



**OPTIMAL PLACEMENT OF ELECTRIC VEHICLE CHARGING
STATIONS ON A DISTRIBUTION NETWORK**

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Tohid HARIGHI

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FOR
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ETHICAL STATEMENT

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Tohid HARIGHI

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(M. Sc. Thesis)

Tohid HARIGHI

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ABSTRACT

Energy and greenhouse gas emission have been high priority topics for both international non-governmental and science-based organizations. That is why electric vehicle usage is a matter of compulsion. In addition, the electric vehicles have played a big role to decrease greenhouse gas emission by their working principles. Hence, petroleum energy consumption method has changed to electric type of the energy and this is an indispensable priority for occupying a clean weather in the future. The only problem is that by increasing electric vehicles, locating charge stations has been considered a dramatically severe problem for the energy providers. These problems are about charge station location and its influence over the grid. However, currently these problems are solved using complex algorithms and some limited parameters. In this thesis, according to location of power transformers in Ankara power system, an algorithm and scenarios are provided for electric vehicle charge stations. Moreover, for the first time the amount of used energy in the mentioned algorithm is calculated. In this algorithm, locating the charge station has been executed regarding grid infrastructure. This algorithm has been tested according to the information of the location. These tests are induced in finding locations technical-wise and location-wise suitable and tests on this algorithm elaborate compatibility of it with other estimation algorithms.

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Coordinating of charge station

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ELEKTRİKLİ ARAÇ İSTASYONLARININ BİR DAĞITIM ŞEBEKESİNE OPTİMUM OLARAK YERLEŞTİRİLMESİ

(Yüksek Lisans Tezi)

Tohid HARIGHI

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ÖZET

Uluslararası sivil toplum ve bilim kuruluşları enerji ve çevre kirliliği gibi başlıkların öncelikli konular olduğu konusunda hemfikirdir. Bu nedenle günümüzde elektrikli araç kullanımı isteğe bağlı olmaktan çıkıp bir zorunluluk haline gelmeye başlamıştır. Buna ek olarak, bu araçlar hava kirliliğinin azaltılmasında önemli rol oynamaktadır. Bu kapsamda enerji tüketimi arzı, petrol ürünlerinden elektrik enerjisine doğru yönelmeye başlamıştır ve bu temiz bir gelecek için gerekli olan ön şartlardan biridir. Ancak, elektrikli araçların yaygınlaşmasıyla şarj istasyonlarının konumlanması elektrik dağıtıcıları için önemli bir problem olarak ortaya çıkmıştır. Bu problemler özellikle istasyonların nerede olacağı ve şebekeye nasıl etki edecektir. Hâlihazırda bu problemlerin kısıtlı sayıda değişkenler kullanılarak karmaşık algoritmalarla çözüldüğü görülmektedir. Bu tez çalışmasında, Ankara ili elektrik şebekesinde bulunan transformatörlerin konumlarına göre, elektrikli araçlar için şarj istasyonlarının konumlandırılma senaryosu oluşturulmuş ve çözüm algoritmaları tanımlanmıştır. Bununla birlikte, ilk defa önerilen özgün algoritma kullanılarak tüketilen elektrik enerji miktarı hesaplanmıştır. Daha sonra olası istasyonların konumları tam olarak tanımlanmıştır. Konumlama yapılırken öncelikle şebekenin alt yapısı tanımlanarak, konum ayrıntıları algoritma haline getirilmiştir. Elde edilen algoritma ilgili bölgenin verileri kullanılarak test edilmiştir. Test sonucunda elektrik araç şarj cihazları için teknik ve bölgesel olarak uygun konumların bulunduğu ve geliştirilen algoritmanın farklı tahmin algoritmalarına uyum sağladığı görülmüştür.

Bilim Kodu : 90502

Anahtar Kelimeler : Elektrikli araçlar, Şarj istasyonu, Yenilenebilir Enerji, Şarj istasyonu konumlandırması

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SYMBOLS AND ABBREVIATION:

The symbols and abbreviations used in this study, together with their explanations, are presented below.

Symbols	Description
p_j^{PD}	Load demand by taking renewable energy source
p_j^L	Forecasted load demand without EVs
p_j^{RES}	Predicted output of RESs
$p_j^{uEV,i}$	Unscheduled total demand
$p_i^{EV,i}$	Predicted EV charging profile
l	Particular EV charging
J	30-minute intervals in a day
m_i	Total number of departure required for charging i^{th} EV
k_i	Total number of interval required for charging i^{th} EV
i	EVs ID
$\bar{G}$	Average grid load before EV plugged in
$\Delta \bar{G}$	Increment of $\bar{G}$ after EV plugged in
$G(t)$	Global load curve
$V_i(t)$	Charging load curve
T	Parking time
T_c	Charging time
p_i	Constant charging power of EV
$C_i(t)$	Charging status function
t_{V2G}	Time of using V2G
S_1^{Cap}	Capacity of EVs in MODE 1
$S_{j,1}^{Cap}$	Capacity of EVs in MODE 1 of the j th EV charge station

Symbols	Description
$P_{k,1}^{Cap}$	Capacity of the kth EV in MODE 1
$P_{k,1}^d$	Discharging power of the kth EV in MODE 1
P_{max}^d	Maximum discharging power
S_2^{Cap}	Capacity of EVs in MODE 2
$S_{j,2}^{Cap}$	Capacity of EVs in MODE 2 of the jth EV charge station
$P_{k,2}^{Cap}$	Capacity of the kth EV in MODE 2
$P_{k,2}^c$	Charging power of the kth EV in MODE 2
S_3^{Cap}	Capacity of EVs in MODE 3
$S_{j,3}^{Cap}$	Capacity of EVs in MODE 3 of the jth EV charge station
$P_{k,3}^{Cap}$	Capacity of the kth EV in MODE 3
S_4^{Cap}	Capacity of EVs in MODE 4
$S_{j,4}^{Cap}$	Capacity of EVs in MODE 4 of the jth EV charge station
$P_{k,4}^{Cap}$	Capacity of the kth EV in MODE 4
S_i^{Dis}	Dispatch for EVs in the ith round of control center
$S_{j,1}^{CS}$	Dispatch for EVs in MODE 1 of the jth EV charge station
$S_{k,1}^{EV}$	Dispatch for the kth EV in MODE 1
$P_{k,1}$	Discharging power of an EV in MODE 1
$S_{j,2}^{CS}$	Dispatch for EVs in MODE 2 of the jth EV charge station
$S_{k,2}^{EV}$	Dispatch for the kth EV in MODE 2
$P_{k,2}$	Discharging power in MODE 2
$S_{j,3}^{CS}$	Dispatch for EVs in MODE 3 of the jth EV charge station
$S_{k,3}^{EV}$	Dispatch for the kth EV in MODE 3

Symbols	Description
$P_{k,3}$	Discharging power in MODE 3
$S_{j,4}^{CS}$	Dispatch for EVs in MODE 4 of the jth EV charge station
$S_{k,4}^{EV}$	Dispatch for the kth EV in MODE 4
B	Building
η_c	Charging efficiency
η_{etoc}	Electricity-to-carbon conversion factor
η_{ftoc}	Fuel-to-carbon conversion factor
C	Cost function
C_{tax}	Carbon emission tax
e	Stored or generated electricity
ec	Electricity charging rate
$ef_{A,B}$	Electricity flow from A to B
f	Fuel consumption
z	The objective function of transmission and distribution cost
X_{ij}	The transmission power flow from substation SSi to SSj
X_m	The electric power flow in apparatus m
X_n	The outage power of load n
a_{ij}	The cost of the transmission and distribution loss during normal operation
b_{ij}	The cost of the transmission and distribution loss during overload operation
c_m	The damage caused by a shortened service life due to overload operation
d_n	The customer's outage cost
V	Relative aging rate
θ_h	Hot-spot temperature
L	Total aging over the time period considered
V_n	Relative aging rate during an interval n

Symbols	Description
N	Total number of intervals during the time period considered
$D_{TR_PHEV_X}$	Oil temperature at the bottom of the winding
A	Top-oil temperature derived as the average of the tank outlet oil temperature and the tank oil pocket temperature
B_m	Mixed oil temperature in the tank at the top of the winding (often assumed to be the same temperature as A)
$T_x - T_r$	Initial load rate without PHEV
C	Temperature of the average oil in the tank (Page)
D	Oil temperature at the bottom of the winding
$\sum TRP$	Sum of the nominal powers of the transformers in parallel
TRP_{Nx}	Rated power of the transformer under analysis
TRP_{Ny}	The nominal power of the transformers in parallel with the transformer being analyzed
f_L	Charge factor of the set of power transformers
L_{max}	Maximum load allowed
N	Total number of power transformers in parallel
a	Transformation ratio
V_p	Primary voltage
V_s	Secondary voltage
β	Coefficient of age of the equipment
C_{fur}	Content of furfural
$F_{C,H}$	Hydrocarbon gas factor function
F_{oil}	Oil factor function

Abbreviations	Description
2DS	2 °C Scenario
6DS	6 °C Scenario
AC	Alternating Current

Abbreviations	Description
AM	Automotive Mode
A-UFLS	Adaptive UFLS
BO	Boiler
CHAdEMO	CHArge de Move
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CS	Charging Station
DC	Direct Current
DOD	Depth of Charge
DSL	Digital Subscriber Line
DSL	Digital Subscriber Line
EL	Building Electric Load
EV	Electric Vehicle
EVI	Electric Vehicles Initiative
Fe	Iron
G	Power Grid
G2V	Grid-to-Vehicle
GDR	Generalized Demand-Side Resources
GHG	Green House Gas
GPS	Global Positioning System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GSM	Global System for Mobile Communications
GTCO₂	Giga Tons of Carbon dioxide
HAN	Home Area Network
HAN	Home Area Network
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
IEA	International Energy Agency
IEC	International Electro Technical Commission
IEEE:	Institute of Electrical and Electronics Engineers

Abbreviations	Description
kWh	kilo Watt hour
LDV	Light-Duty Vehicle
Li	Lithium
LiCoO₄	Lithium Cobalt Oxide
LiFePO₄	Lithium Iron Phosphate Oxide
Li-ion	Lithium-ion
LiMn₂O₄	Lithium ion Manganese Oxide
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NAN	Neighborhood Area Network
NAN	Neighborhood Area Network
NaS	Sodium–Sulfur
NiCd	Nickel–Cadmium
NMC	LiNiMnCoO ₂
PF	Fuel Price
PGU	Power Generation Unit
PHEV	Plug-in Hybrid Electric Vehicle
PP	Electricity Purchasing Price
PS	Electricity Selling Price
SAE	Society of Automotive Engineers
SCADA	Supervisory Control and Data Acquisition
SCADA	Supervisory Control and Data Acquisition
SM	Storage Mode
SOC	State Of Charge
THD	Total Harmonic Distortion
T-UFLS	Traditional UFLS
TWh	Terra Watt hours
UFLS	Under Frequency Load Shedding
UFLS-EV	Adaptive UFLS Strategies with EVs' participation
UNFCCC	United Nations Framework Convention on Climate Change

Abbreviations	Description
V2G	Vehicle-to-Grid
VPP	Virtual Power Plant
W h/L	Watt hour per Liter
WAN	Wide Area Network
WPP	Wind Power Plant
ZnBr	Zinc–Bromine



1. INTRODUCTION

The world population is growing rapidly, so the outcome is greenhouse gas (GHG) emission and energy consumption increase each year. It is not a traditional fuel for transportation at hand where are both clear and efficient (mostly fossil fuels), while on the other hand, electric fleet systems should work with lower GHG emissions and energy loss. However, changing fuels seems good idea to get the fine result here. “To build this happen, in the first step, the electric grids where are used can be smart (as is mostly the case in North America, Europe and pacific Asia)” (IEA, 2016; Erdogan, Erden, and Kisacikoglu, 2018; Kisacikoglu, Erden, and Erdogan, 2018). Electric vehicle and the smart grid have integrated to execute plan. Electric vehicles must connect to the smart grid in the appearance of Vehicle-to-Grid (V2G) or Grid-to-Vehicle (G2V).

V2G technology, the EV and grid share energy from the vehicle to the grid, and vice versa in G2V. Consequently, it could be said that EVs are the subdivision of electric transportation systems and grids. The result of this integration is to have important specific features such as having high storage and low GHG emissions. Considering to some existing options, technologies and disadvantages, all the energy areas actors have developed energy scenarios. They have planned to change the transportation system to an electric transportation system to meet the targets made by IEA 2030 and 2050. The Paris agreement (UNFCCC, 2015a) has helped to decrease GHG emissions in the world, so this agreement declares where countries may come up with plans to decrease the global average temperature up to 2 °C. “The IEA 2DS trajectory sets the goal, which is reducing GHG emissions from 33 GtCO₂ approximately to 15 GtCO₂ in 2050, which is roughly 45% of the CO₂ where was emitted in 2013”. In other hand, in the 6 DS IEA trajectory, GHG emission is approximately 55 GtCO₂. Some predictions of IEA and UNFCCC until 2030 and 2050 on the electric vehicles plans are as follows (IEA, 2016):

- About one billion electric vehicles, comprising above 40 percent of the total LDV stock, that is trajectory 2DS.
- More than 400 million electric two-wheeler vehicle may be produced in 2030.
- All of the cars can be electric two-wheeler vehicles by 2050.
- The EVI members have comprised of 16 governments.

- From 2014 to 2015, new enrolment of EVs (BEV, BEV) increased by 70 percent (more than 550 K sold worldwide)
- Sale list of 2015 in comparison to 2014, increased more than 75 percent electric vehicles in these countries: France, Germany, Korea, Norway, Sweden, The UK and India.
- Price of the plug-in hybrid electric vehicle batteries reduced from USD 1000/kWh in 2008 to USD 268/kWh in 2015, and the target for 2022 is USD 125/kWh.
- Density of the plug-in hybrid electric vehicle batteries increased from 60 W h/L in 2008 to 295 W h/L in 2015, and the target for 2022 is 400 W h/L.

Some countries have taken actions to reach the IEA 2030 and 2050 targets. For example, Ireland created a roadmap from 2011–2050”. This plan, 800K tons of oil and 4 million tons of CO₂ emissions may be decreased by 2050 per annum (SEAI, n.d.). Renewable energies such as wind and solar are very important however they produce energy with zero GHG emissions, and the grids supplied by both energy types are more flexible than grids supplied by only fossil energy (Sarkar and Reuben, 2016; Energinet.dk’s, 2016; Baumhefner, Hwang, and Bull, 2016). All types of renewable energies are only available in special situations because they are not stable energy sources. Because, they may be constructed at any size in everywhere. V2G, the smart grid and micro grid are supplementary to each other and also can expand one another. Renewable energy conversion procedures include AC to DC or the inverse. The DC type of energy supplies batteries, and the EVs’ energy storage system plays a big role in the grid when it needs energy exchange. EVs may save energy when the demand side of the grid strongly decreases, for example a decrease between 23:00 and 05:00. Consequently, reducing the energy level immediately in power plants (in every condition) is not economical. Fossil ICE efficiency in the best condition and with the latest technology is 18~20%. However, the fossil power plant efficiency is 38~40%, and CHP energy efficiency is 60~75% (Combined Heat and Power Basics, 2019). This clearly shows where EVs’ benefit is not limited only to having zero GHG emissions. However, EVs are supplied with electric energy, which is generated as 38~75%, that depends on the energy generating condition, and all mentioned benefits (EVs are supplied by high efficiency energy and reduce GHG emissions) can be improved by V2G technology or similar technologies. This is based on a bidirectional energy transmission system, and some targets are easily reachable, such as peak reduction, stability and reliability of energy. EVs’ batteries, the quantity of the EVs, the time of charge and the power electronic systems’ topologies are forced to use an energy storage

system in charging stations, and this is sensible in grids where are used in the DC line. In this situation, energy is conveyed to the grid in critical situations such as peaks and down time by the stable energy storage in charging stations and the temporary energy storage in EVs (Shirazi, Carr, and Knapp, 2015; IRENA, June 2013; Environmental Assessment of Plug-In, 2017; Heinen, Elzinga, Kim, and Ikeda, 2011; Technology Roadmap, 2011; Lewis, Amr, Francisco, Alessandra, and Deger, 2017). So, electric fleet system is a new technology and it is not predicted in advance. Today, in order to supply EVs, the grid need a plan B to develop and increase the capacity (Sun, Yamamoto, and Morikawa, 2015). Therefore population density, infrastructure of grid, source of energy, habitude of using fleet and some other aspects are perks of the grid development (Zhu, Gao, Zheng, and Du, 2016). Replacement of fleet system is necessary and this program has changed to a legislation in EU. At first sight, it seems like there is a controlling issue, but it is a different deal. For example, regular control problems could be solved with Laplace block diagram node or some other mathematical nodes. In this problem of management program of the grid, there are three parts to be solved to support EVs.

Figure 1.1 gives grids and supply/demand circle in operation. The Grids not only should support EV fleets but also other demands of the grid must be supplied from grid. EVs are not usually supplied in most of the electric networks. And also, Figure 1.2 illustrates supply/demand division in the grid.

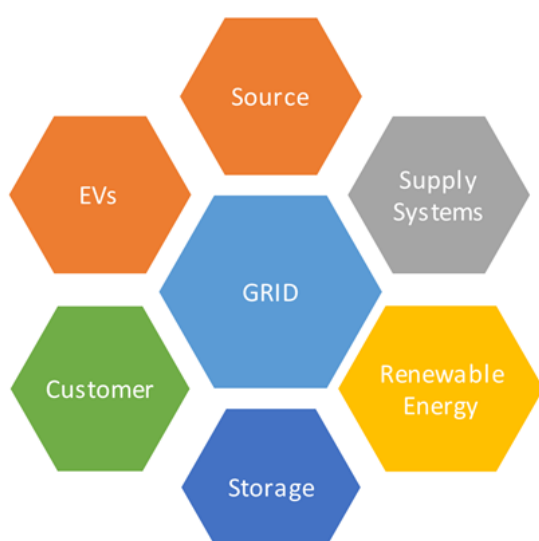


Figure 1.1. Grid and supply/demand circle, EVs and other customers contain the demand side

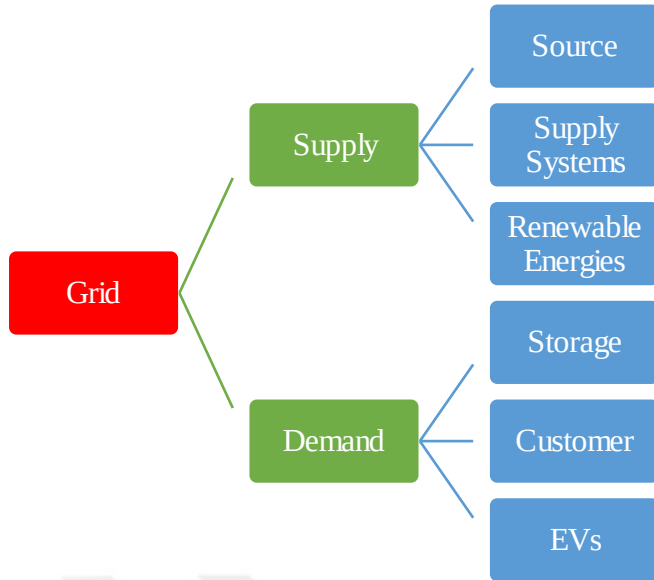


Figure 1.2. Division of supply and demand in a grid, supply can come from a number of sources, and the demand is diverse

Other nodes of the systems have control parameters, such as peak time. But the other parameters and alternatives of nodes may improve or deteriorate charge stations. Charge stations are the points which can transmit power with grid and EVs (Kim, Son, Lee, and Ha, 2017). Determining locations of the charge stations can lead to severe problems in electric network such as problems in low voltage and high voltage infrastructure (Cai, Jia, Chiu, Hu, and Xu, 2014). In some countries, urban growth is very fast but the supply side can only support the regular consumption; so the EV charge station will need a stable and powerful grid to work in peak and off-peak load (charge and discharge function). In this situation, grid cannot respond to charge stations citywide. It does not mean the grids with low capacity cannot support EV charge stations and electric fleet systems. It means the electric fleet systems without required background is useless (Wellisch, Lenz, Faschingbauer, and R. Pöschl, 2015; Harighi, Bayindir, and Hossain, Overview of Quality of Service Evaluation of a Charging Station for Electric Vehicle, 2017; Harighi, Bayindir, and Hossain, Overview of quality of service evaluation of a charging station for electric vehicle, 2017). This thesis describes some hidden threat in grid and that what will happen, when EVs connect to the grid in large scale such as storages. . In such a scenario, the grid infrastructure should be prepared to connect EVs. EVs use both AC and DC type of the electric power and this issue requires a wide range of power electronic equipment. Power electronics, as well as associated cost and loss are the problems in the infrastructure sector. After the infrastructure of the grid, the grid supply balance and storage system conditions are influenced for better

or worse when the EVs are connected to the grid. The local environmental condition and budget are also need to be considered before placing EV charging stations. This paper presents all these considerations with corresponding calculations where may lead to the optimal charging station placement strategy. Prior to this, Zengin et al. calculated the performance profile of a fast charging station with multiple-standard capability (Zengin, 2017). However, they did not consider the work on the estimations required to set up the charging stations. Optimal placement and sizing of such fast charging stations were discussed in (Payam Sadeghi-Barzani, 2014) as well. Zheng et al. studied optimal planning of charging stations with battery swapping facility in (Zheng, 2014). Though they took life-cycle cost into consideration, the environmental factors of the geographical area were overlooked. Battery swapping facilities are also not available commercially currently. Monte Carlo analysis to determine service capabilities of similar facilities was conducted in (Zhang, 2018). Guo et al. employed a fuzzy technique to site selection optimization of EV charging stations (Sen Guo, 2015). In energy policy and environment condition there is a necessity to use renewable energy, Electric Vehicle (EV) and cases like them, which do not work with fossil fuels. The common point of the all mentioned items is working with DC type of electric energy. EVs and renewable energy generation typically need safe and high capacity battery to exchange energy with other grids and customers. So bidirectional energy exchange automatically places the user in whether supply or demand side in the grid. To make it happen the grid needs Energy Storage Systems (ESS) to save energy and use it in critical conditions. The word grid in this study refers to all aspects of the grid such as EVs, renewable energy generators (in home or power plant scale) and local ESSs. To reach mentioned issues, fundamental steps should be taken. DC power line and related cases could be executed by ESS, but it is only the begging. Renewable energy generation in the metropolises, development of the ESS, the telecommunication of the existed area, smart grid and some decentralized power control technologies should be applied to reach the high quality grid besides supporting green technologies. In this study, influence of ESSs in grid and what will be happened, if the grid worked without ESSs are also elaborated.

In one of researches in Finnish, according to decrease GHG emission policy, EnergyPLAN (created by Aalborg University) modelling and 100% renewable energy which are the 2050 targets in Finland (funded and presented by Ministry of Economy and Employment), this research have focused on energy potential and generation in Finland from economy, fuel and CO₂ emission side of issue (Østergaard, 2015). Result of this investigation, countries energy

future should be based on 100% renewable energy and it is possible. Future energy system highly depends on transportation consumption system. The energy scenarios had created for all energy sectors (Power, Heating/Cooling and Mobility) by hourly resolution. In another research which is focused on Delhi, India energy sector with contribution from The Japan Society for the Promotion of Science (JSPS), investigated about Delhi energy future and how can optimize it. Therefore, they found that, integrated-systematic modelling should be used for energy flow in urban energy system. They have used optimal energy scenario in Delhi case and have got energy gap between supply and demand. This research have payed attention on government energy policy to improve demand side of energy sector (Farzaneh, Doll, and Oliveira, 2016). However, government policy and social behavior strongly influence the GHG emission in transport waste sector in some countries such as Austria (Farzaneh, Doll, and Oliveira, 2016). In addition, both of them can be used on electric sector (supply or demand). Reduction of CO₂ is one of the problems in China and some investigators have investigated China CO₂ condition in 2030 by control uncontrolled EVs, V2G and similar transportation systems and it gives advantages in: decrease peak load which is used from EV charging; Help RES power generation; reduce energy generation and EV charging costs (Li, Davis, Lukszo, and Weijnen, Electric vehicle charging in China's power system: Energy, economic and environmental trade-offs and policy implications, 2016). Therefore, some researchers have applied some resolutions in some special situations (EV charge station) which none of them were following a specific algorithm, and we could say they have applied a pattern on an existing grid.

Some methods and algorithms have simulated different cases, they shows that interaction of happenings are not same in all sections of the grids. Algorithms create special condition or purposes, in this section some algorithms, which are used in smart grids and V2G operations, have been explained in continue of the thesis.

In one of researches that they had focused on uncertain situation on V2G operation pricing. They have used Robust Game-Theoretic to treat uncertain issues. This algorithm named ENTRUST (Energy trading under uncertainty in smart grid systems) (Sudip Misra a, Ojha, Mouftah, and Anpalagan, 2016). They have achieved reliability and cost efficiency in energy management. Another grid lead system is Multi-Agent Energy Management. In this system, all demand side of the grid (Home, Building, Industrial and Vehicles) have connection and company in the grid progresses. It can improve systemic autonomy, connectivity, diversity

and emerging in the grid. And in other research in Great Britain (GB) (Meng, et al., Dynamic frequency response from electric vehicles considering travelling behavior in the Great Britain power system, 2016), to solve dynamic frequency response, they have created a dynamic Virtual Energy Storage Systems (VESS). This model used V2G technology and similar technology storages to response grid when it needs emergency energy or rhythm of the energy flow have been disturbed. This model considered response capacity of EVs cluster.

Explained models, scenarios and algorithms are the ways to manage the grid to increase responsibility for EVs, charge stations and interconnected storages. Coordinating of EVs charge stations at first sight need those methods to solve some prerequisites. Researchers have developed some algorithms for EV charge stations such as Flow Refueling Location Model (FRLM) (He, Kockelman, and Perrine, 2019), Maximum Covering Location Problem (MCLP) (Zarandi, Davari, and Sisakht, 2011), Nonlinear Auto-Regressive (NAR) (Heydarian-Forushani, Golshan, and Shafie-khah, 2016), Genetic Algorithm (GA) (Zhou, Yao, Littler, and Zhang, An electric vehicle dispatch module for demand-side energy participation, 2016), Genetic Algorithm-Particle Swarm Optimization (GA-PSO) (Mozafar, Moradi, and Amini, 2017) and Genetic Algorithm-Binary Particle Swarm Optimization (GA-BPSO) (Hu, Zhang, and Zhang, 2019). This case have been studied by considering Ankara metropolitan electric infrastructure and some conditions depending on Ankara electric infrastructure. All algorithms need feeding by data which are created especially for own area even country electric discipline and locating control limit.

Energy plans have same scenarios. The energy efficiency and GHG emission are targets for energy efficiency and GHG emission for each energy scenario's in the world, and scenarios for V2G technology depend on their own location, so different requirements and energy stocks exist all over the world. The road maps created by IEA give the result for general scenarios for 2050. Table 1.1 gives the number of EVs and plug-in hybrid electric vehicles where will be sold in 2050. It is clear where EVs have lower GHG emissions than plug-in hybrid electric vehicles. Considering to the 2050 road map, the North American, European and Pacific countries will have less plug-in hybrid electric vehicles than China and India. It means that their fossil energy consumption in the transportation sector will be lower than India and China.

Table 1.1. Electric vehicles where will be sold in 2050 considering to the IEA scenario

Location	EV	PHEV
North America	8 800 K	3 800 K
Europe	6 400 K	3 100 K
China	9 400 K	11 400 K
India	8 600 K	9 600 K
Pacific	2 400 K	1 300 K

For example, China's government has tried to reduce GHG emission more than other countries. However, the mentioned countries updated their grid from the cyber security, smart and micro grid side of the grid (Tuballa and Abundo, 2016). Energy efficiency is possible, if only the mentioned parameters are used together. Today, energy providers provide energy in different forms such as oil, gas (LPG, CNG and LNG) or electricity. The energy usage method is very important, and it must be observed in all parts of the energy consumption. Energy use percentages, in some places, could be as follows: electricity 30%, heat 40% and transport 30%. In addition, they can be supplied with renewable energy by the CEESA 2050 (Research project Coherent Energy and Environmental System Analysis (CEESA) financed by the Danish Council for Strategic Research.) scenario (Mathiesen, et al., 2015). Control of supply and demand is the primary parameter of energy quality, so reduction of the GHG emissions and the efficiency of energy are possible by assuming supply and demand accurately (Farzaneh, Doll, and Oliveira, 2016; Sonnenschein, Lünsdorf, Bremer, and Tröschel, 2015; Brady and Margaret O'Mahony, 2016). The control of the mentioned items results in facilitates integrating the renewable energy network with the grid and EVs, but it requires data from metrology, the supply and demand of the grid, the infrastructure of the grid and some additional algorithms to provide good and predictable data (Schuller, Flath, and Gottwalt, 2015; Prebeg, Gasparovic, Krajacic, and Duic, 2016; A.Dantas, Castro, Brandão, Rosental, and Lafranque, 2017). V2G technology should be economical, so all of the mentioned items should have a reasonable relation between technical benefits and the economic condition of the investor. The performance of the V2G technology depends on the grid infrastructure and the type of electric vehicle storage system. Their quality and size directly influence the performance of the grid (RickShang and Sun, 2016; Kaschub, Jochem, and Fichtner, 2016). Consequently, not all of them are completely controllable, but they are predictable. Predictable means where the management team can

modify the demand time schedule (Arif, et al., 2016; Soares, Fotouhi Ghazvini, Borges, and Vale, 2017; Noel and Benjamin Sovacool, 2016). Here, some scenarios are reviewed one by one, so all of them are issued for a special location and condition, also any changes in the main scenario can generate different results. Considering to the scenario (can be different in each location), the design of the grid have to be more developable, flexible and manageable than what grids use currently, so grids after design, will be more complex and comprehensive. Scenarios of the grid have some algorithms to use in normal and critical situations and all sections of the grid have a connection with another section of the grid, which is very important to control the grid and one of the grid designing protocols (Mukherjee, Shukla, and Gupta, 2015; Niesten and Alkemade, 2016; Sousaa, Soares, Morais, and Rui Castro, 2016).

The strategy of V2G technology works considering to some plans and targets. Besides, the targets have zero GHG emissions and energy efficiency, such as stability and reliability. Some parameters cause changes in the plan. Infrastructure, energy sources, budget and some other parameters in each country are determined by the energy plan, which is necessary to develop V2G technology. Energy sources and the ability to generate renewable energy are determined with the benefits and market share of V2G technology. Renewable energy developments, V2G technology and the smart grid are impelled alongside (Li, Davis, Lukszo, and Weijnen, Electric vehicle charging in China's power system: Energy, economic and environmental trade-offs and policy implications, 2016; Alavi, Lee, Wouwa, Schutter, and Lukszo, 2017).

The energy sector pricing system is different from other sectors. The supply and demand and determining the cost of the energy by time and other grid priorities give balance and discipline to all the grid. But, in the energy systems, the supply/demand balance is the second important factor. Balancing is a means to distribute energy correctly in the electric grid. The density of the population is not constant in each location, but the specification of the population is clear for governments. Consequently, the location and density of the population, the time of supply/demand, the measure of supply/demand and the balancing of supply/demand (Tafreshi, Ranjbarzadeh, Jafari, and Khayyam, 2016; Liu, Zhu, Pan, and Wang, 2017; Dominkovic, et al., 2016) influence the price of the energy. The location and density of the population determines the average grid demand in all electric grids. There is a high population density mostly located in the downtown of cities or the capitals of counties.

In this condition, the density of the transmission lines is increased, so the ratio of the loss energy is increased. For example, when energy demands are at a high level and the energy generation is low, the cost of energy in these locations is at the highest level (Laurischkat, Viertelhausen, and Jandt, 2016; Hu, Zhan, Zhang, and Song, 2016; Andrenacci, Ragona, and Valenti, A demand-side approach to the optimal deployment of electric vehicle charging stations in metropolitan areas, 2016; Morais, T.Sousa, J.Soares, and Vale, 2015). The time of the electric energy consumption is important; sometimes, all customers of the grid use energy. In this condition, the grid works at full capacity, and this means where it is prone to overload. Consequently, the electric supervisors encourage people to use electric energy from the grid, except for the demand peak time (18:00–22:00) (Guo, Deride, and Fan, 2016; Salah, Ilg, M.Flath, Basse, and Dinther, 2015; Paterakis and Gibescu, 2016). Considering the peak/down time; in some countries, the time zones differs between two and six hours across the country. Figure 1.3. gives some countries' populations in 2016 and 2050 (World Population Data: Focus on Youth, 2017). Today, everyone can generate energy in their own house or office by using renewable energies, but this depends on the environmental condition. On the other hand, by using V2G technology, one can share energy with customers or the grid. Generating energy contributing to the grid and supervising of the pay cache for energies generated from customers (Paterakis and Gibescu, 2016), supervisors have to balance energy on the grid, as an unbalanced grid can damage the grid. They use some methods such as building switching centers to balance energy in the grid (Tarroja, Zhang, Wifvat, Shaffer, and Samuelsen, 2016).

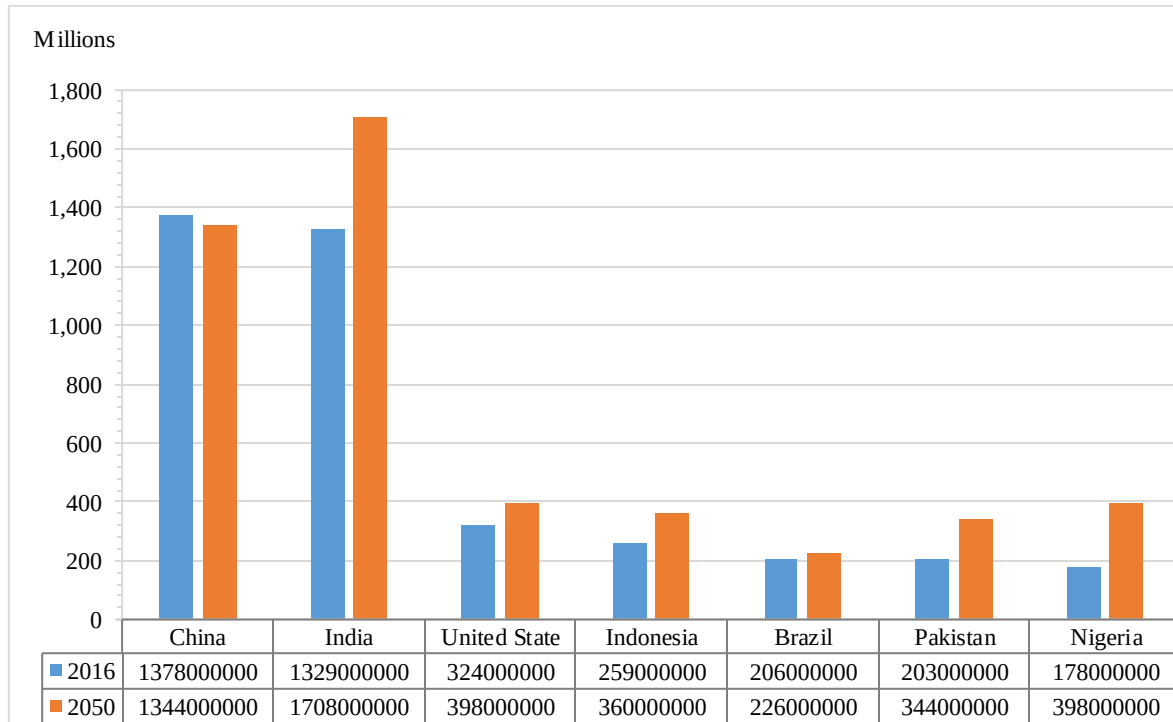


Figure 1.3. Population from 2016–2050 in some countries (Kumar, Anmol.M, and V, 2015)

This clearly shows above-mentioned issues influence the electric grid directly. Social infrastructures, such as the economy, psychology, applied and cognitive science, should be prepared to use EVs with people. People of the world have to use EVs, as fossil energies are going to deplete and people who use the transportation system with fossil energies would increase if the world population continues the present energy consumption method in the transportation system. For other types of energy, consumption differs in each area depending on sunrise and sunset, where in some countries' grids work synchronously. The management group must organize this considering local time and other local abilities (Maheshwari, Kachroo, Paz, and Khaddar, 2015; Bayram and Ustun, 2016; Kabalci, 2016; Ali, et al., 2016). V2G technology helps to reduce the mentioned problems, and governments can create perfect charging and energy-sharing designs and pricing and grid infrastructure control plans with the challenging problems mentioned for the background and future targets. A good control system must be tested in international sample electric grids, and each part of the grid must be tested with international grid patents such as IEEE 33 Node, IEEE 34 Node and IEEE 300-Bus Network. Grid coordination under the mentioned standards provides a wide facility for development, such as grid behavior prediction, charging scheduling and risk management (Luo, Zhu, Wan, Zhang, and Li, 2016; Fang, Yang, Wang, and Yan, 2016;

nezamoddini and Wang, 2016; Honarmand, Zakariazadeh, and Jadid, 2015; Bharati and Paudyal, 2016).

One of the control systems duties is online observation, as the EVs are mobile devices, and they can be on the supply or demand side of the grid (charge/discharge). This provides some favorably strong aspects for people. EVs users can see online the existing charging centers and their status. In the online system, all variable parameters change in each condition. This gives facility to provide fine pricing and a managing system via control system communications such as WAN, HAN, NAN, SCADA, DSL, GSM, satellite and GPS (Emmanuel and RameshRayudu, 2016). In fact, they have a chain connection with other parts of the grid. They are illustrated in Figure 1.4 This also depends on the location and situation, for example using GSM, DSL and satellite as the connection method to connect some data centers with other parts of the grid, and all of them are available everywhere (Martin-Martinez, Sanchez-Miralles, and Rivier, 2016; Manbachi, Farhangi, Palizban, and Arzanpour, 2017; Nafi, Ahmed, Gregory, and Datta, 2016; López, Moreno, Amarís, and Salazar, 2015).

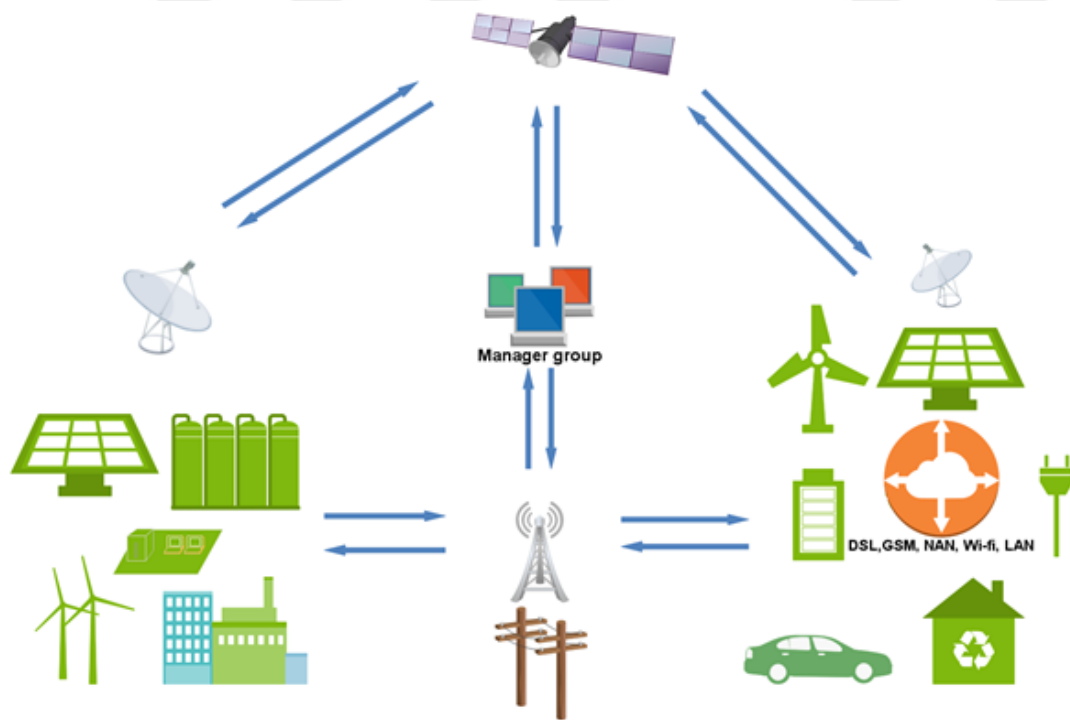


Figure 1.4. Communication system in the electric grid

Data of the EVs send to the EVs' controller operator to control all EVs in each location. However, in some situations, the grid works in uncertain conditions, and uncertain conditions result in different behaviors of the grid. Some methods contribute to calculating the energy cost in uncertain conditions such as the ENTRUST (Energy trading under uncertainty in smart grid systems) algorithm (Sudip Misra a, Ojha, Mouftah, and Anpalagan, 2016), and some other algorithms estimate the active demand load on the grid. Hence the grid has high reliability and is ready for uncertain threats and conditions.

The infrastructure of the model of the grid has based on V2G technology. The mentioned topics are impelled toward the best efficiency and GHG emission targets. Thus, reforming some sections of grid is too hard and needs to be investigated deeply. Fossil power planets, renewable energies and V2G-G2V (subsets of renewable energies) are the inputs of grids. Today, the policy and planning of countries are to require grids to be supplied by renewable energy, and it is subsets to consume green and efficient energy. All energies injected to the grid should be managed, so all types of energies have particularities. For example, convertors of the renewable energies such as DC to AC and reverse generated THD or energies on the storage system should be controlled on the supply/demand side. Electric distribution is the last node of grid electrification. In this section, the grid supplies all demand side of the grid, and the energy distribution condition depends on the location. Grid modelling with V2G technology is the same as the smart grid, so the grid in both systems works unidirectionally. The grid can supply both AC and DC electric energies (Ferreira, Ferreira, Cardin, and Leitão, 2015). Most of the electric devices work with the AC type of electric power. In this situation, energy providers have to provide the AC type of energy and the DC type of energy achieved by DC/AC convertors. The different types of energies are some of the causes of the energy loss. Today, having one of the DC lines from the source to the consumer is compulsory. In such a condition, the AC type of energy has the THD problem. The DC type of energy can respond to a wide range of customers of the grid. Different chargers, different convertors and different sources are examples of the energy type problems. AC and DC customers are also connected, and energy exchange will result in loss of energy and increased THD; however, the DC line has some critical advantages such as reducing energy loss, the response of the local renewable energy source and the other sources where work with the DC type of energy, which can work in a hybrid manner. For example, Egypt and India have tested DC lines in some projects (Erdinc, Paterakis, Pappi, Bakirtzis, and Catalão, 2015; Božič and Pantoš, 2015; Erdinc, Paterakis, and Catalão, Overview of insular power systems under

increasing penetration of renewable energy sources: Opportunities and challenges, 2015; Poullikkas, 2015; Colmenar-Santos, Reino-Rio, Borge-Diez, and Collado-Fernández, 2016; Bhatti, et al., 2016; Bethoux, Labourea, Remyb, and Berthelot, 2017; Elsayed, Mohamed, and Mohammed, 2015; El-Zonkoly, 2015; Thakur and Chakraborty, 2015).

Electric power frequency is one of the most important parameters in the grid. The grid frequency is not controllable when supply and demand are not balanced; usually, the demand side of the grid overcomes the supply. In V2G technology, the charge and discharge influences the grid frequency, especially in the charge condition. EVs have batteries with a large capacity, and the quantity of EVs is high, which means overall energy exchange is homogenized; however, this is not true all the time. All of this has a negative effect on the grid frequency. Consequently, the solution of the frequency issue is to control all parameters and equipment of the grid and demands such as the quantity of the EVs which are active or the EVs' energy capacity. Power systems must be controlled with special control nodes depending on the area, demand and sources (Meng, et al., Dynamic frequency response from electric vehicles considering travelling behavior in the Great Britain power system, 2016; Falahati, Taher, and Shahidehpour, 2016; Sun, et al., 2016; Seneviratne and Ozansoy, 2016; Lakshmanan, Marinelli, Hu, and Bindener, 2016).

A smart and unidirectional power system must be an integrated system. Therefore, all its parts should be connected and work synchronously. The process of the integration needs to provide the capacity and limit some factors depending on the grid design. Each part of the materials mentioned in this paper plays a big role in the power system integration. Why is power system integration important? Because V2G technology disrupts the power system and V2G works correctly when the supply/demand condition is fine. For example, the status of the charging station, the battery status of the EVs and the grid supply/demand power are some aspects of V2G technology related to power system integration. Figure 1.5 gives these facts clearly (Miao, Ramachandramurthy, and Yong, 2016). The power system is integrated to provide low energy loss and high efficiency, so with this technology, the gap of the supply/demand is reduced and the power of the control system is increased; For example, home or office grid integration to generate energy by some local renewable energy sources. The power system infrastructure should be designed considering some parameters such as accessibility, reliability and being able to be developed. Result of this action is the grid can be updated with some technologies such as V2G and the subset technologies. The grid should

support the energy traffic, which is achieved by newer technologies such as V2G or energy storage systems. The grid designers must care about communication between the grid and people. Therefore, in emergency situations, the grid management group may increase or decrease the supply/demand considering to people. This is only a recommendation, which would work with the grid infrastructure.

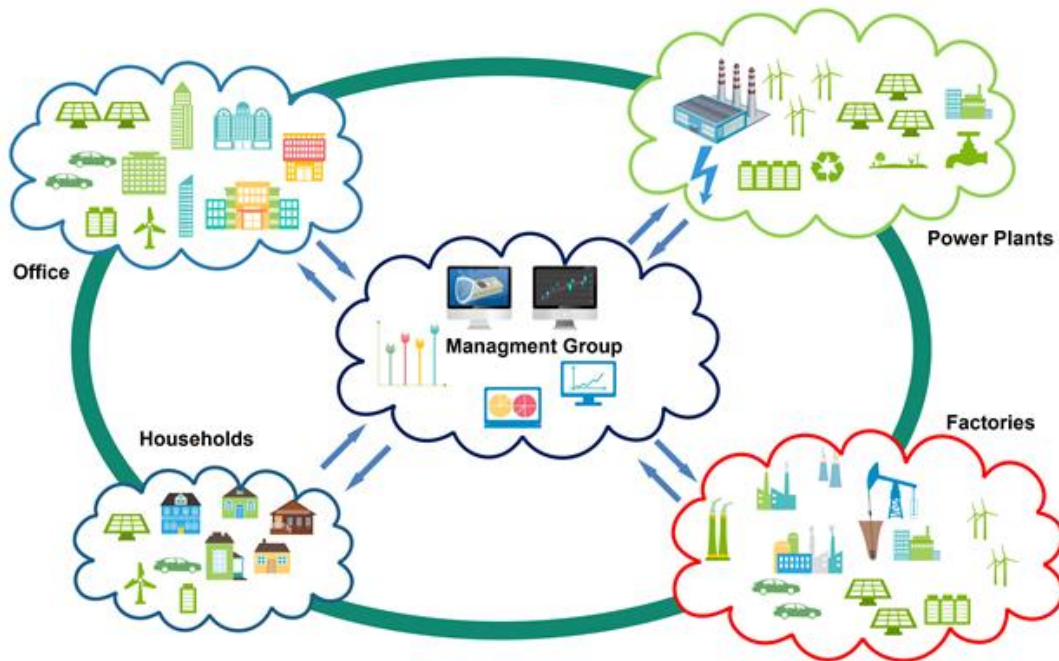


Figure 1.5. All grid energies connect to other sources and customers (Miao, Ramachandaramurthy, and Yong, 2016)

Energy storage types are different in each situation. For example, the hydro power plant uses the pumping of water to save energy. The type of energy storage is categorized by some environmental and advanced parameters, such as GDR or technical aspects, and both must consider each other (Li, Shen, Wang, and Jiang, 2016; Ayodele and Ogunjuyigbe, 2015). The type depends on the rating of power, charge and discharge, the density of power and energy, response time, efficiency, self-discharge and lifetime. EVs batteries must be solid and have the mentioned parameters (Lee and Park, 2015). Today, four types of batteries are better used in electric vehicles, such as Li-ion, NiCd, NaS and ZnBr. However, the specifics are different for each material. The properties of EVs' batteries are given in Table 1.2. (Zhao, Wu, Hu, Xu, and Rasmussen, 2015). The cost of each type of battery is different, but the technical side of this issue clearly shows where Li-ion batteries are the best choice for EVs in every situation. Li-ion batteries with some alloy such as Fe and Mn give the best

performance, so they boost the battery capacity and safety. In the latest measurements, EVs can travel between 250 and 350 miles with Li-ion batteries. Generally, LiFePO_4 , LiCoO_2 and LiMn_2O_4 types of batteries are used in EVs. All of them are produced as anode and cathode types (Li, Shen, Wang, and Jiang, 2016; Zhao, Wu, Hu, Xu, and Rasmussen, 2015; Opitz, P.Badami, L.Shen, K.Vignarooban, and Kannan, 2017). Table 1.3. Illustrates the type of Li battery and its specifications.

Table 1.2. Type of batteries and their specifications (Zhao, Wu, Hu, Xu, and Rasmussen, 2015)

Battery Parameters	NiCd	NaS	ZnBr	Li-ion
Power rating (MW)	0~40	0,05~8	0,05~2	0~0,1
Discharge time	S~h	S~h	S~10 h	Min~h
Power density (W/I)	75~700	120~160	1~25	1 300~10 000
Energy density (Wh/I)	15~8	15~300	65	200~400
Response time	<S	<S	S	<S
Efficiency (%)	60~80	70~85	65~75	65~75
Lifetime in years	5~20	10~15	5~10	5~100
Lifetime in cycles	1 500~3 000	2 500~4 500	1000~3 650	600~1 200
Cost \$ (kW)	500~1 500	1 000~3 000	700~2 500	1 200~4 000
Cost \$ (kW/h)	800~1 500	300~500	150~1 000	600~2 500

Table 1.3. Some type of Li batteries and their specifications (Opitz, P.Badami, L.Shen, K.Vignarooban, and Kannan, 2017)

Type of Li-ion	Practical Energy Density (Wh/kg)	Cycle Life	Safety
C/LiCoO ₂	110~190	500~1000	Poor
C/LiMn ₂ O ₂	100~120	1000	Safer
C/LiFePO ₄	90~115	>3000	Very safe
LTO/LiCoO ₂	70~75	>4000	Extremely safe
LTO/LiFePO ₄	~70	>4000	Extremely safe

The batteries' performance depends on the alloy used, so to know the grade of battery quality, manufactures of EVs or users of the Li battery check the result of tests performed on it. Current, voltage, mechanical strike and temperature are important parameters to must be considered in all tests on the batteries, as these parameters fluctuate during the day.

Mechanical strike is an unavoidable problem, whether the EVs are in the normal or an abnormal condition. In the normal condition, the EV battery is abused by the mechanical strike effect of the road, but the EV batteries have an unreliable behavior in the case of an accident. Thus, it must pass some tests such as the T4 and FMVSS 305 mechanical absorb tests or the battery should conform to some standards such as SAE j2464 (Safety and Abuse Testing) (NATIONS, 2015; Doughty, H., Pesaran, and A., 2012). The battery is strongly sensitive, when the SOC ratio is up to 80%. Figure 1.7 has shown how important mechanical strike and temperature are. They influence the life and all other aspects of the battery (Xiaosong Hua, 2017; Skugor and Deur, 2015; Forrest, Tarroja, Zhang, Shaffer, and Samuelsen, 2016; Farmann, Waag, Marongiu, and Sauer, 2015; Lee and Cheng, 2016; Wang, Lara-Curzio, Rule, and Winchester, 2017; Lin and Tang, 2016).

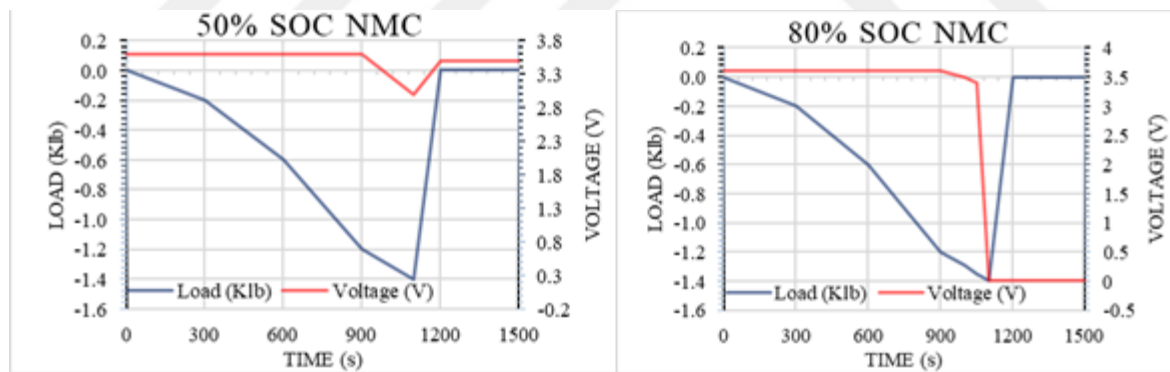


Figure 1.7. Effects of NMC battery mechanical strike (Wang, Lara-Curzio, Rule, and Winchester, 2017)

For example in 2013, during flight JA829J, Japan Airline's (JAL) Boeing 787 APU (Auxiliary Power Unit) battery presented thermal runaway after 52,000 flight hours. Until grounding JA829J, their battery type was lithium cobalt oxide (LiCoO_2). considering to the U.S. National Transportation Safety Board (NTSB) report, this problem was a result of T5 and T6 mechanical absorbance in the APU battery, and finally, a fire broke out (Board, 2014). Figure 1.8 has shown the JA829J and it is burnt battery.



Figure 1.8. JAL J829J LiCoO₂ event battery and the airplane after accident to place

Temperature stability should be considered in all situations, as the battery has different behaviors at each temperature. It does not work perfectly at very extreme temperatures such as -20°C or $120\text{--}130^{\circ}\text{C}$, in this situation, the runaway threat is greater than in the normal condition. Consequently, the EV battery must be protected against temperature (battery heating and cooling system) and the mechanical strike issue (Salpakari, Rasku, Lindgren, and Lund, 2017; Wang, et al., Experimental investigation on EV battery cooling and heating by heat pipes, 2015; Saxena, Floch, MacDonald, and Moura, Quantifying EV battery end-of-life through analysis of travel needs with vehicle powertrain models, 2015). Stable ESSs

are the storages, which depend on the infrastructure of grid. Generally, their locations are determined by grid energy and their storage needs. In this type of storages performance is the first priority, so the safety protocols conditions can easily be passed (Environmental Assessment of Plug-In, 2017). Almost all of charge stations and local ESSs provide free capacity to save energy and use it in critical conditions such as peak times.

Temporary ESSs are the storages used in EVs and mobile charge stations, their priority is safety (Tinton Dwi Atmaja, 2015). EVS battery material is lithium and polymers of the lithium such as (LiCoO₂, Lithium Manganese Oxide (LiMn₂O₄) and Lithium Iron Phosphate (LiFePO₄)). Both of the safety and performance are important in this section, so the EVs and mobile energy stations are unstable devices (Suri and Onori, 2016; Wang, Lara-Curzio, Rule, and Winchester, 2017). All tests and applications such as (T1, T2, T3, T4, T5, T6, T7, and T8) should be passed in all EV batteries (Suri and Onori, 2016). Table 1.4. include shipping UN tests and criteria.

Table 1.4. Shipping UN manual of tests and criteria

Test Title	Shipping UN manual of tests and criteria
Altitude	T1. 6 hr @ 0.11 atm
Temperature Cycling (Thermal Shock)	T2. 10 cycles of 6 hr @ 75°C and -40°C
Vibration	T3. 12 reps up to 8 g peak
Mechanical Shock	T4. 3 ea 150g shocks for cells, 50g shocks for
External Short Circuit	T5. less than 100 mΩ at 55C
Impact	T6. 9.1 kg from 61 cm.
Overcharge	T7. Charge to 200% SOC
Forced Discharge (Over ̸Discharge)	T8. Discharge to 100% SOC

Grid integration contributes to the grid's power efficiency in each branch of the electric grid. The storage system needs more control than other parts of the grid, so the health of the storage systems is critical and sensitive (Beiera, Neef, Thiede, and Herrmann, 2016). The storage control system is not limited to grid storages: EV batteries are part of the grid storage, and thereby, it can control all EVs' storage and the grid storage system, because EVs represent a short-term energy storage for the grid. Therefore, local governments can achieve a storage system without any payment. This is one of the economic benefits of V2G

technology for the grid. The control system and EVs' storage systems protect the grid from shocks when the demand strongly decreases or increases. For the infrastructure of the grid response control for V2G technology and some environmental conditions, the control of the grid requires scenarios, plans and data about the grid's future, so the grid should predict data based on old data, plans and scenarios (Beiera, Neef, Thiede, and Herrmann, 2016; Darcovich, Kenney, MacNeil, and Armstrong, 2015; Suri and Onori, 2016; Khemakhem, Rekik, and Krichen, 2017).

The lifetime of the Li-ion batteries is a complex issue, and it depends on the mentioned parameters such as charge, discharge, thermal condition and some other parameters. Consequently, the electric grid can assume batteries' life and capacity by controlling the grid fully (Calvillo, A.Sanchez-Miralles, and J.Villar, 2016; Groenewald, Grandjean, and Marco, 2017). EVs' batteries are used in AM and SM; however, they are used for both sides of the grid. This option encourages the economics and eventually the cost of the electric power and energy system to change in each location (Lee and Chang, 2016; Speidel and Braunl, 2016; Faessler, Kepplinger, and Petrasch, 2017; Sun, Yamamoto, and Morikawa, 2015; Magnor, Lunz, and Sauer, 2015; Schmalfu, et al., 2015; Tinton Dwi Atmaja, 2015; Aziz, Oda, and Kashiwagi, 2015). Ageing is one of the important problems in V2G technology and bidirectional energy systems. Considering to battery aging, calendar ageing depends on standing time and SOC, and temperature and cycling ageing depends on cycle number, DOD and charging rate. For V2G technology, it is recommended to use LiFePO_4/C cell battery and avoid $\text{LiNiCoAlO}_2/\text{C}$ -based batteries (Petit, Prada, and Sauvart-Moynot, 2016; Harighi, Bayindir, and Hossain, Overview of Quality of Service Evaluation of a Charging Station for Electric Vehicle, 2017).

From the above-mentioned literature, placing of electric vehicle has determined some critic topic over the some technical and social issues. Technical and social problems have investigated or solved on the grids which is built in the past.

This thesis covers discussions about energy scenarios, storage systems and the infrastructure of the grid related to V2G technology. The strategies, policies and targets of the governments and agencies of the world for lower GHG emissions and high-energy efficiency have been recommended. They have changed the grid purpose and duty, but the collection of infrastructures cannot respond to the requirements illustrated in the scenarios. Considering

to the strategies (created for grid upgrades), storage systems (such as batteries and chargers) and the infrastructures of the grid should be replaced by the latest technologies in each section. Today, electric vehicles (EV) are an important part of the transportation system in the world (Un-Noor, Padmanaban, Mihet-Popa, Mollah, and Hossain, 2017). Because CO₂ emissions are expected to decrease while efficiency of energy use will be high. For example, the efficiency can be 42~75% (Agency U. E., n.d.). Behind the scenes there should be powerful and bidirectional grids, which are powered by fossil fuel or renewable energy generators.

In sum, based on the above-mentioned reasons, literature and our perspective, we are on the side of view that state the storages have special burden on the old equipment's such as transformers and their work principles. For example, impulse problem on the transformers is one of the important problem in grids which are connected few charge stations. Placing of electric vehicle solve a big part of these problems. Electric vehicle and storage systems have used different energy consumption method. Hence, they are changed grid's equipment reaction while storage system has worked bidirectional. The grid parts should be adopted by bidirectional systems or try to reduce their interruption, which is built some mistake on the grid.



2. CHARGING SYSTEM ON V2G

The charging system in the electric grid is a bidirectional system, which supports V2G technology. The charging system quality has a special aspect: it is almost determined as the efficiency of the V2G system. The charging system has almost covered the core of V2G. Charging systems are changed in each grid, and this depends on the infrastructure of the grid. Some charging systems support only DC/AC or both of them. Therefore, the chargers produce the considered infrastructure of the grid with various power electronic parts. IEC 62196-2 Type 1, 2, hybrid, SAE J1772 (SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler) Type 1, 2, Combo and CHAdeMO are types of the charger connectors. All of the connectors work in some critical scenarios. For example, CHAdeMO only works in a DC system (Shareef, Islam, and Mohamed, 2016; Yong, Ramachandaramurthy, Tan, and Mithulananthan, A review on the state-of-the-art technologies of electric vehicle, its impacts and prospects, 2015). Table 2.1 gives some charger connectors and types of charge models.

Table 2.1. EV charger connectors' power types (Shareef, Islam, and Mohamed, 2016; Yong, Ramachandaramurthy, Tan, and Mithulananthan, A review on the state-of-the-art technologies of electric vehicle, its impacts and prospects, 2015)

Type of Port	AC	DC
IEC 62196-2	*	Hybrid version
SAE J1772	*	Combo version
CHAdeMO		*

*Available

The bases of energies, like power plants or renewable energy have to convert it to DC type of energy, if the grid has a connection to the storage network. When increasing the number of DC rectifiers, the ratio of the THD is automatically increased on the grid. The creation of DC lines in the infrastructure of the grid is beneficial to the grid, which are used in smart grids and V2G technology; for example, the DC line improves charging stations' performance in public places with solar energy or using a wireless charging system. Power electronic converters always change energy alongside the loss of energy, especially when changing from DC to AC. The infrastructure of the electric grid and THD issues are critical problems, and nowadays, countries are trying to reduce both problems. Table 2.2. has

mentioned the balance of the energy is a big future challenge, and a number of EVs, chargers, populations and spaces of the location have a crucial role in the load spread balance. All of them are important for control and modelling of the grid. Computing their data accuracy contributes to predicting the future of the grid. Nowadays, energy consumption should be efficient. Consequently, heating, cooling and transportation systems are eager to use the electric type of energy as much as possible. The solutions of the grid modelling are different in each location. Creating energy nodes in the urban environment and redistributing energy and DC reserve lines to supply DC base energy equipment are ways to reinforce the infrastructure of the grid (Kalwar, Aamir, and Mekhilef, 2015; Godina R. , Rodrigues, Matias, and Catalão, 2016; Yang H. , Xiong, Qiu, and Dong, 2016; Zhou, Yao, Littler, and Zhang, An electric vehicle dispatch module for demand-side energy participation, 2016; Nunes, Figueiredo, and Brito, 2016). The support of the infrastructure and EVs has induced positive opinions in people's minds, so people are looking at all the facilities of V2G technology (Will and Schuller, 2016).

Table 2.2. Some numerical location data related to V2G technology

EV and Population information	US	China	Japan	UK	The Netherlands
EV (k)	404	312	126	49.67	87.53
Chargers (k)	28.15	46.65	16.12	8.716	17.78
Fast chargers (k)	3.524	12.1	5.99	1,158	0.465
Population (m)	324.6	1373.5	126.8	65.11	17.10
Population per square km	35	145	346	255	412
Area in square km	9 833 520	9 596 961	377 972	242 495	41 543

Potentials to build charging stations for renewable energies having a sensible effect on people's life is important. It is one of the effective factors. Charging systems must be available at EV drivers' homes or offices. In fact, the charging system converts energy and transfers it from EV or grid to the storage system. The storage side of V2G technology (home, office, parking and some public places) might be one of the Virtual Power Plants (VPPs). VPPs can support the grid, and their efficiency is at a medium-high level, such as WPP, solar energy and CHP. Renewable energies can generate energy everywhere and at every scale (Bi, et al., 2016). Table 2.3. shows the major VPPs. It means that EVs complete the energy circle by using V2G technology. In this circle, EVs perform the transmission line

and temporary storage duty. If both the home and office are equipped with VPP and V2G technology and personal EVs could always be connected to grid, all of them would provide some benefits to the energy sector, and these are mentioned below (Pan and Zhang, 2016; Motie, Keynia, Ranjbar, and Maleki, 2016; alirezaei, noori, and tatari, 2016; Zamani, Zakariazadeh, and Jadid, 2016):

- ✓ Low GHG emissions on the supply and demand side
- ✓ Strong reduction of grid shock
- ✓ Reduction of energy cost to help the economy of the home and office
- ✓ Reduction of fossil, coal and nuclear energy contribution

Table 2.3. Accessible VPP distribution by place and source type

Source	Home	Office	Parking	Urban
Solar PV	*	*	*	*
Micro turbine	*	*		*
Regular turbine		*1		
CHP		*1		
Battery	*	*	*	*

*Available

*1: its availability depends on the condition.

Some projects related to V2G have been accomplished, and all mentioned parameters are considered in projects; for example, Taiwan, the U.S. (Florida), The Netherlands and China (Barisa, Rosa, Laicane, and Sarmins, 2015; Hu, Morais, Sousa, and Lind, 2016; Zhao, Onat, Kucukvar, and Tatari, 2016; Lee, Chen, and Chen, 2017). The priority of the source to supply the charging station is local energy production. Electric storage systems and their charging systems in V2G technology, as well as similar technologies (for which, the energy transfer between them is bidirectional) are important part of the grid, so the reason for having this technology is the electric storage systems, which have good energy efficiency. Considering to the mentioned advantages and disadvantages, it seems that the LiFePO₄ type of Li batteries is the best choice between various types of batteries; it is very safe in comparison to other types of batteries.

2.1. Infrastructures and EVs Connection

The base of a system must be in a good shape when it gets updated, therefore there must be high-quality power on both sides (generation and distribution) of the grid (García-Trivino, Torreglosa, Fernandez-Ramírez, and c, 2016; Capasso, Iannuzzib, and Veneria, 2014). The power-capacity of the grid and the quality of the power are both necessary factors. Based on these factors the grid should be smart and micro (micro grid/smart grid) (Zengin, Vardakas, Zorba, and Verikoukis, 2016). The power line should not follow just AC system; as the renewable energy sources (RES), electric fleet systems, and some other systems use DC. None of the converters work properly with AC and they cause side effects such as harmonics (Wang, Zhou, Wang, and Wei, 2015). Thus the grid must support both AC and DC types of energy. Some generators can be connected to grid with DC terminals such as solar and wind energy systems. DC energy can easily be harvested with EVs through charging stations too (Torreglosa, García-Triviño, Fernández-Ramirez, and Jurado, 2016; Shojaabadi, Abapour, Abapour, and Nahavandi, 2016). Recycling of energy by EVs and some storage systems take place through bi-directional terminals, so it is a key point in modern grid systems (Yong, Ramachandaramurthy, Tan, and Mithulananthan, Bi-directional electric vehicle fast charging station with novel reactive power compensation for voltage regulation, 2015). In these situations, grid behavior is very flexible (Fathabadi, Novel grid-connected solar/wind powered electric vehicle charging station with vehicle-to-grid technology, 2017). The DC converters have high-quality and efficient conversion capabilities; with those converters, the customer can use energy in both high and low potentials (Sanchez-Sutilla, Hernández, and Tobajas, 2015). The charging system in any location can be a fast charger or a regular one, depending on the customer base, and as the grid infrastructure allows (Fathabadi, Novel grid-connected solar/wind powered electric vehicle charging station with vehicle-to-grid technology, 2017; Sanchez-Sutilla, Hernández, and Tobajas, 2015; Capasso and Veneri, Experimental study of a DC charging station for full electric and plug in hybrid vehicles, 2015; Hafez and Bhattacharya, 2017; Suganya, Raja, and Venkatesh, 2017). Power injection by solar or wind energy could be executed in all locations of the grid if it has DC systems because DC power line provides a wide range of options for direct supply and demand connections (Capasso and Veneri, Experimental study of a DC charging station for full electric and plug in hybrid vehicles, 2015). Low quantity of converters is the goal in all electric networks. They have a loss in the base topology, which cannot be avoided. For example, from the study of analytical models for the approximation

of conduction and switching losses of the power-switch network in a three-phase AC-DC matrix rectifier, the switching loss is calculated by (Xua, Youa, and Zhangb, 2016):

$$\begin{aligned}
 w_{Toff} &= K_{Toff1}ui + K_{Toff2}ui^2 + K_{Toff3}u^2 + K_{Toff4}u^2i + K_{Toff5}u^2i^2 = w_{Toff}(u, i) \\
 w_{Ton} &= K_{Ton1}ui + K_{Ton2}ui^2 + K_{Ton3}u^2 + K_{Ton4}u^2i + K_{Ton5}u^2i^2 = w_{Ton}(u, i) \\
 w_{Don} &= K_{Don1}ui + K_{Don2}ui^2 + K_{Don3}u^2 + K_{Don4}u^2i + K_{Don5}u^2i^2 = w_{Don}(u, i)
 \end{aligned} \tag{2.1}$$

Where u is voltage; i is current; T is related to the IGBT duty cycle, D is related to diode, and Ki is IGBT switching loss parameters.

On the other side of the charging station efficiency, the building efficiency is very important. In this study, the system has combined cooling, heating and power (CCHP), photovoltaic (PV) generation, and building heating and cooling system. Calculation of energy cost and the result of the cost give operation status (Kuang, Chen, Hua, and Yang, 2017):

$$\begin{aligned}
 C_B &= \sum_t (ef_{G,B,t} \times PP_t - ef_{B,G,t} \times PS_t) \\
 &\quad + \sum_t ef_{G,B,t} \times \eta_{etoc} \times C_{tax} \\
 &\quad + \sum_t (f_{PGU,t} \times PF_t + f_{PGU,t} \times \eta_{ftoc} \times C_{tax}) \\
 &\quad + \sum_t (f_{BO,t} \times PF_t + f_{BO,t} \times \eta_{ftoc} \times C_{tax}) \\
 &\quad + \sum_t (ef_{CS,B,t} \times PT_t - ef_{B,CS,t} \times PT_t)
 \end{aligned} \tag{2.2}$$

Finally, grid infrastructure should be powerful, bi-directional, flexible and suitable to make DC power line provide high-quality electricity while protecting the grid.



3. SUPPLYING V2G BY GRID

The supply side of the grid is a special issue. Energy generation and transmission have different problems. In some situations, the grid has enough power but it cannot provide power to the customers because of not having suitable transmission system (Hafez and Bhattacharya, 2017). The reverse is also true. Fast charge system is much more usable mostly in city centers (Fekete, Lim, Martin, Kuhn, and Wright, 2016; Mouli, Bauer, and Zeman, System design for a solar powered electric vehicle charging station for workplaces, 2016). In this situation, the energy policy is very important. Energy policies have to be adjusted considering to future prospects. Currently, city centers have a huge electric load. As of now, energy companies should support the power and equipment requirements of EV charging stations. Energy consumption in general view and from Electrical Engineering perspectives are very different. People think of energy as fossil fuel, atomic energy, or renewable energies; but electrical engineers define energy as all the things where can generate electricity (Motoaki and Shirk, 2017). So, if a politician proposes a policy without considering the technical side of the issue, it can cause major problems. City centers' electricity supplies need a grid with different energy sources and terminals with enough power, which is a way to solve location problem (Atmajaa and Amina, 2015; Bayati, Abedi, Hosseini, and Gharehpetian, 2017; Cassandras and Geng, 2014). Supply and demand relation should be equal in every instant. For example, in building and charging station efficiency, load balance is (Kuang, Chen, Hua, and Yang, 2017):

$$\begin{aligned}
 &ef_{G,B,t} + e_{BPV,t} + e_{PGU,t} + ed_{BS,t} \times \eta_{d,BS} + ef_{CS,B,t} \\
 &= EL_t + ef_{B,G,t} + \frac{e_{cBD,t}}{\eta_{c,BS}} + ef_{B,CS,t} \quad \forall t
 \end{aligned} \tag{3.1}$$

The energy providers are limited. The grid needs power plants (fossil fuel or renewable power plant) to provide energy to the demand side of the grid.

3.1. Storage

The storage system of the grid is one of the most important parts. Charge and discharge functions in the EVs and the batteries in the charging stations are the base duty of the vehicle to grid (V2G) and grid to vehicle (G2V) services. Storage systems should be placed in safe

and more usable locations such as gas stations so it may be economical and safe. For example, vanadium redox flow batteries can be placed in gas stations and they can support fast charge systems (Cunha, et al., 2016). A PV based charging station with power forecasting capabilities designed for Ankara city, Turkey has been demonstrated previously. Such technologies may improve the grid infrastructure to provide wide options for EV users. Some other storage systems may use certain places and mobile charging stations. Mobile charging stations can help the grid when the grid support overloads of EVs. They should be made by ultra-capacitor and lithium batteries such as $LiTiO/NiMnO_2$ and $LiFePO_4$ (Atmajaa and Amina, 2015). Storage systems in the grid are distributed and need to be controlled accurately. Control systems must control other distributed small-scale control systems (Bayati, Abedi, Hosseini, and Gharehpetian, 2017). For example, in the case study, comprehensive battery ageing model based on data collected from more than 50 long-term ageing tests in which commercial batteries were cycled under a wider range of operational conditions spanning $0^\circ\text{C} \leq T \leq 45^\circ\text{C}$, $15\% \leq \text{SOC} \leq 95\%$, $0\% \leq \Delta\text{SOC} \leq 80\%$, with charging and discharging rates up-to and including the maximum manufacturer defined limits has been considered. The $C_6/LiNiCoAlO_2$ type of battery used in grid side (home or office), the cell temperature of batteries can be calculated by (Kotub, et al., 2017):

$$mc_p \frac{dT}{dt} + hA[T(t) - T_{amb}] = I(V - V_{oc}) \quad (3.2)$$

Where, m is cell mass to the unit gram, c_p is cell heat capacity in joule per kilogram kelvin, T is battery bulk temperature in kelvin, h is heat transfer coefficient in watt per square meter, A is cell surface area, and T_{amb} is ambient temperature. Temperature is one of the important factors influencing degradation. However, capacity fade and power fade also cause battery degradation. Both of them can be calculate by (Kotub, et al., 2017):

$$CF = 1 - \frac{Q - \mu_{CF} Q_{rated}}{Q_{rated} - \mu_{CF} Q_{rated}} \quad (3.3)$$

$$PF = \frac{1}{\mu_{PF}} \left(\frac{R_0 + R_1}{R_0(0) + R_1(0)} - 1 \right) \quad (3.4)$$

Where, PF is power fade, CF is capacity fade, Q is cell capacity, Q_{rated} is the maximum discharge capacity defined by manufacturer, μ_{CF} is factor of the cells' rated capacity, μ_{PF} is factor of the cells' total resistance. Figure 3.1 gives the battery Thevenin model.

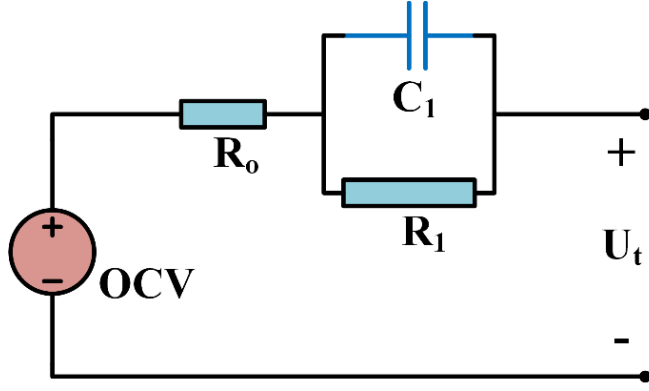


Figure 3.1. Thevenin equivalent model of battery

In addition, cost of the battery degradation can be calculated by (Kotub, et al., 2017):

$$E_{deg} = \max[CF \times E_{batt}, PF \times E_{batt}] \quad (3.5)$$

All of the mentioned issues are related to the battery life but the usage method of the batteries is also important, as they set the battery performance while using them all together on the grid. The battery management system must follow the battery statement considering to the SOC. SOC estimation should consider some other parameters such as thermal and mechanical effects on the storage system since all of them are effective parameters. SOC of the battery is the ratio of battery energy consumption and voltage of the battery. Relationship of the battery SOC and battery voltage curve can be determined by some tests on the battery with some battery test machine in a limited number of cycles (0-1000). SOC conditions in charge/discharge mode and open circuit mode are different. Figure 3.2 shows the difference between (a) voltage / SOC and (b) charging/discharging and open circuit voltage (Haq, et al., State of Charge (SoC) Estimation of LiFePO4 Battery Module Using Support Vector Regression, 2015).

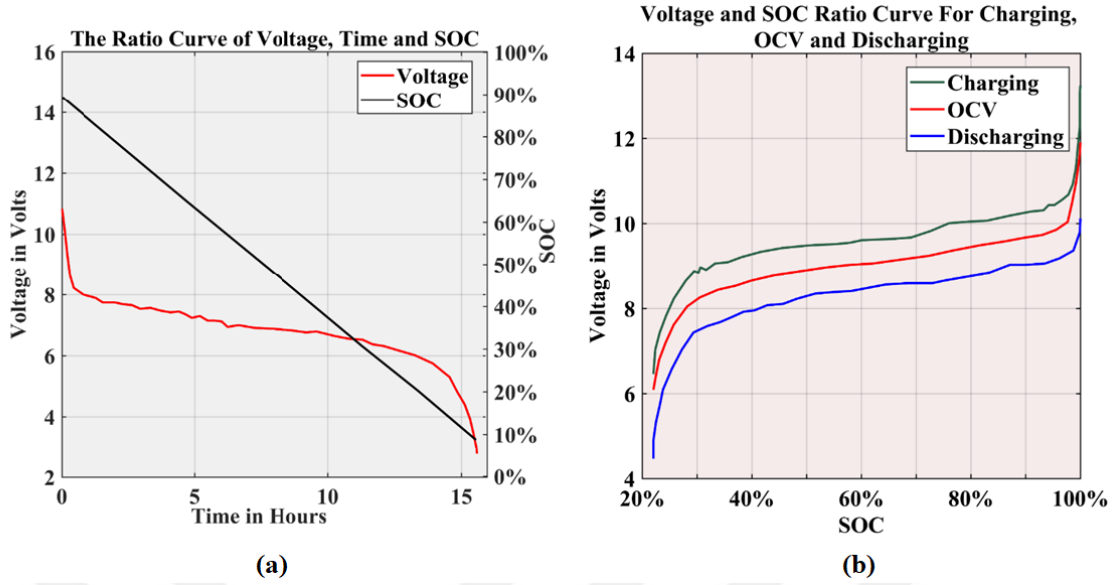


Figure 3.2. (a) Voltage, time and SOC ratio curve: SOC decrease follows a straight line, whereas the voltage stays almost constant over maximum part of the range; (b) voltage and SOC ratio curve in charging, OCV and discharging mode: the graphs are identical for these three scenarios – charging voltage having the highest value, and discharging voltage having the lowest

All SOC estimation algorithms have error ratios and they change between 1% ~ 5%. Extended Kalman filter (EKF) with $\leq 1\%$, genetic algorithms (GA) with $\leq 2\%$ and bi-linear interpolation (bi) with $\leq 5\%$ are algorithms error tested on the LiFePO₄ storage. EKF algorithm is very accurate for estimating targets depending on input data quality, so EKF is an algorithm to find the correct target by target prediction and measurement (Hannan, Lipu, Hussain, and Mohamed, 2017). Also this algorithm is used in aircraft and aircraft detection radars to follow targets, it means that the EKF algorithm is one of the best target following system for users. In SOC estimation, case the OCV and current of circuit can be calculated from (Li, Xiong, Mua, He, and Wang, 2017):

Kirchhoff's law:

$$U_{OCV} = U_T + i_L R_o + U_1 \quad (3.6)$$

$$i_L = C_1 \frac{dU_1}{dt} + \frac{U_1}{R_1} \quad (3.7)$$

Laplace transform:

$$i_L = C_1 s U_1(S) + \frac{1}{R_1} U_1(S) \quad (3.8)$$

$$U_1(s) = i_L(s) \cdot \frac{R_1}{1 + R_1 C_1 s} \quad (3.9)$$

$$U_{OCV}(s) - U_t(s) = i_L(s) \cdot (R_0 + \frac{R_1}{1 + R_1 C_1 s}) \quad (3.10)$$

Bilinear transform:

$$s = \frac{2}{T} \cdot \frac{1 - z^{-1}}{1 + z^{-1}} \quad (3.11)$$

$$U_{OCV}(z^{-1}) - U_t(z^{-1}) = i_L(z^{-1}) \cdot \frac{\frac{R_0 T + R_1 T + 2 R_0 R_1 C_1}{T + 2 R_1 C_1} + \frac{R_0 T + R_1 T + 2 R_0 R_1 C_1}{T + 2 R_1 C_1} z^{-1}}{1 + \frac{T - 2 R_1 C_1}{T + 2 R_1 C_1} z^{-1}} \quad (3.12)$$

Inverse Z-transform:

To simplify the equations, let us consider the following parameters:

$$a_1 = -\frac{T - 2 R_1 C_1}{T + 2 R_1 C_1} \quad (3.13)$$

$$a_2 = -\frac{R_0 T + R_1 T + 2 R_0 R_1 C_1}{T + 2 R_1 C_1} \quad (3.14)$$

$$a_3 = -\frac{R_0 T + R_1 T - 2 R_0 R_1 C_1}{T + 2 R_1 C_1} \quad (3.15)$$

$$U_t(k) = U_{OCV}(k) - a_1 U_{OCV}(k - 1) + a_1 U_t(k - 1) + a_2 i_L(k) + a_3 i_L(k - 1) \quad (3.16)$$

$$M(k) = U_{OCV}(k) - a_1 U_{OCV}(k - 1) \quad (3.17)$$

$$U_t(k) = M(k) + a_1 U_t(k - 1) + a_2 i_L(k) + a_3 i_L(k - 1) \quad (3.18)$$

If transformed into vector notation:

$$\varphi(k) = [1 \ U_t(k - 1) \ i_L(k) \ i_L(k - 1)] \quad (3.19)$$

and

$$\theta(k) = [M(k) \ a_1 \ a_2 \ a_3]^T \quad (3.20)$$

$$U_t(k) = \varphi(k) \theta(k) \quad (3.21)$$

Mentioned methods are to achieve OCV and SOC curve in battery Thevenin model. Some other algorithms such as Recursive Least Squares (RLS) and Least Mean Square (LMS) may

optimize Thevenin model calculation. Also some methods improve both RLS and LMS algorithms. All of the improvement methods are created to reduce base algorithms such as EKF error rate. Considering to context, the storage systems must be powerful and the control systems should have full access. The storage systems work properly when they are designed with proper parameters, and sound understanding of the whole system.

3.2. Environmental Problems

Site selection and modeling of grid depends on environmental conditions, as these are different in each location (Cassandras and Geng, 2014). For example, the environment of Iran is the same as Turkey but environmental conditions of Alaska or Siberia is different from Turkey and Iran. Priority of some factors changes by environmental location. Weather, the flatness of area, shape of the buildings in an area and such cases play vital roles in choosing EV charging station architectures (Alegre, Míguez, and Carpio, 2017). In some cases, the area has a low density of population, which is an ideal condition. So, the management of grid has time to respond to the EV load. However, in most cases, the grid needs power immediately, and energy generators such as renewable energy or CHP should be added quickly. In different locations, it can be determined by high-speed communication systems, such as long-term evolution (LTE). Because of diverse EV battery status and number of charging stations, information must be stored in certain databases to help EV users and grid management (Liu, Zhou, Hu, Xu, and Zhang, 2012). Calculation and prediction of charge status are very easy even without GPS signal or related equipment and it can be transmitted by some telecommunication equipment. It can be calculated with speed and time parameters in comparison to the previous charging station in the trajectory (Andrenacci, Ragona, and Valenti, A demand-side approach to the optimal deployment of electric vehicle charging stations in metropolitan areas, 2016):

$$v_j(t_i, link_i) = \begin{cases} \frac{\sum_{k=1}^N \frac{v_k(t_i \pm \Delta_t, link_i)}{N}}{N} & \text{if } N > 1 \\ v_j(t_{i-1}, link_{i-1}) & \text{if } N = 1 \end{cases} \quad (3.22)$$

Here N is the number of EVs that are temporary in a selected charging station during the time break, $v_j(t_i, link_i)$ is the speed of the j -th vehicle at time t_i in the station $link_i$. It relates to infrastructural issues. For example, an area with unevenness needs more power

and charging station than a more even area. In fact, the environmental conditions determine our grid model and charging station locations (Andrenacci, Ragona, and Valenti, A demand-side approach to the optimal deployment of electric vehicle charging stations in metropolitan areas, 2016). Environmental analysis should be done carefully. Potential of location from each side of the grid (supply/demand) depends on environment conditions such as: weather, structure of the buildings, terrain, potential of renewable energy, electrification of location, and available communication technology.

3.3. Infrastructure

All of the mentioned issues are considered to protect grid and produce high-quality electric power. However, those are just some threats when the grid supplies EVs in a certain location. In one of the MATLAB examples provided in its official website (24-hour Simulation of a Vehicle-to-Grid (V2G) System), by adjusting the number of cars (2 times more than original quantity), results of load curve is observed to change as shown in Figure 3.3 It gives load curve from 1~2 seconds on the grid. They show unexpected incremental behavior in load curve from 9.7×10^6 to 11.8×10^6 . Load increase/decrease needs more/less power supply when the quantity of cars is changed. It may affect the electric power quality in negative direction.

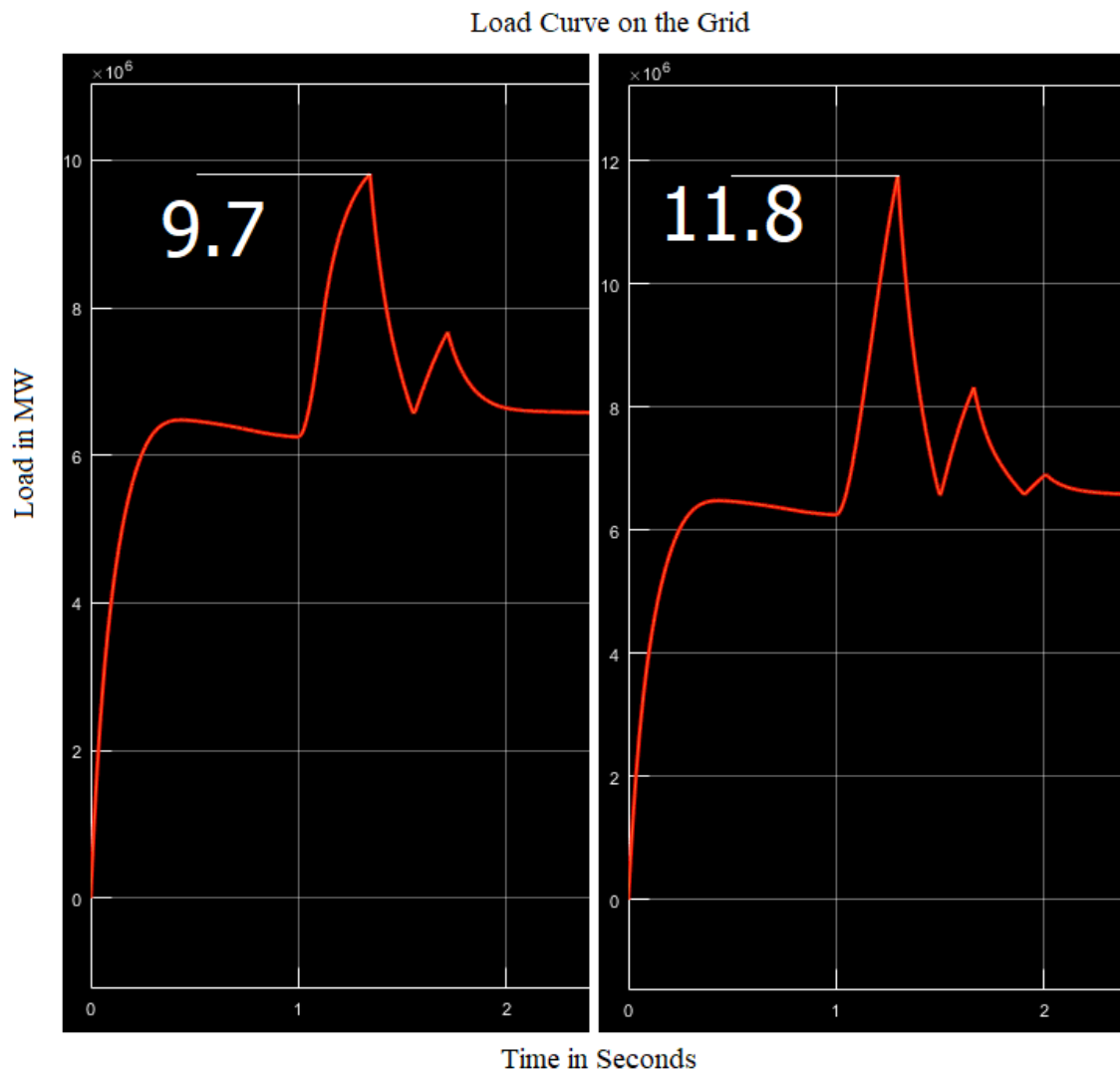


Figure 3.3. Load after and before adjustment of quantity of cars. The amount of 9.7×10^6 rose to 11.8×10^6

Figure 3.4 has shown active power load of the grid in unexpected decrement (1~2 seconds). The active power load at the beginning decreases from 2.9×10^6 in the first situation to 0.9×10^6 in the second situation. After this increase, in the second curve, active power increases from 7.3×10^6 in the first situation to 8×10^6 in the second situation. The negative impact in the second situation is harder than in the first situation. It may reinforce protection error and reduce power quality. So the grid needs power balance when the EV quantity is increased or decreased. Sometimes it may cause errors in the grid.

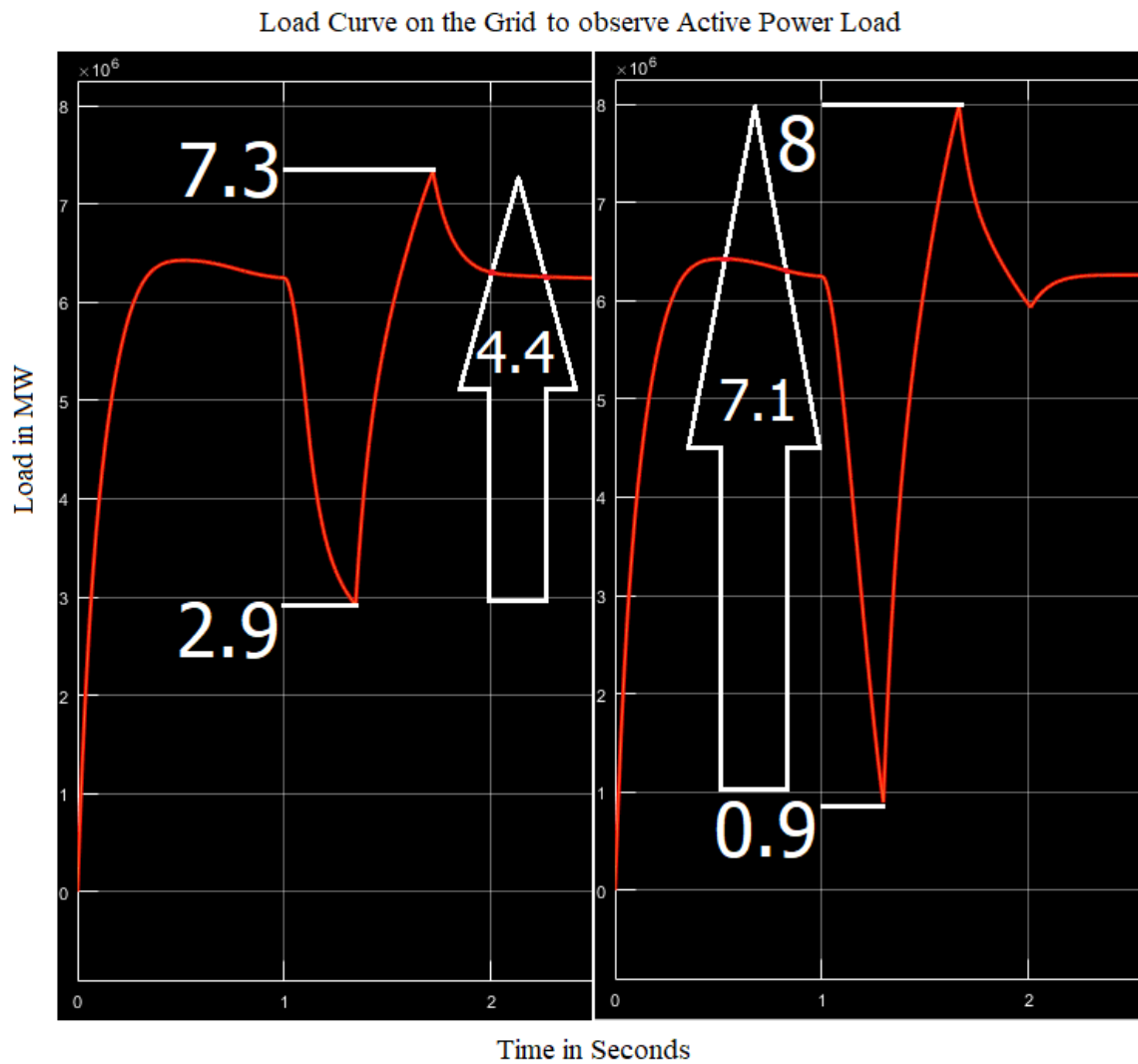


Figure 3.4. Active load after and before adjustment of quantity of cars and their down/apex difference

Figure 3.5 gives reactive power during sudden change. Difference between first and second state is that the sudden apex and downs are increased in the second state. Sudden up and down in reactive curve reduce grid safety, therefore protection system in the grid must be prepared for these changes. In this situation, the grid protection system automatically removes some safety procedures and some real errors. Those problems influence grid responsibility.

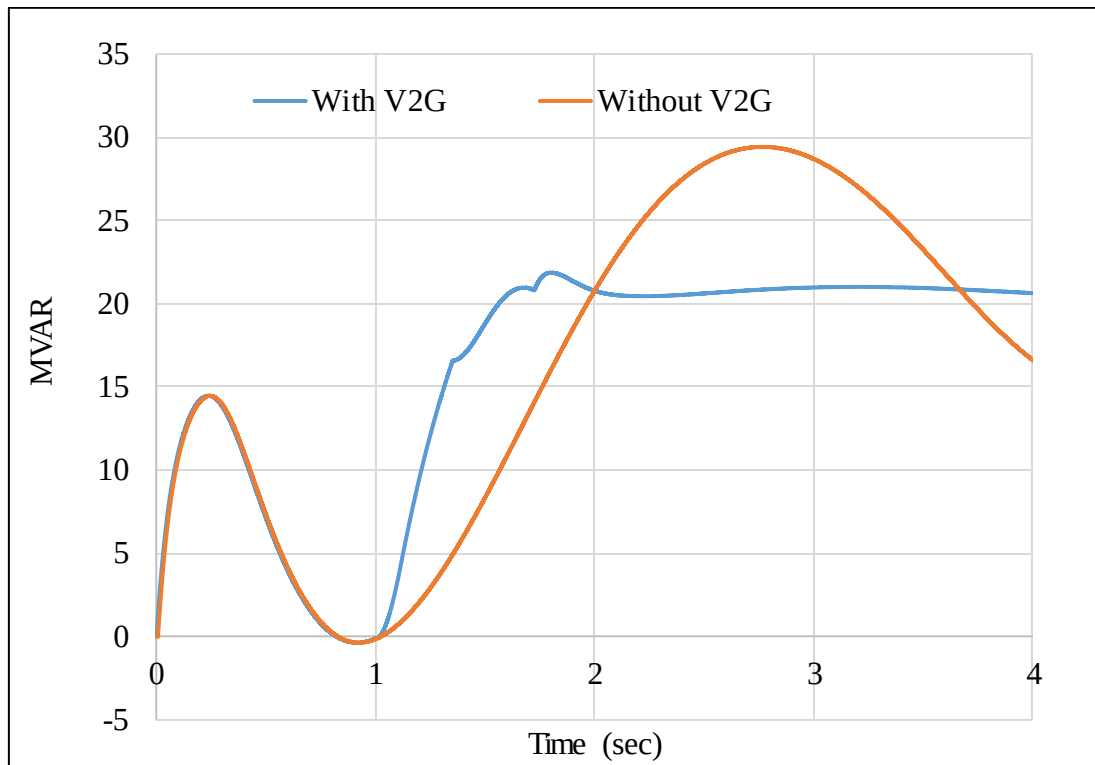


Figure 3.5. Difference of the grid with and without V2G technology in reactive power load analysis

The curves show that grid may be damaged and fail to protect in each unprecedented situation. Grid safety is in danger when the sudden ups and downs happen in the load curve. The following conditions must be considered in the existing situation:

- ✓ Infrastructure equipment should have required ratings in switching and regulating condition. So the grid needs 800V/500V DC line and 240V AC line with more power to support charging station equipment.
- ✓ All existing sources should be used in the grid, although the whole capacity of them should not be used because we need it to reach a balance. The goal is to use clean energy.
- ✓ The cycle of charge and discharge of EVs should be taught throughout the world because the future vehicles are the electric vehicles.
- ✓ Location and area condition must be analyzed by grid designers to provide efficient energy.

The budget delivery schedule should be calculated accurately for encouragement.

The general targets of EVs are to decrease Greenhouse Gas (GHG) emissions and help the electric grid. GHG emission might be reduced by EVs, but the contribution to the grid will not happen without ESSs. They play the role of big and controllable capacitor. It reduces the demand in each location, where energy storages are used for household renewable energy or same applications using with energy storages. Coordinating of the charge stations and other ESSs such as ESSs used in grid, household and charge stations, grid infrastructure and EVs user's behavior are important actors to increase grid quality. For example in case of using flexible energy supply/demand by Photovoltaic (PV) at households decreased system peak demand from 12% to 22% and saved 34% of energy expenses (Wang, Gu, and Li, 2018). In another case in Beijing, China with the 11 880 taxi (EV, Plug-in Hybrid Electric Vehicle (plug-in hybrid electric vehicle) and Internal Combustion Engine (ICE)) the electrification rate increased up to 37% by coordinated charge stations in the location of the gas-stations (Cai, Jia, Chiu, Hu, and Xu, 2014; Shahraki, Cai, Turkey, and Xu, 2015). Sizing, modeling, cost efficiency and coordinating of electric energy storages were improved by some algorithms. For example in case of energy storage sizing and cost of power grid with wind turbine improved by the Point Estimated method and the parallel Branch and Bound algorithm (PE-BB) (Xia, et al., 2018) or the genetic algorithm usually used in distribution systems such as distribution generators (DG) (Zhu, Gao, Zheng, and Du, 2016) but the algorithms accuracy depends on applications and the place they are used. All examples and cases show that Energy Storage Systems (ESS) provide wide variety of options to solve energy peak/decrease problem in large scale, but only ESSs cannot provide good solutions in all locations. To make flexible supply/demand and increase grid quality (Quick response in quality fault), State Of Charge (SOC) and State Of Health (SOH) are critical parameters, so estimation of both of them gives short summary of grid quality fault prevent power. The batteries are not ideal for device and system controlling, such as grid data center or Battery Management System (BMS) must predict SOC status and SOC estimations usually estimated by Kalman Filter (KF) and Extended Kalman Filter (EKF) (Li, Xiong, Mua, He, and Wang, 2017; Few, et al., Prospective improvements in cost and cycle life of off-grid lithium-ion battery packs: An analysis informed by expert elicitations, 2018). During the operations, SOC should be kept on between 10% ~ 20% and 80% (Ke, Chiu, and Wu, Battery Modelling and SOC Estimation of a LiFePO₄ Battery, 2016; Hannana, Lipu, Hussain, and Mohamed, 2017). This effect and same effects causes to create revision in grids infrastructure and capacity mechanism. For example, Figure 3.5 has shown how much of the grid requires investment to increase capacity mechanism in Europe in short and long-term.

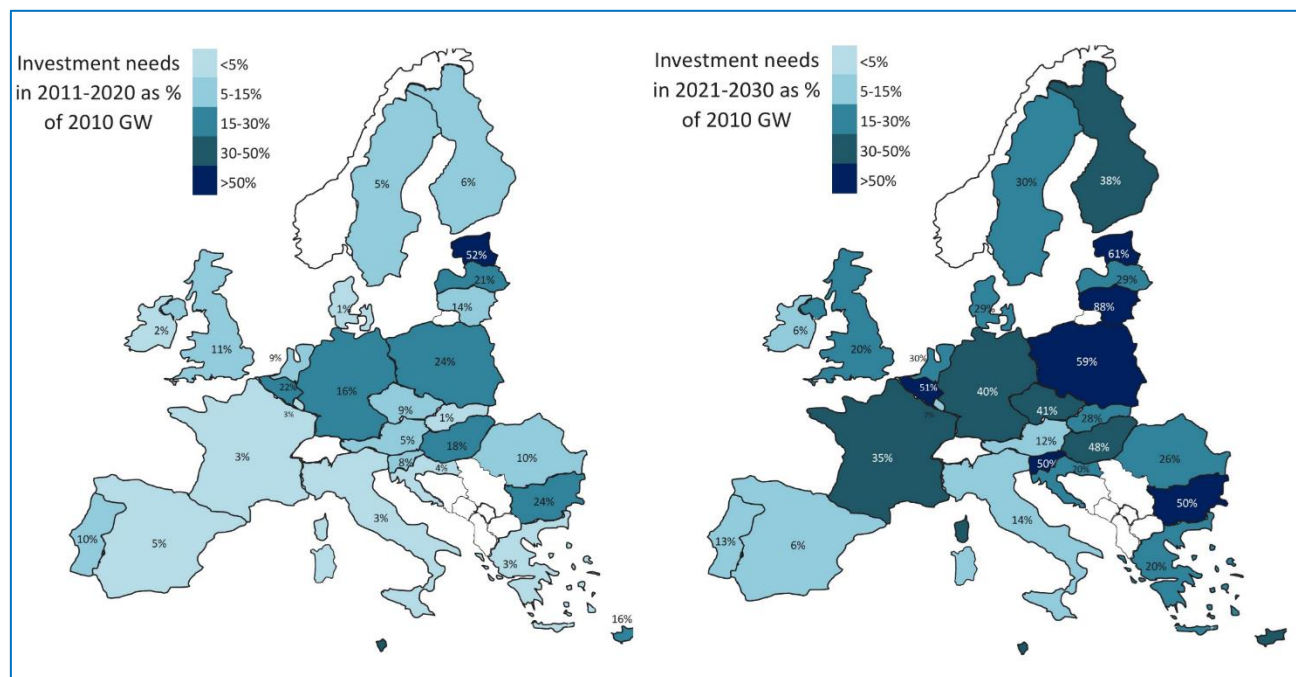


Figure 3.5. Investment needs between 2011 to 2020 and 2021 to 2030 in Europe Union

3.4. Budget

The budget of each project is an important motivation. But the project provision of the budget may happen in two ways. In some projects, it may happen before project initiation. But in some others, it may happen over a short/long time after the project starts. Electric fleet systems need a big budget and it should be supplied before the start of project and provision of project budget will happen after short/long time that depends on the economic condition of the area (Flores, Shaffer, and Brouwer, 2016). The profile of the conception in each location is different from other locations and each has a typical profile. Usage algorithm of some areas is achieved by those profiles (Xiang, et al., 2016). Priority of some factors depends on the custom of location. The budget profiles are calculated by usage pattern in downtown/urban/suburb, infrastructure of grid, and environmental condition. Usage pattern has an influence on energy consumption of the area. For example, people of the Middle East use energy more than people of EU or Asia. However, considering to the environmental condition in the Middle East, the usage should be less. In fact, low price of petrol had a bad influence on the consumption culture; which is used to be the same in the US in the past.

The infrastructure of the grid should be upgraded with the least number of converters and loss, as the energy loss in the grid is against the budget. Some governments save money by

decreasing energy loss and some governments spend money to decrease energy loss (Alhazmi and Salamab, 2017). Finally, the governments should offer some profitable plans to the investors, as the investors determine which projects are economical and which ones are not. To do it in large or medium scale, the governments must be estimated load demand which is requested from people.





4. ELECTRIC VEHICLE LOAD ESTIMATING

To recognize some potential or interconnected supply/demand power in the grid, energy providers must achieve full information of the flowed energies in the grid. It depends on calculation of base power of the grid (Zhang, Gajpal, Appadoo, and Abdulkader, 2018). The estimation has given facility to estimate how many EV or plug-in hybrid electric vehicle may be used in a special locations (Wang, Lin, and Lee, Electric vehicle tour planning, 2018). Therefore, infrastructure of the grid should be ready to respond the EVs which can join annual input cycle. Definite area's potential could be recognized by existed crisis, such as purchasing power, specification of EVs, financial encourager and same factors. They are increased/decreased in each area and they build research design.

4.1. Energy Flow in the Grid

Energy cycle in the grid gives some important information to determine important criteria's. Grid's load in peak time and downtime and grid infrastructure responsibility, reliability and capacity should be estimated by grid energy flow report that was created at the earliest time, such as last year (Clairand, Rodríguez-García, and Álvarez-Bel, Smart Charging for Electric Vehicle Aggregators considering Users' Preferences, 2016). In other side, development of Renewable Energy Source (RES) in the worldwide have similar problem in providing energy by high quality such as the ones which are mentioned in grid without RES and EVs. Grids (with and without RES) need energy storage to solve some problems such as voltage and frequency fluctuations and benefits of electric vehicle which are temporary energy storage for grid. Decreasing of GHG emission and increasing of consumption efficiency are advantages considering environmental issues. Consequently, the grid might support charge and discharge in energy cycle and sever condition (SOC (State Of Charge) lower than %20), the power transformers can be chosen carefully to response EVs and some EVs function such as Vehicle to Grid V2G (Kumar, Sivaneasan, Tan, Ren, and So, 2015).

4.2. Potential of Area

Potential of location is an important factor for both energy provider and customer. This factor and its subsequent changes in some locations, but they have been limited in some categories/

standards. “They facilitate customer to select proper EV and energy provider to create accurate plan to put high quality energy (Gay, Rogers, and Shirley, 2018). Customers expect fast charge, more power to drive and low fee cost and tax (Priessner, Sposato, and Hampl, 2018) , in another side of this issue, providers expect more temporary energy storage and balanced EV injection to grid (Zhang, et al., 2018). Both of them in background of the problem have needed high purchasing power of the location of people and high power electric infrastructure (Egnér and Trosvik, 2018)”.

4.3. Power Allocation for EVs Supply and Demand

EVs supply/demand powers need is one of controversial sections of the clean energy issues, so the grid needs more power to supply the demand from EVs and this problem is reasonable for engineers, but it is not an acceptable trouble for people, still it is complicated problem (PILLOT, 2013). To clearing up this issue, the power (supply/demand) of RES, grid and EV should be separated and in this section of paper, this separation method has been explained. Generally, EVs are subsequences of the RES, Consequently EVs power is calculated from total RES and EVs demand and this algorithm scheduled for each 30-minute interval in a day. This algorithm has shown prediction of load demand by taking renewable energy source calculated by (Kumar, Sivaneasan, Tan, Ren, and So, 2015):

$$p_j^{PD} = p_j^L - p_j^{RES} \quad (4.1)$$

Unscheduled general EV's demand has given by:

$$p_j^{uEV,i} = \begin{cases} 0, 1 \leq j < (m_i - k_i - 1) & \text{and } j \geq m_i, \\ p_i^{EV,i}, (m_i - k_i - 1) \leq j \leq (m_i - 1) \end{cases} \quad (4.2)$$

$$l = j - (m_i - k_i - 2) \quad (4.3)$$

4.4. Ankara Cases Load Investigation

In this thesis, Ankara-Turkey automobile market from Jan 2018 to Sep 2018 has been analyzed by changing electric vehicle system from fossil system to determine how much power grid is needed in various scenarios approximately. The Ankara city is allocated %11~12 of the Turkey's automobile market share from annual automobiles were sold. In

other side of this issue, Turkey has not support BEV fully, but some plug-in hybrid electric vehicle have been sold and the government has created a plan to get electric fleet system in the future. “To imagine and analysis the Ankara city with BEV, existed EVs in the world and specification of them should be estimated by Ankara market share needs”. Some BEV specification has been given in Table 4.1. EVs have suitable cons in comparison to past and it has covered the area potential factors such as purchasing power, but BEVs cost is a poor or average factor. MPG (Mile Per Gallon), EPA (U.S. Environmental Protection Agency) and some similar efficiency parameters are the strong point of BEVs, for example MPG of BEVs have been changed between 72 to 136 and this rate has been assumed about 52 in cars (HONDA Insight), which is worked by fossil fuel (Find and Compare Cars, n.d.; Berman, n.d.).

Table 4.1. Some BEV and plug-in hybrid electric vehicle specification

Vehicle Model	Battery Capacity kWh	Charger Power ^a	Class	Total Range	kWh/100mi gal/100mi	MPG Combined city/highway	Price USD ^b
2019 Hyundai Ioniq Electric	28	6,60 kW	C	200 km	25	136	~ 29 500
2018 Tesla Model 3 Long Range	74	11,5 kW	D	496 km	26	130	~ 44 000
2019 Hyundai Kona Electric	64	7,20 kW	B	415 km	28	120	~ 40 000
Volkswagen e-Golf	35,8	7,20 kW	C	200 km	28	119	~ 32 000
2018 BMW i3 (120Ah)	33	7,4 ~ 22 kW	C	260 km	29	118	~ 43 000
2019 Chevrolet Bolt EV	60	7,20 kW	C	383 km	28	119	~ 37 000
2018 Honda Clarity EV	25.5	6.60 kW	D	143 km	30	114	~ 38 000
2018 BMW i3s (120Ah)	33.0	7.4 ~ 22 kW	C	120 km	30	112	~ 47 650
AUDI e-tron	95	7,0 ~ 150 kW	C	Unannounced	Unannounced	Unannounced	~ 74 800
2019 Nissan Leaf	40	6,60 kW	B	241 km	30	112	~ 36 000
2018 Fiat 500e	24	6,60 kW	B	135 km	30	112	~ 35 000
smart for two electric drive coupe	17,6	7,00 kW	2 Seater	093 km	31	108	~ 26 640
Kia Soul Electric	30	6,60 kW	B	177 km	31	108	~ 34 000
Ford Focus Electric	33,5	6,60 kW	C	185 km	31	107	~ 29 000

Table 4.1. (continue) Some BEV and plug-in hybrid electric vehicle specification

2018 smart for two electric drive convertible	17,6	7,00 kW	2 Seater	92 km	33	102	~ 29 000
2018 Tesla Model S100D	100	7,00 kW	E	536 km	33	102	~ 94 000
2018 Tesla Model X75D	75	7,00 kW	E	380 km	36	93	~ 79 500
PEUGEOT iON	14,5	3,60 kW	A	95 km	Unannounced	Unannounced	~ 23 845
2018 BYD e6	61,4	30 kW AC in 2h / 19,2 kW SAE Level 2 AC charging 8-9h	B	300 km	47	072	~ 45 000
Plug-in Hybrid Car							
2019 Chevrolet Volt	18,4	7,20 kW	C	85/692 km	31/2,4	106/42 °	~ 33 520
2018 Toyota Prius Prime	8,80	7,20 kW	D	40/1030 km	25/1,9	133/54	~ 27 000
2019 Kia Niro Plug-in Hybrid	8,90	3,30 kW	B	26/901 km	32/2,2	105/46	~ 28 200
2019 Ford Fusion Energi Plug-in Hybrid	9	3,30 kW	D	41/981 km	33/2,4	103/42	~ 36 600
2019 Kia Optima Plug-in Hybrid	9,8	3,30 kW	D	46/981 km	33/2,5	103/40	~ 35 290
2018 Hyundai Sonata Plug-in Hybrid	10.0	3,30 kW	D	45/965 km	34/2,6	99/39	~ 35 400
2018 Chrysler Pacifica Hybrid	16	6,60 kW	D	53/917 km	40/3,1	84/32	~ 44 995
2018 Audi A3 e-tron	9	3,30 kW	C	26/643 km	41/2,8	83/36	~ 48 000
2019 Volvo S90 AWD PHEV	10	3,50 kW	D	33/788 km	45/3,4	71/29	~ 75 000
2018 Cadillac CT6 Plug-In	18	3,30 kW	D	50/692 km	54/4,0	62/25	~ 75,000
2018 VolvoXC60 AWD PHEV	10	3,50 kW	E/SUV	29/595 km	53/3,8	59/26	~ 56 700
2019 Volvo XC90 T8	10	3,30 kW	D/SUV	27/788 km	55/4,0	58/25	~ 66 000
2018 BMW 330e	7	3,70 kW	C	22/563 km	47/3,3	71/30	~ 45 600
2019 BMW 530e	9	3,30 kW	D	26/595 km	46/3,4	72/29	~ 52 400
2019 BMW i8 Coupe	7	3,30 kW	F	30/515 km	49/3,7	69/27	~147 500
2018 Mitsubishi Outlander PHEV	12	3,30 kW	D	35/499 km	45/4,0	74/25	~ 40 295

Table 4.1. (continue) Some BEV and plug-in hybrid electric vehicle specification

Mercedes-Benz C350 Plug-in Hybrid	6	3,30 kW	C	15/660 km	56/3,3	51/30	~ 47 900
Mercedes-Benz S560 Plug-in Hybrid	13	3,60 kW	E	Not Measured From the official U.S. government source for fuel economy information			~113 000

a BEVs must be charged in some location and can charge by 50kW Fast Charge.

b costs have reported by MSRP and it may change in some area.

c Second number is for fossil fuel engine.

Opportunity of grid development decreases as the time passes, because the world energy policy follows reduce in GHG emission and fossil energy and breaks to build ICE car till 2030 and 2050 (different in some area). Consequently, the grid load estimation, which have been charged and discharged by BEVs, represent the future. In this paper, we replaced the BEV in the Ankara car market by price range from 29 500 USD to 45 000 USD. Considering the statics given by Turkish Statistical Institute (TÜİK) and Turkish Automotive Distributors Association (ODD), about 41 466 cars were sold from Jan 2018 to Sep 2018 in Ankara. Regarding mentioned method, 10 317 cars out of 41 466 might be electric vehicle, this range covered about %25 of cars which were sold in Ankara and most of their cars are B, C and D class car. From 2015 to 2017 by the TÜİK reports, Ankara automobile market share growth speed is %11,44. Table 4.2. shows some information about some cars quantity in Turkey and Ankara by cars class.

Table 4.2. Sold car by the car class in Turkey and Ankara between Jan 2018 to Sep 2018

	Turkey from Jan 2018 to Sep 2018	Ankara from Jan 2018 to Sep 2018
Class	Quantity	Quantity
A (Mini)	1 071	123
B (Entry)	102 163	11 687
C (Compact)	199 836	22 861
D (Medium)	46 373	5 305
E (Luxury)	10 674	1 221
F (Upper Luxury)	2 348	269
Total	362 465	41 466

Considering table 4.1 and 4.2, to make estimation about EVs stable battery capacity, paying attention to some statistic factors is very important. At first priority, vehicle quantity must be determined by some scenarios and those scenarios should be designed by some major factors such as relationship of the previous car quantity in the statistic reports, car density in definite area and some other limitations which are created from executive power. Car density in definite area is a so haze factor, so it has so many alternatives and all them such as car density and error rate are not clear yet.

4.5. Relationship of the Previous Car Quantity

In this research, clear alternatives by the official statistic reports have been center of attention. By the illustrated information, Figure 4.1 is made by relationship of the previous car quantity in the statistic reports with waterfall algorithm and analysis method. Waterfall algorithms have some important laws such as accuracy of input data in first node and result of it depends on input data. “In first node of this algorithm (relationship of the previous car quantity), cars quantity received from two official organization and if this node is created by error rate, it can give reasonable data (Adetokunbo, Adenowo, 2013)”.

Sum of class B, C and D sold in Ankara is 39 853 and in other hand %1 tolerance existed between government and non-profit organization. Consequently, % ± 1 for Min, % ± 2 for Average and % ± 3 Max have been considered tolerance for each input. In the lack of local sociology information, determining amount of cars sold in the definite period and each car class is impossible, but with considering equal situation for all cases, approaching final value could be possible.

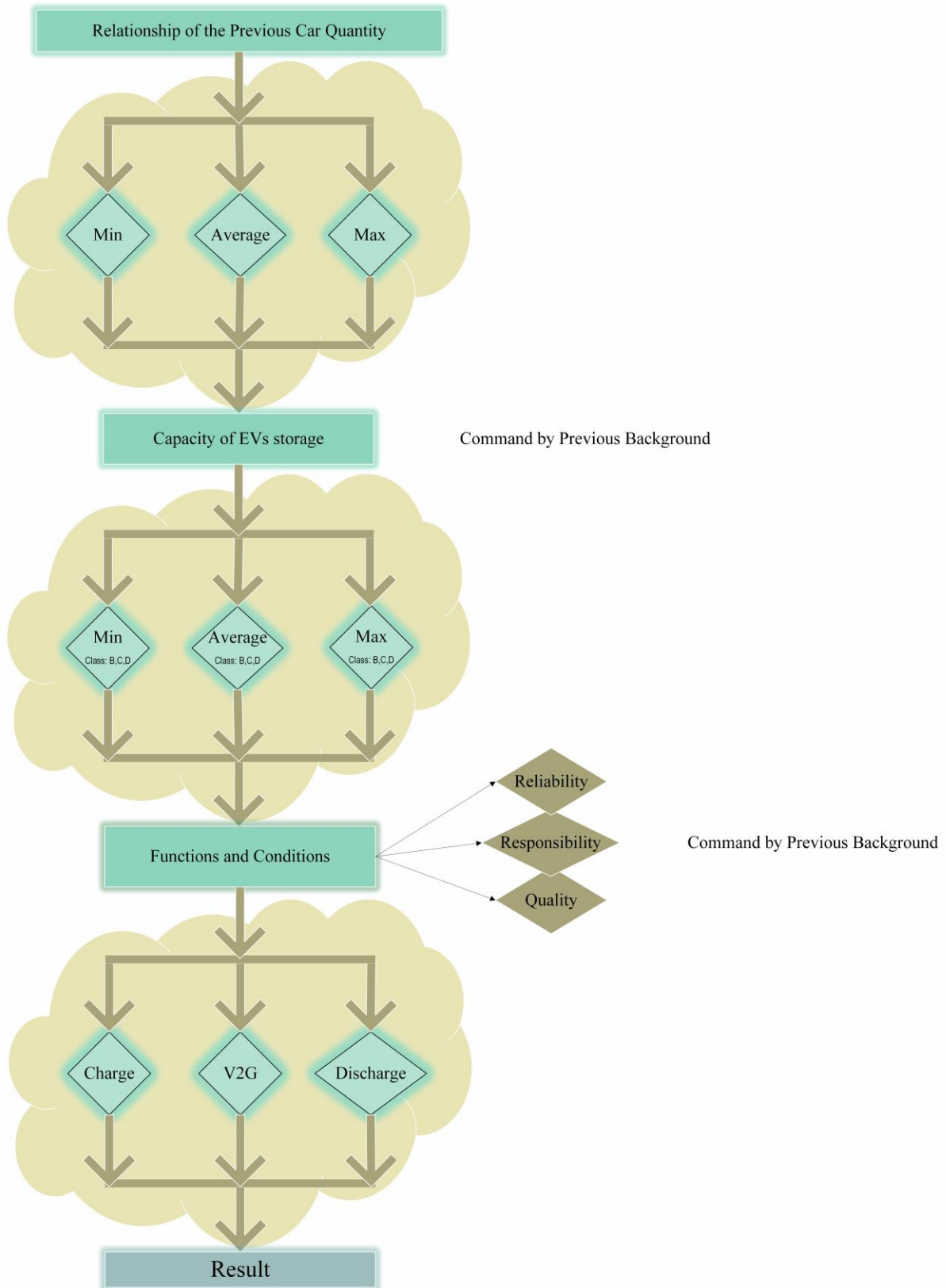


Figure 4.1. Algorithm for load estimation of EVs by relationship of car quantity

4.6. Capacity of EVs Storage

To create input data at the second node, eliminating and calculating cars storage are very important. Considering quantity of sold ICE cars equal to BEV car's (same model, option).

The method facilitates elimination and calculates 9 286 car with lowest error rate. Table 4.3. gives some information about this method.

Table 4.3. Same ICE vehicle and BEV quantity and their total battery capacity

ICE Vehicle Model	Quantity of Sold	BEV Vehicle Model	Battery Capacity kWh	Total Capacity kWh
Hyundai Ioniq	514	2019 Hyundai Ioniq Electric	28	14 392
Hyundai Kona	494	2019 Hyundai Kona Electric	64	31 616
Volkswagen Golf	7 559	2019 Volkswagen e-Golf	35,8	270 612
2018 BMW i3 (120Ah)	32	2018 BMW i3 (120Ah)	33	1 056
Fiat 500	60	2018 Fiat 500e	24	1 440
Kia Soul	119	2019 Kia Soul Electric	30	3 570
Ford Focus	508	2018 Ford Focus Electric	33,5	17 018
Total	9 286			339 704

After eliminating 9 286 vehicles, 30 567 cars need classification by various factors such as battery capacity, body, finance condition, guaranty/warranty and same factors and in the other side of this issue, all BEVs have close cost and various option. Consequently, each of BEVs have one chance for selling and it is about %5.882 (1797) for each BEVs, in Table 4.4. the capacity of total cars by same chance are given. Quantity of sold car in Ankara from Jan 2018 to September 2018 is given in Appendix 4.

Table 4.4. Storage capacity of other remain vehicle by same chance

Vehicle Model	Battery Capacity	Total kWh
2019 Hyundai Ioniq Electric	28,0 kWh× 1797	50 316
2018 Tesla Model 3 Long Range	74,0 kWh× 1797	132 978
2019 Hyundai Kona Electric	64,0 kWh× 1797	115 008
2019 Volkswagen e-Golf	35,8 kWh× 1797	64 333
2018 BMW i3 (120Ah)	33,0 kWh× 1797	59 301
2019 Chevrolet Bolt EV	60,0 kWh× 1797	107 820
2018 Honda Clarity EV	25.5 kWh× 1797	45 823
2018 BMW i3s (120Ah)	33,0 kWh× 1797	59 301
2019 AUDI e-tron	95,0 kWh× 1797	170 715
2019 Nissan Leaf	40,0 kWh× 1797	71 880
2018 Fiat 500e	24,0 kWh× 1797	43 128
2018 BYD e6	61,4 kWh× 1797	110 335
2019 Kia Soul Electric	30,0 kWh× 1797	53 910
2018 Ford Focus Electric	33,5 kWh× 1797	60 199
PEUGEOT iON	14,5 kWh× 1797	26 056
2018 Tesla Model S 100D	100 kWh× 1797	179 700
2018 Tesla Model X 75D	75,0 kWh× 1797	134 775
Total:		1 485 578

By the mentioned sociologic infrastructure information, 1 825 MWh temporary storage have competency to be used in the grid, also error ratio influence the algorithm in the first and second node. But it gives a glance of future supply/demand condition.

4.7. Function and Condition

In this section of algorithm, the designer or operator should consider benefits which exist between people and some other factors mentioned in below bar:

- ✓ It is somehow free and created by people.
- ✓ Storages are not available every time.
- ✓ The grid needs common and special condition from energy storage.
- ✓ Managing energy flow and quality of it.

✓ Energy access plan

Mentioned items are not advantage, disadvantage and benefit, there are some undoubtedly applicable factors to all grids. Just they have different ratio in each grids and subset of grids, but they are doubtlessly gained without pain equipment (Harighi, Bayindir, and Hossain, Overview of quality of service evaluation of a charging station for electric vehicle, 2017). Li-ion (lithium-ion) Storages and same storages with higher quality than Li-ion storages have merit to use in some gap of power quality issue. In some situations, the grid needs to inject energy from other supplier or increase energy load when grid energy increases rapidly. Consequently, charge/discharge, V2G/G2V (Grid to Vehicle) are not ideal or ideal condition. But, total capacity of the storages ready to use and all consumed fuel by ICE cars can give glance of how much energy should be generated to be used daily for EVs.

In some investigations charge/discharge and V2G function have points such as -1, 0 and 1. In some algorithms, the point of function depends on schedule and time inputs. In this paper, all investigations terminate to that; goals (such as GHG emission and improve electrical energy quality) expect some different materials and infrastructure (such as develop electric grid and fuel infrastructure) and all of them response slowly (Harighi, Bayindir, Padmanaban, Mihet-Popa, and Hossain, An Overview of Energy Scenarios, Storage Systems and the Infrastructure for Vehicle-to-Grid Technology, 2018). It is a little philosophical sentence, but it is true. To approach load estimation goals in this section, total load and priority of it are the needs chain and using other cases to get what is expecting the grid. At first, estimation of load fluctuation is on the first priority, so the Ankara's grid does not support any V2G function. Load fluctuation is calculated by (Chen and Wu, 2018):

$$z = \min \left\{ \sum_{t \in T_C} ((\bar{G} + \Delta \bar{G}) - (G(t) + V_i(t)))^2 \right\} \quad (4.4)$$

$$T_C \subset T \quad (4.5)$$

$$V_i(t) = p_i C_i(t) \quad (4.6)$$

$$\sum_t C_i(t) = \text{const} \quad (4.7)$$

$$z = \min \left\{ \sum_t (\bar{G} + \Delta \bar{G})^2 + \sum_t (G(t))^2 - 2(\bar{G} + \Delta \bar{G})(G(t) + p_i C_i(t)) + p_i^2 \sum_t (C_i(t))^2 + 2p_i \sum_t G(t)SC_i(t) \right\} \quad (4.8)$$

Without $C_i(t)$ to calculate original optimal dispatching problem:

$$y = \min\{p_i \sum_t (C_i(t))^2 + 2 \sum_t [G(t) - (\bar{G} + \Delta\bar{G})] C_i(t)\} \quad (4.9)$$

$$-2 \sum_t (\bar{G} + \Delta\bar{G}) C_i(t) = -2 (\bar{G} + \Delta\bar{G}) \sum_t C_i(t) = \text{const} \quad (4.10)$$

$$y = \min\{p_i \sum_t (C_i(t))^2 + 2 \sum_t G(t) C_i(t)\} \quad (4.11)$$

In addition, for V2G function:

$$C_i(t) = \begin{cases} -1 & V2G \\ 0 & \text{idle} \\ 1 & \text{Charging} \end{cases} \quad (4.12)$$

Therefore:

$$\sum_t (C_i(t))^2 = t_c + 2t_{V2G} \quad (4.13)$$

For original optimal dispatch with V2G:

$$y_1 = \min\{p_i t_{V2G} + \sum_t G(t) C_i(t)\} \quad (4.14)$$

It should be categorized by some function and situation to show there priority and modes in Table 4.5. (Liu, et al., 2018).

Table 4.5. Some EVs energy condition on the grid

MODE I	MODE II	MODE III	MODE IV
Inject power to the grid	Stop Charging	Charging	Charging (if other modes not available)
$\begin{cases} S_1^{Cap} = \sum S_{j,1}^{Cap} \\ S_{j,1}^{Cap} = \sum P_{k,1}^{Cap} \\ P_{k,1}^{Cap} = P_{max}^d - P_{k,1}^d \end{cases}$	$\begin{cases} S_2^{Cap} = \sum S_{j,2}^{Cap} \\ S_{j,2}^{Cap} = \sum P_{k,2}^{Cap} \\ P_{k,2}^{Cap} = -P_{k,2}^c \end{cases}$	$\begin{cases} S_3^{Cap} = \sum S_{j,3}^{Cap} \\ S_{j,3}^{Cap} = \sum P_{k,3}^{Cap} \\ P_{k,3}^{Cap} = P_{max}^d \end{cases}$	$\begin{cases} S_4^{Cap} = \sum S_{j,4}^{Cap} \\ S_{j,4}^{Cap} = \sum P_{k,4}^{Cap} \\ P_{k,4}^{Cap} = P_{max}^d \end{cases}$
Control Strategy for EV Charge Station			
$S_{j,1}^{CS} = \frac{S_{j,1}^{Cap}}{S_1^{Cap}} \cdot S_i^{Dis}$ $S_{k,1}^{EV} = \frac{P_{k,1}^{Cap}}{S_{j,1}^{Cap}} \cdot S_{j,1}^{CS}$	$S_{j,2}^{CS} = \frac{S_{j,2}^{Cap}}{S_2^{Cap}} \cdot (S_i^{Dis} - S_1^{Cap})$ $S_{k,2}^{EV} = \frac{P_{k,2}^{Cap}}{S_{j,2}^{Cap}} \cdot S_{j,2}^{CS}$	$S_{j,3}^{CS} = \frac{S_{j,3}^{Cap}}{S_3^{Cap}} \cdot (S_i^{Dis} - S_1^{Cap} - S_2^{Cap})$ $S_{k,3}^{EV} = \frac{P_{k,3}^{Cap}}{S_{j,3}^{Cap}} \cdot S_{j,3}^{CS}$	$S_{j,4}^{CS} = \frac{S_{j,4}^{Cap}}{S_4^{Cap}} \cdot (S_i^{Dis} - S_1^{Cap} - S_2^{Cap} - S_3^{Cap})$ $S_{k,4}^{EV} = \frac{P_{k,4}^{Cap}}{S_{j,4}^{Cap}} \cdot S_{j,4}^{CS}$
V2G power calculation formula			
$P_{k,1} = P_{k,1}^d + S_{k,1}^{EV}$	$\begin{cases} P_{k,1} = P_{max}^d \\ P_{k,2} = P_{k,2}^c + S_{k,2}^{EV} \end{cases}$		
V2G power in mode I, II and III: $\begin{cases} P_{k,1} = P_{max}^d \\ P_{k,2} = 0 \\ P_{k,3} = S_{k,3}^{EV} \end{cases}$			$\begin{cases} P_{k,1} = P_{max}^d \\ P_{k,2} = S_{k,4}^{EV} \\ P_{k,3} = P_{max}^d \end{cases}$

4.8. Proving V2G Benefits for Grid

Energy supply and demand base have information chain to create an energy cycle in the grid. To recognize effect of EVs energy supplement in this research, we focused on two researches on V2G area, which are investigated under frequency load and other one investigate global load characteristics via aggregator. In both of researches it is clear that EVs and storages

cause the grid have softer and smoother load curve and more reliable than the grid without any storage.

In addition, both of investigations and some other investigations use same formula and method, so they show similar results and those results are given in Appendix 2 and 3.





5. PROPOSED SYSTEM FOR EV CHARGE STATION COORDINATION

In this case, four transformer center have considered in start/end point which are supplied by A point and end used by D point. Each point has been analyzed by their maintenance history and current peak load point. Transformer maintenance history and current peak load point can illustrate most of the transformer and quality of that. This research attempts to create a defined glance to recognize points which are necessary for EV charge stations locations that can help to build a connection with the grid plan and bases in one of the real grid. In the next sections, our solution for electric vehicle charge stations coordination will be elaborated with examples. Ankara metropolitan electricity grid is one of the real cases to study and indicate important parameters, when the grid should be ready to supply electric vehicle and storages.

5.1. Areas Controlled by Local Operator

One of the important factors in grid stability depends on the grid size and infrastructure revises, but efficiency and responsibility of it is negotiable. Provinces of Ankara, Bartın, Çankırı, Karabük, Kastamonu, Kırıkkale, and Zonguldak provinces are control by ENERJİSA Company (EnerjiSA, n.d.). At first, stability of grid should be examined from power and size aspects. Figure 5.1 has given area which is controlled by Ankara province.



Figure 5.1. Areas under control of Ankara Province

This area has special specifics which help to stability of the grid. This area is placed in the middle of Turkey and neighbor of five other grid control areas. According to illustrated points, Ankara can receive energy from five different electric areas; it means that this area has enough reserve power line. Inside of this area (mentioned province) is formed from provinces which have energy generation rate more than their consumption rate. Some information about those provinces are shown in Table 5.1.

Table 5.1. Some energy consume and generate details of province which are under controlled of Ankara province (Yılmaz, n.d.)

	Power Plants Quantity	Annual Consumed energy rate in Turkey	Annual Energy Generation in Turkey
Ankara	69	%3.64	~ 9.299 GWh
Kırıkkale	9	%3.44	~ 8.797 GWh
Zonguldak	7	% 4.10	~ 13.332 GWh
Kastamonu	10	% 0.07	~ 188 GWh
Çankırı	3	% 0.01	~ 14 GWh
Karabük	7	% 0.22	~ 575 GWh
Bartın	3	% 0.02	~ 56 GWh

Mentioned information have shown that it can be stable grid in high penetration rate. Energy terminal locations is not in various places, so they are placed in special locations where it can provide high performance with a particular aspects. However, they cannot exceeds an appropriate amount. It is one of the key points in energy transfer between grids and storages,

so both of their accessibility observe different purposes. In other hand, they have just shared point in energy transfer. Figure 5.2 have illustrated this point clearly.

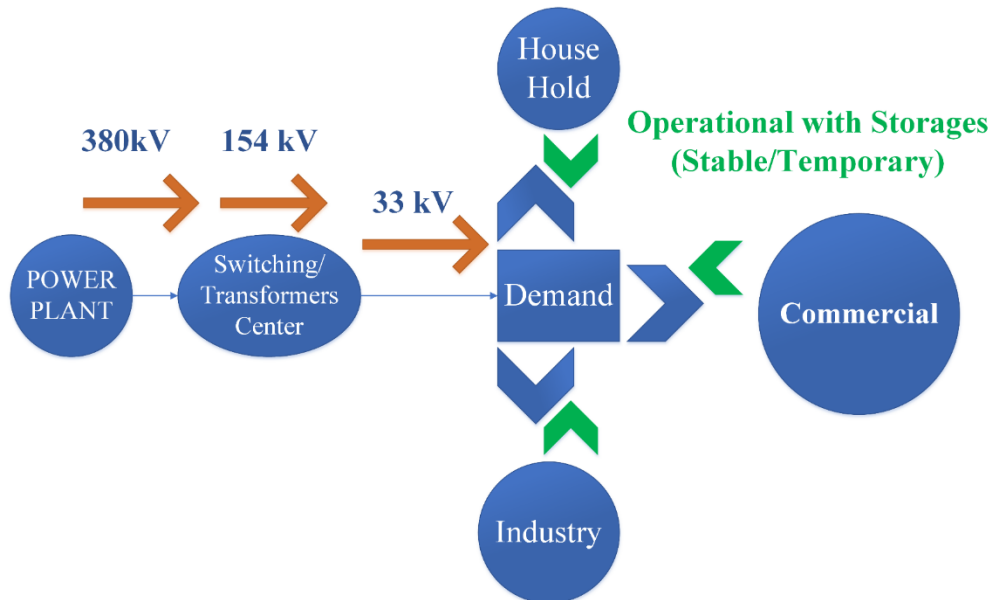


Figure 5.2. Energy injection side and areas can be operational by storages

5.2. Selection of High Efficiency and Operational Locations

Some literatures focused on charge stations distance, it helps customers to receive better service from grid by creating charge stations in reasonable distances in Taiwan (Wang, Lin, and Lee, Electric vehicle tour planning, 2018). Categories of charge stations distance can change quality of power, service, cost and EVs technology acceptance ratio between people. The range of charge stations are determined by various items such as grid infrastructure and existed EVs going around.

After those facts, some locations should be determined by some specifications, if the grid did not use charge stations. It can be different in each grid and it depends on grids condition. According to mentioned information and Ankara metropolitan electrify infrastructure, distance of grid terminals and power capacity (reserve or not) are the critical points in coordination of electric vehicle charge station topic. Cities transportation route are different from power transmission of grid route and each location have specific power capacity details. In first step, designers must select locations (points or places) which have the lowest distance to electric terminals and are suitable for transportation systems. The goal is to measure energy and being responsible for supply and demand. For example, two different

points in Ankara has been assessed, Maltepe and Balgat transformers center. Both of them are in the main and crowded streets. But Maltepe transformer center's condition makes it more operational than Balgat transformer center. Because Maltepe transformer center is close to downtown, some main terminals such as bus and trains (there is 1~2 km distance to downtown, metro, terminals) and this area have many free spaces, parking, schools, hospitals and some ministries. It seems that in this area large amount of vehicles is stationary, it can be a beneficial potential. But Balgat transformer centers does not have those options. In this condition Balgat transformer center loses its priority to build charge station. Figure 5.3 has given both of them locations and Ankara map to explain it clearly.

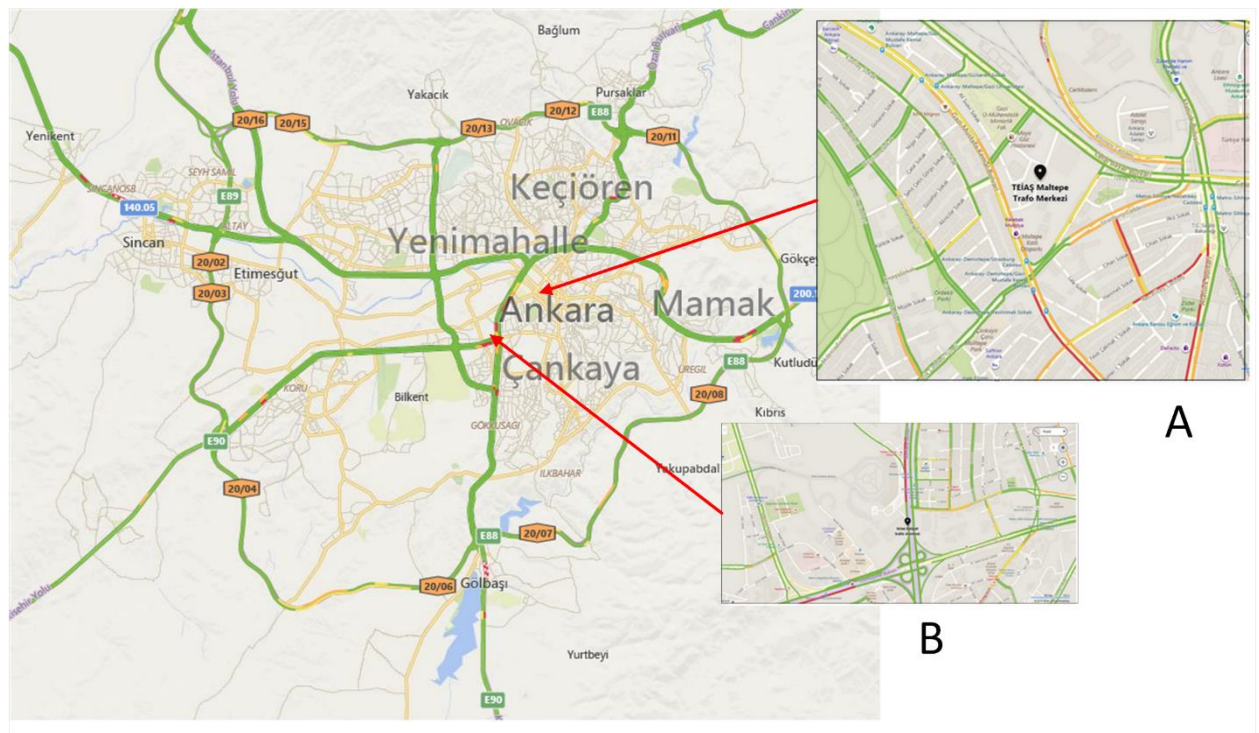


Figure 5.3. Ankara map, Maltepe transformer center area map (A) and Balgat transformer center area map (B) (Bing, n.d.)

According to mentioned information, Figure 5.4 has given procedure of this section. Points should be categorized by reasonable distance such as 30, 35, 40, 45 and 50 km, it depends on the area and infrastructure condition.

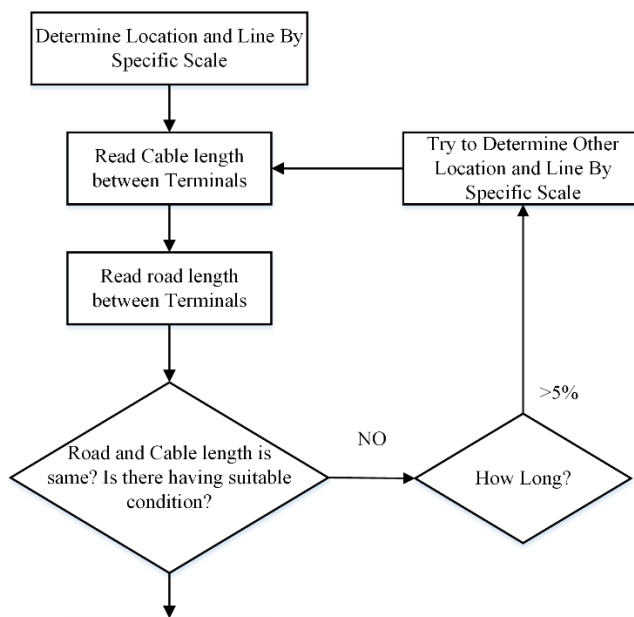


Figure 5.4. Distance determination algorithms flow chart

5.3. Transformers Selection and Assessment of Infrastructure

Transformers are the last operational part of the grid, which influence the grid and charge stations quality directly. Generally, all range of the grid transformers are influenced by storages such as charge stations or grid, in depended storages. Figure 5.5 has given the penetration rate of the transformers by voltage range. Low and mid-range transformers in the grid receive, high impact from power electronic equipment but they need support from high voltage transformers. Consequently, capacity, health, health by load summery, range and priority of them are the first important effective factors chain but Last factors cannot be determined by routine ways, so they depend on grid and location condition on their own operational period.

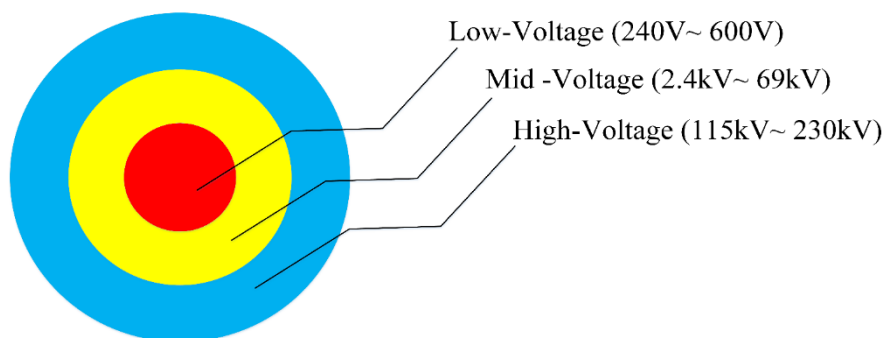


Figure 5.5. Charge stations load/demand penetration in transformers range

Capacity of distribution in transformers have potential to determine something necessary in the grid such as financial problems, aging, health and all priorities of them. Hence, in this algorithm capacity and related problems has a high priority. Low capacity or overload is the first step in the system fail domino (small or huge). Overload in electric equipment's (transformer) cause too many faults in the grid such as health, age and efficiency loss. In second step, it causes an increase in transformers temperature nonlinearly (Godina R. , Rodrigues, Paterakis, Erdinc, and Catalão, Innovative impact assessment of electric vehicles charging loads on distribution transformers using real data, 2016). One of the regular solutions to solve same problems is decreasing or changing the load pattern, which in everywhere have its own special pattern (Clairand, Rodríguez-García, and Álvarez-Bel, Smart Charging for Electric Vehicle Aggregators considering Users Preferences, 2018). Sorting the transformers by the capacity of them, should be separated. The flow chart of sorting has shown in Appendix 4 as Section 2. The purpose of section 2 is determining high priority transformer in the grid.

By the change timeslot in Grid Valley Filling technology (Munoz, Razeghi, Zhang, and Jabbari, 2016), grid demand level, load factor and transformer aging have been changed with reasonable scales. It can reduce load about 4~5 GW in a scenario and ambient transformers temperature 1.06~1.64% instead 52~100% in 50 kVA transformers and 200°C temperature rate. Consequently, the transformer aging is influenced from those statistics, it has changed 17~18 factors instead of 17~96. Another research has illustrated that EVs generate overload and harmful load type that such as shape impulses and the grid problem have been solved by time regime change and transformer hierarchy by MATLAB V9.5 software (Zou, Hiskens, and Ma, 2018) (Shokrzadeh, Ribberink, Rishmawi, and Entchev, 2017).

Solving method can be changed in each location depending on related problems conditions, therefor there is many situations. The smart grid transmission and distribution cost are very important to get some information which has been influential in the other side of the grid. Function of transmission and distribution cost have given in below (Hanai, Kojima, Hayakawa, Shinoda, and Okubo, 2013):

$$\begin{aligned} \text{Min } z = & \sum_{(i,j) \in \text{Line}} a_{ij}(X_{ij}) + \sum_{(i,j) \in \text{OverLine}} b_{ij}(X_{ij}) + \sum_{m \in \text{Over Equip}} c_m(X_m) + \\ & \sum_{n \in \text{OutLoad}} d_n(X_n) + \sum_{n \in \text{OutLoad}} e_n(X_n) + \sum_{m \in \text{Ment Equip}} f_m(X_m) + \\ & \sum_{k \in \text{Power Equip}} g_k(X_k) + \sum_{m \in \text{Fail Equip}} h_m(X_m) \end{aligned} \quad (5.1)$$

Above Equation shows that transmission and distribution cost create a big part of the grid maintenance cost. Next Equation has illustrated aging and loss of life rate of the transformer for an average penetration rate of EV (Godina R. , Rodrigues, Shafie-khah, Matias, and Catalão, 2016) (Turker, Bacha, Chatroux, and Hably, 2012) which is completely depends on transformers temperature.

$$V = e^{\frac{15000}{110+273} - \frac{15000}{\theta_h+273}} \quad (5.2)$$

$$L = \int_{t_1}^{t_2} V dt \quad (5.3)$$

Or:

$$L \approx \sum_{n=1}^N V_n \times t_n \quad (5.4)$$

$$D_{\text{TR_PHEV_X}} = A \times e^{(B \times T_x - T_r)} \quad (5.5)$$

$$V_{\text{TR_PHEV_X}} = \frac{D_{\text{TR_PHEV_WITHOUT}}}{D_{\text{TR_PHEV_X}}} \quad (5.6)$$

$$V_{\text{TR_PHEV_LOW}} = A \times T_x - T_r + B \quad (5.7)$$

$$V_{\text{TR_PHEV_X}} = A \times e^{(B \times T_x - T_r)} + C \times e^{(D \times T_x - T_r)} \quad (5.8)$$

Figure 5.6 clearly has explained temperature influence on the loss of life rate. Monitoring of transformers temperature is one of the effective ways to solve this type problem which is controlled at SCADA or match those setting on relays (Godina R. , Rodrigues, Shafie-khah, Matias, and Catalão, 2016). The transformer overall condition is important when transformer temperature exceed 110°C, so the LOL rate starts to increasing.

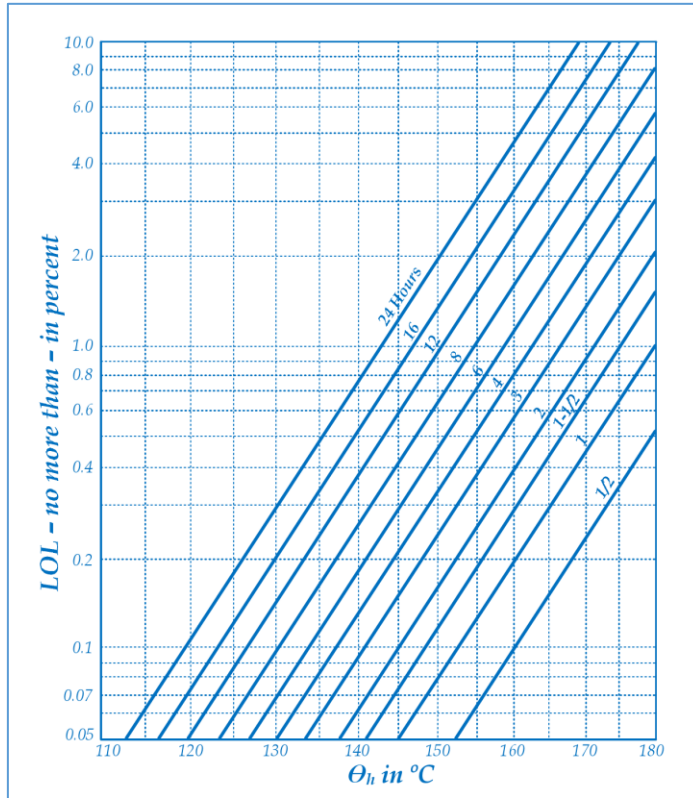


Figure 5.6. LOL and θ_h in different time

Indisputably, sometimes by increasing EVs in each grid, some transformers can be worked on overload area and consequently it leads the grid to crises or some faults. Solution of those capacity problems depends on grid communication infrastructure and grid creation hierarchy. The flow chart of the grid communication infrastructure and the grid creation hierarchy has shown in Appendix 4 as Section three “3”.

According to the grid condition, sometimes some items of the flowchart should be passed together, so there are many factors can be calculate by similar information. In Ankara case, we do not have transformer by smart or online monitoring, therefore we must use some tools which work by summery data. The Table 5.2 have shown information that owner C and D have high priority to create charge station on their locations. For example, data of a real grid (with air quality sensors result) have given in below:

Table 5.2. A real grid transformers center and their environment condition

Transformer Center			Load				
A			649 MW				
Transformer Center		Load	Usage Percentage		Owner	Air Quality	
						PM10	SO ₂
Transformer No.	A1	33.5	62		A	-	-
	A2	58.5	54		A		
B		Total: 238					
Transformer No.	B1	44	60		B	31	7
	B2	60	55		B		
	B3	69	65		B		
	B4	65	74		B		
C		Total: 210					
Transformer No.	C1	48	66		C	52	15
	C2	32	60		C		
	C3	45	61		C	79	15
	C4	18	58		C		
	C5	52	72		C	14	8
	C6	15	48		D		
D		Total: 109					
Transformer No.	D1	37		83	D	41	10
	D2	7 (15 kV)	55		D		
	D3	65	61		C		

In localizing EVs charge stations, the regional condition and some priorities of them are more important than the grid infrastructure on their locations. Therefore they should develop own location grid infrastructure. In most of locations parking and some public locations are beneficial from financial and technical side, to create battery bank and base of EV charge station. In addition, all of them explained in “Selection of High Efficiency and Operational Locations” section of this thesis.

In this case transformers are not smart and the operate group cannot monitor transformers status, so they do maintenance operations by technical data and some estimations. In this case transformers change in 30 year and they work with 55~70 percent of their capacity in load peak time. They give some information of the grid such as transformers work condition. From ANSI/IEEE C57.96-1989 standard (Linsley and White, 1989), the transformers recommended to change in 20 years, transformers can change in up to 20 years, if they have ideal maintenance condition. Transformers life expectancy may calculate by their insulation life equation, it has illustrated in below:

$$\log_e \text{life } (t) = A_e + \frac{B_e}{T} \quad (5.9)$$

$$\log_{10} \text{life } (t) = A_{10} + \frac{B_{10}}{T} \quad (5.10)$$

According to Equation (5.9) and (5.10), Figure 5.7 have illustrated time expectancy curve that is used in Equation (5.9) and (5.10).

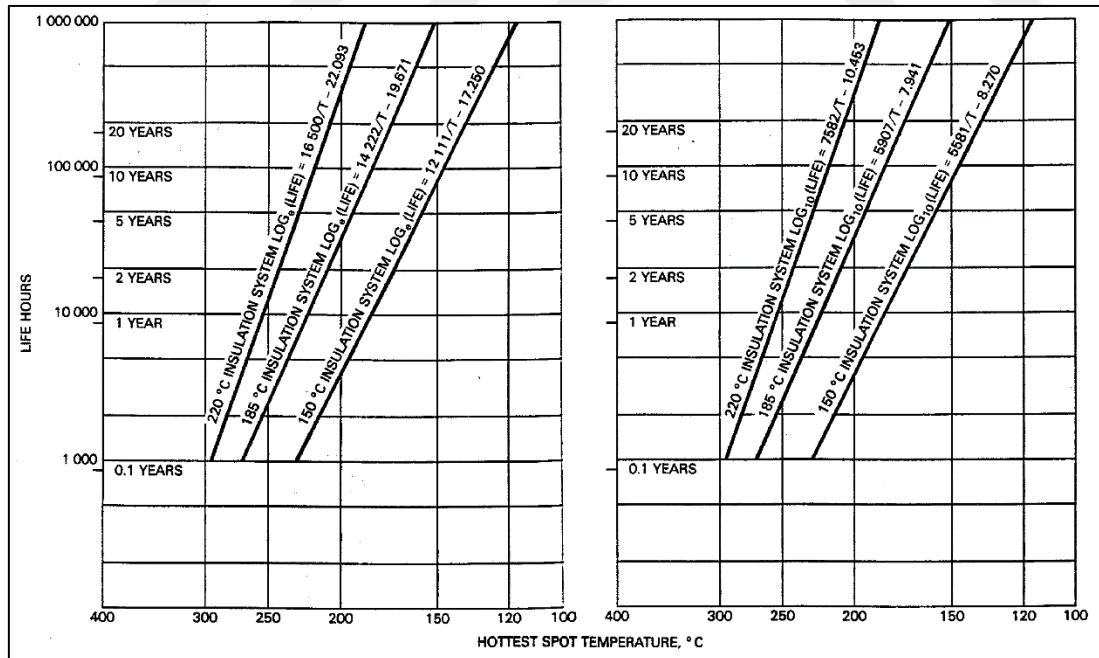


Figure 5.7. Life hours and hottest spot temperatur °C in transformers

Figure 5.7 and related Equations have shown the transformers which have maintenance in fine condition (the grid has passed “Calculate Transformers Health By Load Summery,

Age,” term). In second step, transformers health index should assess accuracy by some standards and score system. Technical condition and their standards should be covered their general status (Schmitz, et al., 2018). Technical and Operational conditional are mentioned in below:

- Technical Condition:
 - ✓ Transformer Parallelism Index
 - ✓ Transformer Reserve Index
 - ✓ Transformer Rated Power
- Operational Condition:
 - ✓ Main Health Index (HI m)
 - ✓ Insulating Paper Health Index (HI iso)
 - ✓ DGA Health Index (HI CH)
 - ✓ Oil Health Index (HI oil)

In this section of the paper, they have explained shortly mentioned index.

5.3.1. Transformer parallelism index

Transformer Parallelism Index is determined, if transformers are under load and analysis, when it coupled with another transformer and which part of the grid demand is suitable for this parallelism. This value can change from 0, where parallel transformers cannot work in parallel or they are not able to take charge of the connected equipment under the load, to 1, where transformers can respond the demand. The interval 0 to 1 has illustrated percentage value in transformer under the load that can response the maximum load power. This index is accepted from 120% to 140% in Brazil by standard ONS NT 038/2014 (standard, 2014). It has illustrated in Figure 5.8 in below.

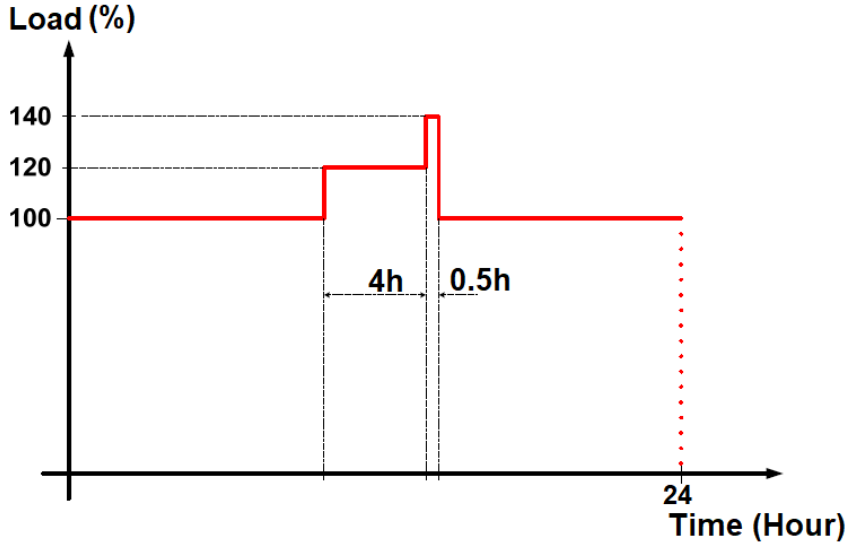


Figure 5.8. Acceptable over load by ONS NT 038/2014

Transformer Parallelism Index value has illustrated in Equation (5.11) to (5.12):

$$\begin{cases} 1 & \frac{TRP_{Ny}}{TRP_{Nx}} > \frac{f_L}{L_{max} - f_L} \\ \frac{TRP_{Ny}(L_{max} - f_L)}{TRP_{Nx} \cdot f_L}; \frac{TRP_{Ny}}{TRP_{Nx}} \leq \frac{f_L}{L_{max} - f_L} \wedge 0 < f_L \leq L_{max} \\ 0 & f_L > L_{max} \vee f_L = 0 \end{cases} \quad (5.11)$$

$$TRP_{Ny} = \sum TRP - TRP_{Nx} \quad (5.12)$$

$$f_L \geq 0 \quad (5.13)$$

$$TRP_{Ny} \geq 0, \forall y \in N \quad (5.14)$$

$$TRP_{Nx} \geq 0, \forall x \in N \quad (5.15)$$

5.3.2. Transformer reserve index

Transformer Reserve Index is an index of transformers to increase safety and reliability. It is very important index to identify whether the power equipment can respond the normal failure and random interruption or not. However the charge stations and specifically fast charge stations which their production is increased. They produce impulse signals in their connected transformers and they must be responded from transformers. An example of this condition from real data has been explained in research from São Miguel Island. Figure 5.9 has illustrated this fact in a curve by time and daily load (Godina R., Rodrigues, Paterakis, Erdinc, and Catalão, Innovative impact assessment of electric vehicles charging loads on distribution transformers using real data, 2016).

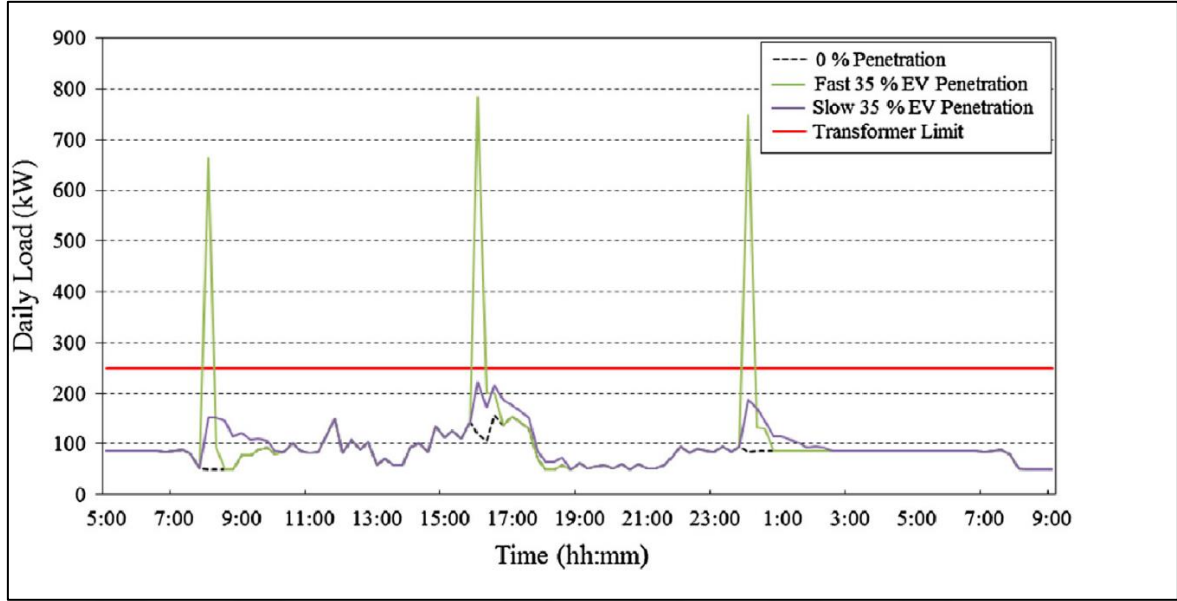


Figure 5.9. transformer impuls in fast and slow charge system by daily load versus time

This problem can rather be solve by reserve index, but not completely. To solve mentioned issue, except transformer reserve, charge stations storage reserve is more sensible. Hens both of the reserves should be increased logically.

5.3.3. Transformer rated power

Capacity of transformers is one of the important factors to receive good feedback from both supply and demand side of the grid. Temperature in all aspects of the transformers depend on transformer rated. It must be stable on their operational area.

5.3.4. Transformer main health index (HI_m)

The transformer main health index has always been important factor in transformer operational period. This index has been sensitive by temperature fluctuate which is changed in various ratio in transformer life, so it depends on system summary. Transformers Main Health Index (HI_m) has been determined by initial main health index reference point which is named HI_0 . HI_m is defined by Equation (5.16) and (5.17) mentioned below:

$$HI_m = HI_0 \times e^{\beta \times (T_2 - T_1)} \quad (5.16)$$

$$\beta = \frac{\ln 6,5 - \ln 0,5}{T_2 - T_1} \quad (5.17)$$

5.3.5. Transformers insulating paper health index (HI_{iso})

Insulate paper in each transformer has determined the efficiency of transformer and it is life directly. The transformer condition can be illustrated by identifying this index. Transformers Insulating Paper Health Index (HI_{iso}) can be recognized by analyzing some gases such as carbon monoxide and carbon dioxide in the transformer which is damaged by overheating in their lifetime. Transformers Insulating Paper Health Index (HI_{iso}) has presented in Equation (5.18):

$$HI_{iso} = \omega_1 HI_{C,O} \times \omega_2 HI_{fur} \quad (5.18)$$

$$HI_{fur} = 3.344 \times (C_{fur})^{0.413} \quad (5.19)$$

From (En-Wen and Bin, 2014), where C_{fur} is content of furfural to determine, HI_{fur} is index of it, from (Schmitz, et al., 2018) when $C_{fur} = 5$ means that the transformer is deteriorated and it can break down, in this condition $HI_{fur} = 6.5$, in other hand $C_{fur} = 0.01$ when it is newer and $HI_{fur} = 0.5$. $HI_{C,O}$ has defined by carbon monoxide and carbon dioxide gases analysis.

5.3.6. Transformer DGA health index (HI_{CH})

Transformer DGA health index (HI_{CH}) is one of important and regular tests to determine power transformers health. In this health index, the value of hydrogen (H_2), methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), acetylene (C_2H_2), carbon monoxide (CO) and carbon dioxide (CO_2) have been analyzed in transformer to estimating power transformer material condition and consequently transformer physical condition can be elaborated. DGA health index (HI_{CH}) has been illustrated in Equation (5.20):

$$HI_{CH} = \sum_{i=1}^5 \omega_i \cdot F_{C,H}(i) \quad (5.20)$$

Where, $F_{C,H}$ is quantify of transformer ageing, determined the hydrocarbon gas factor function and ω is weight of presented gases.

5.3.7. Transformer oil health index (HI_{oil})

Transformer oil index can have some errors such as acid value, high fluctuate of voltage, micro water and dielectric losses. In addition, the above-mentioned factors are the result of transformers cooling system and transformer topology which is reacted in transformer oil. This index calculation has given in Equation (5.21):

$$HI_{oil} = \sum_{i=1}^4 \omega_i F_{oil}(i) \quad (5.21)$$



6. RESULTS AND DISCUSSION

In the result section of thesis, our researches have explained that there are many factors which have influenced charge stations distribution system. In this thesis, air quality, transformers condition, change infrastructure location and local condition have illustrated that there are very important facts to feed the algorithms which are mentioned in introduction section five. For example, Gaussian distribution in Equation (6.1) and Figure 6.1 method can give different results when it depend on three factor than two factors. Indeed, the factors change the distribution system variance and reference of their changes.

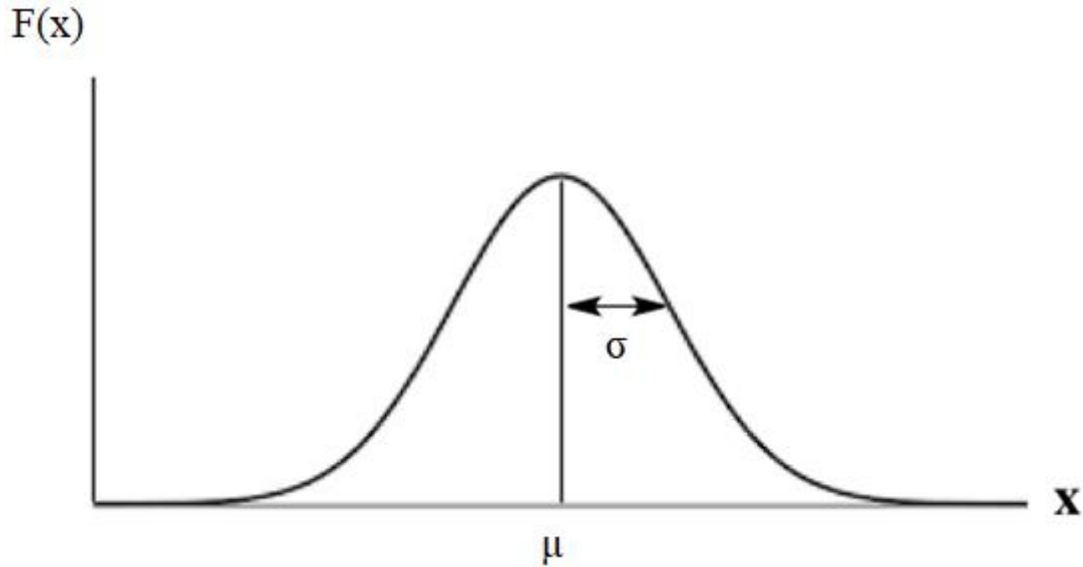


Figure 6.1. Sample of normal distribution curve

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \quad -\infty < x < +\infty \quad (6.1)$$

In addition, it is one of the distribution systems between different types. Today, most of the distribution systems work by multi-functional operations or based on same system. Genetic Algorithm is the most used algorithms for the same goals. However, they can work by different variables and functions. Control of each algorithm has its own special strategy and their responsibility efficiency depends on valid operational information from the location. Figure 6.2 has illustrated a hierarchy of input data for algorithms. In addition, operations in each algorithm will change if other priorities are used in their hierarchy.

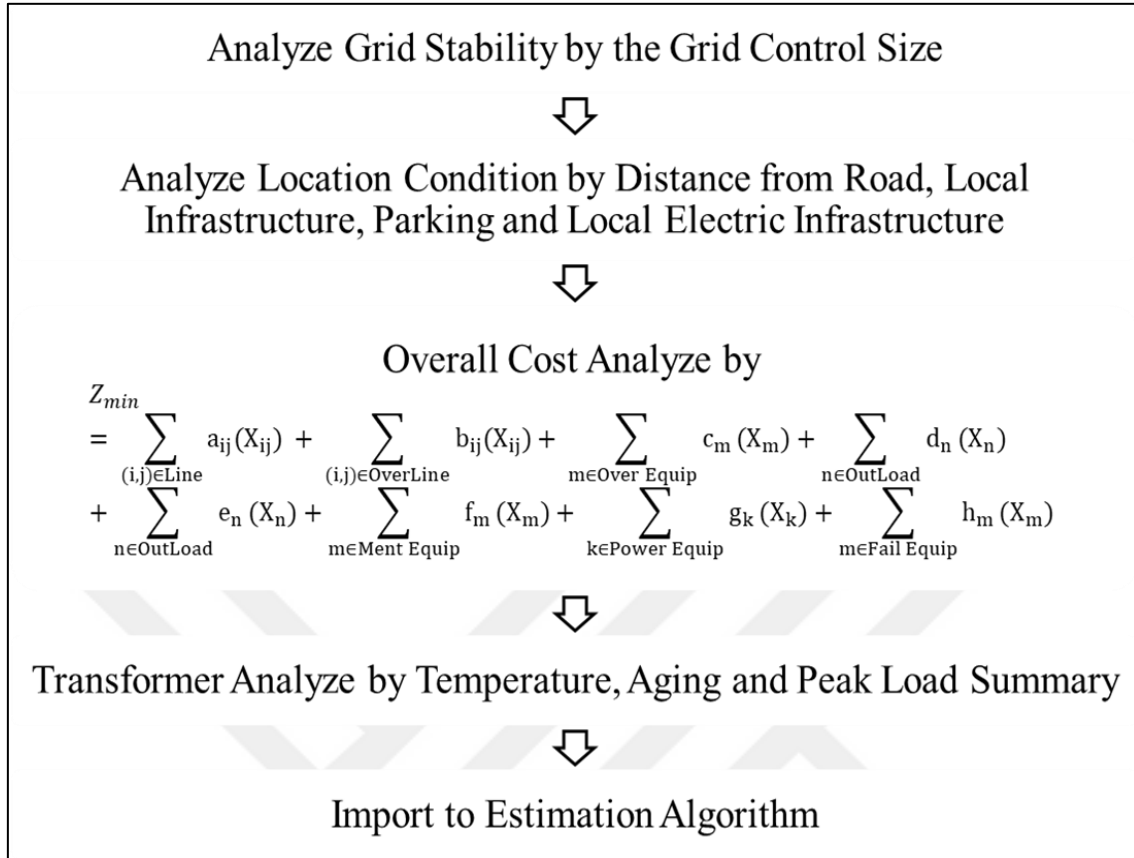
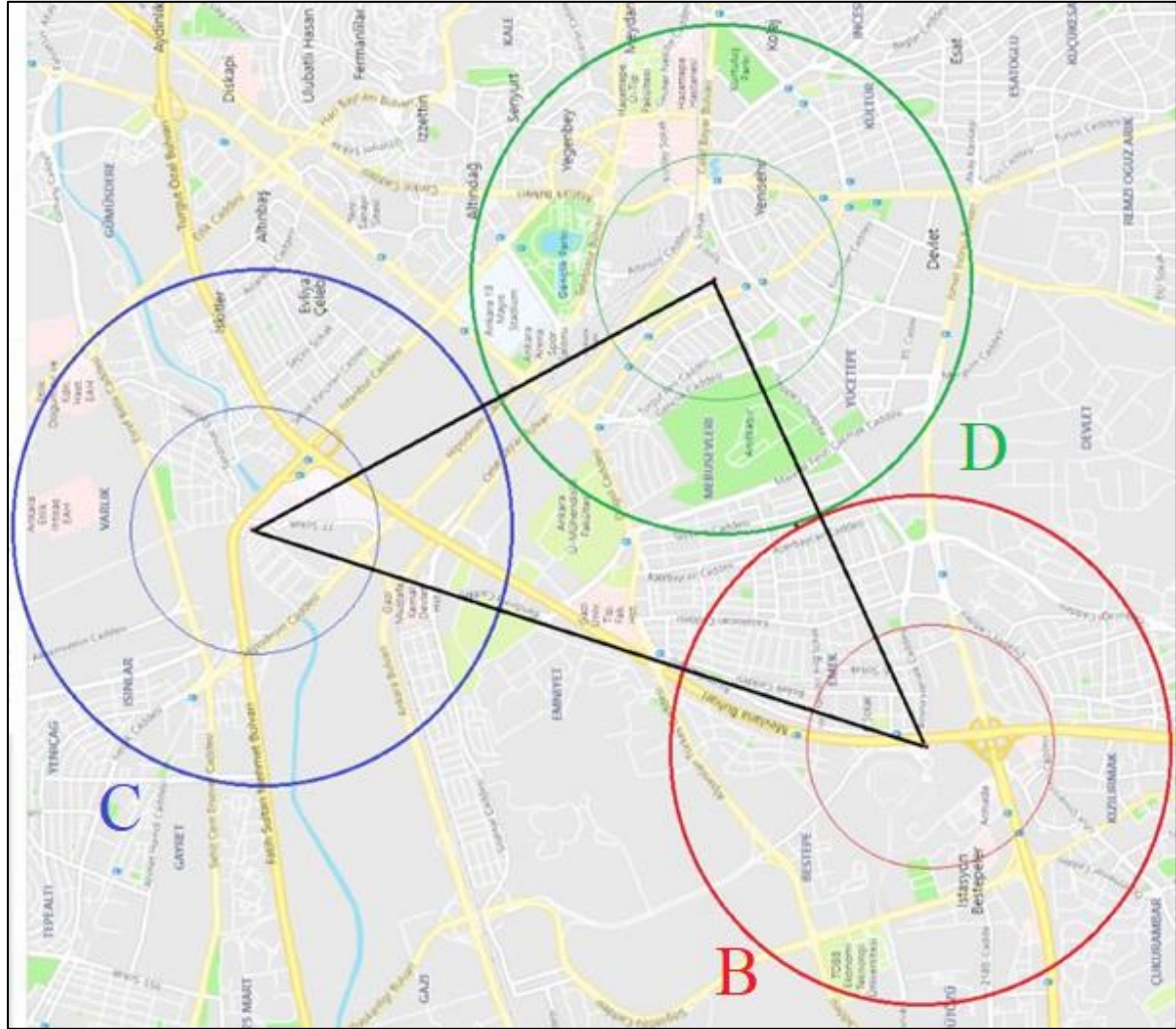


Figure 6.2. Hierarchy of algorithm input data

In this case, result of the (Distribution Methods Outputs) block depends on Turkish Energy policy which is created for long term in each country. According to data, which is mentioned in table one, two and location information, the GA is a reasonable method to create charge station point, so there are many divers reasons and information which can change algorithm targets. The information, which is issued by first data can be changed or improved by GA algorithm.

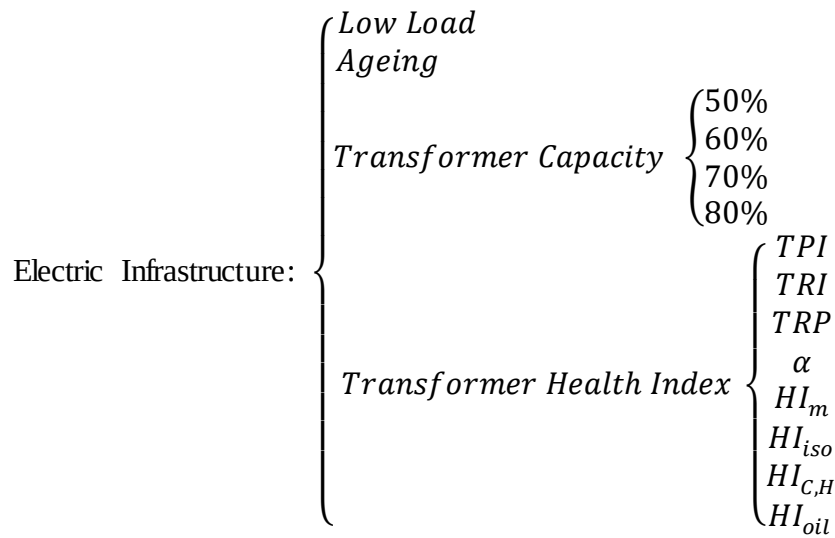
According to above-mentioned operations, three points (B, D and C) have been determined as locations to build EV fast charging stations in Ankara. There are sufficient reasons to select the mentioned transformer centers, by the time they have some difference between mentioned points. Some local infrastructure and transformer responsibility factors have different factors which can be solved by some location problem using (GA). Map 1 have illustrated points which are created by mentioned criteria.



Map 6.1. Selected points in Ankara (by Bing (Here) map)

These points have been determined by below parameters which are mentioned in below:

Location: $\begin{cases} \text{Distance} \\ \text{Local Infrastructure} \\ \text{Parking} \\ \text{Electric Infrastructure} \end{cases}$



By the mentioned factors, the designers should give some scores to parameters to determine factors' priority then their data might be ready to input on estimating algorithms. For example, in GA it can solve by the Figure 6.3 method which shows GA flow chart:

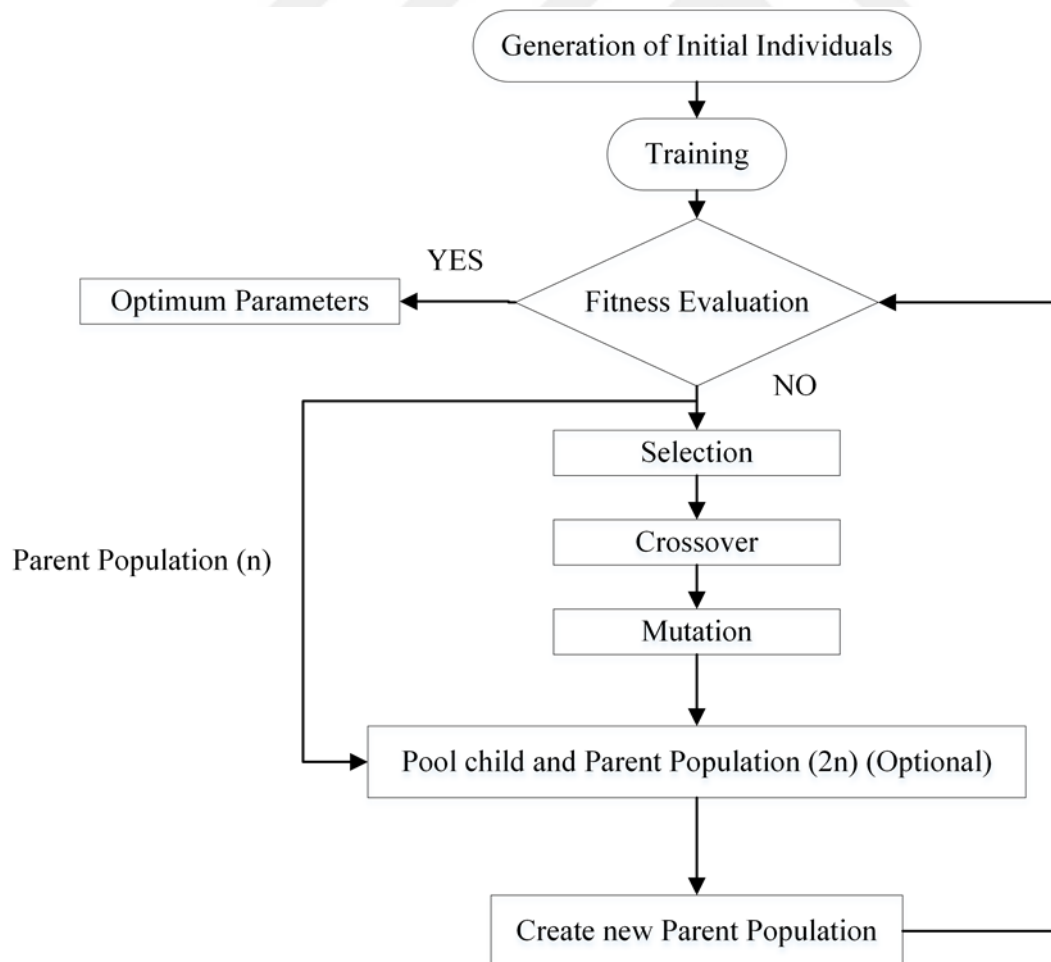


Figure 6.3. Flow chart of GA estimation method

The algorithm can adapt in most of the estimating algorithms.

Chromosome structure:

a	b	c	d
Gen_1	Gen_2	Gen_3	Gen_4
			

Area 1

Location	27	24	27	12
Electric Infrastructure	9	6	15	9

Area 2

Location	6	24	9	27
Electric Infrastructure	18	24	24	21

Area 3

Location	27	15	6	27
Electric Infrastructure	15	21	21	18

From the above-mentioned information there are six chromosome have created by location and infrastructure gens. The chromosomes have illustrated in below:

Chromosomes 1: [27; 24; 27; 12]

Chromosomes 2: [09; 06; 15; 09]

Chromosomes 3: [06; 24; 09; 27]

Chromosomes 4: [18; 24; 24; 21]

Chromosomes 5: [27; 15; 06; 27]

Chromosomes 6: [15; 21; 21; 18]

For running GA

Initialization

Chromosomes 1: [a; b; c; d]: [27; 24; 27; 12]

Chromosomes 2: [a; b; c; d]: [09; 06; 15; 09]

Chromosomes 3: [a; b; c; d]: [06; 24; 09; 27]

Chromosomes 4: [a; b; c; d]: [18; 24; 24; 21]

Chromosomes 5: [a; b; c; d]: [27; 15; 06; 27]

Chromosomes 6: [a; b; c; d]: [15; 21; 21; 18]

Evaluation

$$F_obj[1]=((27+(2*24)+(3*27)+(4*12)-30))=174$$

$$F_obj[2]=((9+(2*6)+(3*15)+(4*9)-30))=072$$

$$F_obj[3]=((6+(2*24)+(3*9)+(4*27)-30))=159$$

$$F_obj[4]=((18+(2*24)+(3*24)+(4*21)-30))=192$$

$$F_obj[5]=((27+(2*15)+(3*6)+(4*27)-30))=153$$

$$F_obj[6]=((15+(2*21)+(3*21)+(4*18)-30))=162$$

Selection

To determining chromosome by high probability the $F_obj[i]$ should be fittest by fitness function. For fitness function, $1/F_obj[i]+1$ function have calculated in below:

$$Fitness[1]=0.005714285$$

$$Fitness[2]=0.013698630$$

$$Fitness[3]=0.006250000$$

$$Fitness[4]=0.005181347$$

$$Fitness[5]=0.006493506$$

$$Fitness[6]=0.006134969$$

$$\text{Total Fitness} = 0.043472737$$

Probability

Probability of each chromosome equal by $P[i] = \text{fitness}[i] / \text{Total Fitness}$

$$P[1]= 0.005714285/0.043472737= 0.131445255$$

$$P[2]= 0.013698630/0.043472737= 0.315108524$$

$$P[3]= 0.006250000/0.043472737= 0.143768265$$

$$P[4]= 0.005181347/0.043472737= 0.119186123$$

$$P[5] = 0.006493506 / 0.043472737 = 0.149369615$$

$$P[6] = 0.006134969 / 0.043472737 = 0.141122216$$

Cumulative Probability

$$C[1] = 0.131445255$$

$$C[2] = 0.131445255 + 0.315108524 = 0.446553779$$

$$C[3] = 0.131445255 + 0.315108524 + 0.143768265 = 0.590322044$$

$$C[4] = 0.131445255 + 0.315108524 + 0.143768265 + 0.119186123 = 0.709508167$$

$$C[5] = 0.131445255 + 0.315108524 + 0.143768265 + 0.119186123 + 0.149369615 = 0.85887778$$

$$C[6] = 0.131445255 + 0.315108524 + 0.143768265 + 0.119186123 + 0.149369615 + 0.141122216 = 0.999999998 \approx 1.0$$

Randomization

$$R[1]: 0.37$$

$$R[2]: 0.008$$

$$R[3]: 0.971$$

$$R[4]: 0.829$$

$$R[5]: 0.735$$

$$R[6]: 0.359$$

By those random patterns, new chromosomes have listed in below:

Chromosomes 2: [09; 06; 15; 09] >>>>> New Chromosome 1

Chromosomes 1: [27; 24; 27; 12] >>>>> New Chromosome 2

Chromosomes 6: [15; 21; 21; 18] >>>>> New Chromosome 3

Chromosomes 5: [27; 15; 06; 27] >>>>> New Chromosome 4

Chromosomes 5: [27; 15; 06; 27] >>>>> New Chromosome 5

Chromosomes 2: [09; 06; 15; 09] >>>>> New Chromosome 6

And

Chromosome 1: [09; 06; 15; 09]

Chromosome 2: [27; 24; 27; 12]

Chromosome 3: [15; 21; 21; 18]

Chromosome 4: [27; 15; 06; 27]

Chromosome 5: [27; 15; 06; 27]

Chromosome 6: [09; 06; 15; 09]

Crossover

In this case, the crossover rate have set between from 0.2 to 0.5.

R[1]=0.518

R[2]=0.343

R[3]=0.383

R[4]=0.708

R[5]=0.311

R[6]=0.481

By the new randomization and chromosomes, the problem can present in below:

Chromosome 2: [27; 24; 27; 12]

Chromosome 3: [15; 21; 21; 18]

Chromosome 5: [27; 15; 06; 27]

Chromosome 6: [09; 06; 15; 09]

By the random numbers that have given in crossover section, new chromosomes have determined by:

Crossover change rate:

CROSSOVER RATE for new chromosomes:

C[1]= 2

C[2]= 2

C[3]= 1

C[4]= 2

Chromosome 2: Chromosome 2 $\times$ Chromosome 3= [27; 24; 27; 12] $\times$ [15; 21; 21; 18] =
[27; 24; 21; 18]

Chromosome 3: Chromosome 3 $\times$ Chromosome 5 = [15; 21; 21; 18] $\times$ [27; 15; 06; 27] = [15; 21; 06; 27]

Chromosome 5: Chromosome 5 $\times$ Chromosome 6 = [27; 15; 06; 27] $\times$ [09; 06; 15; 09] = [27; 06; 15; 09]

Chromosome 6: Chromosome 6 $\times$ Chromosome 2 = [09; 06; 15; 09] $\times$ [27; 24; 27; 12] = [09; 06; 27; 12]

New chromosomes have illustrated in below:

Chromosome [1]: [09; 06; 15; 09]

Chromosome [2]: [27; 24; 21; 18]

Chromosome [3]: [15; 21; 06; 27]

Chromosome [4]: [27; 15; 06; 27]

Chromosome [5]: [27; 06; 15; 09]

Chromosome [6]: [09; 06; 15; 09]

Mutation

Mutation function can be determine by total gen=number of gen in chromosome*number of population. $4*6=24$. Mutation rate in this case limited in $pm=10\%$. By the mentioned information:

Chromosome [1]: [09; 06; 15; 09]

Chromosome [2]: [27; 24; 21; 18]

Chromosome [3]: [15; 21; 06; **24**]

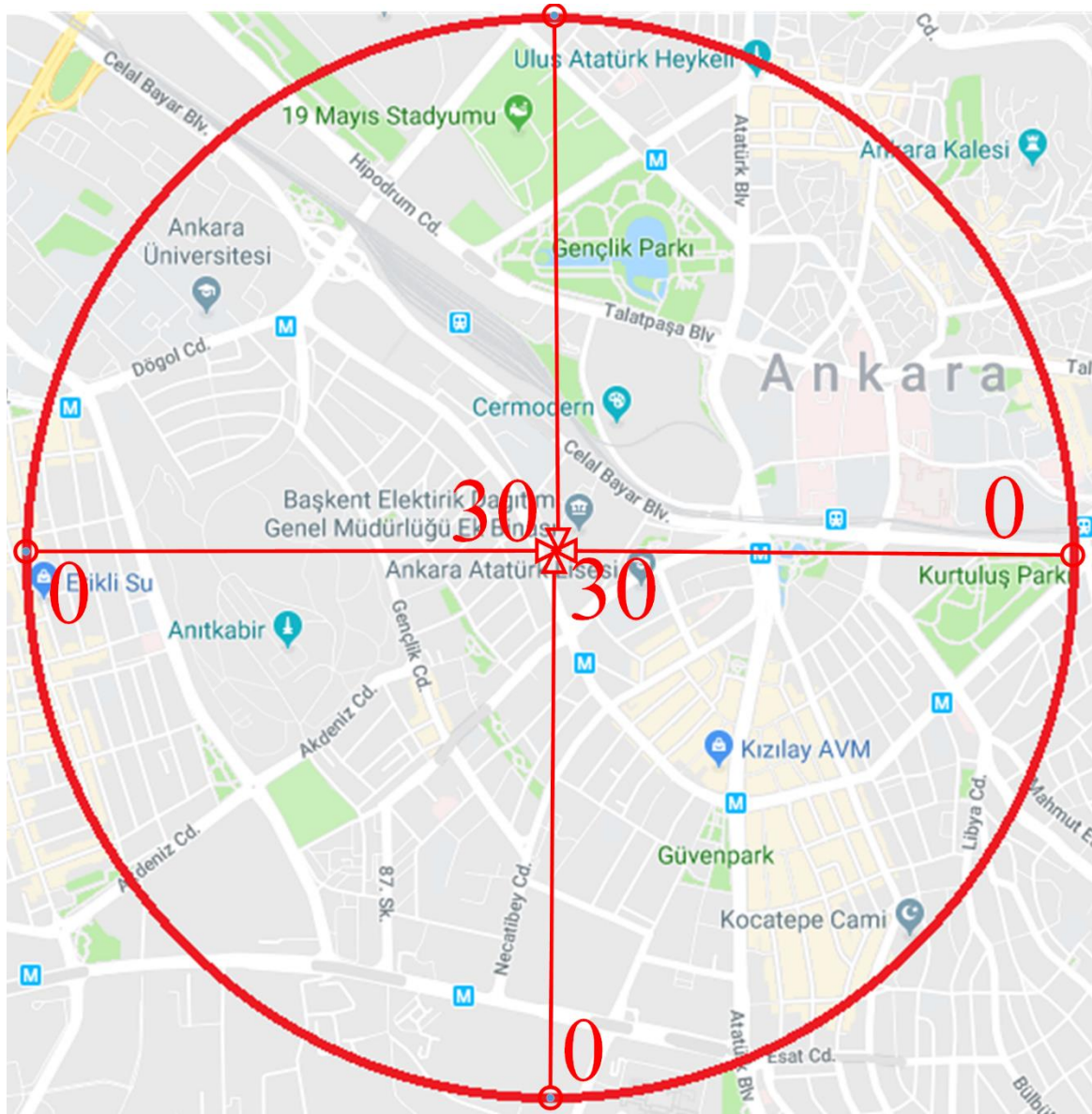
Chromosome [4]: [27; 15; 06; 27]

Chromosome [5]: [27; 06; 15; 09]

Chromosome [6]: [09; **21**; 15; 09]

According to the above-mentioned calculation which has based on GA, each transformer center should be scored from 0 to 30 score (it depend on our estimation algorithm). For example, D transformer center has elaborated in chromosome 1 and 2. In our system, each point has mentioned by a pair of chromosome, first chromosome is for determine location and second is for grid infrastructure. The chromosomes 1 and 2 at first input are Chromosomes 1: [27; 24; 27; 12], Chromosomes 2: [09; 06; 15; 09] and after GA calculation

we have Chromosome [1]: [09; 06; 15; 09], Chromosome [2]: [27; 24; 21; 18]. It means that we should look points inside the D area according to chromosome 1 and 2 and their subsequence parameters. In addition, all gens have been identified by scores which are determined by designer team or organization and it can be changed by estimation algorithm.



Map 6.2. D Point transformer area by the areas score (0~30)

In the map 6.1 has given three points A, B, C and D. the points have determined by the transformers center hierarchy in the Ankara metropolitan ($A > B > C > D$). The green circle means fine point in the map with high priority and the red circle means low priority in the map. The points have determined by the parameters which have mentioned in page 78 (Location: Distance, Local infrastructure, Parking, Electric infrastructure and Electric

Infrastructure: Low Load, Ageing, Transformers Capacity and transformers Health Index). These parameters have been created by the designer and should be calculated by the estimation algorithms. In our calculation, the points have been determined by the parameters priority and D point is selected by the algorithm so location and location infrastructure have more priority in the algorithm hierarchy.





7. CONCLUSION

In this thesis, an algorithm is provided in Appendix 4 which explains hierarchy of how location of EV charge stations should be determined by experimental exemplification from some literatures and Ankara case. This algorithm is made up of three sections, finding location by some specification of grid infrastructure, Categorizing capacity of transformers and transformers analysis. This algorithm especially has been created for grid designers who recently have started to determine some points for charge station in the cities. In Ankara case, stability of the grid is eliminated from the algorithm, because it is a stable grid. This work and similar works hold balance of GHG emission and grid infrastructure benefits. Last but not least, this thesis try to build congruence and connection between theory of algorithm, programming languages and practical strategy for the grid.

According to the mentioned information in Section 5 and 6, GA principles in the case of Ankara metropolitan are adopted by various types of GAs, however it has been provided true results, applying the basic and main GA algorithm. It can be declared that our algorithm can work in other complex GA types. In addition, GA complex versions must meet the basic GA versions requirements. This thesis indicated that the transformers condition, electric infrastructure, budget and some various aspects, which are influenced by the energy consumption are important factors to approach this issue. This research has shown that maintenance history of the grid equipment and infrastructure are the key points in determining some points in electric vehicles charge stations.



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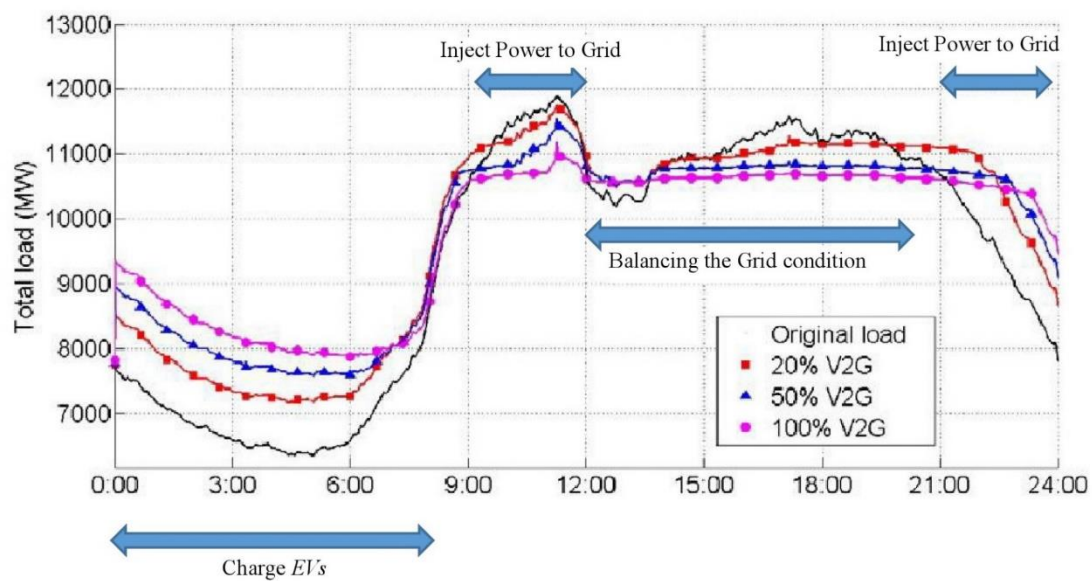


APPENDIX

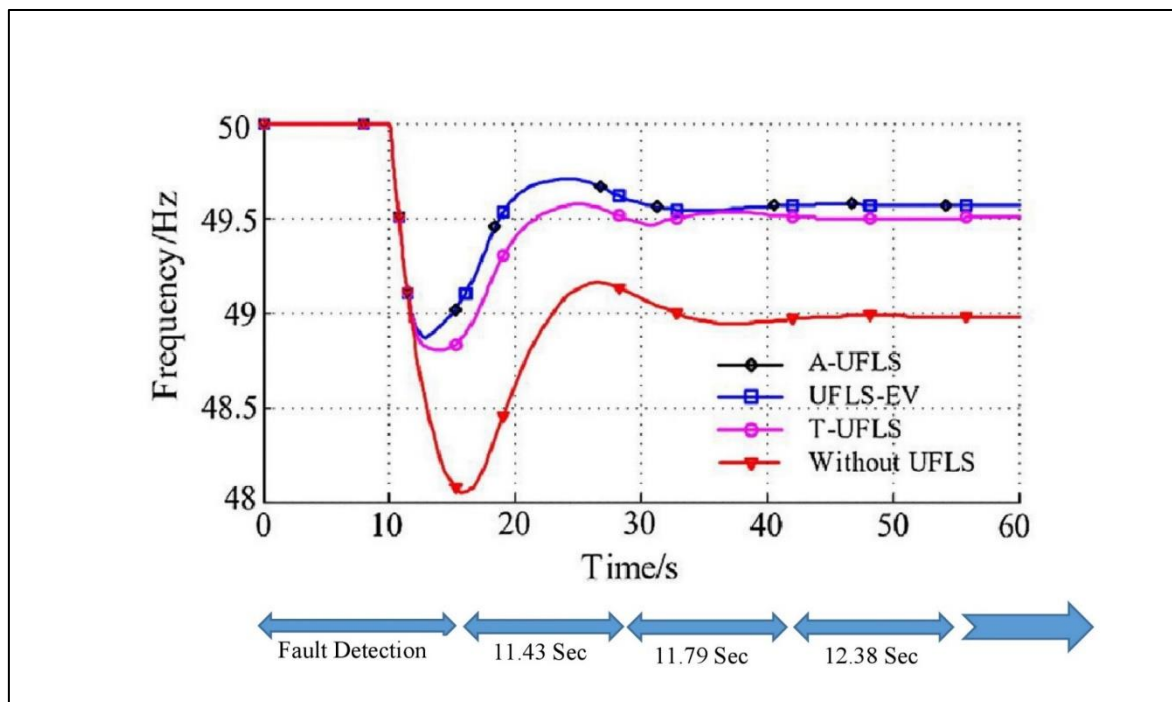
Appendix 1. Amount of cars

Vehicle Manufacture	Quantity
ALFA ROMEO	121
AUDI	5 282
BMW	5 244
CITROEN	747
DS	87
FIAT	63
FORD	6 662
HONDA	3 275
HYUNDAI	4 521
INFINITI	15
JEEP	1 429
KIA	152
LEXUS	15
MAZDA	169
MERCEDES-BENZ	2 914
MINI	757
MITSUBISHI	161
NISSAN	11 423
OPEL	5 040
PEUGEOT	1 615
RENAULT	2 964
SEAT	703
SKODA	13 393
SANGYONG	146
SUBARU	959
TOYOTA	987
VOLKSWAGEN	19 434
VOLVO	1 918

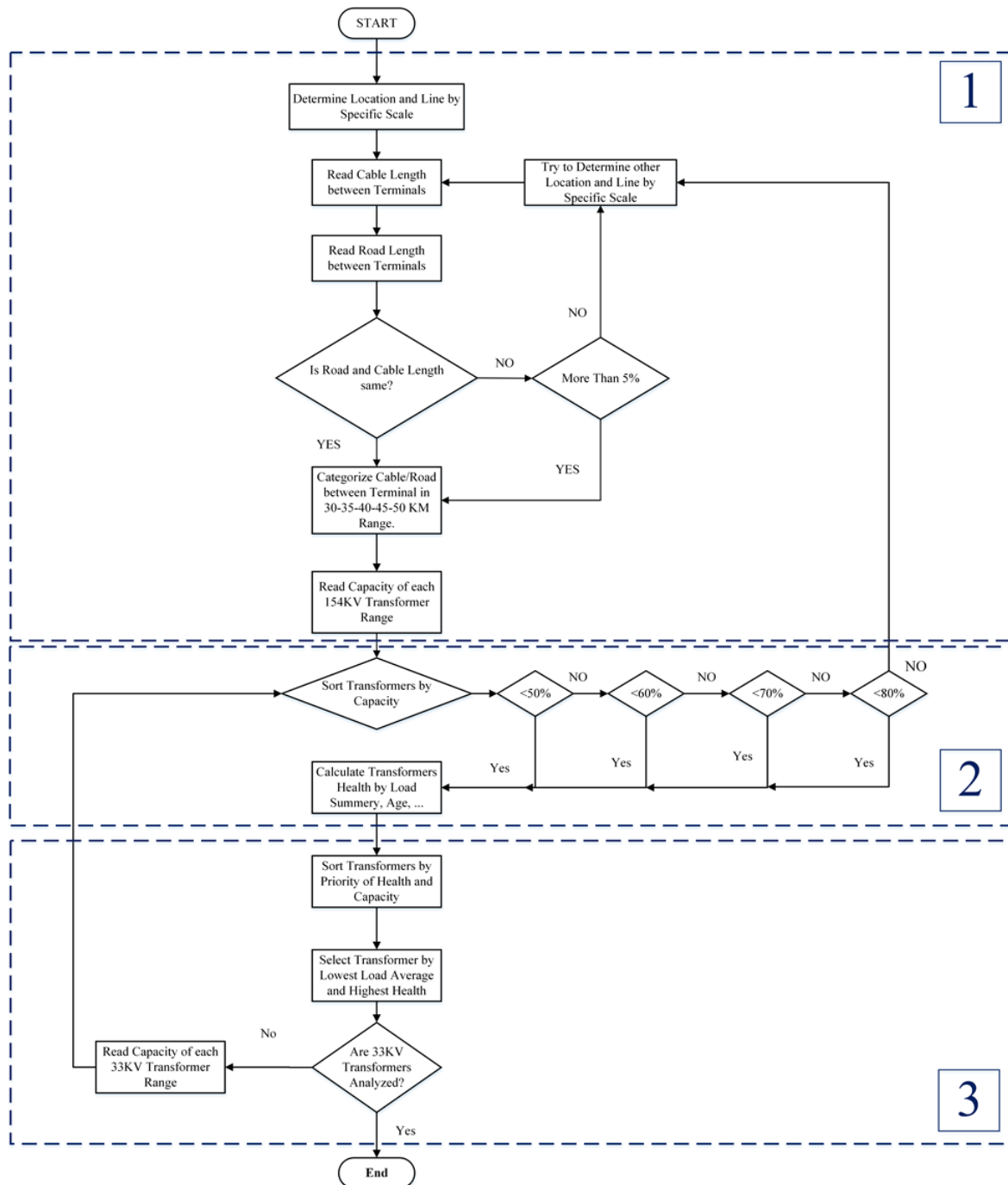
Appendix 2. Grid load curve



Appendix 3. Grid frequency reaction



Appendix 4. Algorithm flow chart



CURRICULUM VITAE

Personal Information

Surname, Name : HARIGHI, Tohid
 Nationality : IRANIAN
 Date and Place of Birth : 22.05.1991, KHOY
 Marital status : Married
 Phone number : +90 552 275 8556
 Fax : +98 44 3626 0090
 E-mail : tohidharighi@gmail.com



Education

Degree	School/ Program	Graduation Date
MSc	Gazi University / Electrical Engineering	Ongoing
Undergraduate	I.A of Tabriz University / Electrical Engineering	2016
High School	Hadaf High School	2009

Professional Experience

Year	Place of Work	Position
2019 - Now	Turkish Accelerator and Radiation Laboratory TARLA (Ankara University Institute of Accelerator Technologies)	Engineer
2017-2019	Department of Electrical and Electronics Engineering at Gazi University	Manager
2017-2018	TUBITAK (Project)	Engineer
2011-2013	Self-employed (Innovation)	Manager

Foreign Language

English, Farsi, Azeri, Arabic, Turkish

Publications

Harighi, T., Padmanaban, S., Bayindir, R., Hossain, E. and J. B. Holm-Nielsen. (2019). Electric Vehicle Charge Stations Location Analysis and Determination – Ankara (Turkey) Case Study. *Energies* 12, (Accepted Paper).

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Hobbies

Rally, Mounting, Walking



GAZİ GELECEKTİR..