



Design of a Grid Connected Solar Charging Station for Electric Vehicles

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Accepted 17 February 2022

Abstract

The increasing energy need in today's world and the recent energy crises have led to many problems, and in the face of these issues, countries are trying to mitigate the harms caused by the existing system, especially to nature, with new energy sources and systems. As new studies emerged regarding these issues in the field of transportation, due to the serious investments in this area, it became possible to switch to electric vehicle production and to break away from internal combustion vehicles that are harmful to nature. In this study, which was carried out in the context of this development, which is a particularly important breakthrough for foreign-fossil fuel-dependent countries such as our country, a design was developed for a charging station with a roof installation panel, that can provide energy feedback to the grid in the case of high or insufficient electrical energy production from solar panels for electric vehicles. As a result of the field and examination requirements for installation, the system outputs were created with simulations and iterations made using the Simulation and Iteration Program for SPP Systems program (PVSOL), and the results were evaluated and made ready for implementation.

Keywords: Electric vehicles, Solar energy, Panel, Electricity, Energy optimization, Charging station, Simulation

1. Introduction

Rapidly depleting petroleum resources in the world, possible energy crises as a result of these decreasing resources, environmental problems caused by fossil fuels and many other factors have brought about new research endeavors in the energy sector. As a result of these endeavors, electric vehicles have started to take their place in the market today and some companies have even started mass production.

Although our country is highly dependent on foreign countries in terms of oil and its derivatives, our country, which is in a much more fortunate geography than the European region in terms of electricity production with alternative production sources such as solar production and dams, may have a very important place in the electric vehicle market with an electric charging station network that it can

establish using solar energy power plant and other alternative source power plants to reduce its dependence on petroleum-derived resources and to meet its energy need within its own borders and therefore make an important breakthrough from foreign dependency to high export rates [1]. To answer the question of what steps need to be taken to make such a system possible, we need to consider how and in what ways we are currently using and will be using electrical energy, which has made developing new transportation technology, like autonomous vehicles, a necessity and is also accepted as an answer to that necessity. Based on this idea, it is beneficial to first examine the types of electric vehicles and the charging structures of these vehicles.

2. Electric Vehicles and Charging Connection Structures

In recent years, there have been periodic problems in the supply of fossil fuels. Also, not all the effects of the gases coming out of the exhausts of existing

vehicles on the environment are known and studies aiming to learn and prevent these effects are still ongoing [2]. Due to these reasons, in line with the

developing economy, automotive manufacturers in developed states and countries are working on alternative solutions to vehicle technology. Of these alternatives, electric vehicle technologies are the most up-to-date and are defined as the vehicle technology of the future. If we look at it from the

structural systems point of view, we can examine the existing vehicle types under 3 categories [3].

- Fully electric vehicles (TEA)
- Hybrid electric vehicles (HEA)
- Fuel cell electric vehicles

2.1 Charging Connector Connections and Standards-Based Modes

Electric vehicle charging is divided into different types and the systems to which manufacturers are connected, the existing standards of the countries where they produce and the charging structure of the system integrated into the vehicle have led to the development of charging systems covering the standard and safety systems suitable for all vehicles produced. If we examine the charging modes developed according to the voltage and output values regulated within the scope of these standards and the voltage type, socket type, voltage, and current values contained in these modes, the systems are briefly as follows.

Mode 1, in short, is the domestic charging structure. Alternative current (AC) can go up to 250V in one phase and 480V in 3 phases through an outlet and is at the level of 16A, but it is not preferred because it does not have a security system [4].

Mode 2 is a version of the mode 1 system that has been secured by adding communication with the adapter connection and has been upgraded to 32A [5].

Mode 3, There is an input system with 7 pins on it. These 7 pins have different functions. Three separate phases (L1, L2, L3), neutral connection, grounding connection, and control and communication pins (Proximity & Control Pilot) There are 4 charging stages, 3.7 kVA (16A, Single Phase - 230V AC), 7.4


kVA (32A, Single Phase – 230V AC), 11 kVA (16A, Three Phase – 400V AC), 22 kVA (32 A, Three-Phase – 400V AC)

Mode 4 is a regulated mode for fast charging and covers charging from Direct current (DC) powered stations up to 500A. It ensures that the AC source drawn from the mains is converted to DC via the inverter at a fast-charging station and given directly to the vehicle's battery pack (without entering the rectifier). Current max. The value is measured as 300 kWh [6].

CHAdEMO, in this charging standard, which emerged in the Far East, there is also a DC socket in addition to the socket where you can charge the Mode 3 type. It offers to charge up to 250 V DC and 200 A [3].

CSS (Combine Charge System), According to the type and power of the connected energy source, the 7-pin part at the top performs Mod3 type charging and the lower part performs Mod4 type charging. The DC charging station has a charging power ranging from 22kW to 300kW and can be charged at varying times depending on the capacity of the vehicle [7].

In Table 1 below, power values are given within the scope of charging cable types, input module structures, and standards [8].

Connector Standard	Connector and input structure	Connector Specifications
IEC 62196-2		230V(1 phase) – 400V(3 phase) 16A/32A /64A 3,7kW – 43kW Type 1 (SAE J1772), Type 2 (MENNEKES) Type 3 (SCAME)

SAE J1772		120V(1 phase) – 240V (2 phase) 6A/32A
CHAdeMO		250V DC 8A-200A
IEC 62196-3 – CCS COMBO		500V DC 600A 300kW Type 4

Table 1. Connector connection and types

3. Solar Charging Station Project Overview and Analysis

In the light of the widespread development we have mentioned, the idea of establishing a charging station that allows investment to meet the increasing need again has emerged, a station that will pay for itself while meeting today’s needs, and that allows us to invest in its future development in the face of

increasing need in the future [9]. The products required for the installation of a charging station and the selection of these products should be made entirely on the basis of a system that corresponds to the need. Cost and maintenance costs are also among the first factors, to be taken into account.

3.1. Photovoltaic Panel, Inverter, and Internal MPPT Selection and Compatibility Phase

Solar panels, or photovoltaic panels, are structures that absorb the sun's rays and refract these rays repeatedly, which makes their cells behave as if the rays are striking again and again, producing electricity in the form of circulating the electrons they detach from the photons in their cells [10].

(Grid Connected Inverters), Off-Grid (Grid Independent Inverters), Hybrid (Inverters Using Battery and Grid Simultaneously), Micro Inverters. Since the choice made in this regard could possibly be insufficient for the system, the on-grid inverter was chosen by also considering the cost factor [11].

The most suitable panel model for the system to be installed, which was selected as the most suitable in terms of structure, efficiency, cost, and compatibility with the inverter, was chosen to be the CWT450-144PM-HC product made by the domestic manufacturer company CW Enerji Muhendislik Ticaret Sanayi Ltd. Sti. The inverter, known as a power converter, is an electrical power converter that converts current into alternating current. The AC power generated as the output of the inverter can be of any voltage and frequency depending on the transformers, switching, and control circuits used. As mentioned, the inverters used in GES systems are full sine inverters, but they are divided into 4 groups with new models currently being developed. On-Grid

The main task of the MPPT (Maximum Power Point Tracking) is to monitor the instantaneous energy production levels of the cells on the panels, thus achieving the highest production level under given conditions and keeping the system at this level, ensuring that the production remains at the most efficient level [12]. The panel inverter compatibility calculation to be used in the system was calculated within the scope of the Excel study made for the purpose of measuring compliance in the light of the catalog values, at the same time, the selection of the appropriate panel was made in line with this calculation, and the MPPT module compatibility was also done using the Excel file as seen in Table 2.

Table 2. Panel-inverter harmony Excel table visual

PANEL INFORMATION;			INVERTER INFORMATION;		
Maximum Temperature(tmax):	85	°C	Inverter Max.DC Input Voltage:	1100	In
Minimum Temperature(tmin):	-40	°C	Inverter Min. DC Input Voltage:	200	In
PV Temperature Rate of Return (Voc)(k):	-0,304	%/°C	Inverter Max. MPPT Input Voltage:	1000	In
PV Temperature Rate of Yield (Vmp)(k):	-0,36	%/°C	Inverter Min. MPPT Input Voltage:	200	In
PV Standard Test Conditions(tnom):	25	°C	MPPT Array Input Count:	2	Custom
Max. Number of Series Panels(a):	13	Custom	MPPT Max. Input Current:	26	A
Maximum Voltage (Vmp):	41,4	In	MPPT Short Circuit Input Current:	40	A
Open Circuit Voltage (Voc):	49,2	In			
Short Circuit Current (Isc):	11,61	A			
Maximum Current (Imp):	10,87	A			
1.Case:	Voc(-10°C) =	707,6534	<	1100	Appropriate
2.Case:	Voc(25°C) =	552,1027	>	200	Appropriate
3.Case:	Vmp(25°C) =	606,0132	<	1000	Appropriate
4.Case:	Vmp(70°C) =	451,0116	>	200	Appropriate
	Inverter Max. Short Circuit Current=	23,22	<	40	Appropriate
	Inverter Max. Switching Current=	21,74	<	26	Appropriate

The panel inverter compatibility calculation to be used in the system has been calculated with the help of the Excel table above, based on the following criteria.

- Instantaneous panel cell temperature
- Maximum required MPPT power
- Panel residual current value
- Panel maximum power, rated power, and minimum power ratings

- Harmonic filtering (automatically provided by the inverter in the form of a value below 3%)
- PV module-inverter compatibility equations

Following the calculations, the 100kWh SUN2000-100KTL-M1 model by the Huawei company (which can operate up to 150kWh with its full sine intelligent structure if needed) was selected in the system [13].

3.2. Evaluation of the Work on the Area and Area Selected for System Installation

The area the installation will be made is on the main road route in Bursa Province Gemlik District, which is located very close to the Turkey Auto Entrepreneurs Group (TOGG) company facilities, which will be completed soon, and in the state-allocated part of the AWM parking lot, which uses the same parcel as the indicated roof of the Akmanlar wooden construction materials building, which is nearby to existing workplaces as seen in Figure 1 [14]. Building information;

- Height from the ground: 12 meters

- Roof slope: 6.24%
- The panel area for the southern part of the ridge section of the roof is 529.6 m²
- The panel area for the southern part of the ridge section of the roof is 534 m²
- The number of 144-cell panels to be placed on the roof is 488 in total
- Reinforced mesh model with roofing material metal shingle panel layout



Figure 1. Satellite image of the selected location.

The modeling image of the PVSOL (The design and simulation software for photovoltaic systems) building can be seen in Figure 2.

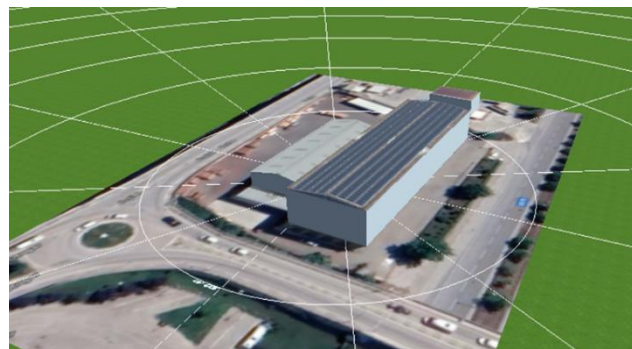


Figure 2. PVSOL Modeling image.

Another step of the system field installation phase is the selection of the charging station device and the installation of the system's panel. Considering the selection of a device with communication and control protocols, it was deemed appropriate to integrate 4

charging stations from the product into the system. The selected product was the DC High-Speed Charge Station- Electrical Vehicle, EVC03 DC 90 CHSP, made by the ZES (Zorlu Energy Solution) company [15].

The panel assembly part needed to be installed in accordance with the TEDAŞ (Turkey Electricity Distribution Inc.) regulations and to provide approval for the necessary permits [16].

- 50×10 mm², 4,45kg/m Copper Busbar (total 44.5kg),
- 8 mm Diameter, 0.25 kg/m, Copper Busbar (total 5kg),
- Class 1 Type Insulator (6 units),
- Lily AWG 3 (72.8 kg/km) (total 3.2 kg),
- Single Tensioner: Swallow – 3/0 (2 sets),
- 230/400V, 50 kA Metal Oxide (ZNO) Surge arrester (2 pcs.),
- 220 V, 25 A Switch Auto Fuse (2 pcs.),
- 220 V, 40A, Switched Auto Fuse (4 pcs.),
- Leakage relay 200A 230/400V (2pcs)
- Combi x/100 V, x/5 A, Electronic Meter (1 item),
- 3 Phase, 4 Wire, 4 Tariff, Dement meter, Active Electronic Electricity Meter (1 item)
- 3x 80 A, Icn = 8 kA, 1.7xIcn, Power Layer: 0.5 Thermal Magnetic Compact Switch (2 pcs),
- 3x 400 A, Icn=25 kA, 2.1xIcn, Power Layer: 0.25 Thermal Magnetic Compact Switch (4 pcs),
- Panel Carcass (110x120x207cm), known as Fixed and Automatic Compensation,
- At 400 Volts, Power Capacitor Battery (40 kVA),
- ABB CM UFD network relay (1 item) to separate the system from the network in case of unusual events that will occur in the network
- 3x2500/5, 15 VA, Sn:0,5 Current transformer (2 pieces) to measure the current

- passing through the circuit from the connection from both sides of the roof block
- Finally, one of the most important parts, the emergency stops button (2 pieces) to be used to stop the system manually.

In this installation, the cable selection, the cable being the connecting element that will hold the above-described system together, was selected using calculations in Excel format, and a sample calculation is seen in Table 3.

Table 3. A sample calculation of the AC cable transport voltage drop in the system elements

AC CABLE CURRENT TRANSPORT AND VOLTAGE REDUCTION CALCULATION TABLE			
CONVEYABLE POWER (kW):	185		
TRANSPORT DISTANCE (mt):	75		
CABLE CUTOOUT:	120		
NUMBER OF CABLE CIRCUITS:	2		
CABLE CURRENT TRANSPORT CAPACITY:	435		
NOMİNAL CURRENT(C):	267,34	CU VOLTAGE DROP (%):	0,71688
NOMİNAL CURRENT*1,2(C):	320,81	AL VOLTAGE DROP (%):	1,14469
NOMİNAL CURRENT*1,25(C):	334,18		
CABLE CURRENT CARRYING VALUE(C):	752,46		

4. Programming, Simulation Phase, and System Evaluation

The system was arranged in the context of the above-mentioned evaluation and TEDAŞ specifications and implemented in the PVSOL simulation program. The mentioned system includes electricity purchase and

sale fees, system energy balance, and cost analysis based on the integration and outputs of the selected products and systems.

4.1. Registered Electric Vehicle Groups and Graphs Obtained in the Context of Simulation

In order to avoid unknown factors in terms of system functionality, a total of 35 vehicles with different charge types and battery values from the most preferred models and brands in the region today were registered, and the effects of daily and weekly use of the registered vehicles on the system were determined. 5 different vehicle models charging with Japanese DC charging socket types and features were

- Model 3: AUDI e-tron 50 Quattro 90kWh (DC Charging) 5 vehicles and an average range of 341 km,
- Model 4: Renault ZOE R135/Z.E. 22kWh (AC charging) 10 vehicles and an average range of 386 km,
- Model 5: Honda e Advance-Package 16" 56 kW (DC charging) 5 vehicles and an average range of 222 km,

In the region where the system, which was measured using 5 different simulation programs where the data closest to the real value was obtained and which was prepared using the obtained data, is installed;

- Sunbathing, radiation, radiation, and horizontal diffuse values as shown in Figure 3.

recorded in the system and outputs were observed [17].

- Model 1: Volkswagen Golf.3 1st 11kWh (AC Charging) 10 pcs vehicles and an average range of 424 km,
- Model 2: BMW i3 50kWh (DC Charging) 5 vehicles and an average range of 359 km,
- 21-year production rate monitoring of panels are as shown in Figure 4.
- Output values according to the difference in the roof direction and connection types of the inverters
- Ambient temperature and panel temperature values as shown in Figure 5.
- Inclined surface radiation values
- Measured values over the realistic system

The graphs obtained from these values are as given below [6].

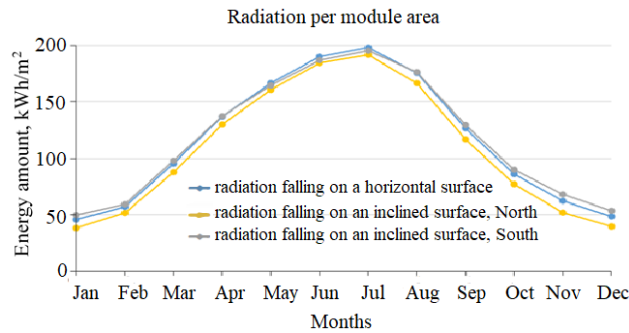


Figure 3. Horizontal radiation and radiation graph per module area

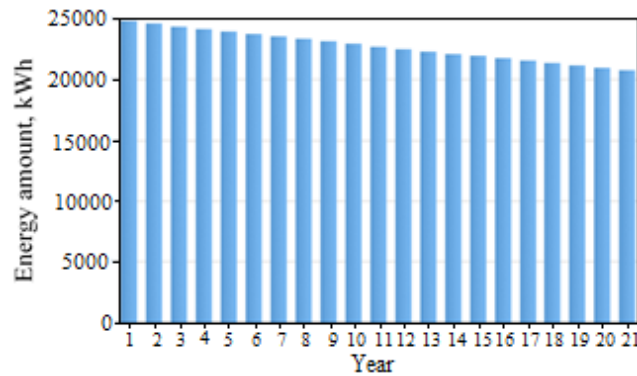


Figure 4. As a result of 21 years of iteration, the yield reduction rate of the panel is given.

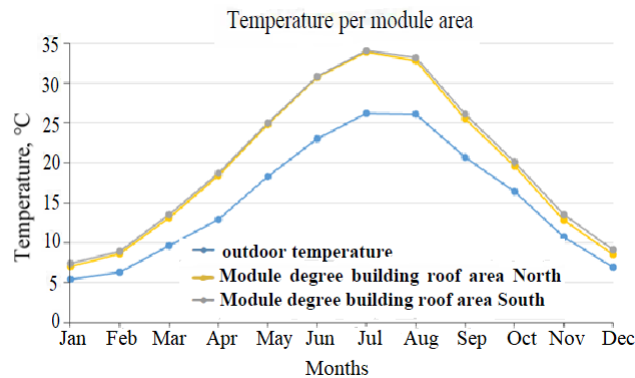


Figure 5. Temperature curves are given per module area in the direction in which the panels are installed

After the connections were completed within the framework of the calculations made above and the regulations created in this direction and as a result of the values obtained with the graphical results, the vehicles were registered to the system, the average

consumption for the unregistered vehicles and the system were determined (60000kWh per year), and the results were obtained by making the system general simulation calculation as shown in Tables 4-7.

Table 4. Total production, consumption, vehicle usage, non-internal monthly average consumption, and received and given values from the network.

Months	PV (AC mains)	Average Consumption added off the record	Stand by (Inverters)	Vehicle charging (from panels)	Vehicle charging (from the grid)	Received from the grid	Grid
	Kwh	Kwh	Kwh	Kwh	Kwh	Kwh	Kwh
Jan	8348	5095.9	4.9	5595.5	5086.5	8620.3	1185.5
Feb	10507.5	4602.7	4.2	7315	4018.1	6957.3	1524.7
Mar	17546.8	5095.9	4.3	8971.7	3252.1	6245.7	6468.7
Apr	25385.5	4931.5	3.8	10914.3	1427.2	3947.9	12056.7
May	29937.2	5095.9	3.8	11496.1	1443.3	3794.3	15692.6
Jun	33700.3	4931.5	4	11914.5	668	2798.6	18981.1
July	34524	5095.9	3.8	12043.6	945.4	3207.2	19642.7
Aug	30667.2	5095.9	3.7	11849.2	1109.9	3607.5	16216.2
Sept	22547.7	4931.5	4	10176.2	1940.8	4572.6	10067.9
Oct	15486.7	5095.9	4.3	8802.4	3437.2	6503.1	4650.1
Nov	11315.5	4931.5	4.7	7494.3	4070	7318.6	2133.7
Dec	8881.1	5095.9	5.3	6736.9	4824.5	8327.1	545.7

Table 5. System energy balance sheet values are given with positive and negative values.

Total Radiation - Horizontal.	1,389.72 kWh/m ²	
Deviation from the standard spectrum	-13.90 kWh/m ²	-1.00 %
Ground Reflection Coefficient (Albedo)	0.66 kWh/m ²	0.05 %
Orientation and Tilt of the module surface	-6.10 kWh/m ²	-0.44 %
Module-independent shading	-7.46 kWh/m ²	-1.14 %
Reflection on the module surface	-16.93 kWh/m ²	-1.24 %
Total Radiation on the Module	1,353.46 kWh/m ²	
	1,353.46 kWh/m ²	
	x 1062.232 m ²	
	= 1,437,688.93 Kwh	
Total PV Radiation	1,437,688.93 Kwh	
Contamination	-6,872.11 Kwh	-0.48 %
STC Conversion (Nominal efficiency of module 2.67 %)	-1,135,005.80 Kwh	-79.33 %
Rated PV Energy	295,811.02 Kwh	
Module-specific partial shading	0.00 Kwh	0.00 %
Low light performance	-7,186.92 Kwh	-2.43 %

Deviation from the nominal module temperature	-12,959.82 Kwh	-4.49 %
Diodes	-0.74 Kwh	-0.50 %
Non-compliance (manufacturer information)	-5,513.29 Kwh	-2.00 %
Incompatibility (configuring/shading)	0.00 Kwh	0.00 %
PV energy (DC) without inverter regulator	270,150.99 Kwh	
DC startup output could not be reached	-9.39 Kwh	2.00 %
Regulation for MPP-voltage range	0.00 Kwh	0.00 %
Max. Regulation for DC Current	0.00 Kwh	0.00 %
Max. Editing for DC Performance	0.00 Kwh	0.00 %
Max. Performance/regulation for AC cos phi	0.00 Kwh	0.00 %
MPP Matching	-472.05 Kwh	-0.17 %
PV Energy (DC)	269,669.54 Kwh	
The energy at Inverter Inlet	269,669.54 Kwh	
The input voltage deviates from the rated voltage	-245.51 Kwh	-0.09 %
DC/AC Transformation	-5,254.87 Kwh	-1.95 %
Consumption at Standby (Inverters)	-50.91 Kwh	-0.02 %
Total cable losses	-15,321.81 Kwh	-5.80 %
PV Energy (AC) Excluding Standby Use	248,796.44 Kwh	
PV module energy (AC network)	248,847.35 Kwh	

Table 6. Simulation results are included in the table of general value and result outputs and CO₂ emission value measurements.

PV module output	219.6 kWp
Annual Specific Earnings	1,132.95 kWh/kWp
System utilization rate (PR)	82.7 %
PV module energy (AC network)	248.847 kWh/Year
Charging the electric vehicle	139.684 kWh/Year
The arrangement at the feeding point	6 kWh/Year
Mains supply	109.166 kWh/Year
Personal Power Consumption	56.1 %
Avoided CO ₂ emissions	116.934 kg/year
Consumer (Informal charging and system)	60.000 kWh/Year
Consumption at Standby (Inverters)	51 kWh/Year
Charging of electric vehicle (registered)	145.533 kWh/Year
Total consumption	205.583 kWh/Year
Welcomed with PV	137.353 kWh/Year
Welcomed by e-vehicle	0 kWh/Year
Covered by the grid	65.900 kWh/Year
Solar Energy Ratio	67.9 %
Initial charging	1.844 Kwh
Charging of the electric vehicle (Registered Total)	145.533 kWh/Year
Charging of electric vehicle (PV system)	113.310 kWh/Year
Charging of electric vehicle (Mains)	32.223 kWh/Year
Discharging the electric vehicle to meet consumption	0 kWh/Year
Losses due to charge/discharge	20.357 kWh/Year
Station losses	17.043 kWh/Year
Consumption by mileage traveled	109976 Kwh

Distance traveled annually	632235 kilometer
With solar energy value met	492249 kilometer
Total consumption	205.583 kWh/Year
Covered by the grid	65.900 kWh/Year
Degree of autarky	67.9 %

Table 7. Total cost based on the financial analysis values of the system and energy cost ratios and parameters per vehicle trip

Mains supply in the first year (including performance degradation of the module)	108.807 kWh/Year
PV module output	219.6 kWp
Commissioning of the system	10/05/2022
Evaluation Period	20 Years
Interest in the principal	0.17 %
Return on Assets	19.06 %
Economic Parameters	
Accumulated cash flow (cash balance)	11,716,056.59 ₺
Depreciation period	5.7 Years
Cost of electricity generation	0.8 ₺/kWh
Cost of a trip without PV	60.66 ₺/100 km
Cost of travel with PV	27.69 ₺/100 km
Payments Overview	
Installation Costs	3,100,935.00 ₺
Installation Expenses	3,100,935.00 ₺
Incoming Subsidies	0.00 ₺
Operating expenses	15,000.00 ₺/Year
Operating expenses	15,000.00 ₺/Year
Consumption-related costs	5,000.00 ₺/Year
Consumption Costs	5,000.00 ₺/Year
Annual Miscellaneous Expenses	5,000.00 ₺/Year
Other Expenses	5,000.00 ₺/Year
Payments and savings	
Total payment made by the Network Operator in the first year	136,008.47 ₺/Year
The sum of the savings in the first year and the charging fees received from the vehicles (18% value)	382,246.47 ₺/Year
TEDAŞ tariffs - Business Administration (Offset)	
Validity	15/05/2022 - 14/05/2042
Special Feeding Fee	1.25 ₺/kWh
comes from feeding to the grid	136,008.47 ₺/Year
Tariff entered (TEDAŞ Specification Values)	
Energy Price	2.64 ₺/kWh
Base price	45.00 ₺/Month
Inflation Rate for Energy Price	7.43 %/Year (Month-Based)

5. Conclusion

The system planned to be installed is to be established very close to the local vehicle factory TOGG, which is close to completion, as well as to the city of Bursa, which is close to the GEMPORT international port and has made a name for itself in the automotive industry in our country, and to many factories that are engaged in high-volume production activities, such as Renault. The planned system is located in a very active region, as mentioned in detail in the area selection section with roof-integrated modeling.

The system was designed with the aim of being able to respond to an average of 50 vehicles with the number of unregistered vehicles and the registered

vehicle system determined by the calculation of the system simulation, and the consumption amounts included on the basis of this value, with the electrical energy produced from the panels to meet the charging need of these vehicles up to 67.9%. It provides a 19% return on assets and 56.1% operational power consumption in accordance with today's payment system, independent of the charging station fees from the electricity that is not used in the current period in production and sold to the grid.

While the panels used in the system produced 219.6 kWp output, it produced 248.847 kWh/year, thus providing the opportunity to supply 137,353 kWh of the 205 kWh/year energy needed from the panels,

while 109,166 kWh of electricity was sold to the grid

With this structure, the system was put into a 20-year iteration with the electricity bill earnings account that was not added to the charging fees of electric vehicles, where the amortization period was 5.8 years and the costs remained at the current level of 7%, which is the monthly rate of change of inflation, and where the principal was 0,17% natural. Even in the absence of any non-interest investment in the bank account, it made a profit of 11,716.056.09 ₺ at the end of the 20th year, and this value offers the opportunity to generate income up to 324-962% as a result of vehicle fees and the transactions to be applied to the deposited money.

Considering these earnings rates, the system is open to future developments. One potential development being the installation of the hybrid inverter system, which is currently very high in cost, in which the

to generate income.

system is connected to the grid while allowing the system to turn itself over during periods of power interruption with battery connection or without the need for electricity purchase while remaining connected to the network in periods of possible insufficient production or instant high need.

In addition to these changes, in order for the system to be an investment for the future, the number of users that the system wants to respond to can be expanded with panels, inverters, panels, and new charging stations that will respond to the necessary permits and appropriate conditions in the near future by making the necessary negotiations within the roof of the AWM, which is located in the parcel within the same area as the installed system and the roof and new floor of which is still in construction.

References

- [1] B. van Kamp, I. and van den Berg, F., (2018). Health Effects Related to Wind Turbine Sound, Including Low-Frequency Sound, and Infrasound. *Acoustics Australia*, 46(1), 31-57. Doi: 10.1007/s40857-017-0115-6
- [2] Jiang, X., and others, (2017). Coordination Dispatch of Electric Vehicles Charging/Discharging and Renewable Energy Resources Power in Microgrid, *International Congress of Information and Communication Technology (ICICT)*
- [3] McLaren, J., Miller, J., O'shagusseney, E., Wood, E., & Shapiro, E. (2016). Emissions associated with electric vehicle charging: Impact of electricity generation mix, charging infrastructure availability, and vehicle type (No. NREL/TP-6A20-64852). National Renewable Energy Lab. (NREL), Golden, CO.
- [4] International Electrotechnical Commission, (2011). IEC 61851-1 - Electric vehicle conductive charging system - Part 1: General requirements.
- [5] Lie, T.T., Prasad, K., Ding, N., (2017). The electric vehicle: a review, *International Journal of Electric and Hybrid Vehicles*, 9, 49
- [6] Nordelöf, A., Messagie, M., Tillman, A., & Söderman, M. (2014). Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles—what can we learn from life cycle assessment? *The International Journal of Life Cycle Assessment*, 1866-1890.
- [7] Anderson E., 2014, Real Time Pricing for Charging Electric Vehicles, *Energy Policy Institute's Fourth Annual Energy Policy Research Conference (V.27, I.9)*
- [8] Gomez, J.C, Medhat, M.M, "Impact of EV Battery Chargers on the Power Quality of Distribution Systems", *IEEE Transactions on Power Delivery*, vol.18, no.3, 2015.
- [9] Zhang, W., Huang, M., & Jiang, J. (2015). Optimal daytime charging strategies for electric vehicles considering photovoltaic power system and distribution grid constraints. *Mathematical Problems in Engineering*

- [10] Colak I., Bayındır R., Aksoz A., Hossain E. and Sayılğan S., 2015, Designing a Competitive Electric Vehicle Charging Station with Solar PV and Storage, 2015 IEEE International Telecommunications Energy Conference (16321779)
- [11] Husain, İ., “Electric and Hybrid Vehicles Design Fundamentals”, CRC Press, New York, 2003
- [12] Delucchi, M., & Jacobson, M. (2011). Providing all global energy with wind, water, and solar power, Part II: Reliability, system and transmission costs, and policies. Energy policy, 1170-1190
- [13] Tulpule, P., Marano, V., Yurkovich, S., & Rizzoni, G. (2013). Economic and environmental impacts of a PV powered workplace parking garage charging station. Applied Energy, 323-332
- [14] Carter, R, Electric Vehicle Charging Station Placement and Management Yanhai Xiong Nnayang Technological University 2018
- [15] Ertugrul, N. (2016, November). Battery storage technologies, applications, and trend in renewable energy. In the 2016 IEEE International Conference on Sustainable Energy Technologies (ICSET) (s. 420-425). IEEE
- [16] Stapleton, G., & Susan, N. (12-Nov-2012). Grid-connected solar electric systems: the Earthscan expert handbook for planning, design and installation.
- [17] Van Den Bossche, P. (2014). Electric vehicle conductive charging system-Part 24: Digital communication between a dc EV charging station and an electric vehicle for control of dc charging. IEC, 1-63.