IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⁜ Impact Factor 8.021 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 11, Issue 7, July 2023

DOI: 10.17148/IJIREEICE.2023.11701

Integrating Solar PV, Wind Energy and Wireless Charging for Electric Vehicles on Roads

Ummemisbah Bhisti[1], Pramod Patil[2], Kunal Chougale[3], Nirmal Patil[4], Rahul Kale[5]

Student, Electrical Engineering Department, DKTE'S Society Textile and Engineering Institute, Ichalkaranji, India [1-5]

Abstract: Electric vehicles (EVs) are becoming increasingly popular due to their potential to reduce carbon emissions and improve air quality. The use of EVs can significantly reduce carbon emissions from the transportation sector, which is one of the largest sources of greenhouse gas emissions globally. As renewable energy sources such as solar and wind become more prevalent, the carbon footprint of EVs will continue to decrease. Electric vehicles (EVs) are expected to have a significant impact on the load of the conventional electric grid. To mitigate the potential impact of EV charging on the grid, various strategies are being implemented. One such strategy is the described in this paper. The main objective of research is to make use of renewable energy sources like solar and wind energy in combination with wireless technology which can help to reduce the carbon footprint of EVs and reduce the strain on the conventional electric grid. This will help to dramatically shorten EV charging periods and extend their range, making them more suitable for long-distance travel. The paper states the practical model and its calculation and simulations at the end.

Keywords: Electric Vehicle, Solar Energy, Wireless Charging Grid, CO2 Emissions, Power.

I. INTRODUCTION

A PV and wireless-based EV charging system combines photovoltaic panels and wireless technology to provide a sustainable way of charging electric vehicles. This innovative technology promotes sustainable energy use and has the potential to revolutionize the electric vehicle industry.

ELECTRIC VEHICLE

Electric vehicles (EVs) are a rapidly growing technology that offer a number of benefits over traditional vehicles, including lower fuel costs, reduced emissions, and improved performance. The primary advantage of EVs is that they emit fewer harmful pollutants. EVs require less maintenance because they have fewer moving components than conventional vehicles. Though EVs have been around since the 1830s, it wasn't until the 1990s that they began to make a comeback driven by advancements in battery technology and concerns about environmental pollution.

CONVENTIONAL GRID

Conventional electric grid faces issues such as transmission losses, poor power quality, and a lack of access to energy in remote areas. Researchers are also examining the social and economic impacts of these alternatives, such as community-owned micro-grids that provide affordable and reliable energy to rural areas while boosting local economies. India's conventional electric grid has an installed capacity of over 380 GW, primarily fueled by coal, which results to increase carbon footprint. The government initiatives is promoting renewable energy sources and investing in upgrading transmission and distribution infrastructure.

CONVENTIONAL GRID

Conventional electric grid faces issues such as transmission losses, poor power quality, and a lack of access to energy in remote areas. Researchers are also examining the social and economic impacts of these alternatives, such as community-owned micro-grids that provide affordable and reliable energy to rural areas while boosting local economies. India's conventional electric grid has an installed capacity of over 380 GW, primarily fueled by coal, which results to increase carbon footprint. The government initiatives is promoting renewable energy sources and investing in upgrading transmission and distribution infrastructure.

DOI: 10.17148/IJIREEICE.2023.11701

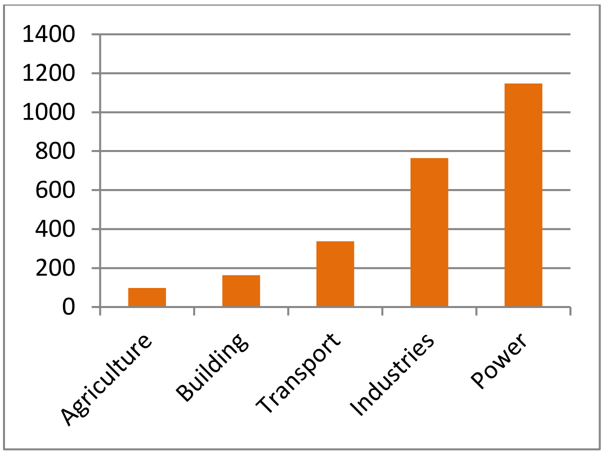


Fig 1: CO2 emissions from the Indian energy sector

SOLAR ENERGY

Solar energy has become a popular source of renewable energy globally due to falling solar panel costs, government incentives, and growing environmental concerns. Solar energy technologies are of two types: photovoltaics (PV) and concentrating solar-thermal power (CSP). The International Energy Agency predicts that solar energy could become the world's largest electricity source by 2035. He et al. (2020) found that solar power integration in Taiwan could improve energy efficiency and reduce carbon emissions. Solar power currently accounts for about 3% of the world's electricity generation, with China being the largest producer, followed by the United States, Japan, and Germany. The integration of solar energy into the grid can be challenging due to its intermittent nature, and this has led to the development of energy storage systems to store excess solar energy for later use. Rasheduzzaman et al. (2021) review article discussed challenges & opportunities in integrating solar energy into the grid & highlighted the importance of energy storage systems & smart grid technologies. In conclusion, solar energy is a rapidly growing industry that provides clean and sustainable energy. The use of solar energy is not limited to electricity generation, as it can be used in various ways. One study by Li et al. (2021), finds energy storage and smart grid tech improve reliability and stability of China's solar grid, with policy support.

WIRELESS CHARGING

Wireless charging technology using magnetic resonance coupling has been around since Nikola Tesla demonstrated it in the 19th century, but only recently has it become useful. Today, there are almost six different wireless charging methods in use.

Wireless charging technology, using magnetic resonance coupling, it can potentially enable EVs to charge while driving. This concept, also known as dynamic charging, involves installing wireless charging pads on the road surface that can charge EVs while they are in motion. The technology is similar to wireless charging pads used for smartphones, with a transmitter coil on the road generating a magnetic field to create electrical current in a receiver coil in the vehicle.

Electromagnetic induction transfers electricity from the first coil to the second, achieving a charging efficiency of 80-90%, equivalent to cable charging. Arash Tavakoli et al. (2020) analyzed the efficiency of wireless power transfer (WPT) systems for EVs and suggested optimizing parameters for improvement. The technology relieves drivers of concerns about running out of battery power, reducing the need for frequent recharging stops.

Hyung-Jun Kim et al. (2020) assessed the safety of wireless charging technology for EVs and found that exposure levels were safe. Along with that California Department of Transportation tested a wireless charging system for electric buses on a dedicated lane, effectively charging buses while moving.

Wireless technology is a game changer which eliminates the need for a physical connection between the charger and the EV, which saves time and makes charging more convenient, it saves time and avoids the hassle of handling charging cables. Moreover, dynamic charging has the potential to significantly reduce charging times and increase the range of EVs, making them more practical for long-distance driving.

Calculation

I. SOLAR:

The number of solar panels needed to charge an electric vehicle depends on several factors, such as the size of the solar panels, the efficiency of the panels, the capacity of the EV's battery, the amount of sunlight available in the area, and the charging time required.

ISO 3297:2007 Certified ⁜ Impact Factor 8.021 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 11, Issue 7, July 2023

DOI: 10.17148/IJIREEICE.2023.11701

Assuming an average EV battery capacity of 60 kWh and an average solar panel efficiency of 15%, we would need about 400 square feet of solar panels to generate enough electricity to charge an EV for a daily commute of 40 miles. However, this is just an estimate and the actual number of solar panels needed may vary depending on the factors mentioned above. Based on the this assumption the following calculations are performed-

Consider annual solar energy output for one system as $T_{Solar/yr}$, system size *S* (KW), capacity factor *C* and annual sunshine hours as *H* which is expressed as follows-

$T_{Solar/yr}$ = *S. C. H* (1)

The capacity factor is the percentage of solar energy converted into electricity by a PV system, with a typical value around 20%.

$T_{Solar/yr}$ = *60 x 0.20 x 2,500* *(From I)*

$T_{Solar/yr}$ =*30,000 kWh/year* *(2)*

This means that the PV system would generate approximately 30,000 kilowatt-hours (kWh) of electricity per year, assuming standard test conditions and no other external factors affecting the system's performance.

According to the Society of Manufacturers of Electric Vehicles (SMEV), there were about 143,837 EVs sold in India in the fiscal year 2020-21. The number includes all types of electric vehicles such as two-wheelers, three-wheelers, four-wheelers, and buses. However, it's important to note that this number represents only a fraction of the total number of vehicles in India, which is estimated to be over 200 million.

If one PV system of EV generates approximately 30,000 kilowatt-hours (kWh) of electricity per year, then the total kWh of electricity generated $T_{Solar\ for\ vehicles}$ by total number of vehicle $T_{vehicles}$ is 143,837 EV cars can be calculated as:

$T_{Solar\ for\ vehicles}$ = $T_{Solar/yr}$ *x* $T_{vehicles}$ (3)

$T_{Solar\ for\ vehicles}$ = *30,000 x 143,837* *(From 3)*

$T_{Solar\ for\ vehicles}$ = *4,315,110,000 kWh per year.* *(4)*

Therefore, 143,837 EV cars would generate approximately 4,315,110,000 kWh of electricity per year using PV systems.

According to the Central Electricity Authority of India, the conventional power generation capacity of India for the financial year 2020-21 was 374.7 GW consider it as 'T_{Con}'. The total energy generated by the conventional grid during this period was around 1,482 billion kWh (or 1.482 trillion kWh) of electricity.

If the PV system generates 4,315,110,000 kWh per year (4) i.e $T_{Solar\ for\ vehicles}$ and the conventional grid generates 374.7 GW per year 'T_{Con}', then the percentage contribution of the PV system '$\%_{Solar}$' to the conventional grid would be:

$\%_{Solar}$ = *(*T_{Con} *x h x d x C) 100%* (5)

$\%_{Solar}$ = *(374.7 GW x 24 hours x 365 days x 0.2)100%* *(From 5)*

$\%_{Solar}$ = *(3,282.3225 B kWh)100%*

Convert *kWh* to *GWh*= 3,282.3225 x 1,000,000 = 3,282,322,500 *GWh*

(3,282,322,500 *GWh* / 1,482,000,000 *GWh*) x 100% = 221.48%

$\%_{Solar}$ = 221.48% (6)

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 8.021 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 11, Issue 7, July 2023
DOI: 10.17148/IJIREEICE.2023.11701

Therefore, the PV system would contribute approximately 221.48% of the total electricity generated by the conventional grid.

To calculate the reduction in carbon emissions from the PV system's contribution to the grid, we need to know the carbon intensity of the grid, which is the amount of carbon emissions per unit of electricity generated.
Assuming a carbon intensity I_c of 0.82 kg CO_2/kWh (which is the average for India according to the International Energy Agency), the 4,315,110,000 kWh of electricity generated by the PV system would result in a reduction of approximately 354,003 metric tons of CO_2 emissions per year.

This is calculated as follows:
Total electricity generated by the grid per year T_{Con}: 1,482 billion kWh.
Total CO_2 emissions from the grid per year CO_{2grid}: 1,482 billion kWh x 0.82 kg CO2/kWh = 1,214,440,000 metric tons of CO_2.
PV system's contribution to the grid per year $T_{Solar\ for\ vehicles}$: 4,315,110,000 kWh.

CO_2 emission from the PV system's contribution to the grid per year CO_{2Solar}: :

$$CO_{2Solar} = T_{Solar\ for\ vehicles}\ x\ I_c \quad (7)$$

$$CO_{2Solar} = 4{,}315{,}110{,}000\ x\ 0.82$$

$$CO_{2Solar} = 3{,}538{,}389 \text{ metric tons } CO_2 \text{ per year.} \quad (8)$$

Therefore, the PV system's contribution would result in a reduction of approximately 1,210,901,611 metric tons of CO_2 emissions per year.
i.e (1,210,901,611 metric tons of CO_2/ 1,214,440,000 metric tons of CO_2) x 100 = 99.70% (9)

II. WIND:

Placing wind turbines across the road in India would not be a feasible option as it may disrupt traffic and cause safety concerns. However, if we consider the installation of wind turbines in suitable locations in India, the amount of power generated would depend on various factors such as wind speed, turbine size, and location.
The potential power generation capacity of wind energy in India is estimated to be around 38.789 GW, according to the Ministry of New and Renewable Energy as of 2020-21 fiscal year say it as $T_{Wind/yr}$.
To calculate the contribution of wind energy to the conventional grid, we can use the following formula:

$$\%_{Wind} = (T_{Wind/yr}/T_{Con})\ x\ 100 \quad (10)$$

Plugging in the values:
Convert GW to GWh: 38.789 GW x 8760 hours = 339791.64 GWh.

$$\%_{Wind} = (339791.64\ GWh\ /\ 1482{,}000{,}000\ GWh)\ x\ 100$$

$$\%_{Wind} = 22.93\% \quad (11)$$

To calculate the contribution of the wind energy system of 38.789 GW per year on a conventional grid of 1,482 billion kWh, we can use the following steps:
Total electricity generated by the grid per year T_{Con}: 1,482 billion kWh

Total CO_2 emissions from the grid per year CO_{2grid}: *1,214,440,000 metric tons of CO_2*

CO_2 emission from the wind energy system's contribution to the grid per year CO_{2Solar}:

$$CO_{2Solar} = T_{Wind/yr}\ x\ I_c \quad (12)$$

$$CO_{2Solar} = 338.4\ B\ KWh\ x\ 0.82$$

$$CO_{2Solar} = 277{,}488{,}000 \text{ metric tons of } CO_2 \quad (13)$$

DOI: 10.17148/IJIREEICE.2023.11701

Therefore, the wind energy system's contribution would result in a reduction of approximately 936,952,000 metric tons of CO_2 emissions per year, which is approximately 77% of the total CO_2 emissions from the conventional grid. (14)

The total reduction of CO_2 per year will be CO_{2Total}:

= PV system's reduction+ wind energy system's reduction

=1,210,901,611 + *936,952,000*

=2,174,853,611 metric tons of CO_2 reduction (15)

To calculate the percentage of total CO_2 emissions from the conventional grid that would be reduced, we can divide the total reduction in CO_2 emissions by the total CO_2 emissions from the conventional grid and multiply by 100:

$\% \, CO_{2Total} = CO_{2Solar} / CO_{2grid}$ (16)

$\% \, CO_{2Total} =$ *(2,174,853,611 metric tons of CO_2 / 1,214,440,000 metric tons of CO_2) x 100*

$\% \, CO_{2Total} =$ *77.44%* *(17)*

Therefore, the total contribution of both the wind energy system and the PV system on the conventional grid would result in a reduction of approximately 77.44% of the total CO_2 emissions from the conventional grid.

Therefore, it is clear from the calculations above that using solar and wind energy for electric vehicles alone may significantly cut carbon emissions.

WORKING

The proposed project is a highly innovative and efficient system for charging electric vehicle (EV) batteries using three sources - solar, grid, and wireless charging. This multi-source charging system is designed to overcome the limitations of traditional EV charging systems, such as low efficiency and limited range, by utilizing multiple sources of power to charge the batteries.

The system works by constantly monitoring the input voltage levels from the three sources - solar, grid, and wireless charging - and comparing them to determine which source has the highest voltage. The charger will automatically switch to the source with the highest voltage to charge the battery, ensuring that the battery is charged as efficiently as possible.

When the EV is stationary and connected to the grid, the charging will be done using the grid supply. However, when the EV is in motion, it will have access to only two sources of power - solar and wireless charging. The system will again compare the voltage levels of these two sources and switch to the source with the highest voltage to charge the battery.

The charging process is highly user-friendly, as the source of charging and the battery voltage levels are displayed on an LCD screen, allowing the user to monitor the charging process in real-time. This means that the user does not have to worry about manually switching between charging sources, as the system automatically handles the charging process based on the available sources of power.

Overall, the proposed system is an excellent solution for efficient and convenient charging of EV batteries. By utilizing multiple sources of power, the system can overcome the limitations of traditional charging systems and provide an environmentally friendly solution for powering electric vehicles. The system is highly automated, user-friendly, and cost-effective, making it an excellent choice for anyone looking to reduce their carbon footprint while also enjoying the convenience of electric vehicle travel.

ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified ⁜ Impact Factor 8.021 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 11, Issue 7, July 2023
DOI: 10.17148/IJIREEICE.2023.11701

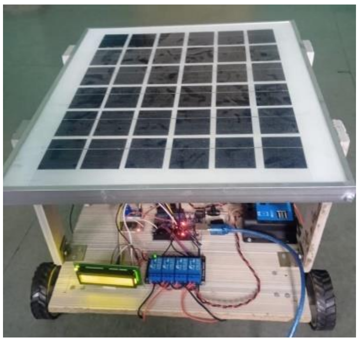


Fig. Solar PV Architecture.

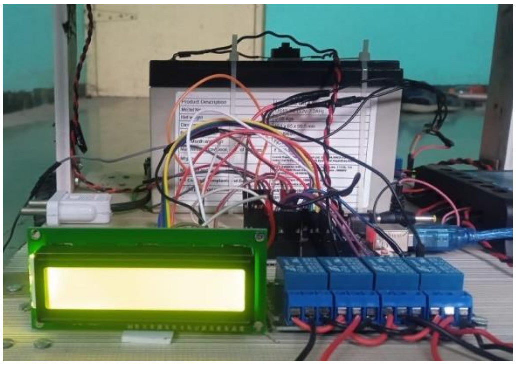


Fig. System Connection of battery, relays, LCD.

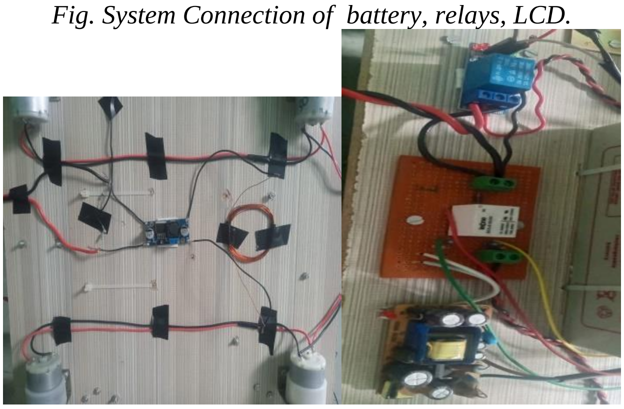


Fig. System Connection of Motors.

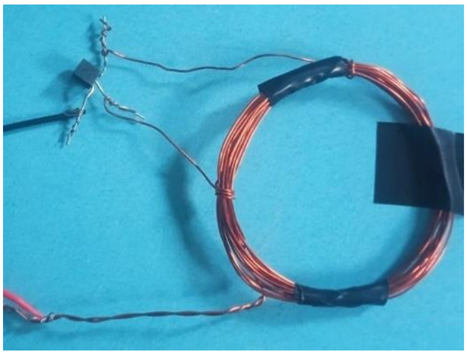
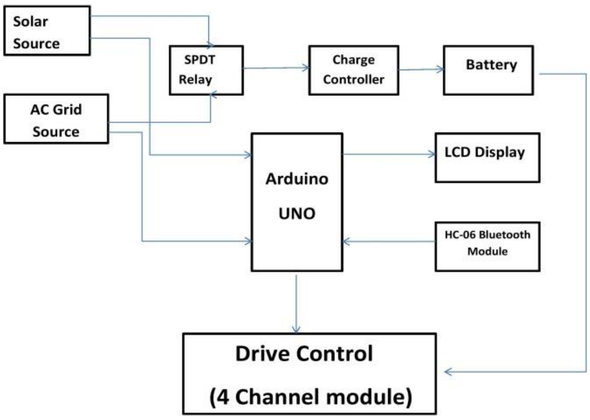


Fig. Connection of Coil Implemented on Road.

IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526
International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified ⁑ Impact Factor 8.021 ⁑ Peer-reviewed / Refereed journal ⁑ Vol. 11, Issue 7, July 2023
DOI: 10.17148/IJIREEICE.2023.11701



This is an Arduino program designed to control a robot using a remote controller connected to a SoftwareSerial port. The robot can move forward, reverse, turn left, and turn right using a combination of four DC motors connected to the pins of the Arduino board.

The program also monitors three power sources, namely solar, grid, and wireless charging, and switches between them as required using relays. Additionally, the program displays the status of a battery's charge level using a Liquid Crystal Display (LCD).

The loop function reads the values from three analog pins corresponding to the power sources and decides which source is most suitable based on their voltage levels. The program then displays the selected power source on the LCD and switches the relays accordingly. When the robot is in motion, the loop function reads characters from the SoftwareSerial port, interprets the received characters as a command, and controls the motors accordingly. The robot's motion can be controlled using the remote controller connected to the SoftwareSerial port. The functions forward(), reverse(), left(), right(), and stop_() are responsible for controlling the direction of motion of the robot. The function cap_display() reads the voltage level of the battery and displays the percentage of charge remaining on the LCD.

Overall, this program combines motor control, power management, and data display features, making it a useful tool for robot control and management in various applications.

CIRCUIT EXPLANATION-

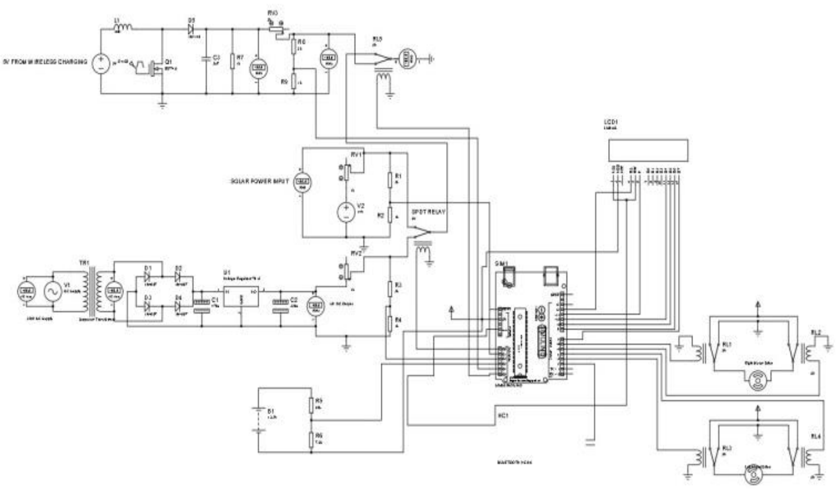


Fig. System Architecture

WIRELESS CHARGING CIRCUIT-

An overview of the design, implementation, and functionality of solar-powered electric vehicle (EV) charging systems is given in this study. The author examined several components of solar-powered EV charging systems, including solar cells, charging algorithms, power electronics, and control systems, using a thorough analysis of the body of current research. The benefits of solar-powered EV charging stations are emphasized in the report, including the reduction of greenhouse gas emissions, the provision of energy independence, and the lightening of the burden on the electric grid. The article does, however, also emphasize the difficulties in putting them into practise. Future research and development recommendations are made in the paper's conclusion.

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified ⁙ Impact Factor 8.021 ⁙ Peer-reviewed / Refereed journal ⁙ Vol. 11, Issue 7, July 2023
DOI: 10.17148/IJIREEICE.2023.11701

SOLAR CIRCUIT-

The circuit consists of a 12V solar panel connected in series with a 1k resistor RV1, acting as a current limiter. The voltage is then divided between two resistors, R1 and R2, connected in parallel with the solar panel and RV1. The output voltage is a fraction of the input voltage, determined by the resistance values of R1 and R2. The output voltage is given to the input pin A1 of the Arduino, which converts the analog voltage value to a digital value for further processing. Overall, the circuit acts as a voltage divider, reducing the solar panel voltage to a level that can be read by the Arduino, with the output voltage dependent on the ratio of the resistance values of R1 and R2.

AC GRID-

The given circuit is a simple AC to DC voltage converter circuit. The AC supply from the grid is first connected to a rectifier, which converts the AC voltage into a DC voltage. The regulated DC voltage is then passed through a voltage regulator to ensure that the output voltage remains constant despite any fluctuations in the input voltage.

A variable resistor is connected across parallel to the voltage regulator to simulate a load on the circuit. Two resistors, R3 and R4, are also connected across parallel to the voltage regulator to act as a voltage divider circuit. The voltage across R4 is the output voltage of the circuit, which will be a fraction of the input voltage, depending on the ratio of the resistance values of R3 and R4.

Overall, the circuit is designed to convert AC voltage to regulated DC voltage and provide a stable output voltage. The variable resistor simulates a load on the circuit, while the voltage divider circuit helps to reduce the output voltage to a suitable level for various applications.

RESULTS

Simulation is done by using Proteus Software. Following images shows the simulation output for Solar, Grid, Wireless Charging mode.

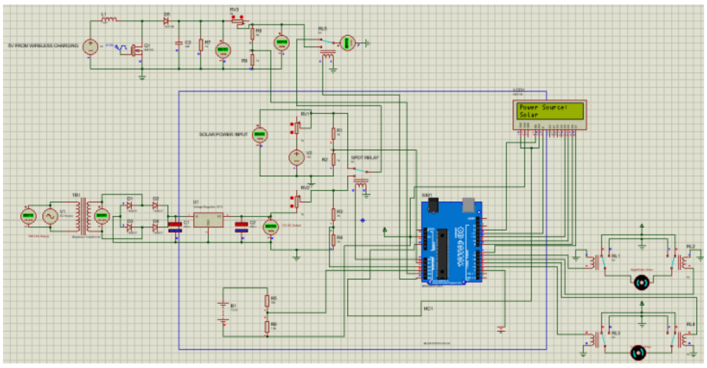


Fig. Simulation output for Solar

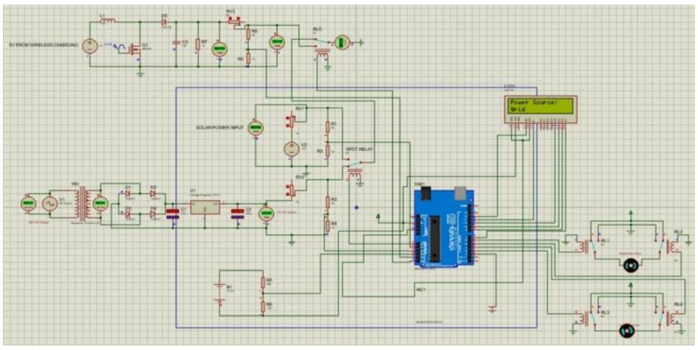


Fig. Simulation output for Grid

ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ⁑ Impact Factor 8.021 ⁑ Peer-reviewed / Refereed journal ⁑ Vol. 11, Issue 7, July 2023

DOI: 10.17148/IJIREEICE.2023.11701

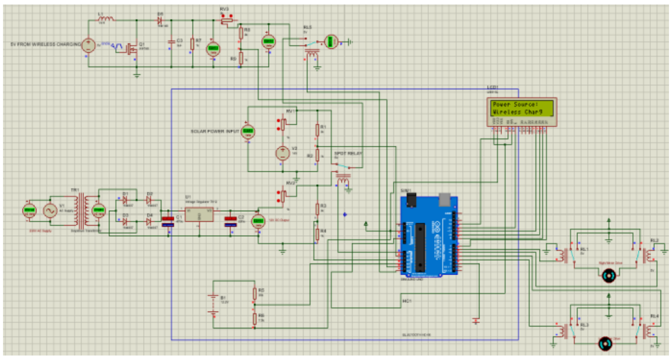


Fig. Simulation output for Wireless Charging

Charging through PV Panel:

To calculate the charging time, we need to use the formula:

$t_{charging}$ = *Ah / (P x η)* *(18)*

Where, $t_{charging}$ − Charging time,

Ah− Battery capacity is 86.4 Wh

P− Power is 10W

η− Efficiency is 80%

$t_{charging}$ = *86.4 Wh / (10 W x 0.80)*

$t_{charging}$= *10.8 hours*

Therefore, it would take approximately 10.8 hours to fully charge the battery.

Charging through Grid:

Wattage of 230V AC to 12V DC Converter: 24 W

Output Current of 230V AC to 12V DC Converter: 2A

To calculate the charging time, we need to use the formula:

$t_{charging}$ = *Ah / (P x η)*

Where, $t_{charging}$ *− Charging time,*

Ah− Battery capacity is 86.4 Wh

P− Power is 24W

η− Efficiency is 80%

$t_{charging}$= *86.4 Wh / (24 W x 0.80)*

$t_{charging}$ = *4.5 Hours*

Therefore, it would take approximately 4.5 hours to fully charge the battery.

Discharging of Vehicle:

To calculate the discharging time, we can use the formula:

$t_{discharging}$= *Ah/* I_L

Where,

$t_{discharging}$ = *Discharging time*

Ah= Battery capacity is 7.2 Ah

I_L = *Load Current 300 mA x 4 = 1.2 A*

$t_{discharging}$ = *7.2 Ah / 1.2*

$t_{discharging}$= *6 hours*

DOI: 10.17148/IJIREEICE.2023.11701

Therefore, the discharging time would be approximately 6 Hours.

In this scenario, we have calculated the charging and discharging times for an EV with a voltage of 12 V, power of 10 W, and current rating of 0.833 A, which charges a 12V, 7.2 AH battery with a capacity of 86.4 Wh and an efficiency of 80%. Our calculations show that it would take approximately 10.8 hours to fully charge the battery, and the discharging time would be approximately 6 Hrs.
Note: These calculations are based on ideal conditions and do not take into account factors such as battery aging, temperature, or charging/discharging cycles.

TABLE I COMPARISTION BETWEEN THE SOURCES

	Sources		
	SOLAR	**GRID**	**WIND (WIRELESS)**
Annual Solar Energy Output	374.7 GW	168.7GW	38.789 GW
Contribution- Of total electrical by conventional grid	221.48%	-	22.93%
CO2 Production in Metric tons	3,538,389	1,214,440,000	277,488,000
Reduced amount of CO2	1,210,901,011 metric tons	-	936,952,000 metric tons
Reduced amount of CO2 in Percentage	99.70%	-	77.44%
Charging Time	10.8 hr	4.5 hr	4.32 hr

CONCLUSION

Arduino program combines motor control, power management, and data display features, making it a useful tool for robot control and management in various applications.
Proposed system is an excellent solution for efficient and convenient charging of EV batteries. By utilizing multiple sources of power, the system can overcome the limitations of traditional charging systems and provide an environmentally friendly solution for powering electric vehicles. The system is highly automated, user-friendly, and cost-effective, making it an excellent choice for anyone looking to reduce their carbon footprint while also enjoying the convenience of electric vehicle travel.

REFERENCES

[1] M. Akmal, A. Jawad and A. A. Tarabsheh, "Design and Simulation of Solar Grid-Connected Charger for Electric Vehicles," 2018 UKSim-AMSS 20th International Conference on Computer Modelling and Simulation (UKSim), Cambridge, UK, 2018, pp. 108-113, doi: 10.1109/UKSim.2018.00031.
[2] F. Locment, M. Sechilariu and C. Forgez, "Electric vehicle charging system with PV Grid-connected configuration," 2010 IEEE Vehicle Power and Propulsion Conference, Lille, France, 2010, pp. 1-6, doi: 10.1109/VPPC.2010.5729016.
[3] T. W. Ching and Y. S. Wong, "Review of wireless charging technologies for electric vehicles," 2013 5th International Conference on Power Electronics Systems and Applications(PESA), Hong Kong, China, 2013, pp. 1-4, doi: 10.1109/PESA.2013.6828235.
[4] Yuvaraja S1 , Narayanamoorthi R1 *, Jagabar Sathik Mohamed Ali 2 and Dhafer Almakhles 2, “A Comprehensive Review of the On-Road Wireless Charging System for E-Mobility Applications,” 2022, Frontiers in Energy Research.
[5] C. L. Bartberger, “The Magnetic Field of a Plane Circular Loop”, Volume 21, Issue 11 November 1950, Journal of Applied Physics 21, 1108-1114 (1950)
[6]Bouanou, Tasnime, Hassan El Fadil, Abdellah Lassioui, Ouidad Assaddiki, and Sara Njili. 2021. "Analysis of Coil Parameters and Comparison of Circular, Rectangular, and Hexagonal Coils Used in WPT System for Electric Vehicle Charging" *World Electric Vehicle Journal* 12, no. 1: 45. https://doi.org/10.3390/wevj12010045
[7] P. Ning, J. M. Miller, O. C. Onar and C. P. White, "A compact wireless charging system for electric vehicles," 2013 IEEE Energy Conversion Congress and Exposition, Denver, CO, USA, 2013, pp. 3629-3634, doi: 10.1109/ECCE.2013.6647179.

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified ⩰ Impact Factor 8.021 ⩰ Peer-reviewed / Refereed journal ⩰ Vol. 11, Issue 7, July 2023
DOI: 10.17148/IJIREEICE.2023.11701

[8] Nguyen Thi Diep1 , Nguyen Kien Trung2 , Tran Trong Minh3, "Wireless power transfer system design for electric vehicle dynamic charging application", International Journal of Power Electronics and Drive System (IJPEDS) Vol. 9, No. 4, September 2020, pp. 1468~1480 ISSN: 2088-8694, DOI: 10.11591/ijpeds.v10.i3.pp1468-1480.
[9] Naoui Mohamed a , Flah Aymen a , Mohammed Alqarni b , Rania A. Turky c , Basem Alamri d , Ziad M. Ali e,f , Shady H.E. Abdel Aleem g, "A new wireless charging system for electric vehicles using two receiver coils", 2021, Ain Shams Engineering Journal, ScienceDirect.