energy battery is installed, giving it a shorter range. The 2014 Nissan Leaf, a midsize car, is the best-selling example. It has a 24 kWh battery and an 84-mile range (DOE/ EPA 2014b). A more recent addition to the limited-range BEV market is the Ford Focus Electric compact car, which has a 76- mile range (DOE/EPA 2014c).

2.2.3 Type 3: Range-Extended Plug-in Hybrid Electric Vehicles

A range-extended PHEV2 is similar to a long-range or limited-range BEV in that the battery can be charged from the electric grid. However, the battery is smaller than that in a BEV, and the vehicle has an onboard ICE fueled by gasoline or diesel fuel that is able to charge the battery during a trip. Although extended trips fueled only by electricity are not practical, the vehicle has a total range comparable with that of a conventional vehicle because of the onboard ICE. The 2014 Chevrolet Volt with an AER of 38 miles (DOE/EPA 2014d) is the best-selling example, and the 2014 Ford Energy models (Fusion Energy and CMax Energy) that have AERs of 20 miles are other prominent examples.

2.2.4 Type 4: Minimal Plug-in Hybrid Electric Vehicles

Minimal PHEVs are PEVs whose small batteries can be initially charged from the electric grid to provide electric propulsion for an AER that is much less than the average daily travel distance for the driver. Among many examples, the 2014 Plug-in Toyota Prius is a minimal PHEV in that its AER is only 6 miles (DOE/EPA 2014e).

Table 2.2: Definitions and Examples of the Four Types of Range in Electric Vehicles [4].

Vehicle	Battery Capacity[a]	All-Electric Range[b]
Type 1. Long-Range Battery Electric Vehicle. Can travel hundreds of miles on a single battery charge and then be refueled in a time that is much shorter than the additional driving time that the refueling allows, much like an ICE vehicle or HEV.		
 **2014 Tesla Model S** © Steve Jurvetson, licensed under Creative Commons 2.0 (CC-BY-2.0)	85 kWh nominal	265 miles
Type 2. Limited-Range Battery Electric Vehicle. Is made more affordable than the long-range BEV by reducing the size of the high-energy battery. Its limited range more than suffices for many commuters, but it is impractical for long trips.		
 **2014 Nissan Leaf** ©2014 Nissan North America, Inc. Nissan, Nissan model names, and the Nissan logo are registered trademarks of Nissan	24 kWh nominal (~21 kWh usable)	84 miles
 **2014 Ford Focus Electric** Image courtesy of Ford Motor Company	23 kWh nominal	76 miles
Type 3. Range-Extended Plug-in Hybrid Electric Vehicle. Operates as a zero-emission vehicle until its battery is depleted, whereupon an ICE turns on to extend its range.		
 **2014 Chevrolet Volt** © General Motors	16.5 kWh nominal (~11 kWh usable)	38 miles
Type 4. Minimal Plug-in Hybrid Electric Vehicle. Is mostly an HEV. Its small battery can be charged from the grid, but it has an all-electric range that is much smaller than the average daily U.S. driving distance.		
 **2014 Toyota Plug-In Prius** Image courtesy of Toyota Motor Corporation	4.4 kWh nominal (~3.2 kWh usable)	11 miles (blended) 6 miles (battery only)

The following Figure 2.4 also shows a comparison of some types of electric cars, which depends on the charge time of the car, the maximum speed that the vehicle can reach, and the distance covered.

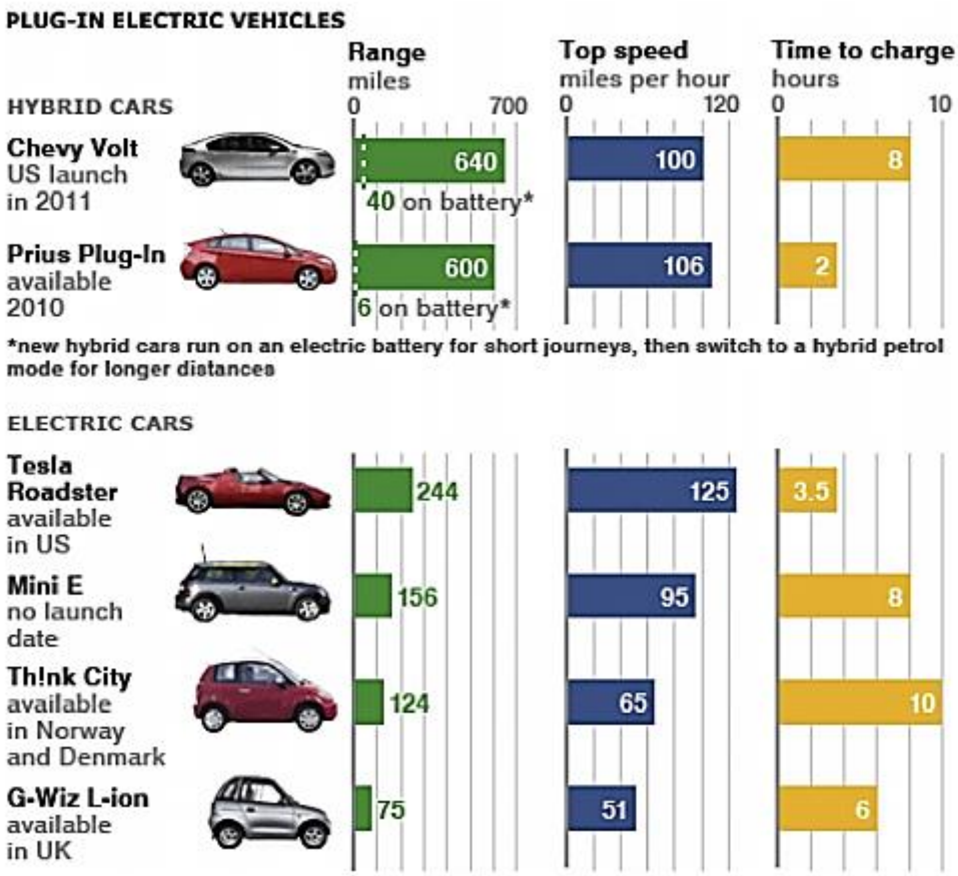

Figure 2.4: Performance of some electric vehicles as of 2009 [8].

2.3 Batteries in EV

In electric vehicle, rechargeable battery served as energy source for all its system operation which include electric motor for propulsion system and also other auxiliary components. How far the car can go is a key component to be explained in changing the perception of the consumer where the anxiety range becomes a barrier to purchase an EV. Driving range is closely related to the energy capacity of the battery. Battery with high energy capacity will result in longer driving distance [9].

The investigations reveals that, Li-ion as the battery with high energy density cover more area or distance travel.

2.3.1 Types of battery used in EV

1) Lead Acid.

2) Nickle-Metal-Hydrite (NiMH).

3) Nickel-Cadmium (NiCd)

4) Lithium Ion (Li-ion)

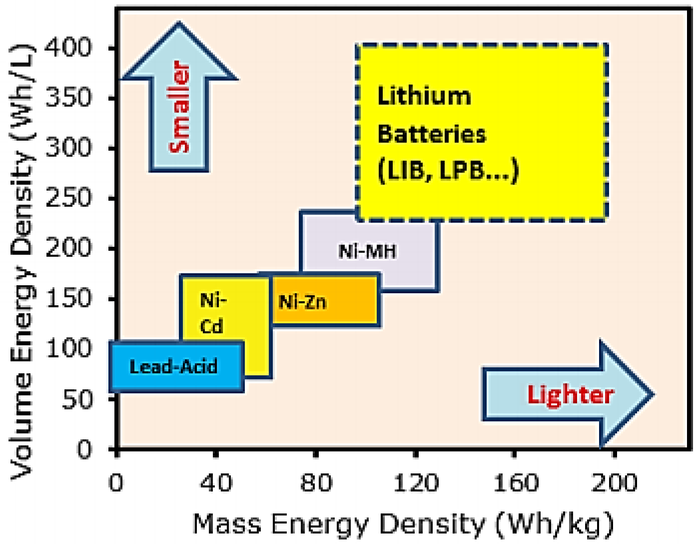

Figure 2.5: The volume energy density and the mass energy density for various battery types [4].

Table 2.3: Different types of EV batteries [9].

Battery type	Nominal Volt. (V)	Rated Capacity (Ah)
Lead acid	6	225
NiCd	6	180
NiMH	201.6	6.5
Li-ion	360	33.1

Figure 2.5 shows the Li-ion battery is one of the two leading battery used in the EV technology aside from NiMH [12]. This type of battery wins over Nickle chemistries due to several factors which include more energy capacity in much lighter package , low in self discharge and good temperature performance. And the good news about Li-ion is the environmental friendly factor where almost all parts of battery components are recyclable. Li-ion is a preferred choice for most of hybrids and battery EV.

Figure 2.6, shows the range comparison between Li-ion and NiMH. Based from Figure 2.6, Li-ion provides more distance travelled by the vehicle as it have more energy density than NiMH. Table 2.4 tabulated the simulation outcome between Li-ion and NiMH [11].

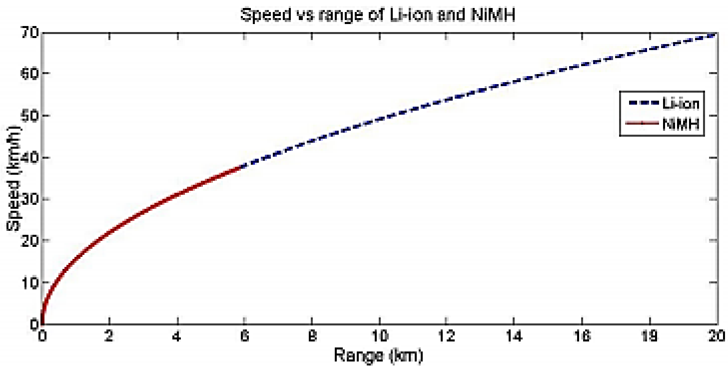

Figure 2.6: Speed vs range between Li-ion and NiMH [9].

Table 2.4: Comparison of speed and range for Li-ion and NiMH [9].

	Range (km)	Speed (km/h)
Li-ion	20	70
NiMH	6	40

Chapter 3

CHARGING TECHNOLOGIES

3.1 The EV Charging Modes

An electric vehicle charging station, also called EV charging station, electric recharging point, charging point, charge point and EVSE (Electric Vehicle Supply Equipment), is an element in an infrastructure that supplies electric energy for the recharging of plug-in electric vehicles, including all-electric cars, neighborhood electric vehicles and plug-in hybrids. As plug-in hybrid electric vehicles and battery electric vehicle ownership is expanding, there is a growing need for widely distributed publicly accessible charging stations, some of which support faster charging at higher voltages and currents than are available from domestic supplies. Many charging stations are on-street facilities provided by electric utility companies, mobile charging stations have been recently introduced. Some of these special charging stations provide one or a range of heavy duty or special connectors and/or charging without a physical connection using parking places equipped with inductive charging mats[20].

The charging scheme and configuration of several PEVs are described in the International Electro technical Commission Standard (IEC 61851-1) and Society of Automotive Engineers standard (SAE J1772). Charging mode was defined in connection mode of DC power and AC power based on the battery charger and the position of charging such as normal charging mode used in residential distribution network. Therefore, the standard charging power levels of the IEC 61851-1 and SAE J1772 standard were used in private sectors, domestic environments, or public areas [21].

The IEC 61851-1 Committee on “Electric vehicle conductive charging system” has then defined 4 Modes of charging, concerning:

1) The type of power received by the EV (DC, single-phase or three-phase AC).
2) the level of voltage (for AC in range between single-phase 110V to three-phase 480V).
3) The presence or absence of grounding and of control lines to allow a mono or two-way dialogue between the charging station and EV.
4) The presence and location of a device protection.

Table 3.1: IEC EV charging modes based on IEC 61851-1 [21].

Connection Mode	Grid connection	AC voltage	AC current	Type of charge
Mode 1 (AC)	1 phase	230 V	16 A	Slow
	3 phase	400 V	16 A	Slow
Mode 2 (AC)	1 phase	230 V	32 A	Slow
	3 phase	400 V	32 A	Slow
Mode 3 (AC)	1 phase	230 V	32 A	Slow
	3 phase	690 V	250 A	Medium
Mode 4 (DC)	–	600 V	400 A	Fast

3.1.1 Mode 1: Household Socket and Extension Cord

The vehicle is connected to the power grid through standard socket-outlets present in residences, which depending on the country are usually rated at around 10 A. To use mode 1, the electrical installation must comply with the safety regulations and must have an earthing system, a circuit breaker to protect against overload and an earth leakage protection. The sockets have blanking devices to prevent accidental contacts[20].

The first limitation is the available power, to avoid risks of heating of the socket and cables following intensive use for several hours at or near the maximum power (which varies from 8 to 16 A depending on the country)fire or electric injury risks if the electrical installation is obsolete or if certain protective devices are absent.

The second limitation is related to the installation's power management as the charging socket shares a feeder from the switchboard with other sockets (no dedicated circuit) if the sum of consumptions exceeds the protection limit, the circuit-breaker will trip, stopping the charging All these factors impose a limit on the power in mode 1, for safety and service quality reasons. This limit is currently being defined, and the value of 10 A appears to be the best compromise.

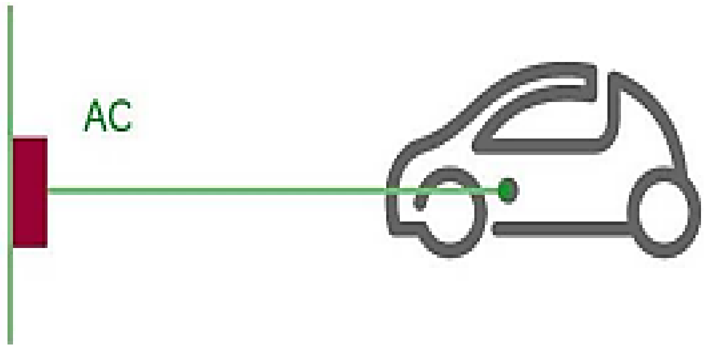

Figure 3.1: Mode 1 type connection (Household Socket And Extension Cord) [42].

3.1.2 Mode 2: Domestic Socket And Cable With Protection

The vehicle is connected to the main power grid via household socket-outlets. Charging is done via a single phase or three-phase network and installation of an earthing cable. A protection device is built into the cable. This solution is more expensive than Mode 1 due to the specificity of the cable.

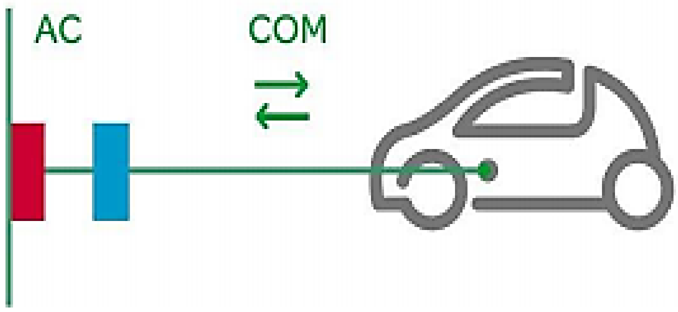

Figure 3.2: Mode 2 type connection (Domestic Socket And Cable With Protection) [42].

3.1.3 Mode 3: Specific Socket on A Dedicated Circuit

The vehicle is connected directly to the electrical network via specific socket and plug and a dedicated circuit. A control and protection function is also installed permanently in the installation. This is the only charging mode that meets the applicable standards regulating electrical installations. It also allows load shedding so that electrical household appliances can be operated during vehicle charging or on the contrary optimize the electric vehicle charging time.

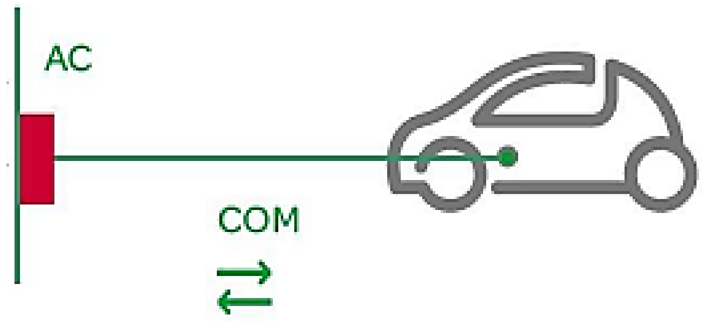

Figure 3.3: Mode 3 type connection (Specific Socket On A Dedicated Circuit) [42].

3.1.4 Mode 4: DC Connection for Fast Charging

The electric vehicle is connected to the main power grid through an external charger. Control and protection functions and the vehicle charging cable are installed permanently in the installation.

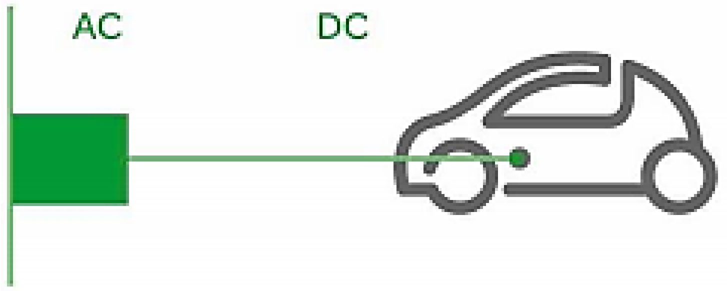

Figure 3.4: Mode 4 type connection (Direct Current Connection For Fast Charging) [42].

3.2 Charging levels

Table 3.2: Levels of EV charging according to SAE[22].

Source	Level	Voltage	Phase	Max current	Max power (kW)	Time (h)
AC	Level 1	120	Single	16	1.9	6 - 24
	Level 2	240	Single	80 (typical 40)	19.2	2 - 8
	Level 3	TBD	TBD	TBD	TBD	TBD
DC	Level 1	200-450	DC	<= 80	<= 19.2	~ 20 min
	Level 2	200-450	DC	200	90	~ 15 min
	Level 3	TBD (may cover 200-600)	DC	TBD (may cover up to 400)	TBD (may cover up to240)	TBD

TBD-to be defined

There are three levels of charging, Level 1 charging, Level 2 charging, and Level 3 charging. The Society of Automotive Engineers (SAE) J1772 standard recommends that Level 1 and Level 2 EVSE be located on-board the vehicle, while Level 3 is external to the vehicle[23].

3.2.1 Level 1 Charging

This charging method uses the typical 120 Vac, 15 A single phase outlet as the charging source and provides 2–5 miles of range per 1 hour of charging time. Typically, 8 hours of charging will provide 40 miles of travel range. The EV or PHEV uses the SAE J1772 standard connector.

3.2.2 Level 2 Charging

All commercial EVs and PHEVs have the ability to charge using Level 1 or Level 2 charging systems. Level 2 charging uses a 208 V (typical in commercial applications) or 240 Vac (typical in residential applications) to supply charging current of up to 80 A (19.2 kW) and provides 10–20 miles of range per 1 hour of charging time. Level 2 charging also uses the SAE J1772 ac charge port to charge the vehicle batteries.

3.2.3 Level 3 Charging

Level 3 charging, provides a rapid charging method to charge the vehicle batteries at installed stations. This charging method uses a 208/480 Vac, 3-phase source with a dc output to the vehicle and provides 50–70 miles of range per 20 minutes of charging time.

3.3 Types of charging connectors

Everyone wants to charge their electric vehicle at home, at work, or a public station, one thing is essential: The outlet of the charging station has to match the outlet of your car. More precisely, the cable that connects the charging station with your vehicle has to have the right plug on both ends. So there are Four types of plugs, two for alternating current (AC)which allow charging up to 43 kW and two for direct current (DC) which allow fast-charging up to 350 KW as shown in Figure 3.5.

3.3.1Types of AC connectors

Type 1: Alternate names: J1772, SAE J1772.

Type 2: Alternate names: IEC 62196, Mennekes.

3.3.2 Types of DC connectors

1) CHAdeMO.

2) CCS Combo.

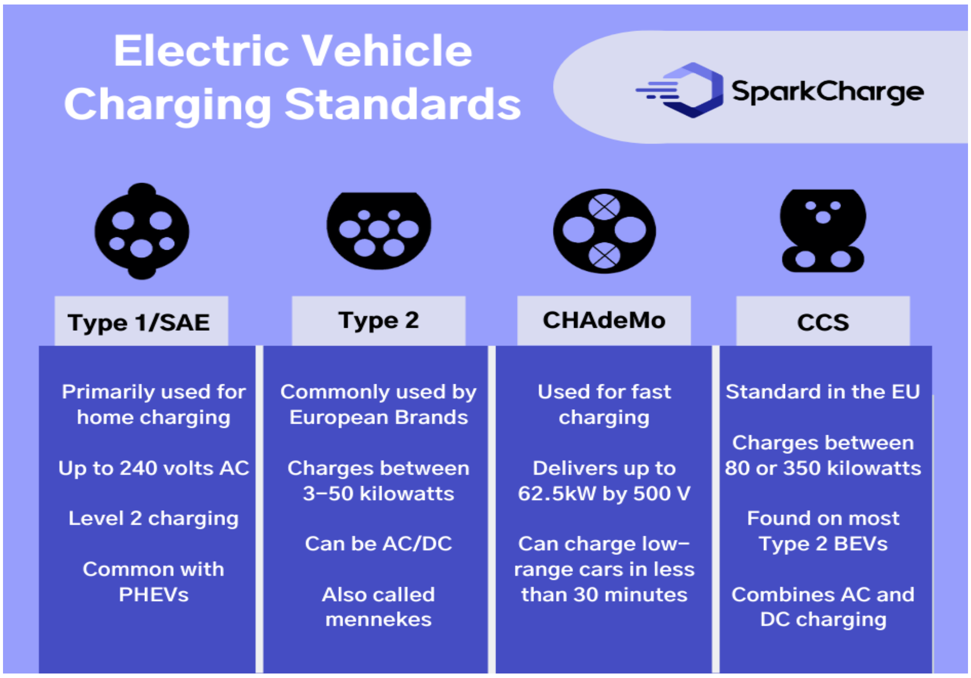

Figure 3.5: Types of charging connectors [43].

3.4 Charging Schemes

With the integration of EVs, where the batteries are charged from the power grid, arises the concept grid-to-vehicle (G2V). However, due to the capacity of the EVs to store energy, using bidirectional battery chargers, it is possible to send energy in the opposite way from the EV batteries to the power grid. [24,25]

3.4.1 Vehicle-to-Grid (V2G) Operation Mode

During the V2G operation mode the energy flows from the batteries to the power grid. In this operation mode the ac-dc full-bridge bidirectional converter works also as an inverter, however, with sinusoidal current injection. The dc-dc buck-boost bidirectional converter works as boost converter aiming to discharge the batteries with constant power . In this operation mode, the ac-dc converter control is similar to the one used in the G2V operation mode. To synthesize the reference current it was also used the predictive current control. The main difference is the dc-dc operation [26].

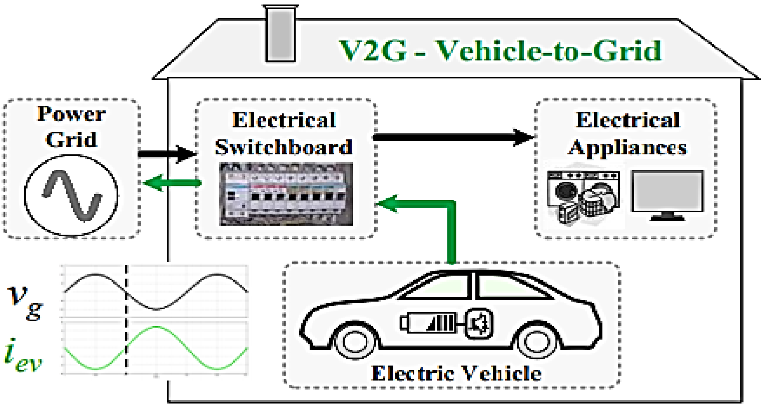

Figure 3.6: V2G – Vehicle-to-grid operation mode [24].

The basic concept of vehicle-to-grid power is that EDVs provide power to the grid while parked. The EDV can be a battery–electric vehicle, fuel cell vehicle, or a plug-in hybrid. Battery EDVs can charge during low demand times and discharge when power is needed. Fuel cell EDVs generate power from liquid or gaseous fuel.

3.4.2 GRID-TO-VEHICLE (G2V) OPERATION MODE

During the G2V operation mode the energy flows from the power grid to the batteries. In this operation mode the ac-dc full-bridge bidirectional converter works as active rectifier with sinusoidal current consumption and unitary power factor. The dc-dc buck-boost bidirectional converter works as buck converter aiming to charge the batteries with different stages of current and voltages. [25]

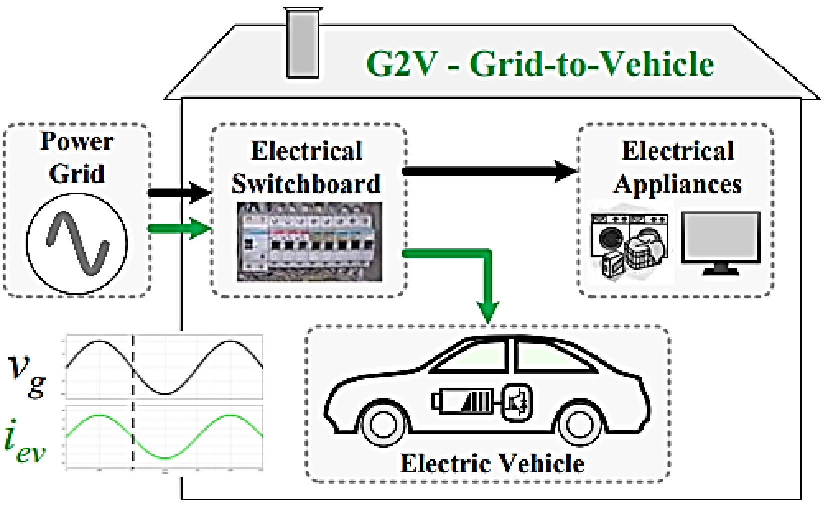

Figure 3.7: G2V – Grid-to-vehicle operation mode [24].

where the batteries are charged from the power grid, arises the concept grid-to-vehicle (G2V).However, due to the capacity of the EVs to store energy, using bidirectional battery chargers.

3.4.3 HOME-TO-VEHICLE (H2V) OPERATION MODE

The principle of operation of the H2V mode. In this operation mode the power flows from the power grid to the EV batteries, or vice-versa, in accordance with the energy provided to the other electrical appliances in the home. The H2V operation mode is an improvement of the G2V and V2G operation modes. It consists in adjusting the current or voltage during the batteries charging (relation with the G2V operation mode), or in adjusting the current during the batteries discharging (relation with the V2G operation mode). It is important to note that the operation in these two cases is totally independent. [20]

A. H2V Combined with Grid-to-Vehicle.

During this operation mode the power flows from the power grid to the EV batteries in accordance with the power required by the other electrical appliances in the home. This functionality aims to prevent overcurrent trips of the main circuit breaker installed in the home.

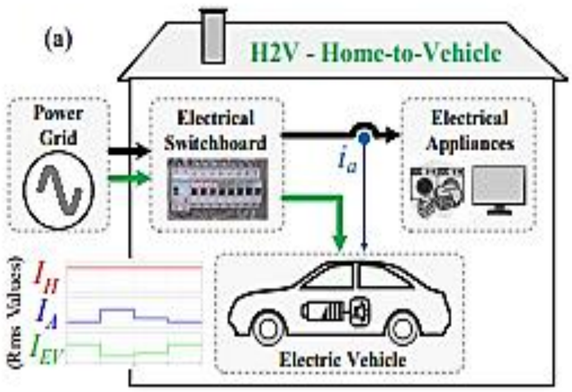

Figure 3.8: HOME-TO-VEHICLE with Grid-to-Vehicle [24].

B. H2V combined with Vehicle-to-Grid.

During this operation mode the power flows from the EV batteries to the power grid also in accordance with the power that flows to the other electrical appliances. This functionality also aims to prevent overcurrent trips of the main circuit breaker installed in the home.

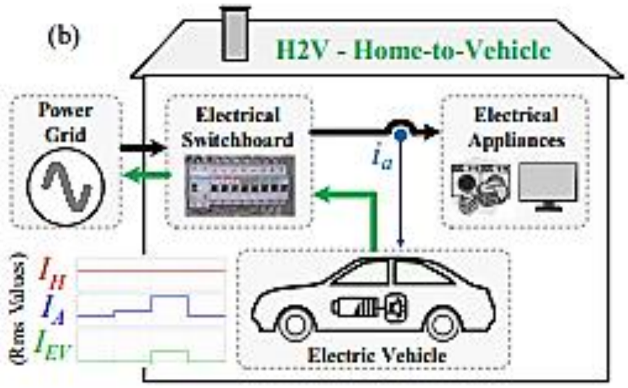

Figure 3.9: HOME-TO-VEHICLE with Vehicle-to-Grid [24].

3.5 Planning the locations of the charging stations

PEV charging station planning has become a research hotspot over recent years, We can generally divide this literature into two categorical perspectives:

1. Transportation Approach:

Planning of gasoline stations has been studied for decades and the corresponding methodologies have been adopted and redeveloped for PEV charging station planning. These methods can be further divided into three major methodologies:

a) Nodal demand-based planning [27,28].
b) Transportation simulation-based planning [29,30].
c) Traffic flow-based planning [31-32].

The nodal demand based planning methods assume PEV charging occurs on some geographical nodes of the target planning area and locate the charging stations to satisfy charging demand [27-28].

2. Electrical Approach:

As a new type of power demand, the PEV charging station planning in power systems has also drawn much attention. Existing work usually aims to site charging stations in power systems to satisfy power system economic or security operation constraints, while minimizing the investment costs for the charging stations and corresponding power grid upgrades [33].

CHAPTER 4

Charging stations

4.1 Introduction

Hebron is a Palestinian city and the center of Hebron Governorate, It is located in the West Bank, about 35 km south of Jerusalem. Founded by the Canaanites in the early Bronze Age, today it is considered the largest city in the West Bank in terms of population and area, as its population in 2016 reached about 215 thousand people and an area of 42 km2. The city is of economic importance, as it is one of the largest economic centers in the West Bank.

4.1.1 Hebron City Network

Hebron Electric Limited Liability Company was established in 2000 on an area of 91 km2 to serve 340,000 citizens of Hebron and Halhul, with a capital of 25 million Jordanian Dinars and assets of 91 million NIS. The percentage of electricity customers in Hebron and Halhul is 100%, with 50,409 customers until the end of 2017 [34].

Electrical power system is divided into three types, generation, transmission and distribution. HEPCo is considered as a distribution company, which is supplied from Israeli Electric Company.

HEPCo has a flexibility in controlling the distribution electricity to different areas illustrated in Figure 4.1 which are; Hebron city, Halhul, Essa, Loza, Beit Enun Baq‟a, Dowara, Oddese, Qilqes, Jalajel. The estimated number of people who are supplied by electricity from HEPCo is around 250,000 inhabitants [34].

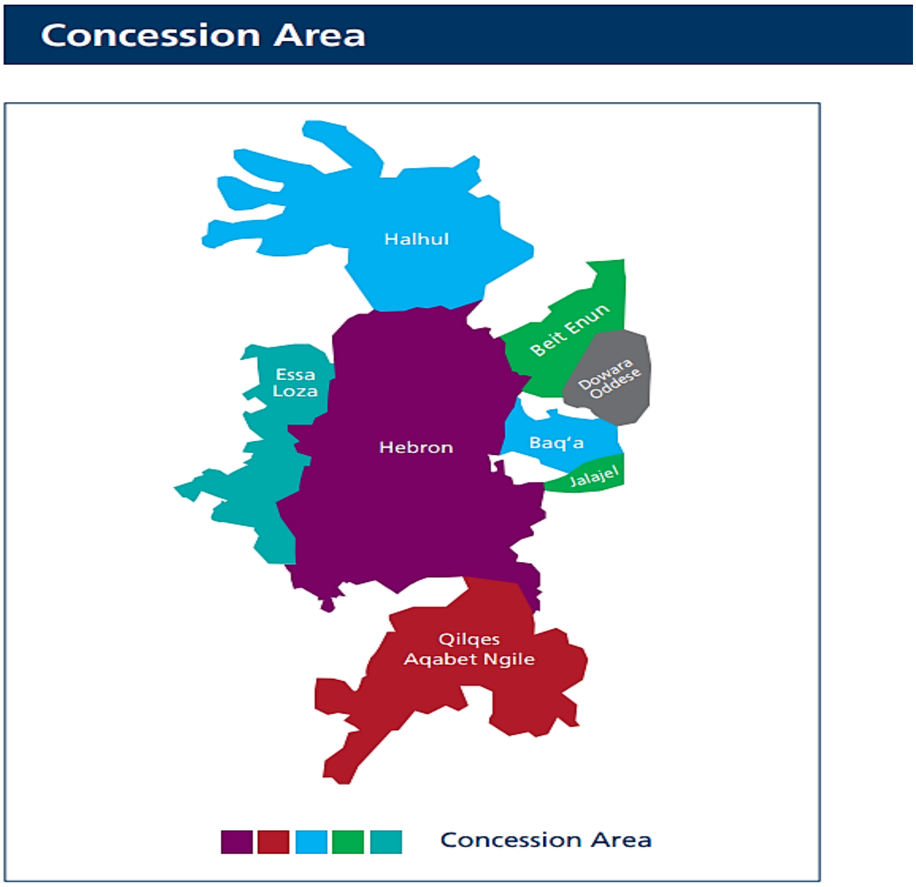

Figure 4.1: Concession area map [34].

HEPCo is supplied from IEC with 161 kV and the transformer convert it to 33 kV, however, each substation has a type of 33/11 kV transformer and most loads are connected by distribution transformers 11/0.4 kV as shown in Figure 4.2

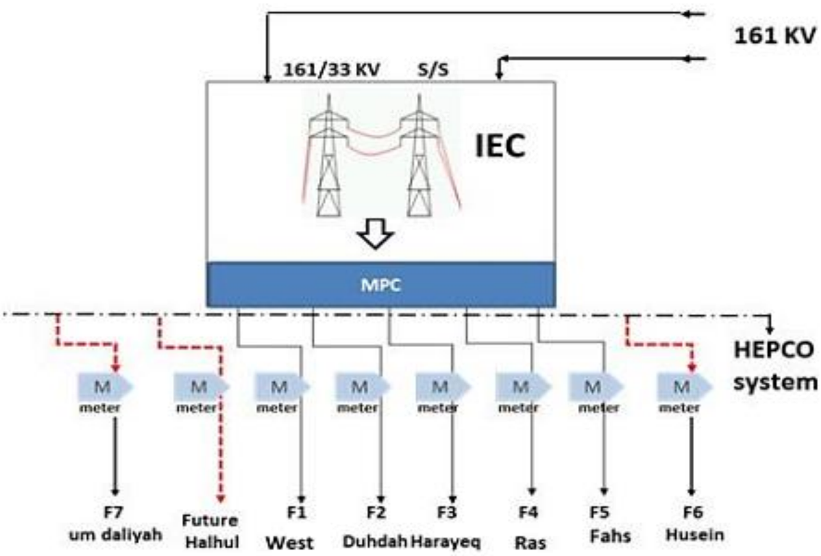

Figure 4.2: Source of Electricity in the HEPCo [34].

4.1.2 HEPCo system

- Main Power Center (MPC):

Main power center (MPC) was established to bridge between main connection points from IEC on 33 kV networks and the 33 kV networks exiting the station and heading towards main transforming substations (33/11 kV). MPC transfer capacity and electric loads from IEC Station to HEPCo seven main substations [34].

- substations:

Each one of the seven substations in the grid has two transformers or three transformers.

- Distribution transformers:

Hebron electrical power company contains 668 transformers, these transformers have a wide range of (kVA), from (100- 1000) kVA.

- Overhead lines and underground cables:

Cables are used for transmitting electricity from generating station to the consumer; they can be laid through underground or overhead.

4.2 The location of the charging stations in the HEPCo network

Based on the planning methods mentioned in the previous section (3.5), and based on the expected demand from customers in ordering them to acquire electric cars and their need for electric charging stations, we have adopted planning on the transportation approach, given that the Hebron Electricity Company provides the necessary Subscriptions in every location on its network Which is of utmost importance to meet the needs of customers and to cover the largest geographical area in the city of Hebron. The following areas were chosen:

- Halhul Bridge Area
- Al Salam Street Area
- Al Tahreer Street Area
- Jabal Al Rahmah Street
- Um Al Daliyeh Area
- Ein Sara Street Area
- Nimra Street Area

The following Figure 4.3 shows the distribution of stations in the city of Hebron using map:

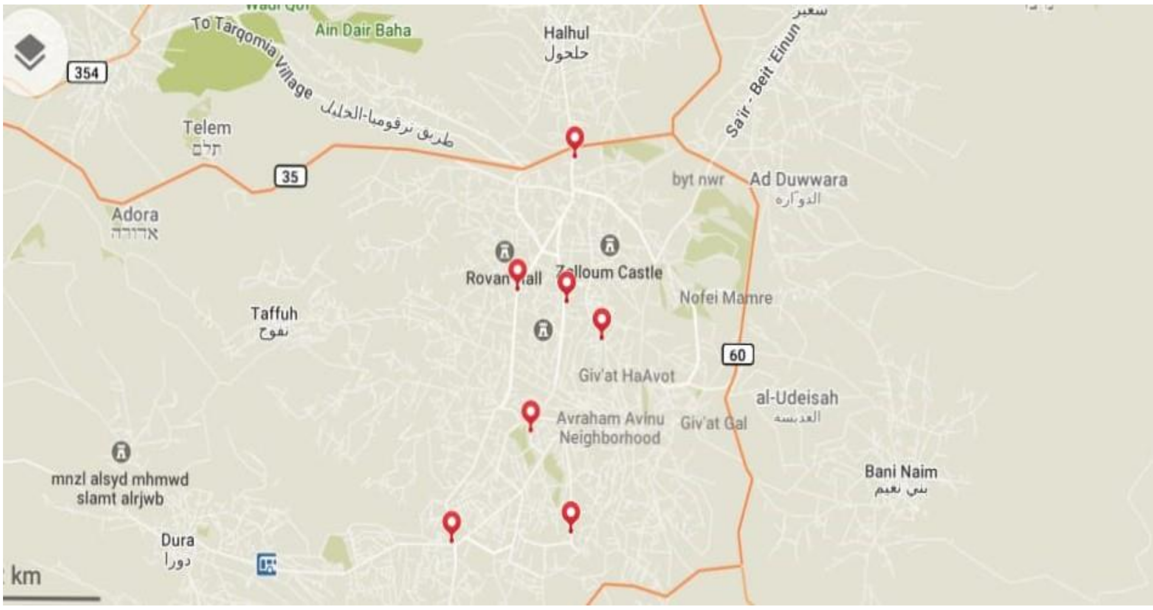

Figure 4.3: Distribution of stations in the city of Hebron.

4.3 ETAP Applications

ETAP is the most comprehensive solution for the design, simulation, and analysis of generation, transmission, distribution, and industrial power systems.

ETAP organizes your work on a project basis. Each project that you create provides all the necessary tools and support for modeling and analyzing an electrical power system. A project consists of an electrical system that requires a unique set of electrical components and interconnections. In ETAP, each project provides a set of users, user access controls, and a separate database in which its elements and connectivity data are stored [35].

The following Figure 4.4 shows the numerous options and applications of ETAP.

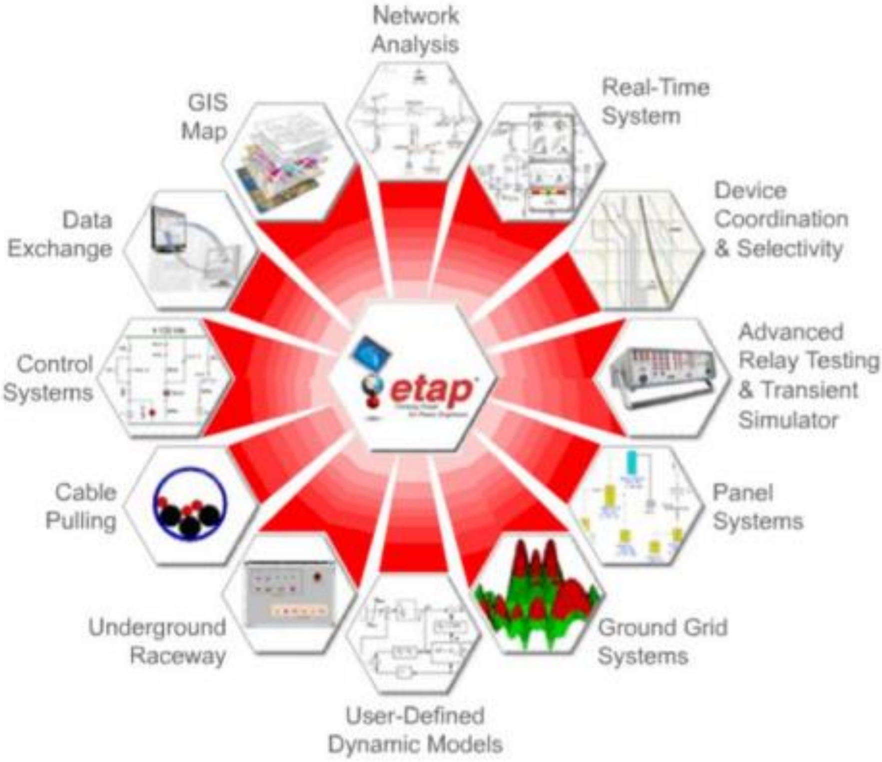

Figure 4.4: ETAP applications [35].

Why using ETAP:

We use ETAP because it is suitable to study power flow losses and it has many options such as [35]:

• Virtual reality operation.

• Total integration of data (electrical, logical, mechanical, and physical attributes).

• Ring and radial systems.

• No system connection limitations.

• User access control and data validation.

• Multiple loading conditions.

• Asynchronous calculations, allow multiple modules to calculate simultaneously.

• Unlimited isolated subsystems.

4.3.1 ETAP simulation of HEPCo

Through an ETAP Applications, we will do a simulation to add Vehicle Charging Stations on the HEPCo network whose locations were described in the previous section.

The following Figure 4.5 an illustration of a portion of the network on a program ETAP.

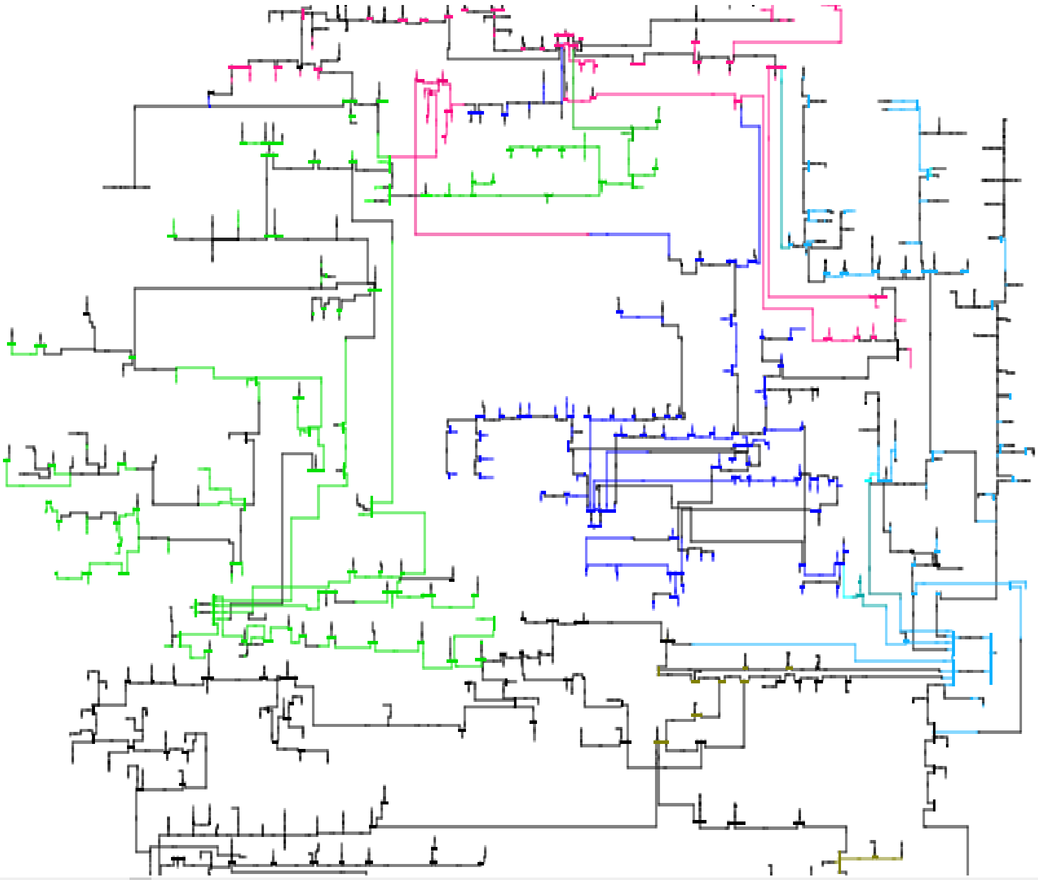

Figure 4.5: ETAP simulation of HEPCo [34].

4.3.2 The location of the charging stations in the ETAP

After determining the locations of the stations in the city of Hebron geographically, we connected the stations on the Hebron electricity network for which a single line diagram was built on ETAP to suit the site on the network that was determined by the transformers that provide service to this site, as the following table 4.1 displays the connection point on the network.

Table 4.1: Points connecting stations on the Hebron electricity network.

Location	Name of the station	Point of connection with the network
Halhul Bridge Area	Hulhul Bridge Station	T6000(Halhul Bridge)
Al Salam Street Area	Al Salam Station	T601(Electrod)
Al Tahreer Area	Altahreer Station	T564(Altahreer)
Jabal Al Rahmah Area	Jabal Al Rahmah Station	T490(Jabal AL Rahmah)
Um Al Daliyeh Area	Um Al Daliyeh Station	T494(Um Al daliyeh
Ein Sara Street Area	Ein Sara Station	T350(Alhosain building)
Nimra Street Area	Nimra Station	T400(nimra mosque)

As shown in Table 4, we have connected the stations on the network without any change or modification to them, as the connection was on the existing transformers to study the implications as a result of adding them, and below we will show the mechanism of linking to the network using ETAP.

The following Figure 4.6 shows the method of connecting the station to the network from the outside, as the station was connected to the transformer located by the Ac cable on the buss located between the station and the transformer:

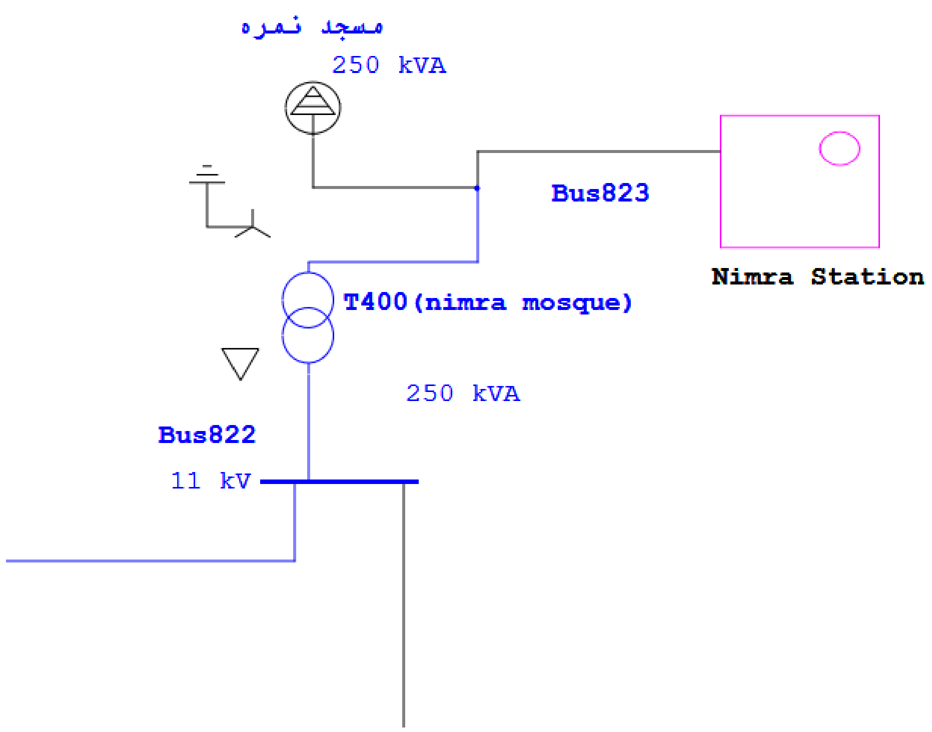

Figure 4.6: The exterior of the Nimra station by Etap.

The following Figure 4.7 shows the method of connecting the station from the inside:

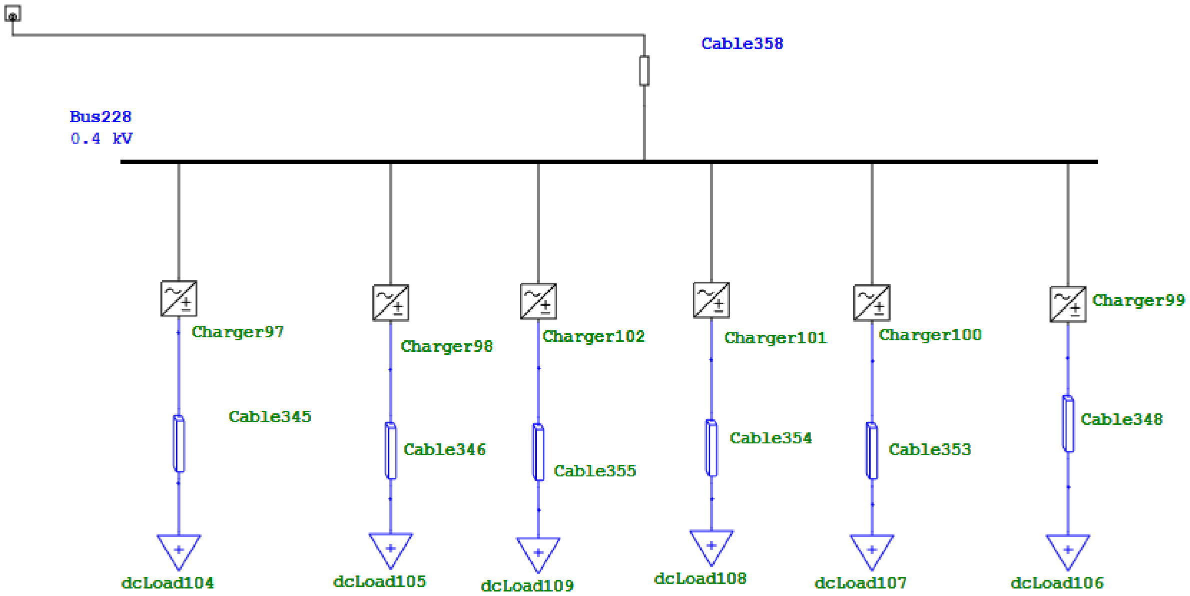

Figure 4.7: The interior of the Nimra Station by Etap.

In the previous Figure 4.6 and Figure 4.7, a method for connecting the Nimra station to the network using ETP was shown, and this work applies to the rest of the stations.

4.4 scenarios for stations

We will estimate the loads on the stations by proposing scenarios for the charging operations of cars at each station and during separate periods of the day, especially the peak hour in which the largest load can be affected on the network and by selecting a default number of electric cars according to the density of each region and different times on Throughout the day.

Loads are suggested according to the following:

1- Minimum load at (2:00-10:00)

2- Medium load at (11:00-18:00)

3- Maximum load at (19:00-21:00)

In this table, we review the cars that were used in the proposed scenarios and are among the cars expected to be used in the future. This provides opportunities to use the proposed stations in the city of Hebron to carry out car charging operations, which are loads on the Hebron network.

Table 4.2: Electric vehicle suggested for future use.

Manufacturer	type	Battery size (kwh)	Rang electric (miles)
BMW i3	BEV	33	114
Nissan Leaf 2012	BEV	30	156
Fiat 500e	BEV	24	84
Tesla Model S	BEV	85	256

The following curves show the estimation of loads for each station during day periods:

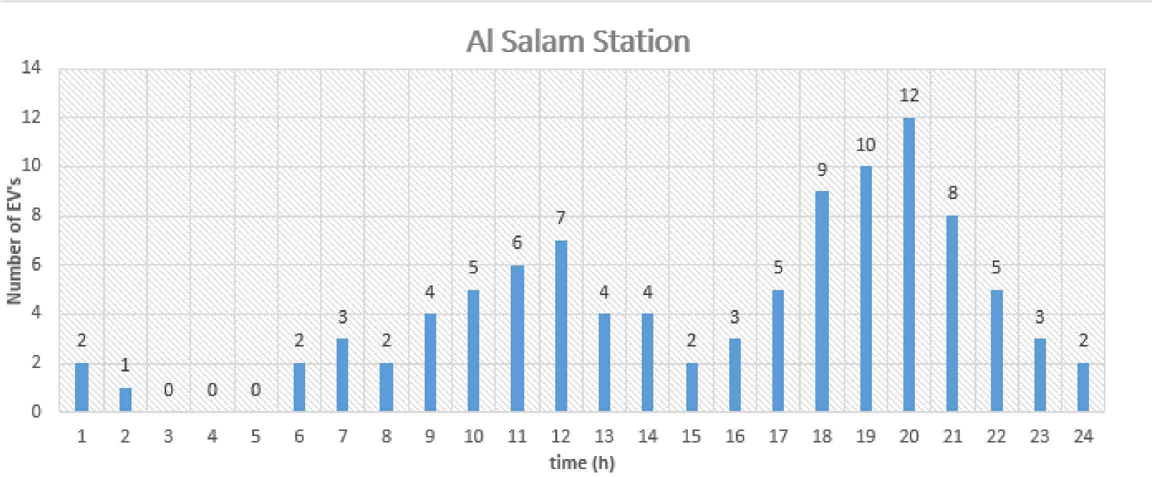

Figure 4.6: Al Salam Station.

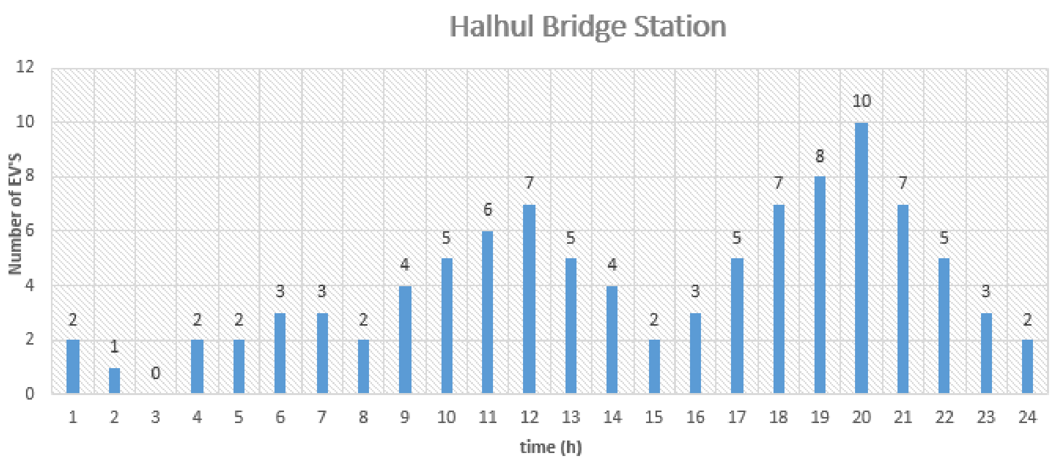

Figure 4.7: Hulhul Bridge Station.

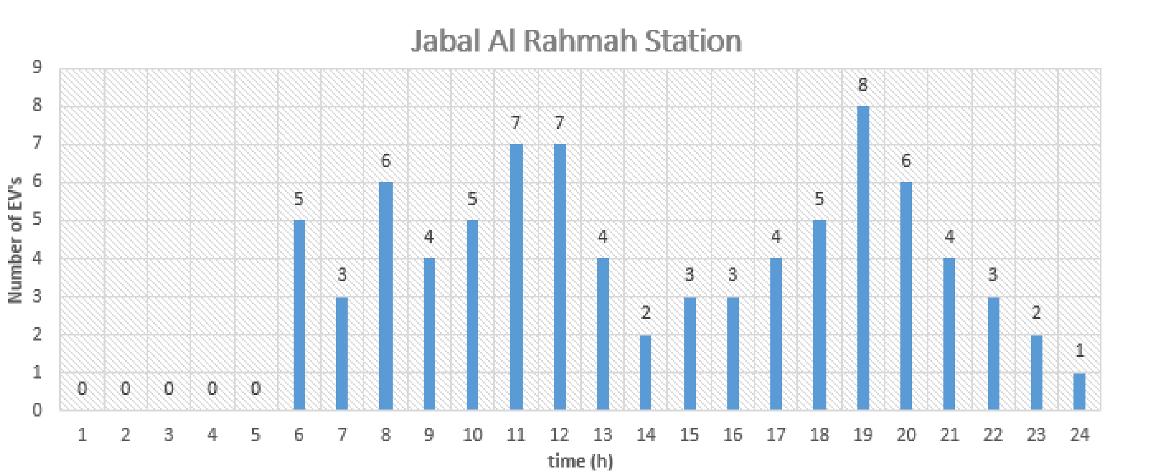

Figure 4.8: Jabal Al Rahmah Station.

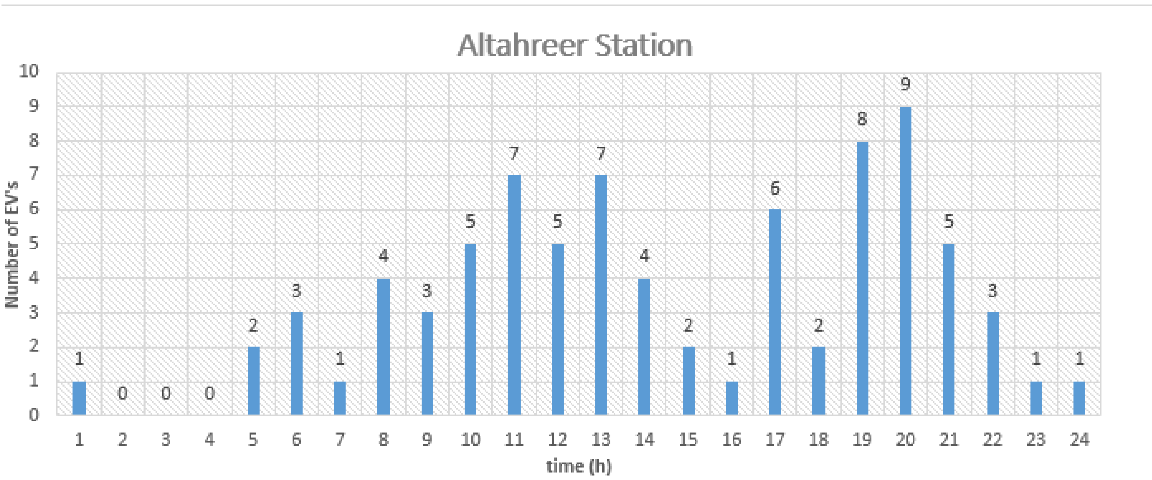

Figure 4.9: Altahreer Station.

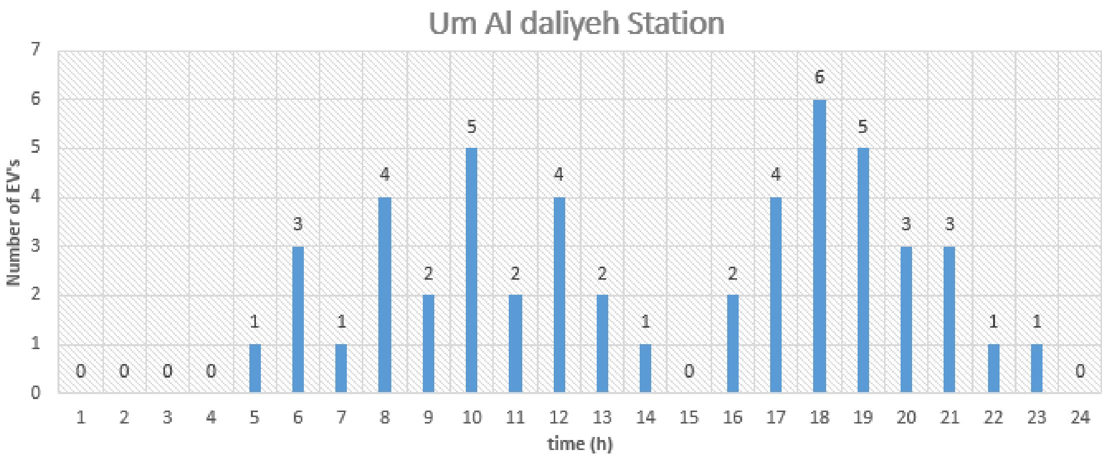

Figure 4.10: Um Al Daliyeh Station.

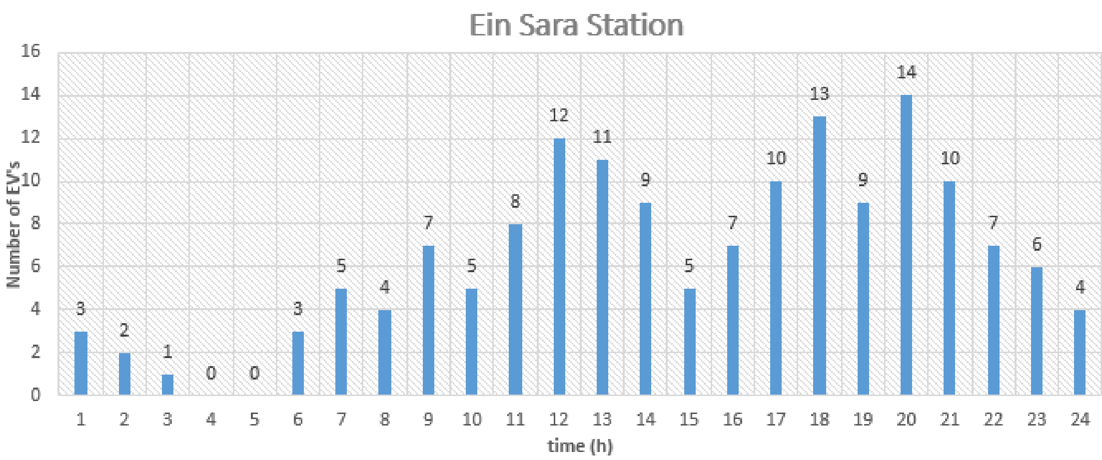

Figure 4.11: Ein Sara Station.

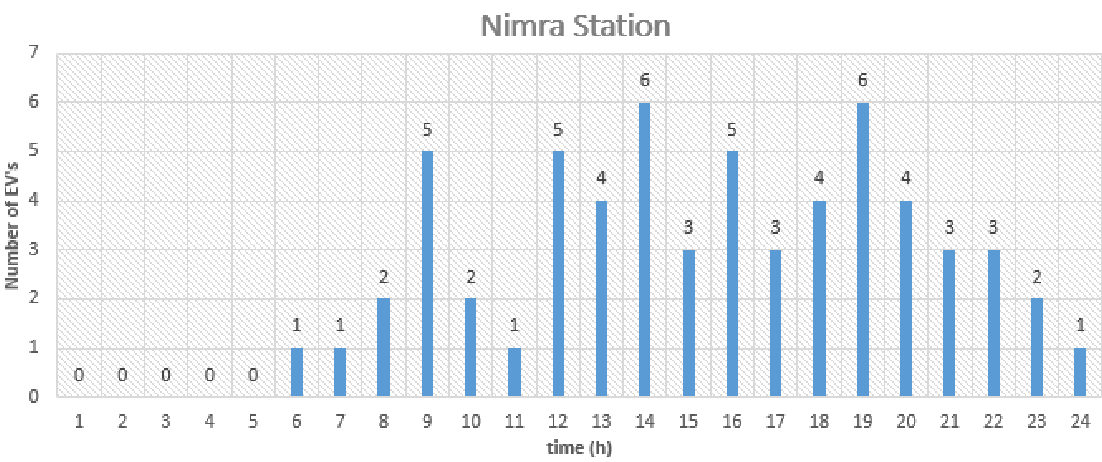

Figure 4.12: Nimra Station.

4.5 The behavior of EV's charging

During the charging process for electric cars, each car has a specific behavior that differs from the rest of the cars, depending on the battery capacity and the charging method, whether it is AC or DC. Therefore, we will present the behavior of the electric vehicle charging process that was used and the type of charging process used during a certain period of time.

The following curves show the charging behavior of the electric cars mentioned in Table 4.1, showing the type of vehicle and the charging method:

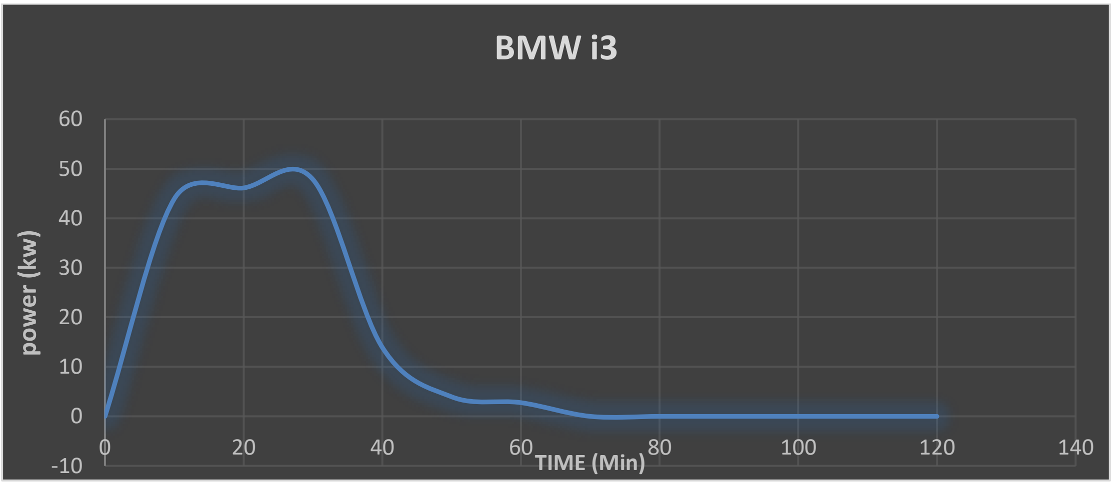

Figure 4.13: BMW i3 fast charging in 30 minutes [38].

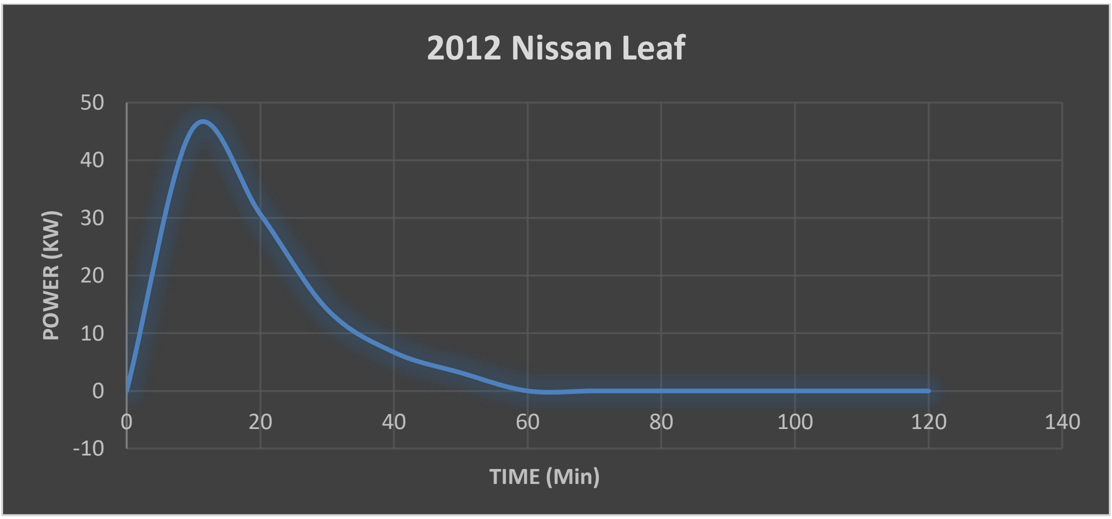

Figure 4.14: A DC fast charge is shown for a 2012 Nissan Leaf charged with a 50KW [36].

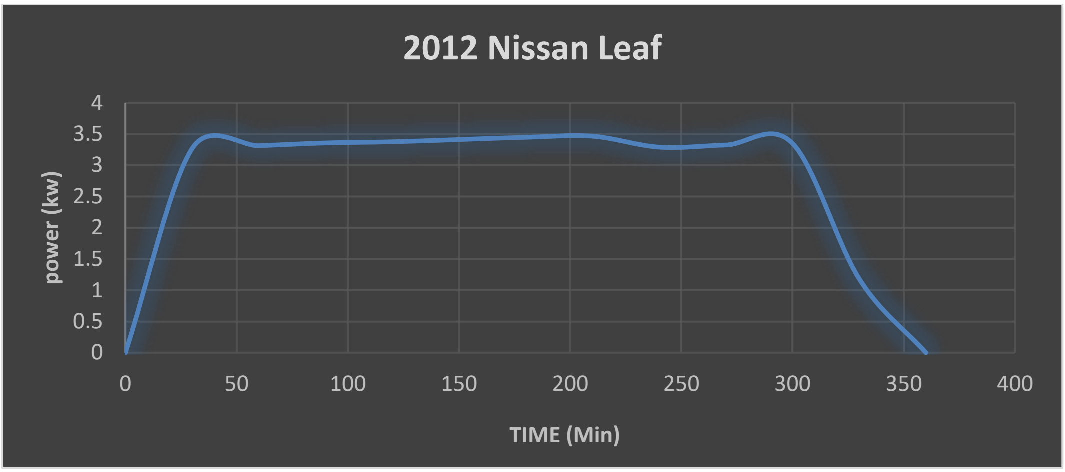

Figure 4.15: An ac level 2 charge is shown for a 2012 Nissan Leaf charged with a 33KW [36].

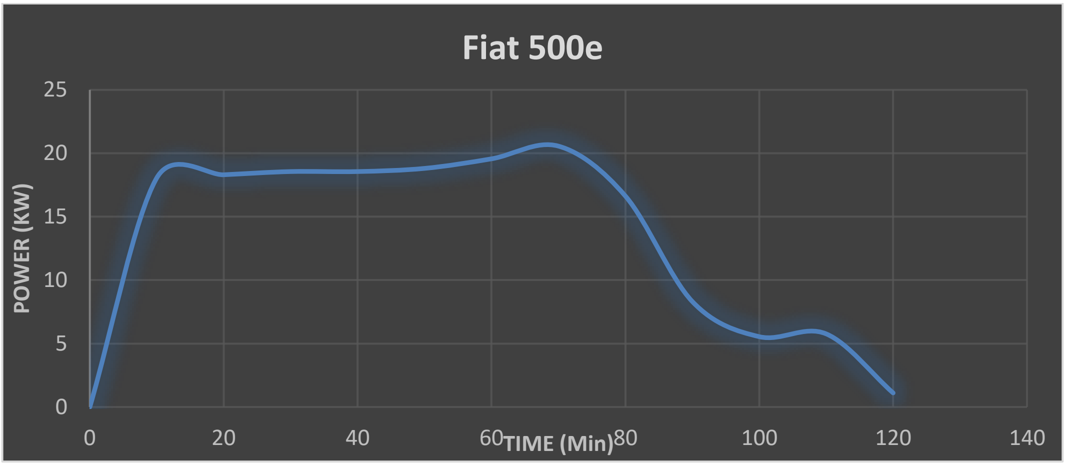

Figure 4.16: Fiat 500e Fast charge [37].

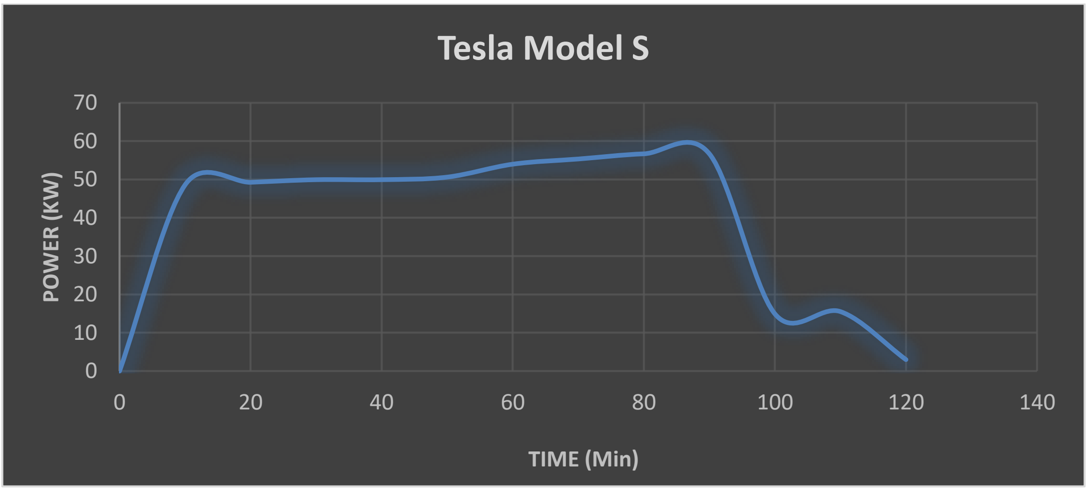

Figure 4.17: Tesla Model S Fast charge [37,39].

The previous curves show the progress of the charging process over some time with the value of the energy consumed according to the type of the charging process, as it gradually begins until it reaches the highest energy value and then begins to decline until it reaches a fully charged battery, as the charging process using DC is faster and the battery charge reaches 80 % In a period estimated at 30 minutes.

Through Figure 4.14 and Figure 4.15 we show that use of the Nissan Leaf 2012 in the proposed scenarios by two methods of the charging DC fast charge and AC level 2, as the difference in that is the period of the charging process.

4.6 Scenarios for charging at stations

As we mentioned earlier in the proposed scenarios for the stations, where the charging process is divided into three different periods that we distributed during the day, and therefore we will simulate the effects in these periods as we take the highest power value for each car consumed during the charging process, and accordingly we will develop four proposed scenarios for the charging process.

The following Table 4.3 represents the maximum value of power consumed during the charging process for each electrical vehicle:

Table 4.3: The maximum power for each EV.

Type of EV	Maximum power (kw)
BMW i3	47.82
Nissan Leaf 2012 Fast charge	45.66
Nissan Leaf 2012 level 2	3.46
Fiat 500e	20.56
Tesla Model S	56.68

4.6.1 The scenario at maximum load

In this scenario, it was assumed that there is the largest number of EV that are accommodated in each station, and the maximum value of the power consumed by each EV during the charging process is assumed, as this represents the maximum load that can occur on the network during the charging process, as the following Table 4.4 shows the number of EV in each station and the value of the power consumed by this station.

Table 4.4: Number of EV and power consumed at maximum load.

Type of EV / Stations	BMW i3	Nissan Leaf 2012 Fast charge	Nissan Leaf 2012 level 2	Fiat 500e	Tesla Model S	Total EV's in the station	Total power in the station (kw)
Halhul Bridge	2	2	4	1	1	10	278.04
Al Salam Street	2	2	3	2	2	11	351.82
Al Tahreer	1	1	2	2	1	7	198.2
Jabal Al Rahmah	1	1	2	1	2	7	234.32
Um Al Daliyeh	1	1	1	2	1	6	194.74
Ein Sara Street	2	1	5	2	1	11	292.52
Nimra Street	1	1	2	1	1	6	177.64
Total	10	9	19	11	9	58	1727.28

4.6.2 The scenario at medium load

In this scenario, we assumed the average number of EV that are accommodated in each station, and we assumed the maximum value of energy consumed by each EV during the charging process, as this represents the medium load that can occur on the network during the charging process, as the following Table 4.5 shows number of EV In each station and the energy value consumed by that station.

Table 4.5: Number of EV and power consumed at medium load.

Type of EV / Stations	BMW i3	Nissan Leaf 2012 Fast charge	Nissan Leaf 2012 level 2	Fiat 500e	Tesla Model S	Total EV's in the station	Total power in the station (kw)
Halhul Bridge	1	1	2	1	0	5	120.96
Al Salam Street	1	1	2	1	1	6	177.64
Al Tahreer	1	1	1	0	0	3	96.94
Jabal Al Rahmah	0	0	1	1	1	3	80.7
Um Al Daliyeh	0	1	1	1	0	3	69.68
Ein Sara Street	1	0	2	1	1	5	131.98
Nimra Street	1	0	1	0	1	3	107.96
Total	5	4	10	5	4	28	785.86

4.6.3 The scenario at minimum load

In this scenario, we assumed the lowest number of EV that are accommodated in each station, and we assumed the maximum value of energy consumed by each EV during the charging process, as this represents the minimum load that can occur on the network during the charging process, as the following Table 4.6 shows number of EV In each station and the energy value consumed by that station.

Table 4.6: Number of EV and power consumed at minimum load.

Type of EV / Stations	BMW i3	Nissan Leaf 2012 Fast charge	Nissan Leaf 2012 level 2	Fiat 500e	Tesla Model S	Total EV's in the station	Total power in the station (kw)
Halhul Bridge	1	0	1	1	0	3	71.84
Al Salam Street	0	0	1	0	1	2	60.14
Al Tahreer	1	0	0	0	0	1	47.82
Jabal Al Rahmah	0	0	0	0	1	1	56.68
Um Al Daliyeh	0	0	1	1	0	2	24.02
Ein Sara Street	1	1	1	0	0	3	96.94
Nimra Street	0	1	0	0	0	1	45.66
Total	3	2	4	2	2	13	403.1

The state of the maximum load has the greatest impact on the network, so we will choose this case to study the effects that affect the network and find appropriate solutions for it because when finding solutions to the maximum load, this solution includes the medium load case and the minimum load case and therefore we can charge the electric vehicle in a proper manner without affecting the network.

4.6.4 The scenario of two hours charging

In this scenario, a simulation of the electric vehicle charging process is performed during a certain period of time (two hours) at the highest number of EV's in each station, where the value of the consumed power of each EV is entered within 10 minutes as this scenario will be after finding the appropriate solution at the highest Load and thus reflect the value of losses on the network during shipping, and the following Table 4.7 shows the value of the power every 10 minutes for each EV:

Table 4.7: The power in (KW) for each electric vehicle during the charging process at tow hours.

	Power (KW)				
Type of EV / Time (Min)	BMW i3	Nissan Leaf 2012 Fast charge	Nissan Leaf 2012 level 2	Fiat 500e	Tesla Model S
0	0	0	0	0	0
10	43.92	45.666	3.267	18.0576	48.59136
20	46.116	30.654	3.267	18.3084	49.26624
30	47.824	14.148	3.267	18.5592	49.94112
40	13.93	6.698	3.312	18.5592	49.94112
50	3.95	3.152	3.312	18.81	50.616
60	2.765	0	3.312	19.5624	53.9904
70	0	0	3.357	20.5656	55.34016
80	0	0	3.357	16.632	56.68992
90	0	0	3.357	8.316	56.68992
100	0	0	3.375	5.544	14.9184
110	0	0	3.375	5.76576	15.515136
120	0	0	3.375	1.1088	2.98368

Table 4.8: The power in (KW) for each station during the charging process at tow hours.

	Power (KW)						
Type of EV / Time (Min)	Halhul Bridge	Al Salam Street	Al Tahreer	Jabal Al Rahmah	Um Al Daliyeh	Ein Sara Street	Nimra Street
0	0	0	0	0	0	0	0
10	258.8	322.22	180.79	211.3	177.53	234.49	163
20	233.9	298.24	169.05	200	165.79	224.94	151
30	205.5	270.68	155.52	186.9	152.26	213.12	137
40	123	188.15	114.28	145.7	110.97	138.14	95.7
50	96.86	162.97	101.59	133.8	98.64	115.83	83.1
60	92.31	162.55	102.49	136.9	99.18	115.18	82.9
70	89.3	161.85	103.16	137.9	99.81	113.21	82.6
80	86.71	156.67	96.64	136.7	93.29	106.69	80
90	78.39	140.03	80	128.4	76.65	90.05	71.7
100	33.93	51.01	32.73	42.1	29.36	42.84	27.2
110	34.75	52.65	33.77	43.52	30.4	43.88	28
120	17.56	18.27	11.92	13.8	8.55	22.03	10.8

Table 4.9: The power in (KW) for the total station during the charging process at tow hours.

Time (Min)	Total power (KW)
0	0
10	1547.94
20	1443.53
30	1320.91
40	915.91
50	793.14
60	791.56
70	787.87
80	756.7
90	665.18
100	259.16
110	266.98
120	102.95

In this Chapter, the method of work that we have performed is presented sequentially, which gives a clear vision of the work, and therefore we will present the problems that appeared on the network as we mentioned earlier in Chapter 1 where the results appeared and the appropriate solution methods are presented in Chapter 5.

Chapter 5

Simulation and Analysis

Initially, the Hebron electricity network was chosen in order to develop a strategic future planning for the loads expected to enter the Hebron electricity network by adding electric vehicle charging stations.

The Hebron electricity network, on which we added loads of electric vehicle charging stations, which was built on Etap within a Power Factor (PF) equal 92%, and the transformer loads with a load of 40% of the rated kVA for each transformer in order to reach the total peak value of the HEPCo network, which is 115MWh according to HEPCo.

The following Table 5.1 shows the load distribution on seven main feeding stations for HEPCo network:

Table 5.1: Load distribution to substations in HEPCo.

ID	rated kv	MW	Mvar	Amp	%PF
UM AL-DALIYEH	33	16.504	7.393	316.4	91.26
AL-RAS	33	18.251	9.15	357.2	89.39
AL-HUSSEIN	33	14.806	7.596	291.1	88.97
AL-HARSYEK	33	10.399	5.203	203.4	89.43
AL-GHARBIA	33	15.279	7.193	295.5	90.47
AL-FAHS	33	20.49	6.487	376	95.34
AL-DAHDAH	33	17.927	8.083	344	91.16
TOTAL		113.656	51.105		

The following Figure 5.1 displays the load ratio for each sub-station:

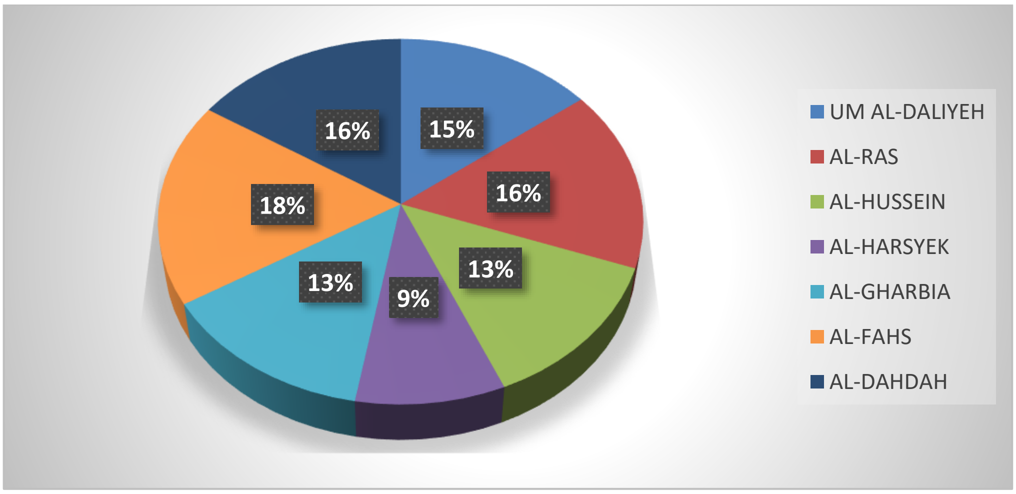

Figure 5.1: Loading ratio for each sub-station

Table 5.2: Total power and losses.

Total Power	113.656 MW
Total Demand	110.021 MW
Apparent Losses	3.635 MW
Number of loads	668

Power imported from Power Grid = 113.656 MW

Total power losses = 3.635 MW

$$percentage\ of\ the\ losses = \frac{\text{Total power losses}}{\text{Power imported from Power Grid}} \times 100\%$$

$$= \frac{3.635}{113.656} \times 100\% = 3.198\%$$

In this case, the distribution of the loads on the substations was presented, and the results also showed that the percentage of losses incurred on the network amounted to 3.198%, and the results are presented attached in Appendix.

5.1 Case 1 results

In this case, the results of the scenario of the maximum load obtained as a result of adding the largest number of the electric vehicle to the charging stations that we have connected to the network, which represent the highest load on the network resulting from adding the stations.

Table 5.3: Load distribution to substations in HEPCo at maximum load.

ID	rated kv	MW	Mvar	Amp	%PF
UM AL-DALIYEH	33	16.459	7.416	315.8	91.17
AL-RAS	33	19.51	9.958	383.2	89.07
AL-HUSSEIN	33	15.382	8.203	305	88.24
AL-HARSYEK	33	10.64	5.421	208.9	89.1
AL-GHARBIA	33	15.408	7.978	303.6	88.8
AL-FAHS	33	20.49	6.487	376	95.34
AL-DAHDAH	33	18.609	8.182	355.6	91.54
TOTAL		116.498	53.645		

The following Figure 5.2 displays the load ratio for each sub-station:

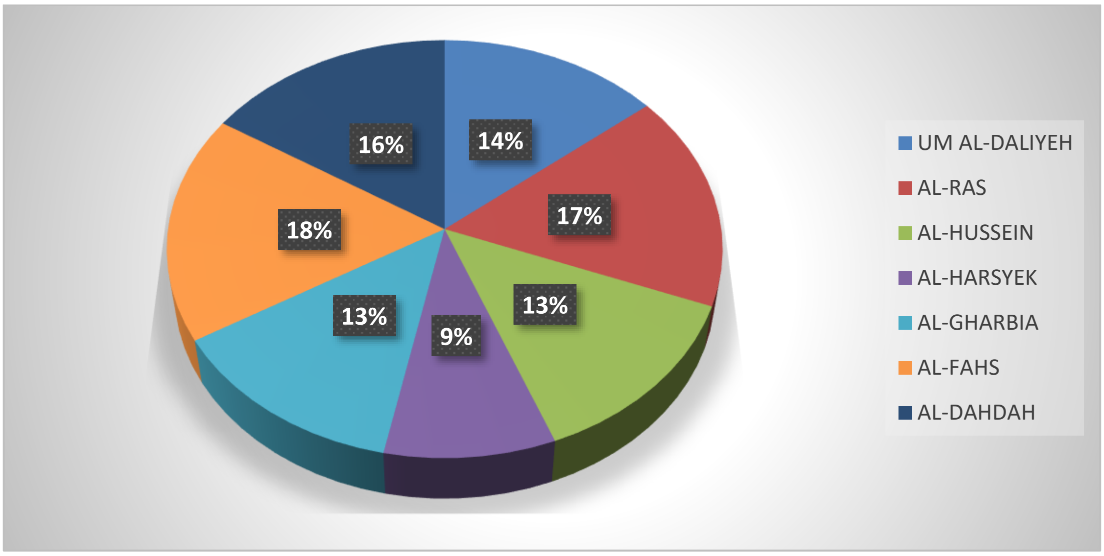

Figure 5.2: Loading ratio for each sub-station at maximum load.

Table 5.4: Total power and losses at maximum load.

Total Power	116.499 MW
Total Demand	112.194 MW
Apparent Losses	4.304 MW
Number of loads	726

Power imported from Power Grid = 116.499 MW

Total power losses = 4.304 MW

$$percentage\ of\ the\ losses = \frac{\text{Total power losses}}{\text{Power imported from Power Grid}} \times 100\%$$

$$= \frac{4.304}{116.499} \times 100\% = 3.694\%$$

The following Table 5.5 shows the losses incurred by the substation's transformers in KW and Kvar. It also includes the results of the voltage drop and the load percentage.

Table 5.5: Loading And power losses on substations transformers at maximum load.

ID	Losses (KW)	Losses (Kvar)	% Drop	Loading (input)	Loading (output)
T1 AL-RAS	73	949.4	0.66	109.5	104.9
T2 AL-RAS	73	949.4	0.66	109.5	104.9
T1 AL-DAHDAH	33.4	434.8	1.51	72.3	69.9
T2 AL-DAHDAH	24.7	321.3	1.51	62.1	61.5
T3 AL-DAHDAH	33.4	434.8	1.51	72.3	69.9
T1 AL-FAHS	29.5	383.1	1.27	67.8	67
T2 AL-FAHS	29.5	383.1	1.27	67.8	67
T3 AL-FAHS	41.9	544.2	1.27	82.9	79.9
T1 AL-GHARBIA	28.9	578.2	1.65	66.7	64.6
T2 AL-GHARBIA	28.9	578.2	1.65	66.7	64.6
T1 AL-HARSYEK	29.3	380.9	1.14	67.6	65.1
T2 AL-HARSYEK	18.9	245.7	1.14	54.3	53.6
T1 AL-HUSSEIN	46.3	601.3	1.41	87.2	84.1
T2 AL-HUSSEIN	46.3	601.3	1.41	87.2	84.1
T1 UM AL-DALIYEH	49.6	644.8	1.73	90.3	87.3
T2 UM AL-DALIYEH	49.6	644.8	1.73	90.3	87.3
TOTAL	636.2	8675.3			

The following Table 5.6 shows the losses of the distribution transformers to which the charging stations are connected in KW and Kvar. It also includes a presentation of the results of the voltage drop and the voltage percentage on the buss.

Table 5.6: Losses of the distribution transformers to which the charging stations are connected at maximum load.

Station	ID	Losses (KW)	Losses (Kvar)	% Bus Voltage From	To	% Drop
Halhul Bridge	T6000(Halhul Bridge)	16.6	58.1	101.1	96.0	5.08
Al Salam	T601(Electrod)	11	38.5	100.5	97.3	3.22
Jabal Al Rahmah	T490(Jabal AL Rahmah)	29.5	44.3	99.8	88.9	10.92
Altahreer	T564(Altahreer)	28.5	42.7	97.6	84.3	13.27
Um Al daliyeh	T494(Um Al daliyeh)	11.7	17.6	99.5	96.1	3.33
Ein Sara	T350(Alhosain building)	20.2	30.3	101.1	96.6	4.47
Nimra	T400(nimra mosque)	14.1	21.1	100.8	94.9	5.89

The following Table 5.7 shows the transformers that were overloaded as a result of adding charging stations.

Table 5.7: Transformers that were overloaded at maximum load.

Transformers		
ID	Loading (input) %	Loading (output) %
T1 AL-RAS	109.5	104.9
T2 AL-RAS	109.5	104.9
T350(Alhosain building)	121.5	116.1
T400(nimra mosque)	160.5	151.2
T490(Jabal AL Rahmah)	287.9	256.4
T564(Altahreer)	349.7	302.1
T6000(Halhul Bridge)	124.3	118.1

The following Table 5.8 shows the cables that were overloaded as a result of adding charging stations.

Table 5.8: Cables that were overloaded at maximum load.

Cables	
Name	Cable Loading (%)
Cable43	217.04
Cable303	103.69
Cable344	107.92
Cable362	129.69
Cable362	153.48
Cable401	166.11
Cable2387	126.86
Cable2389	130.68
Cable2517	146.69
Cable2594	144.22

5.2 Case 2 results

In this case, the results of the scenario of the medium load obtained as a result of adding the average number of the electric vehicle to the charging stations that we have connected to the network, which represent the medium load on the network resulting from adding the stations.

Table 5.9: Load distribution to substations in HEPCo at medium load.

ID	rated kv	MW	Mvar	Amp	%PF
UM AL-DALIYEH	33	16.459	7.416	315.8	91.17
AL-RAS	33	19.175	9.553	374.8	89.51
AL-HUSSEIN	33	15.076	7.843	297.3	88.71
AL-HARSYEK	33	10.507	5.292	205.8	89.31
AL-GHARBIA	33	15.293	7.955	301.6	88.72
AL-FAHS	33	20.49	6.487	376	95.34
AL-DAHDAH	33	18.227	7.612	345.6	92.28
TOTAL		115.227	52.158		

The following Figure 5.3 displays the load ratio for each sub-station:

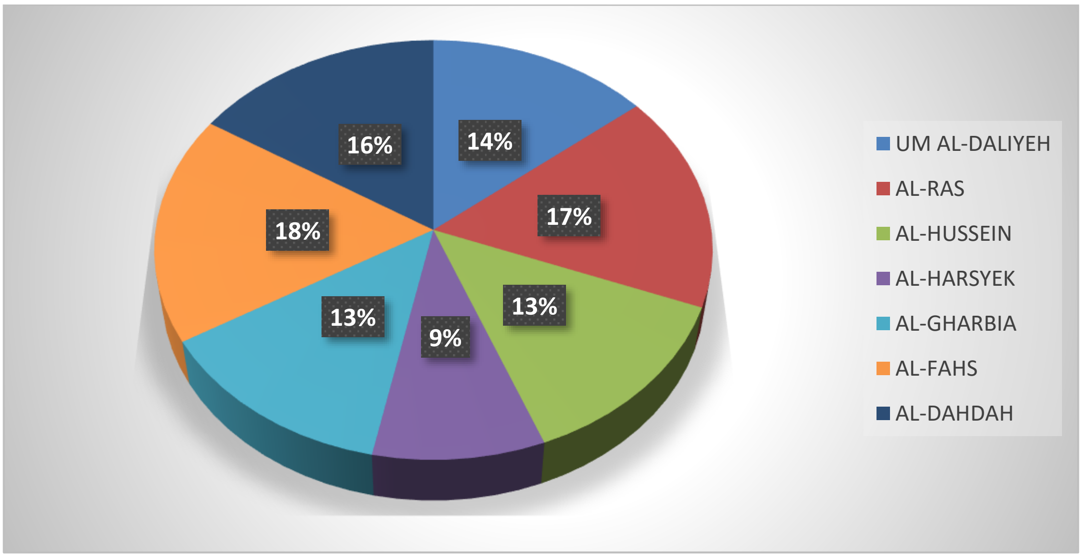

Figure 5.3: Loading ratio for each sub-station at medium load.

Table 5.10: Total power and losses at medium load.

Total Power	115.227
Total Demand	111.453
Apparent Losses	3.775
Number of loads	726

Power imported from Power Grid = 115.227 MW

Total power losses = 3.775 MW

$$percentage\ of\ the\ losses = \frac{\text{Total power losses}}{\text{Power imported from Power Grid}} \times 100\%$$

$$= \frac{3.775}{115.227} \times 100\% = 3.276\%$$

The following Table 5.11 shows the losses incurred by the substation's transformers in KW and Kvar. It also includes the results of the voltage drop and the load percentage.

Table 5.11: Loading And power losses on substations transformers at medium load.

Name	Losses (KW)	Losses (Kvar)	% Drop	Loading (input)	Loading (output)
T2 AL-RAS	69.8	908	0.83	107.1	102.7
T1 AL-RAS	69.8	908	0.83	107.1	102.7
T1 AL-DAHDAH	31.6	410.7	1.68	70.2	68
T2 AL-DAHDAH	23.5	305.8	1.68	60.6	60.1
T3 AL-DAHDAH	31.6	410.7	1.68	70.2	68
T1 AL-FAHS	29.5	383.1	1.27	67.8	67
T2 AL-FAHS	29.5	383.1	1.27	67.8	67
T3 AL-FAHS	41.9	544.2	1.27	82.9	79.9
T1 AL-GHARBIA	28.5	570.7	1.66	66.3	64.2
T2 AL-GHARBIA	28.5	570.7	1.66	66.3	64.2
T1 AL-HARSYEK	28.5	370.7	1.19	66.7	64.3
T2 AL-HARSYEK	18.3	238.4	1.19	53.5	52.8
T1 AL-HUSSEIN	44	571.4	1.56	85	82.1
T2 AL-HUSSEIN	44	571.4	1.56	85	82.1
T1 UM AL-DALIYEH	49.6	644.8	1.73	90.3	87.3
T2 UM AL-DALIYEH	49.6	644.8	1.73	90.3	87.3
Total	618.2	8436.5			

The following Table 5.12 shows the losses of the distribution transformers to which the charging stations are connected in KW and Kvar. It also includes a presentation of the results of the voltage drop and the voltage percentage on the buss.

Table 5.12: Losses of the distribution transformers to which the charging stations are connected at medium load.

Station	ID	Losses (KW)	Losses (Kvar)	% Bus Voltage From	To	% Drop
Halhul Bridge	T6000(Halhul Bridge)	4.2	14.8	101.3	99.0	2.35
Al Salam	T601(Electrod)	5.6	19.5	100.7	98.6	2.19
Jabal Al Rahmah	T490(Jabal AL Rahmah)	4.8	7.2	100.1	95.9	4.19
Altahreer	T564(Altahreer)	6.9	10.4	99.1	92.7	6.41
Um Al daliyeh	T494(Um Al daliyeh)	4.2	6.3	99.8	97.9	1.9
Ein Sara	T350(Alhosain building)	8.1	12.2	101.3	98.8	2.51
Nimra	T400(nimra mosque)	5.9	8.9	101.0	97.3	3.71

The following Table 5.13 shows the transformers that were overloaded as a result of adding charging stations.

Table 5.13: Transformers that were overloaded at medium load.

Transformer		
ID	Loading (input)	Loading (output)
T1 AL-RAS	107.1	102.7
T2 AL-RAS	107.1	102.7
T490(Jabal AL Rahmah)	116.1	111.3
T564(Altahreer)	175.2	163.9

The following Table 5.14 shows the cables that were overloaded as a result of adding charging stations.

Table 5.14: Cables that were overloaded at medium load.

Cable	
Name	Cable Loading (%)
Cable2387	126.86
Cable2389	130.68
Cable2517	146.69
Cable2594	144.22

5.3 Case 3 results

In this case, the results of the scenario of the minimum load obtained as a result of adding the lowest number of the electric vehicle to the charging stations that we have connected to the network, which represent the lowest load on the network resulting from adding the stations.

Table 5.15: Load distribution to substations in HEPCo at minimum load.

ID	rated kv	MW	Mvar	Amp	%PF
UM AL-DALIYEH	33	16.578	7.416	315.8	91.17
AL-RAS	33	19.095	9.958	383.2	89.07
AL-HUSSEIN	33	14.96	8.203	305	88.24
AL-HARSYEK	33	10.451	5.421	208.9	89.1
AL-GHARBIA	33	15.256	7.978	303.6	88.8
AL-FAHS	33	20.49	6.487	376	95.34
AL-DAHDAH	33	18.081	8.182	355.6	91.54
TOTAL		114.911	53.645		

The following Figure 5.4 displays the load ratio for each sub-station:

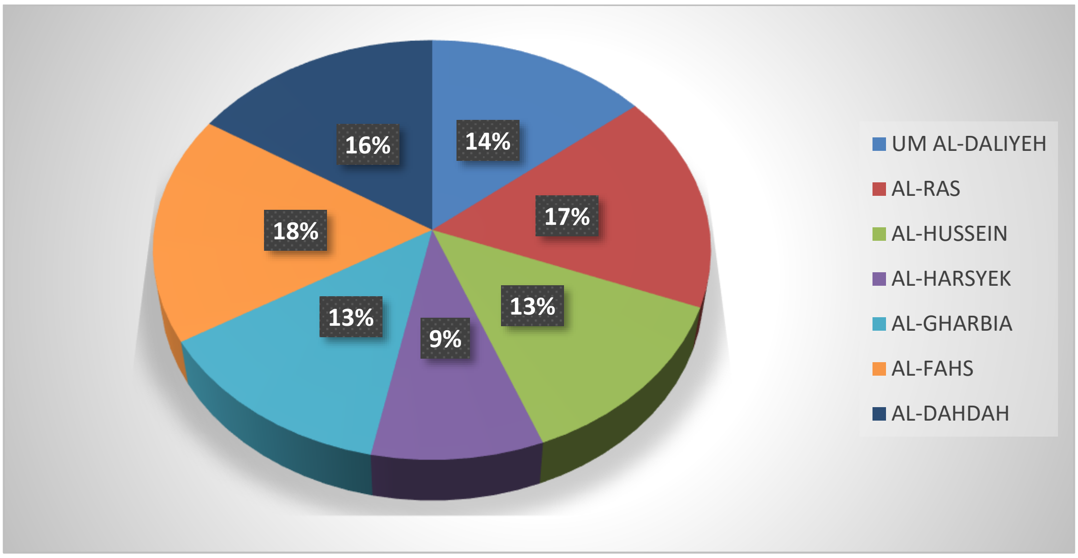

Figure 5.4: Loading ratio for each sub-station at minimum load.

Table 5.16: Total power and losses at minimum load.

Total Power	114.911
Total Demand	111.21
Apparent Losses	3.701
Number of loads	681

Power imported from Power Grid = 114.911 MW

Total power losses = 3.701 MW

$$percentage\ of\ the\ losses = \frac{\text{Total power losses}}{\text{Power imported from Power Grid}} \times 100\%$$

$$= \frac{3.701}{114.911} \times 100\% = 3.22\%$$

The following Table 5.17 shows the losses incurred by the substation's transformers in KW and Kvar. It also includes the results of the voltage drop and the load percentage.

Table 5.17: Loading And power losses on substations transformers at minimum load.

ID	Losses (KW)	Losses (Kvar)	% Drop	Loading (input)	Loading (output)
T1 AL-RAS	69.2	899	0.87	106.6	102.3
T2 AL-RAS	69.2	899	0.87	106.6	102.3
T1 AL-DAHDAH	31	402.7	1.72	69.5	67.4
T2 AL-DAHDAH	23.1	300.3	1.72	60.1	59.6
T3 AL-DAHDAH	31	402.7	1.72	69.5	67.4
T1 AL-FAHS	29.5	383.1	1.27	67.8	67
T2 AL-FAHS	29.5	383.1	1.27	67.8	67
T3 AL-FAHS	41.9	544.2	1.27	82.9	79.9
T1 AL-GHARBIA	28.4	568.5	1.66	66.2	64.1
T2 AL-GHARBIA	28.4	568.5	1.66	66.2	64.1
T1 AL-HARSYEK	28.2	366.6	1.22	66.4	64
T2 AL-HARSYEK	18.1	235.5	1.22	53.2	52.5
T1 AL-HUSSEIN	43.2	561.1	1.61	84.2	81.4
T2 AL-HUSSEIN	43.2	561.1	1.61	84.2	81.4
T1 UM AL-DALIYEH	37.8	490.9	2.19	78.8	76.6
T2 UM AL-DALIYEH	49.1	638.2	2.19	78.8	76.6

The following Table 5.18 shows the losses of the distribution transformers to which the charging stations are connected in KW and Kvar. It also includes a presentation of the results of the voltage drop and the voltage percentage on the buss.

Table 5.18: Losses of the distribution transformers to which the charging stations are connected at minimum load.

Station	ID	Losses (KW)	Losses (Kvar)	% Bus Voltage		% Drop
				From	To	
Halhul Bridge	T6000(Halhul Bridge)	3	10.6	101.4	99.4	1.96
Al Salam	T601(Electrod)	3.1	10.9	100.8	99.3	1.57
Jabal Al Rahmah	T490(Jabal AL Rahmah)	2.8	4.2	100.1	97.0	3.17
Altahreer	T564(Altahreer)	2.4	3.6	99.7	96.0	3.71
Um Al daliyeh	T494(Um Al daliyeh)	2.8	4.2	99.9	98.4	1.51
Ein Sara	T350(Alhosain building)	5.3	8	101.3	99.2	2.16
Nimra	T400(nimra mosque)	2.3	3.5	101.1	98.8	2.25

The following Table 5.19 shows the transformers that were overloaded as a result of adding charging stations.

Table 5.19: Transformers that were overloaded at minimum load.

Transformer		
ID	Loading (input)	Loading (output)
T1 AL-RAS	106.6	102.3
T2 AL-RAS	106.6	102.3
T564(Altahreer)	103.8	100

The following Table 5.20 shows the cables that were overloaded as a result of adding charging stations.

Table 5.20: Cables that were overloaded at minimum load.

Cable	
Name	Cable Loading (%)
Cable2387	127.28
Cable2389	131.11
Cable2517	147.18
Cable2594	144.7

5.4 solving problems

In general, there are many methods used to reduce energy loss in the distribution network, as we used some of these methods to solve the problems that we encountered on HEPCo, and in the following, we review those methods:

1. Network reconfiguration.
2. Network reconductoring.
3. Distribution transformer locating and sizing.
4. High voltage distribution system.
5. Flexible Alternating Current Transmission System (FACTS).
6. Adding a New Sub-Station.

In this case, we proposed a solution to the problems that appeared on the network as a result of adding charging stations, as we developed this solution at the maximum load that affects the network, and below we will show this solution:

Table 5.21: The steps for the solution.

Steps	Explanation
Step 1	Adding a new sub-station (Al-Salah Al-Riyadi) that contains two transformers, each transformer with a capacity of 13 KVA, with a total of 26 KVA.
Step 2	Reconfiguration of loads in the vicinity of (Alsala-Alriyadia), where the feeder (Diwan Al-Mohatasab) feeding the periphery of (Alsala-Alriyadia) was separated, and the feeder was added to (Alsala-Alriyadia) station.
Step 3	Separation of the feeder (Al-Mazrouk) from (AL-DAHDAH) station and adding the feeder to (Alsala-Alriyadia) station.
Step 4	Separation of (AL-GHARBIA) station from (AL-DAHDAH) station at Bass (Ajlouni) and feeding this feeder from (Alsala-Alriyadia) station only in case of a high load on (AL-GHARBIA) station when necessary.
Step 5	Adding a 10 KVA capacity transformer to the (AL-RAS) station.
Step 6	Reconfiguration of loads to (AL-FAHS) and (UM AL-DALIYEH) station.

As shown in Table 5.21, in step No. 6 the loads were redistributed between (AL-FAHS) station and (UM AL-DALIYEH) station due to the presence of load on (AL-FAHS) station and also the presence of an overload on the cable fed from the station (UM AL-DALIYEH), thus solving the cable overload problem shown in the following Table 5.22:

Table 5.22: Cables that were overloaded.

Cables	
Name	Cable Loading (%)
Cable2387	126.86
Cable2389	130.68
Cable2517	146.69
Cable2594	144.22

5.4.1 Solving problems for the stations

Table 5.23: The solution developed for the affected stations.

Station	Explanation
Halhul Bridge	Adding a new transformer with a capacity of 630 KVA to the network and connecting the station with two cables on the two busses to distribute the loads to them.
Jabal Al Rahmah	Replace the transformer from 160 KVA to 400 KVA.
Altahreer	Replace the transformer from 100 KVA to 630 KVA.
Ein Sara	Adding a new transformer with a capacity of 630 KVA, connect the charging station to it, supply it from the (Alsala-Alriyadia) station, and connect the station to the transformer with two cables on two busses to distribute the loads to them.
Nimra	Replace the transformer from 400 KVA to 630 KVA.

As the following Table 5.24 shows, new cables have been added to the charging stations to distribute the load on the passes inside the station due to the high load on the cables in the charging stations (Halhul, Ain Sarah and Al-Salam), and also to raise the thickness of the cables affected by the overload in the rest of the stations:

Table 5.25: Cables that were overloaded in the stations.

Cables	
Name	Cable Loading (%)
Cable43	217.04
Cable303	103.69
Cable344	107.92
Cable362	129.69
Cable362	153.48
Cable401	166.11

5.4.2 Case results

Table 5.26: Load distribution to substations in HEPCo after edit

ID	rated kv	MW	Mvar	Amp	%PF
AL SALA	33	6.084	2.568	115.5	92.13
AL-DAHDAH	33	15.671	7.469	303.7	90.27
AL-FAHS	33	19.329	6.423	356.4	94.9
AL-GHARBIA	33	15.279	7.193	295.5	90.47
AL-HARSYEK	33	12.381	6.357	243.5	88.96
AL-HUSSEIN	33	12.164	6.106	238.1	89.37
AL-RAS	33	18.342	8.647	354.8	90.45
UM AL-DALIYEH	33	16.114	6.564	304.4	92.61
TOTAL		115.364	51.327		

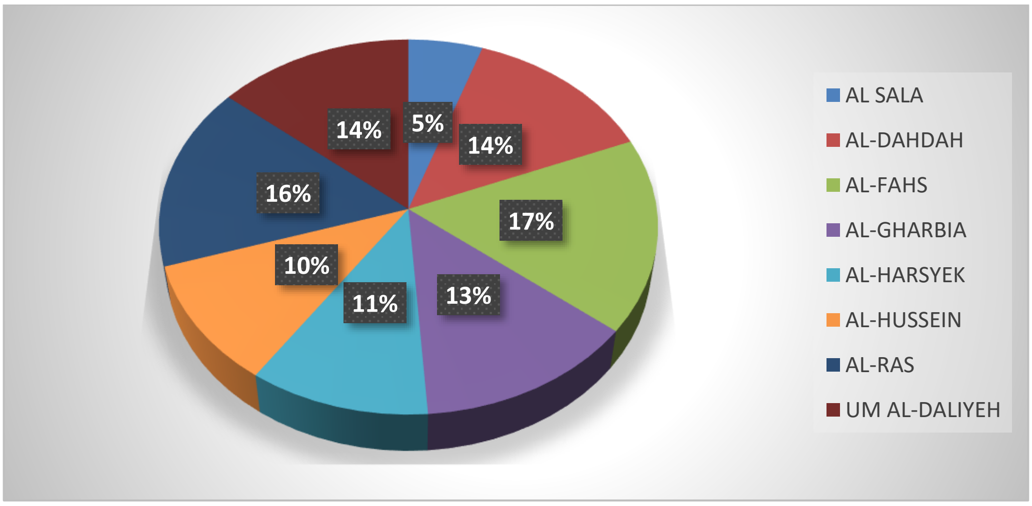

Figure 5.5: Loading ratio for each sub-station after edit.

Table 5.27: Total power and losses after edit.

Total Power	115.365
Total Demand:	111.893
Apparent Losses	3.472
Number of loads	726

Power imported from Power Grid = 115.365 MW

Total power losses = 3.472 MW

$$percentage\ of\ the\ losses = \frac{\text{Total power losses}}{\text{Power imported from Power Grid}} \times 100\%$$

$$= \frac{3.472}{115.365} \times 100\% = 3.009\%$$

In this case, the charging process will be run within two hours at maximum load after applying the appropriate solutions, as the charging process, in this case, will be intact and also with less losses.

The following Figure 5.6 shows the total power consumed by electric vehicle charging stations during the two-hour charging process on HEPCo:

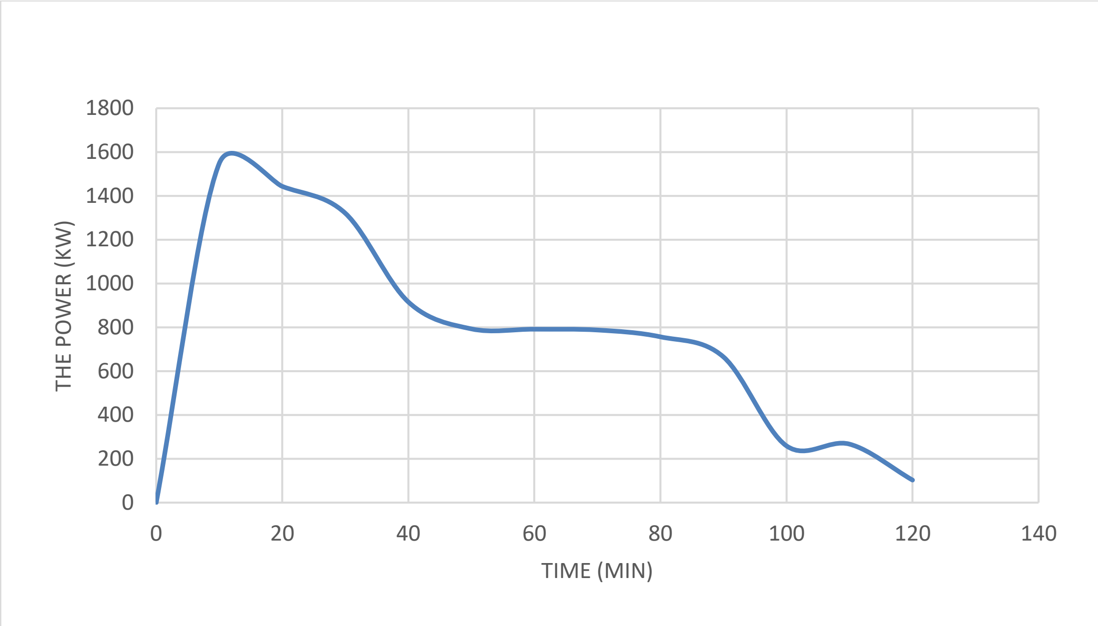

Figure 5.6: Total power in two hours.

The following Figures 5.6,5.7 show the total losses on HEPCo during the two-hour charging process:

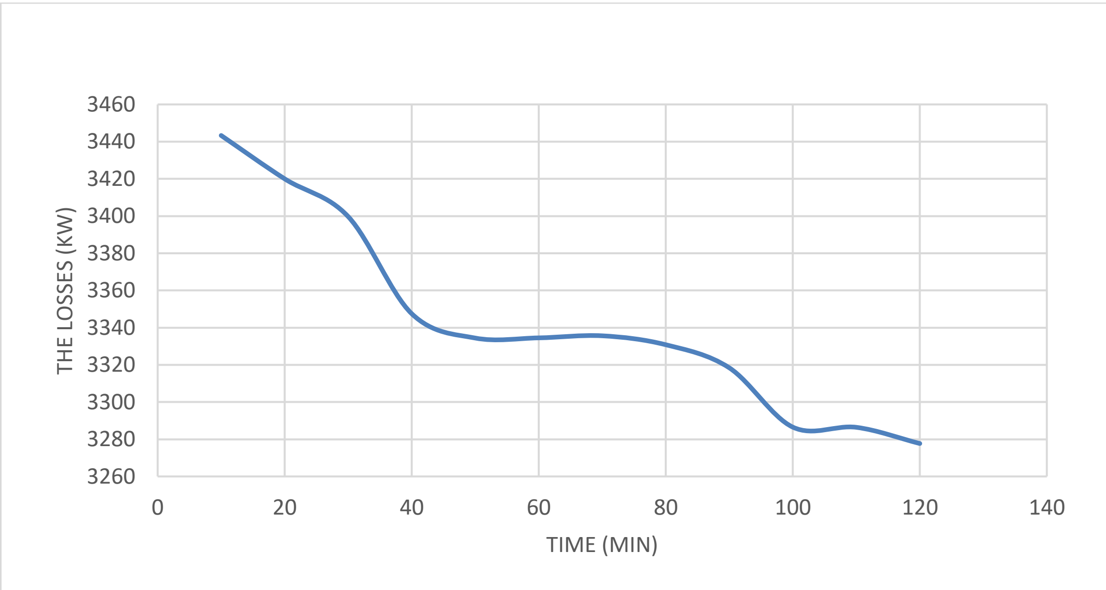

Figure 5.7: The total losses in KW.

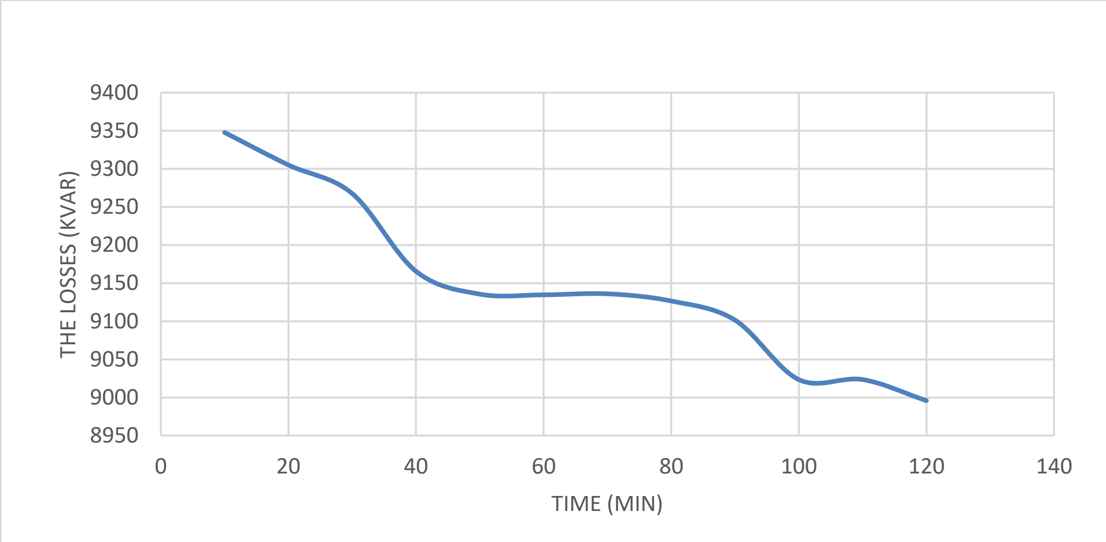

Figure 5.8: The total losses in Kvar.

5.5 Losses clarification

In this part, we made a comparison of losses in the cases we did, where the following Table 5.28 shows the value of losses without the presence of station loads on HEPCo and after adding the loads, and the value of losses after making an appropriate solution on HEPCo.

Table 5.28: Losses in each case.

Case	Losses (KW)	Losses (Kvar)
No load	3635.3	10354.8
Minimum load	3698.9	10325
Medium load	3772.3	10643.6
Maximum load	4298.4	11623
Maximum load after the solution	3472.2	9396.3

Table 3 shows that the value of losses after the solution that we made on the network in the case of maximum load is much less than the value of losses before the adjustment of 826.2:

$$4298.4 - 3472.2 = 826.2\ KW$$

Also, the value of losses after modification on the HEPCo network at the maximum load of electric vehicle charging stations is less than the value of losses in the case of the no-load of charging stations on the network:

$$3635.3 - 3472.2 = 163.1\ KW$$

Annual operating hours = number of hours * number of days * number of months

= 24 * 30 *12

= 8640 h

Utilization factor $= \frac{Maximum\ MVA\ Demand}{Transformer\ MVA\ Rating} = \frac{124.61}{309}$ = 0.403

Annual cost for losses = total power losses * 8640 * price of kw * Utilization factor

= 826.2 * 8640 * 0.378 *0.403

= 1087416.151 NIS /Y

5.6 Conclusions & Recommendations

5.6.1 Conclusion

1- After studying the medium voltage network in HEPCO, we note that the percentage of energy loss at the present time is acceptable and a normal value, as we note that with the development of the loads on the network in general and in particular the new loads from the electric vehicle charging stations, the losses have clearly increased.

2- The results of the highest load showed that it has the largest loss occurring on the network, which requires setting future development plans for the network in order to reduce losses that may occur on the network.

3- The results showed that the solution scenario that we proposed from redistributing the loads to the feeders of the substations and adding the new station is an effective way to reduce energy loss and solve the problem of overloading on the feeder stations.

4- The improvement of the medium voltage network and the reduction of energy losses on it will positively affect the low voltage network.

5- The development of the network and the reduction of losses is reflected in the economic side of HEPCO, which saves huge sums of money every year, and this wasted money is invested in developing the network continuously and making strategic planning for future new loads.

6- Through this project, we found out that it is possible to add charging stations for electric cars to the Hebron electricity grid, but within the solutions that we have developed and other solutions as well.

5.6.2 Recommendations

Recommendations for Hebron Municipality:

1. Use electrical analysis programs such as Etap or others, and network development to get a clear view of the network, which helps in controlling it better.
2. Adding new substations with studies on their best location.
3. Redistribution of loads and further studies on the redistribution of loads in each substation.
4. Establishing a future development plan for the network to receive new loads from electric vehicle charging stations or receiving vehicle charging units in homes.

Recommendations for our university:

1. Simulation software courses are needed for students to understand more about the electrical grid and how it works, based on our studies in our college.
2. Conducting more scientific visits to learn more about the parts of the electrical network and substations.
3. Provide an original copy of the analytical program (etap), which gives more features and more accuracy in the results.

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