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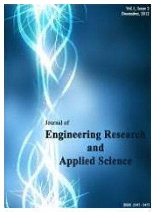

Design and Optimization of Grid-Supported Solar Vehicle Charging Stations

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Abstract
Due to technological developments and population growth, the energy need of our country and the world is increasing day by day. At the same time, as a result of the use of fossil energy resources, the world faces the threat of global warming. It has been determined that carbon emission, which is the cause of global warming, is the leading energy and transportation sectors in our country. Electric vehicle charging stations need to be provided with energy generated by renewable energy sources. In the study, the number of electric vehicles and charging stations in Turkey and the world and the solar charging station status for Turkey were investigated. For the charging of electric vehicles, grid-supported vehicle charging station design was made and working conditions were determined. The electric vehicle load profile for the designed charging station was created using various analyzes. Using the genetic algorithm method for the designed solar charging station, the installation cost was determined based on the number of photovoltaic panels and batteries. In addition to the installation cost, the amount of carbon emissions for the charging stations and the amount of energy received over the network were determined for both cases. As a result, the results of optimization for both cases were compared and the results were discussed. Clean energy generated from energy sources that are available for charging is a necessary stage in achieving the zero emission target in the introduction of electric vehicles.

Keywords: *Solar Energy, Charging Station, Electric Vehicles*

1. Introduction
In the history of humanity, people have been in a constant state of development. Within this development, humanity has made a great progress as of the 19th century and this development has brought about a great need for energy. The consumption brought about by this increase in energy demand has brought the threat of global warming to the surface as of the 21st century. All countries are in a great effort to prevent global warming. In this context, with agreements such as the Paris Climate Agreement and the Kyoto Protocol, they have started to take serious steps for zero carbon emissions in the future.

In our country, it is necessary to examine the distribution of carbon emissions among sectors because it is relevant to the subject. According to the latest data published by the Turkish Statistical Institute (TurkStat) on March 29, 2023, energy-related emissions accounted for the largest proportion of CO2 equivalent in 2021 with 71.3%, followed by industrial processes and product use with a rate of 13.3%, agriculture with a rate of 12.8% and the waste sector with a rate of 2.6% [1].

Since the largest share of greenhouse gas emissions comes from the energy sector, it is once again seen that renewable energy sources must be produced in order for the energy produced to reach the desired targets.
When the greenhouse gas emissions in the energy sector are examined in more detail, a serious CO2 emission is produced in transportation. For this reason, serious steps need to be taken in the field of transport to reduce CO2 emissions.

Some countries are trying to ensure the use of fully electric vehicles in 2030 with legal regulations. It has been decided that the car we will produce in Turkey will be electric and as of 2023, our electric vehicle is on the roads.

As a result of these steps taken by the countries, technological developments in the transportation sector have confirmed that electric vehicles will replace vehicles using conventional fuel.

Although there are developments and steps for the transportation sector to reduce CO2 emissions, the production of electricity from fossil fuels, which will

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be used to charge electric vehicles that produce zero emissions, is not a step towards reducing CO2 emissions in the full sense. In order to fully reduce CO2 emissions, the electricity to be produced for the charging of electric vehicles must also be from renewable energy sources.

In this sense, the subject of research is reducing CO2 emissions and with the technological development towards electric vehicles, the issue of solar charging stations, which are a renewable energy source, is gaining importance.

2. Solar Energy

Solar energy is vital for all living things. Solar energy is an inexhaustible and clean energy source among renewable energy sources. In order to produce electricity in our country and globally, its use is becoming widespread because it does not cause carbon emissions and countries continue to increase their solar energy investments day by day. Our country has also become aware of solar energy and in this context, it encourages the increase of solar energy investments in order to reduce the production of electricity from fossil fuels and to reduce foreign dependence on energy.

2.1. Electricity Generation Statistics from Solar Energy

According to the latest data published by the International Renewable Energy Agency (IRENA), the renewable energy capacity by the end of 2022 was 3372 GW. Hydroelectric power capacity was 1256 GW, solar energy was 1053 GW, wind energy was 899 GW. The other renewable energy source, bioenergy, has reached a capacity of 149 GW, geothermal 15 GW and ocean energy 524 MW [2].
Renewable energy capacity increased by 295 GW in 2021 compared to the previous year. Solar energy continued its leadership in renewable energy sources and a capacity increase of 192 GW was realized. Wind energy increased by 75 GW, hydroelectric power by 21 GW, bioenergy by 8 GW and geothermal energy by 181 MW [2].

In the light of the data in the world, the highest capacity increase among renewable energy sources has been experienced in solar energy.
In Turkey, the total installed capacity of renewable energy sources among primary sources was 57029 MW according to the April 2022 data of the Turkish Electricity Transmission Joint Stock Company (TEİAŞ). Hydroelectric power reached 31583 MW, wind power 11439 MW, solar power 9916 MW, geothermal energy 1719 MW, biomass 1982 MW and waste heat 390 MW [3].

According to the primary sources for our country, the total installed power has been 104473 MW. Natural gas has reached a capacity of 25364 MW, imported coal 10374 MW, lignite 10192 MW, hard coal 841 MW, renewable energy 57029 MW and another 673 MW [3].

According to primary sources, the share of renewable energy sources in the electricity production of our country is increasing as can be seen. The production of electricity from solar energy also has an important place in the obvious.

3. Electric Vehicles

In line with the zero emission target, electric vehicles have been produced and started to be used instead of fossil fuel vehicles. Electric vehicles are completely green and do not cause carbon emissions.

3.1. Working Principle of Electric Vehicles

Electric vehicles consist mainly of electrical and mechanical components. Electric vehicles take the thrust required for movement from the electric motor. The power generated from the electric motor is provided with the necessary mechanical parts. The electric motor, on the other hand, provides the necessary electrical energy from the battery group in itself while providing the movement energy. The main components of the electric car; battery group, electric motor, power control system and mechanical transmission parts.

3.2. Types of Electric Vehicles

Battery electric vehicles

- Hybrid electric vehicles
- Plug-in Hybrid electric vehicles

4. Charging Stations

4.1. Charging Standards

For the charging of electric vehicles, charging stations and charging standards for electric cars have been developed by some organizations operating in this field. The main factor in the formation of these standards has been car manufacturers. In order to make a difference between electric vehicles, different charging standards have been determined in vehicle production. Some of these charging standards that have been developed are; IEC 61851 and IEC 62196, which are used in many countries, especially in European countries, determined by the International Electrical Commission (IEC), are the CHAdeMO standard developed by J1772 created by the American Society of Automotive Engineers (SAE), Tokyo Electric Power Company (TEPCO) and the CHAdeMO association established by Japanese vehicle manufacturers. In our country, the Turkish Standards Institute has developed a standard to be applied for electric vehicles and electric vehicle charging stations by creating TS 13909 and TS 13912 standards based on IEC charging standards.

At this point, sanctions have started to be applied to be on a single type of charging input, such as different brands of chargers for the charging process of mobile phones. Electric vehicle charging standards are also likely to agree on a single charging standard in the coming years.

The main charging standards are;

- IEC international charging standards
- CHAdeMO charging standards
- SAE charging standards

4.2. Charging Station Types

Charging station types are divided according to the current and voltage used for charging. Types of stations;

- Slow charging stations
- Normal charging stations
- Fast-charging stations
- Green charging stations

4.3. The State of Electric Vehicles and Charging Stations in the World

4.3.1. The state of electric vehicles in the world

The number of electric vehicles worldwide broke a record in 2021 despite the Covid-19 pandemic, supply chain disruptions and the chip crisis, as it did in 2020. So much so that 120000 vehicles sold in all of 2012 were sold in just one week in 2021 [4].

In 2022, battery electric vehicles (BEA) and plug-in hybrid electric vehicles (FHEA) sold 10 million more electric vehicles, an increase of 60% compared to 2021. With this increase in 2022, the total number of electric vehicles worldwide has risen to over 26 million [4].

Electric vehicles have achieved the largest increase among other vehicle types worldwide. A large part of the vehicles sold is China. In 2022, 5.9 million electric vehicles were sold, an increase of 60% compared to 2021. After a few years of stagnation in Europe, it was 2.7 million, which is 15% compared to the same period of the previous year. With these rates, 85% of total sales are made up of China and Europe. The other 15% is made up of the United States of America (USA) and other countries. In the USA,80 0000 sales were made in 2022, an increase of 55% compared to the previous year [4].

With the total increases, the total number of electric vehicles in China has reached approximately 13.8 million. Europe has approximately 8 million electric vehicles and the United States has approximately 3 million electric vehicles [4].

4.3.2. The state of the electric vehicle charging station in the world

The total number of charging stations worldwide has reached approximately 2.7 million. In 2021, approximately 9 00000 new charging stations were installed. Due to the impact of the pandemic, the increase of 45% in 2020 was 37% for 2021 and 55% in 2022 [4].

China is also the world leader in terms of the number of charging stations. It has 85% of the fast charging stations and 50% of the slow charging stations in the world. As a result of the stations installed in China for 2022, the number of public slow charging stations is approximately 360000. Fast charging increased by almost 90% to 760000 [4].

Europe comes in second place in terms of the number of charging stations and as a result of new installations there are over 460000 slow charging stations in total, an increase of 50% compared to other years. Fast-charging stations increased by 55% to approximately 70,000. In the U.S., slow charging stations saw a 9% increase. As a fast charging station, 6300 installations were made in the USA in 2022. In total, there are 28,000 charging stations in the U.S. by the end of 2022. Korea, on the other hand, has 184000 charging stations, doubling the number of slow charging stations compared to the previous year [4].

4.4. Status of Electric Vehicle and Charging Stations in Turkey

4.4.1. The state of electric vehicles in Turkey

According to TURKSTAT data, the first electric and hybrid vehicle was registered in Turkey in 2011. As of March 2023, the total number is 171518 [5].
As of the end of 2022, the number of electric vehicles sold increased by 132% compared to 2021. As of March 2023, the number of electric vehicles alone has been determined as a total of 19395 units.

Although the total number of electric vehicles is 19395 units for the time being, it is foreseen that this number will increase rapidly in the coming years, especially with our domestic electric vehicle Turkey Automobile Enterprise Group (TOGG), 1-1.5 million electric vehicles will be on the roads.

4.4.2. Electric vehicle charging station status in Turkey

In 2023, with the newly established charging stations, the number of electric vehicle charging stations was 4498. Of the charging stations that have been installed, there are 898 fast charging stations and 3600 slow charging stations. Due to the development of the electric vehicle market, the number of charging stations is constantly increasing.

4.4.3. The state of grid-powered solar electric vehicle charging stations

Unfortunately, except for a few initiatives established in our country for electric vehicles, they are electric vehicle charging stations that are fed directly over the network.

5. Solar Charging Station Optimization

In order to reduce the optimum installation cost and carbon emissions for the solar charging station, optimization work will be carried out by making acceptances in this section.

5.1. Solar Charging Station Features

The charging unit power of the station will be DC 50 kW and there will be 3 charging units with two sockets to charge two vehicles at the same time. The location of our charging station was chosen as Istanbul because it has the most electric vehicles.

The working principle of our solar electric vehicle charging station is Figure 1. is also shown.

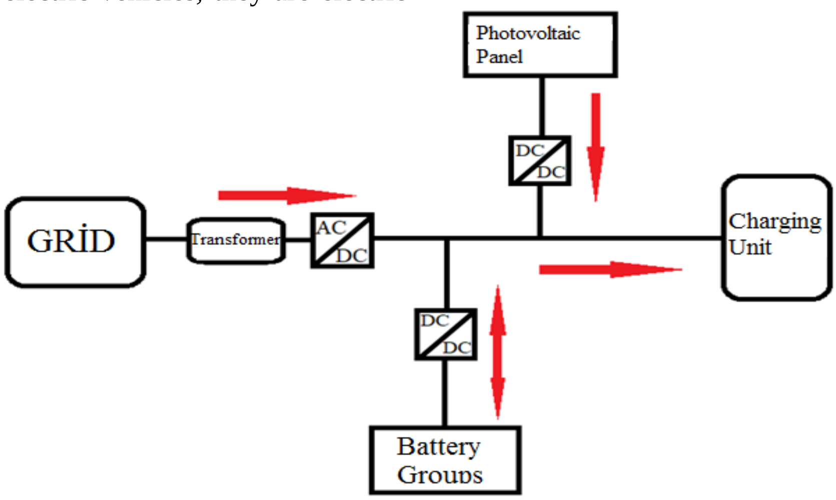

Figure 1. Working principle of solar powered electric vehicle charging station

5.2. Electric Vehicle Technical Specifications

Various brands are available as fully electric vehicles in Turkey. However, for our study, the Renault ZOE model, which is fully electric, will be used in our study on the income status, average distance to be taken, general conditions and sales figures in Turkey.

The battery capacity of our A vehicle is seen as 52 kWh. The calculations to be made will be made on this battery capacity [6].

5.3. Charging station usage statistics

After selecting the vehicle battery power to be optimized for working with the general features of the charging station, it is important to know in which time zones of the day the charging station is used and the number of vehicles using the station within these time zones.

With the information that the highest number of electric vehicles for Turkey is in Istanbul, it has been seen that a charging station usage graph can be created over the Google popular hours graph for Istanbul. For this reason, an electric vehicle charging station in Istanbul has been provided access to the popular hours graph as in Figure 2. Taking the popular hours graph, the weekday and weekend usage amounts graph is modeled as Figure 3.

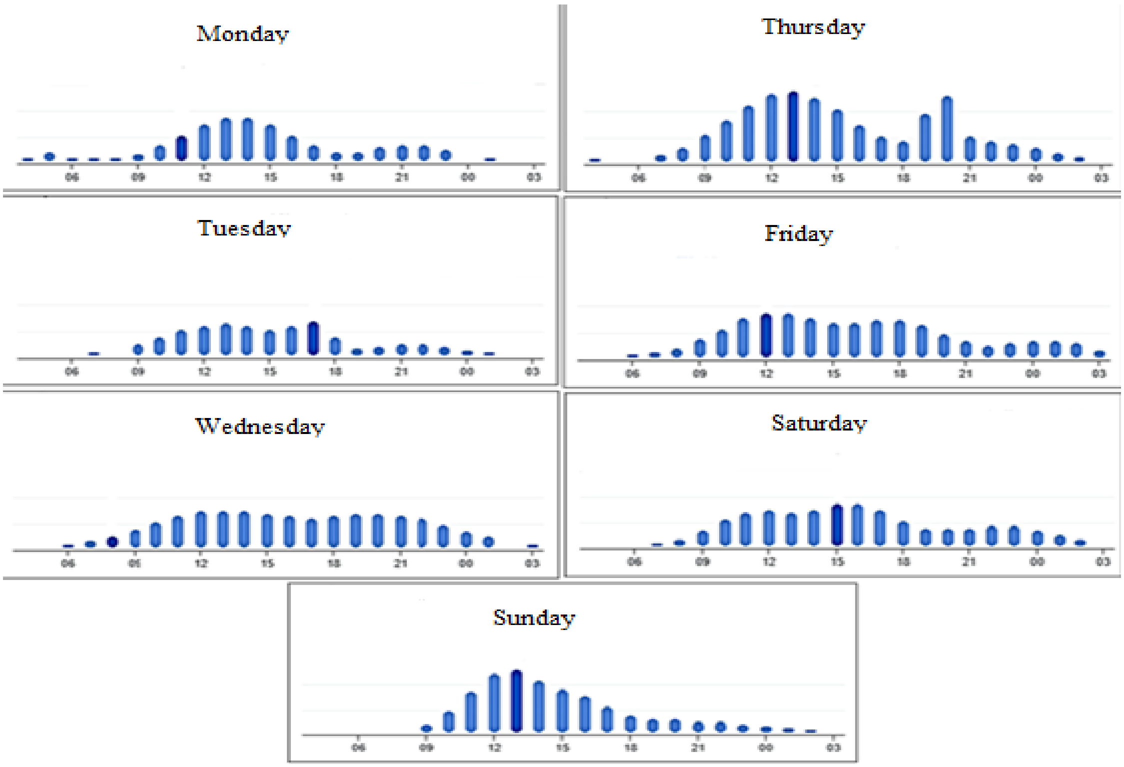

Figure 2. Popularity graph [7]

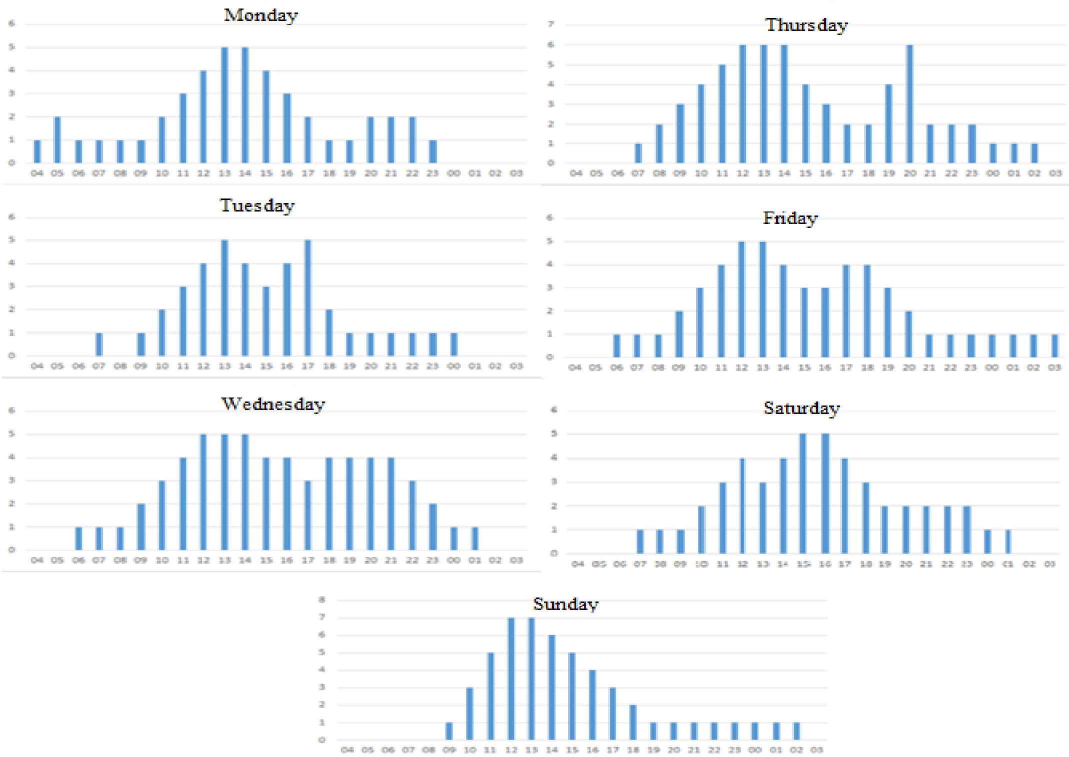

Figure 3. Modeling the popularity graph

Using data from the modelling, five different methods were applied to determine the amount of demand and distributions for the charging station. Applied methods from Monte Carlo simulation and time series analysis methods, moving average method, weighted average method, exponential correction method and trend analysis method were applied to the obtained data.

5.3.1. Monte Carlo simulation

For weekdays and weekends, it was first found how many times it was repeated by investigating the number of incoming vehicles with the amount of demand in the data from the table. After finding the frequencies of the incoming vehicle number data, ie their frequencies, their probabilities were calculated according to the number of vehicles in order to perform the simulation. As a result of the calculation of their probabilities, their cumulative sum was made and the random number intervals to be given for the simulation were determined. 24 random numbers were generated as many hours in a day. The randomly generated numbers were repeated over all days. This step is then called for values corresponding to the random numbers on it. After the values were called, the average of the numbers obtained was taken and the number of vehicles that came as a result of the weekly simulation we wanted was obtained.

5.3.2. Moving average method

In the moving average method, the averages for the four hours preceding the hour to be determined were taken and created using Equation 1.

$$Moving\ average = \frac{\sum number\ of\ vehicle\ in\ the\ previous\ n\ hours}{n} \quad (1)$$

5.3.3. Weighted moving average method

The method of weighing using modeling data is based on the principle that the average weight is summed for the hour to be estimated, starting with the one that was closest to the previous four hours, by giving weights and the calculation formula is shown in Equation 2.

$$\text{Weighted moving avarage} = \frac{\sum\left(\frac{\text{n the weight of te hour}}{\text{number of vehicle arriving n hours}}\right)}{\sum(\text{Weights})} \quad (2)$$

For the weighted moving average calculation, the data closest to the number of vehicles to be estimated is given as 70%. The values were determined by giving 20% and 10% respectively to the next time zones.

5.3.4. Exponential correction method

In this method, modeling data was analyzed using Equation 3 given below.

Hour forecast=last hour forecast+α(last hour actual value - last hour forecast) (3)

The correction constant used in the *formula must be between α* 0 and 1. The calculations are also taken as a constant 0.1.

5.3.5. Trend analysis method

Equation 4 will be used for the trend analysis method. In order to create Equality 4, the equations in Equality 5 and Equality 6 and the values of a and b will be calculated.

$$T_i = a + bY_i \quad (4)$$

$$a = (\sum Y_i/n - b(T_i/n) \quad (5)$$

$$b = (n\sum T_{iY_i} - \sum Y_i \text{ x } \sum T_i) / n\sum T_i^2 - (\sum T_i)^2 \quad (6)$$

In these equations;

T_i = the period denoting hours

Y_i = the number of electric vehicles that come as a result of modeling on weekdays and weekends

is expressed.

Found use Equality 4-6 for weekday value of a 2,3409125 and value of b 0,013913. For weekend value of a 2,15942 and value of b 0,003913. After the calculated values, the results of the analysis were obtained.

5.3.6. Determination of the error rate of the analysis methods performed

After the analysis methods, the error rates will be determined for each method applied in order to select the one closest to the right in all analyzes. It will be used as data for the use of charging stations with the lowest error rate and will be used for later stages.

The formulas of mean absolute error, mean squares error, average absolute error percentage (AAEP) and square root of mean error squares (RMSE) will be used to perform error checking.

$$Mean\ Absolute\ Error = \frac{\sum |\ Number\ of\ vehicle - Result\ |}{n} \quad (7)$$

$$Mean\ Squares\ Error\ = \frac{\sum(Number\ of\ vehicle - Result)^2}{n} \quad (8)$$

$$AAEP\ = \frac{\sum \mid Number\ of\ vehicle - Result \mid Number\ of\ vehicle}{n} \quad (9)$$

$$RMSE\ = \sqrt{\frac{\sum(Number\ of\ vehicle - Result)^2}{n}} \quad (10)$$

The least errors in the results of the analyses were the method and the weighted moving average method that was closer to the modeling, and the data obtained will be used for the daily charging frequency of the electric vehicle charging station in Figure 4.

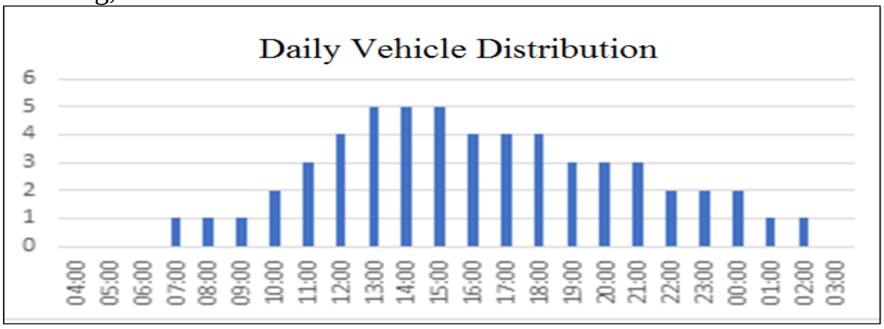

Figure 4. Daily distribution of electric vehicles arriving at the charging station

5.4. Power Drawn from Solar Charging Station

The number of vehicles arriving daily in the one week was determined as a total of 56 electric vehicles. It is assumed that incoming electric vehicles will charge the batteries between 20% and 80%.

The daily load status of the electric vehicles that will come for charging is shown in Figure 5.

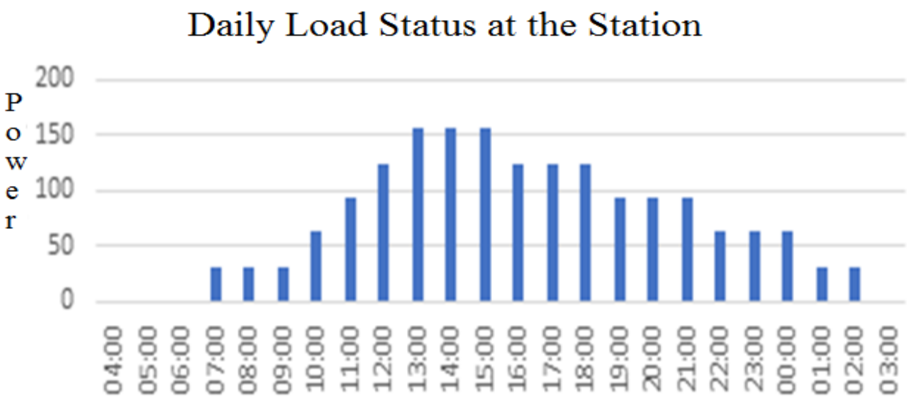

Figure 5: Daily load status at the station

5.5. Optimization of Electric Vehicle Charging Station

It is necessary to specify the features of the PV panel and battery energy storage system (BEDS) to be used to determine the optimum number of PV panels and batteries to be used for the electric vehicle charging station. The features are indicated in Figure 6 and Figure 7.

In case of receiving electricity from the network, it is necessary to know in the tariffs in terms of cost. Figure 8 currently shows the unit costs of electrical energy.

PV Panel Features	
Cell Type	Mono-C Silicon Bifacial PERC
Number of Cells	144 Half Cells
Maximum Power (W)	540
Open Circuit Voltage (V)	49,50
Short Circuit Current (A)	13,85
Dimensions (LxWxK) (mm)	2279 x 1134 x 40 ± 2
Price ($)	243
Lifetime (Years)	30

Figure 6. PV Panel Features [8]

Battery Energy Storage System Features	
Nominal Energy Storage Capacity (kWh)	50
Rated Rated Power (kVA)	45
Number of Batteries	12
Cell Type	LiFePO4
Self-discharge rate	0.002
Depth of Discharge (DOD) (%)	90
Cycle	6000
Price ($)	100.000

Figure 7. Battery Energy Storage System Features [9]

Tariff Name	Single Time ($/kWh)	Day (06-17) ($/kWh)	Puant (17-22) ($/kWh)	Night (22-06) ($/kWh)
Public and Private Services Sector and Other (30 kWh/day and below)	0,117	0,156	0,228	0,099
Public and Private Services Sector and Other (30 kWh/day and above)	0,155	0,156	0,228	0,099

Figure 8: Turkey electricity pilaw price tariff chart [10]

As we have seen examples today, PV panels are now installed on the pump areas of fuel stations, ie canopies. The designed electric vehicle charging station will also be used in canopy areas with the same idea. In case of insufficient, administrative buildings and even the installation area of the station will be installed in appropriate areas.

For Turkey, the station façade widths to be established in accordance with the "Regulation on the Facilities to be Built and Opened by the Highways" are determined as a minimum. The electric vehicle charging station to be built is designed as 50 meters of the canopy façade width. The total canopy area was determined as 2000 square meters [11].

Considering that a panel size of approximately 2 square meters is for the charging station designed to be installed on the canopy, a maximum of 800 panels will be installed considering the distances between PV panel arrays. If the number of PV panels to be installed in S PV is mentioned, the constraint in Equality 11 is obtained.

$$S_{PV} \leq 800 \qquad (11)$$

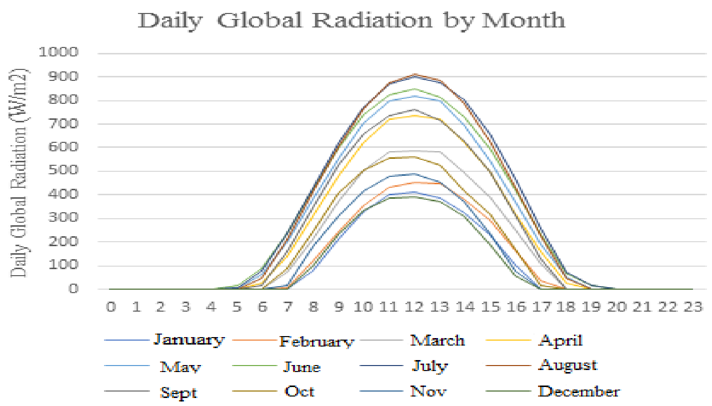

Figure 9: Month-by-month and average daily global irradiance of the station location

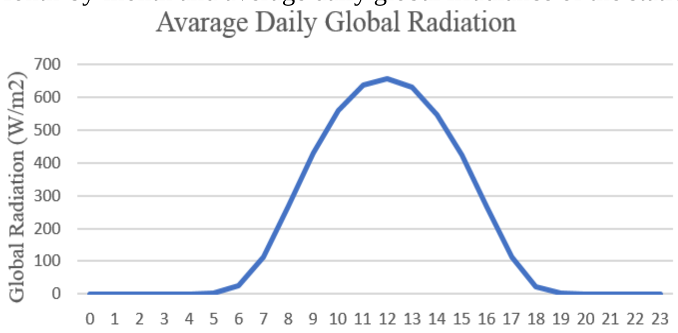

Figure 10. Average daily global radiation of the station location

Equality 12 is used to make the power calculation of the PV panel at the time t.

$$P_{\text{PV-çıkış}}(t) = P_{\text{Nom}} x \left(\frac{G(t)}{G_{\text{stk}}}\right) x[1+K_T(T_c(t) - T_{\text{stk}})] \qquad (12)$$

In equation 12, the power of the P_{Nom} panel under the standard test conditions given as a reference, the global solar radiation measured on the PV panel at the time of G(t) t, the global solar radiation under the standard test conditions of the G_{stk} (G_{stk} = 1000 W/m^2), the temperature coefficient varying according to the characteristic of the K_T panel, *the Tc(t)* t defines the temperature of the panel at the time and T_{stk} defines the temperature under standard test conditions (T_{stk} = 25^{o}C).

Since the temperature will not be examined for the optimization study, *Tc(t)* = 25^{o}C is taken. After all; Equality 13 is obtained.

$$P_{\text{PV-çıkış}}(t) = P_{\text{Nom}} x(G(t)/1000) \qquad (13)$$

For the electric vehicle charging station, the power to be obtained from the panels at the total time t is obtained as Equality14.

$$P_{PV}(t) = S_{PV} x P_{Nom} x(G(t)/1000) \qquad (14)$$

The mathematical model for charging and discharging at moment t for BEDS is shown in Equality 15 [33].

$$\text{E}_{\text{BEDS}}(\text{t})=\text{E}_{\text{BEDS}}(\text{t-1}).(1\text{-}\sigma)+\left[\text{P}_{\text{BEDS}}^{\text{şarj}}(\text{t}).\eta_{\text{BEDS}}^{\text{şarj}}.\alpha_1(\text{t})\text{-P}_{\text{BEDS}}^{\text{deşarj}}(\text{t}).\eta_{\text{BEDS}}^{\text{deşarj}}.\alpha_2(\text{t})\right].\Delta\text{t} \qquad (15)$$

Equality 15 de *E* BEDS*(t)* denotes the energy of the $_{BEDS}$ at time t, the *self-discharge* rate of the σ battery system, the charging power at time t, the discharge power at time t, and the efficiency at charge and discharge, and the time interval considered.

$$P_{BEDS}^{şarj}(t) P_{BEDS}^{deşarj}(t) \eta_{BEDS}^{şarj} \eta_{BEDS}^{deşarj} \Delta t$$

The expressions and used in equation 15 are used to determine that the charging and discharging of BEDS will not occur at the same time.$\alpha_1(t)\alpha_2(t)$

$$\alpha_1(\text{t})+\alpha_2(\text{t})=1 \qquad (16)$$

During the charging process, the Escore will take the values of 17, while during the discharge process, the Equation will take the values of 5.18.

$$\alpha_1(t)=1, \alpha_2(t)=0 \quad (17)$$

$$\alpha_1(t)=0, \alpha_2(t)=1 \quad (18)$$

Equation 19-21 for BEDS needs to be set out for certain restrictions.

$$P_{BEDS}^{deşarj}(t)<P_{max}^{deşarj} \quad (19)$$

$$P_{BEDS}^{şarj}(t)<P_{max}^{şarj} \quad (20)$$

$$E_{BEDS}^{min}\leq E_{BEDS}(t)\leq E_{BEDS}^{max} \quad (21)$$

The maximum and minimum values of the BEDS energy specified in equation 21 relate to the percentage of deep discharge (DOD) of the battery used. This relationship is shown in Equality 22.

$$E_{BEDS}^{min}=(1\text{-}DOD).E_{BEDS}^{max} \quad (22)$$

5.5.1. Cost function for optimization

It is necessary to determine the equation in order to make optimization. In this context, for the optimization of the genetic algorithm, it is aimed to determine the number of solar energy panels and BEDSs to be used for the installation of solar electric vehicle charging stations and to calculate them in a way that will have the least cost as a result.

The cost of station installation for this purpose will be referred to as the total cost (TM). TM formula specifies the PV panel and BEDS installation cost (KM) and SKM_ii specifies the number of PV panels and BEDS. The optimization equation will be Equality 23.

$$TM=\sum_{i=1}^{n} KM_i x S_i \quad (23)$$

For the total cost, the change that may occur during the year is not taken into consideration of the item such as maintenance. The life span for PV panel is close to the life of the station. BEDS is expected to approach station life with the development of battery systems.

The cost of electricity will be calculated over Equality 24.

$$M_{şebeke}=\sum_{t=1}^{T} (P_{şebeke}(t).E_{tarife}(t)) \quad (24)$$

In equality, t tells the grid tariff price at the time.E_{tarife}

5.5.2. Environmental function

Renewable energy sources are becoming of great importance for reducing pollution environmentally. If renewable energy is insufficient, electricity has to be taken from the network. Due to the receipt of electrical energy from the network, the atmosphere is damaged due to CO 2 and CO 2 equivalents CH_4 and N_2 O gases. The greenhouse gases to be used will be defined to include all other gases under the name of CO 2 equivalent.

The environmental function is the second purpose function;

$$E_{env} = \sum_{t=1}^{T}(E_{CO_2-co}(t)) = \begin{cases} 0, & P_{grid}(t)=0 \\ P_{grid}(t)(e_{CO_{2}-eş}), & P_{grid}(t)\neq 0 \end{cases} \quad (25)$$

This equation also includes the emission of the total gases, CO 2, CH 4 and N 2 O are the emission factors of the CO 2 equivalent at the time t of their gases, and finally the $E_{env}E_{CO_{2co}}(t)$ emission factors as the CO2 equivalent of CO $_2$, CH $_4$ and N_2O gases, the expression of which will also be adjusted according to the selected energy type.

5.5.3. Constraints for optimization

Equality restriction; For charging at the station, the charging load at the time t must be equal to the total power supplied via the PV panel, BEDS and mains.

$$\frac{P_{EV}(t)}{\eta_{şarj}}\text{-}P_{PV}(t)+P_{BEDS}^{şarj}(t).\eta_{BEDS}^{şarj}.\alpha_1(t)\text{-}\frac{P_{BEDS}^{deşarj}(t)}{\eta_{BEDS}^{deşarj}}.\alpha_2(t)= P_{şebeke}(t) \quad (26)$$

It is known that charging and discharging cannot be done at the same time as mentioned in Equation 25 and Equation 16. Decision variables and positive values should be selected.$S_{PV}S_{BEDS}$

Restriction of inequality; This inequality constraint has previously given definitions for BEDS in Equality 19-21. In addition , as shown in Equation 26, it can only receive the power required for the station from the grid.

$$P_{şebeke}(t)\geq 0 \quad (27)$$

6. Results

The optimization of the grid-supported solar electric vehicle charging station is examined on two cases. In the first case, BEDS will only be charged with electrical energy produced through PV panels. No energy will be taken from the network in any way.

In the second case, electrical energy can be taken from the network and the night tariff, where the energy received from the network is the cheapest, ie between 22:00 and 06:00, the stored energy of the battery will be used and the load demand of the electric vehicles coming during these hours will be met over the network.

6.1. Failure to Receive Electrical Energy from the Network

The designed grid-supported electric vehicle charging station was provided with the electrical energy produced through PV panels without receiving energy from the network and the energy and load demand required for the battery on recurring days without receiving energy from the network.

The program was run fifty times for genetic algorithm optimization. The data resulting from the optimization were recorded and the optimum PV panel number and BEDS number averages were taken and the minimum cost was obtained.

Due to the lack of electrical energy over the network, the number of PV panels is expected to be close to the maximum number of 800 PV panels, and as a result, the installation of 720 PV panels has been the most optimum result for the system.

One of the reasons for the results close to the maximum level of the number of PV panels is the amount of energy that needs to be provided for BEDS.

Since no electrical energy is received from the network for the situation, the energy to be stored over the battery must be responded to the load demand until 18:00 and 05:00 when the sun starts to rise, as shown in Figure 10. As a result of the optimization, it was determined that the required energy capacity was 896.22 kWh and it was the optimum number for 18 BEDS stations. The minimum corporate cost was determined as 1974960,00 $.

Since no electrical energy is used over the grid, carbon emissions are not caused environmentally.
The power graph at the station as a result of optimization and the capacity ratio of the BEDS to be used are shown in Figure 11.

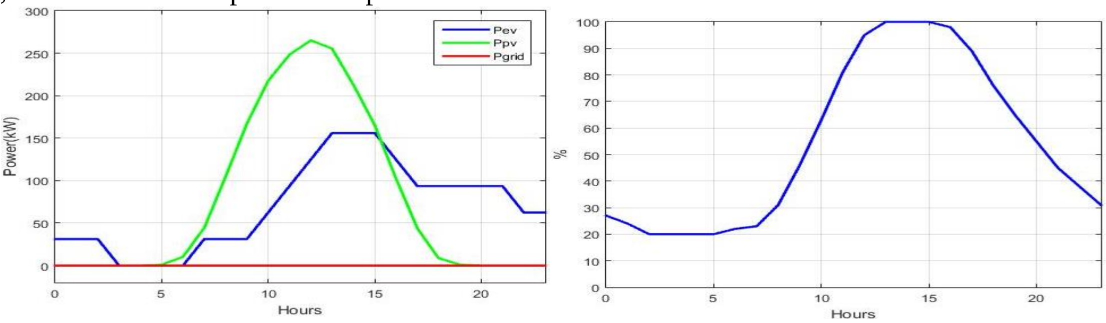

Figure 11. PV panel, load and network powers on the station and BEDS capacity ratio state-1

6.2. Receiving Electrical Energy from the Network

The electrical energy produced through the PV panels during the periods when the solar rays are sufficient for the load demand for the charging station will be given directly for the electric vehicle charging. During the day when solar energy is sufficient, the energy required for BEDS will be met by the electrical energy produced by PV panels. The electrical energy required for electric vehicles in the time frame when the incoming charging load cannot be met by PV panels will be provided through BEDS. At night time, when the electricity tariff is the cheapest, i.e. between 22:00 and 06:00, the charging load of the electric vehicle in the system will be covered by the network.

The program was run fifty times for genetic algorithm optimization. The data resulting from the optimization were recorded and the optimum PV panel number and BEDS number averages were taken and the minimum cost was obtained.

According to the results of the optimization, the optimum number of PV panels was determined as 653. The energy capacity required for BEDS was found to be 623.93 kWh, which is the optimum number for 13 BEDS stations. The minimum institutional cost was determined as $ 1458679.

The power graph at the station as a result of optimization and the capacity ratio of the BEDS to be used are shown in Figure 12.

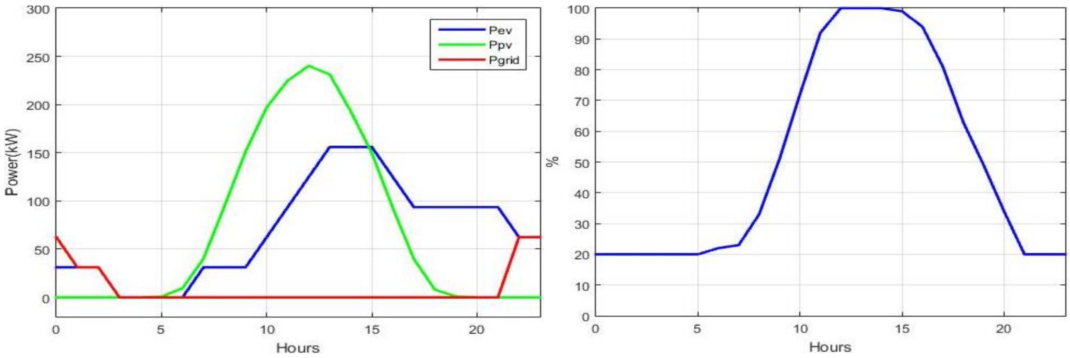

Figure 12. PV panel, load and network powers on the station and BEDS capacity ratio status-2

The electrical energy received over the network is not included in the installation cost. The cost of electrical energy received over the network is the operating cost. However, the amount of electrical energy received from the grid causes carbon emissions. It has been determined that 218.4 kWh of electrical energy will be taken daily over the network and 79716 kWh of electrical energy will be used annually. You will be paid annually for the electric power of $ 7891.88.

Carbon emission due to the electrical energy used For Turkey, the equivalent parameter of 0.484 tons of CO2 per 1MWh will be used for consumption at distribution points calculated by the Ministry of Energy and Natural Resources of the Republic of Turkey. [12].

As a result of the electrical energy received over the network, the annual carbon emission amount was determined as 38582,544 kg $CO_{2\text{-}co}$/kWh.

Considering that the BEDS system has 6000 cycles, it is seen that the lifetime of BEDS is 16 years. Assuming that the annual electricity price increase is 10% per year, it is determined that a total of 1594320 kWh of energy will be taken from the network for the station, 452007,70 $ will be paid, and approximately 360 tons of $CO_{2\text{-}co}$/kWh emission will be produced in return.

7. Conclusion

Design and optimization work has been carried out for grid-supported solar vehicle charging stations. Two situations for the charging station were investigated, as well as installation costs and carbon emission rates for operating situations.

The load profile was revealed by applying analysis methods over the modeling data to determine the number of incoming vehicles by determining the load profile for the station as a real point.

The genetic algorithm was decided by performing the literature review of the optimization study and the optimum installation cost was calculated by optimizing in both cases.

As a result of the optimization, it has been seen that the energy needs of BEDS and electric vehicles are in accordance with climate change agreements and zero emission target only if energy is provided through PV panels. In the second case, it was seen that only the cheapest night tariff caused serious carbon emissions in the case of purchasing electrical energy over the grid. When the installation costs are compared, even if the second situation seems to be more advantageous, it is evaluated that the station life reaches the same values with the electrical energy to be provided over the network later when the life of the station is considered at least as much as the life of BEDS.

In line with the reduction of carbon emissions and the zero carbon emission target of the Paris Climate Agreement, the use and dissemination of environmentally friendly electric vehicles without emission emissions instead of the existing gasoline and diesel vehicles used in transportation has become a necessity instead of being recommended.

In line with the global target, many countries are taking giant steps to encourage electric vehicles and take initiatives for the necessary charging infrastructure.

In order for electric vehicles to become widespread, it is absolutely necessary to increase and expand the installation of charging stations. While installing the charging stations, the network infrastructure should be developed in parallel.

Even if electric vehicles are called clean and environmentally friendly, the energy used to charge electric vehicles with electricity obtained from conventional fuels causes the environmentalist understanding and zero emission target to move away.

The electricity to be used for the charging of electric vehicles must be produced from renewable energy sources. In this respect, the use of solar energy for the charging process of electric vehicles in renewable energy sources is one step ahead of other energy sources.

Although steps have been taken to charge electric vehicles for our country, the electricity used for charging is used over the network. Unfortunately, a large part of the electricity produced in our country is produced from conventional sources. For this reason, in the investments to be made for the charging of electric vehicles, it is necessary to give importance to the charging of electric vehicles with electricity produced with renewable energy sources, especially solar energy.

In order to reduce carbon emissions and reach the targets set, we can accept Turkey at the initial stage of electric vehicles and charging stations. In order to achieve the goals, the designed and optimized solar-powered charging stations need to be rapidly expanded. The reason for this is that the emission results clearly show that every step taken using clean energy sources will bring us one step closer to the goal of zero carbon emissions.

The study is intended to set an example for our country and raise awareness about the clean energy steps to be taken.

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