

Multi Source Energy Management System In E.V Charging Station

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Abstract- This paper explores the design and implementation of an Energy Management System (EMS) for Electric Vehicle (EV) Charging Stations, utilizing microcontroller technology to optimize energy usage. The proposed system integrates renewable energy sources, dynamically adjusts charging schedules based on real-time energy availability and demand, and ensures efficient energy utilization. By addressing challenges like peak energy demand and renewable energy variability, the EMS enhances the sustainability and reliability of EV charging infrastructure. Simulation and experimental results demonstrate the effectiveness of this system in achieving energy efficiency and reducing environmental impact.

Keywords- Energy Management System, EV Charging Stations, Microcontroller, Renewable Energy Integration, Sustainable Energy, Real-time Energy

I. INTRODUCTION

The increasing global focus on reducing carbon emissions and mitigating climate change has led to a rapid transition toward electric vehicles (EVs) as a viable alternative to conventional combustion engine vehicles. This shift is not only driven by the need for sustainable transportation but also by the demand for cleaner, more efficient, and cost-effective energy solutions. As EV adoption surges worldwide, the need for an effective and scalable Electric Vehicle Charging Station (EVCS) infrastructure has never been more critical. However, this rapid growth in EVs introduces a significant challenge—the efficient and reliable management of energy at these charging stations.

Electric Vehicle Charging Stations, which serve as the central hub for charging EVs, must cater to an ever-increasing load of vehicles while ensuring the stability and reliability of the overall power grid. The design and operation of these stations demand an Energy Management System (EMS) to balance the electricity demand and supply, optimize the use of renewable energy sources, and ensure the efficient operation of the station. An EMS is responsible for coordinating the charging process, reducing operational costs, and minimizing energy losses, which directly impacts the sustainability of EV infrastructure. It aims to ensure the

optimal distribution of electrical power based on real-time conditions, including fluctuations in demand and the availability of renewable energy.

In recent years, with the proliferation of low-cost yet powerful microcontroller-based solutions, there has been a significant advancement in the development of intelligent, automated systems for controlling and optimizing the operation of EV charging stations. Microcontrollers are at the heart of modern EMS, offering a compact, cost-effective, and efficient way to manage power distribution, monitor system parameters, and communicate with other devices and users. These small-scale computing devices can handle complex algorithms in real-time, making them ideal for use in energy management applications where real-time decision-making is essential.

A microcontroller-based EMS in an EVCS can manage various tasks such as load balancing, power flow control, and demand-response operations. The system can intelligently switch between different energy sources, including grid power, solar power, and energy storage systems, based on the operational requirements and availability of energy. By incorporating renewable energy sources, the EMS helps reduce the dependence on conventional power grids, lowers carbon emissions, and enhances the sustainability of EV infrastructure. The use of energy storage, such as batteries, allows for the storage of excess energy generated during off-peak hours or from renewable sources, which can then be used during periods of high demand, providing both economic and environmental benefits.

Moreover, the ability to monitor and manage multiple charging stations and vehicles simultaneously in real time is a key advantage of integrating microcontroller-based EMS. Communication protocols such as IoT (Internet of Things) and cloud-based systems enable the transfer of data between the charging stations, users, and grid operators, ensuring seamless operation. Real-time monitoring of energy consumption, status of the charging units, and user preferences can be integrated into the system to provide users with a better experience and to ensure that the energy distribution is optimized according to demand.

The proposed Energy Management System for EV Charging Stations using microcontrollers aims to address these challenges by presenting an intelligent, scalable, and cost-effective solution. The system will focus on optimizing energy consumption through smart algorithms, improving the efficiency of power distribution, integrating renewable energy, and ensuring the overall reliability of the charging station. This EMS will not only benefit the operators by reducing costs but also contribute to the larger goal of transitioning to a greener and more sustainable transportation ecosystem.

II. SYSTEM OVERVIEW

The following section deals with components used in the project. Table 1 shows the components and specification

TABLE I. DESCRIPTION OF COMPONENTS USED

| COMPONENTS | SPECIFICATION | REQUIREMENTS |
|-----------------------------|--|--------------|
| ATmega328p | length of belt: 80 inch width of belt: 5 inch material: resin | 1 |
| LCD Display | 5.5 volt, 16*2 LCD Communication I2C protocol | 1 |
| DC motors | 24V; 30rpm | 1 |
| Transformer | AI- 5.7, output- +5V, Secondary Voltage- 12V | 1 |
| Voltage Regulator (IC 7805) | Input voltage range 7V- 35V Output voltage range 5.2V- 4.8V | 1 |
| Filter | 25V, 1000uF | 1 |
| Solar panel | 14Watt | 1 |
| Connectors | - | As Required |

The ATmega328P microcontroller is the core component of the system, selected for its high performance and power efficiency. It is an 8-bit AVR microcontroller operating at a clock frequency of up to 20 MHz. With 32 KB of flash memory, 2 KB SRAM, and 1 KB EEPROM, it provides sufficient storage for program execution and data management. The microcontroller features 23 general-purpose I/O pins, 10-bit ADC, PWM channels, and communication protocols such as UART, SPI, and I2C, making it ideal for embedded applications. In this project, it manages input sensing, energy management, and output control.

A 16x2 LCD module is utilized for displaying real-time system parameters, including solar power generation,

battery status, and operational states. This alphanumeric display supports two lines of 16 characters each and operates using the HD44780 controller. It features adjustable contrast, backlighting for low-light visibility, and supports both 4-bit and 8-bit interfacing modes, making it compatible with various microcontroller systems.

The system employs a DC motor to simulate mechanical operations, such as cooling or actuator control. The motor operates on a DC supply, typically between 6V and 12V, and supports speed control through Pulse Width Modulation (PWM) signals generated by the microcontroller. Its simplicity, reliability, and ease of control make it a suitable choice for demonstrating physical movements within the system.

A step-down transformer is used to convert high-voltage AC mains (230V) to low-voltage AC (commonly 12V or 9V). This component ensures the safe operation of the system by providing an appropriate input voltage for subsequent rectification and regulation stages. The transformer is designed with laminated iron cores to minimize eddy current losses and insulated windings for electrical safety.

The IC 7805 voltage regulator is incorporated to provide a stable 5V DC supply to the microcontroller and other components. Operating with an input voltage range of 7V to 35V, the IC delivers a regulated output with a maximum current rating of 1.5A. It is equipped with protection features, including thermal shutdown, short-circuit prevention, and overvoltage protection, ensuring reliable operation under varying load conditions.

Filter capacitors are used to smooth the rectified DC voltage from the transformer-rectifier stage. Electrolytic capacitors, typically ranging from 100µF to 1000µF, minimize ripple voltage and provide a stable DC supply for sensitive electronic components. These capacitors are placed strategically in the circuit to enhance the overall efficiency and reliability of the power supply.

A 14W solar panel serves as the primary renewable energy source, converting sunlight into electrical energy through photovoltaic cells. The panel, consisting of monocrystalline or polycrystalline silicon cells, delivers a maximum power output of 14W under standard test conditions (irradiance of 1000 W/m² and cell temperature of 25°C). It typically provides an output voltage of 12V with a corresponding current of approximately 1.2A under optimal sunlight conditions. This solar panel not only charges the system's battery but also powers the microcontroller and other components, promoting sustainable energy practices.

III. SOLAR DESIGN

a solar pv system design can be done in three steps:
 Load estimation Load estimation of number of pv panels
 Estimation of battery bank Base condition:

1 car+ 1 emergency vehicle (9 watts each), central battery unit
 5(9 watts each) for 6 hrs a day.

The total energy requirement of the system (total load)

I.e. total connected load to pv panel system = no. Of units ×
 rating of equipment = $5 \times 9 + 2 \times 9 = 63$ watts Total watt-
 hours rating of the system = total connected load (watts) ×
 operating hours = $63 \times 6 = 378$ watt-hours

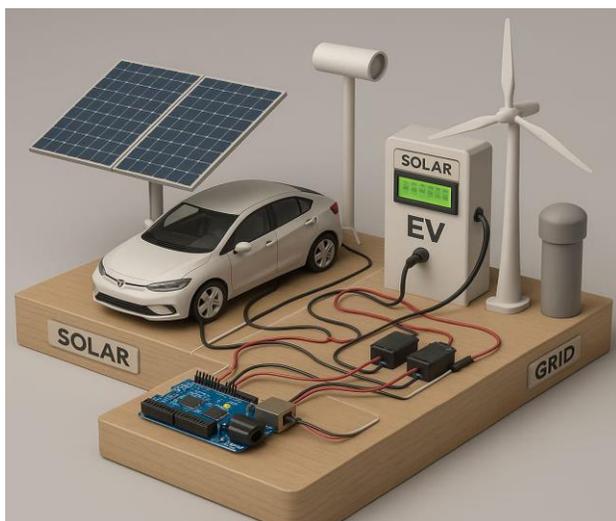
Actual power output of a pv panel = peak power rating ×
 operating factor = $10 \times 0.75 = 7.5$ watt

The power used at the end use is less (due to lower combined
 efficiency of the system = actual power output of a panel ×
 combined efficiency = $7.5 \times 0.81 = 6$ watts (va) = 6 watts

Energy produced by one panel in a day = actual power output
 × 6 hours/day (peak equivalent) = $24.3 \times 6 = 145.8$ watts-hour

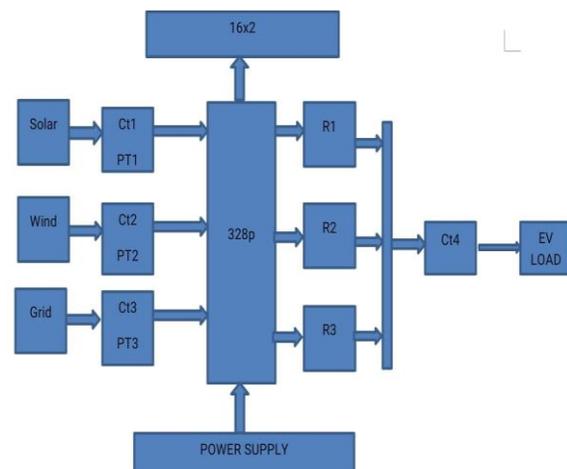
Number of solar panels required to satisfy given estimated
 daily load: = (total watt-hour rating (daily load)/ (daily energy
 produced by a panel) = $378/145.8 = 2.592 = 2$ (round figure)
 (note that our requirement only 1 panel because ev
 discharging that can give the supply load maintaining) Inverter
 size is to be calculated as: total connected load to pv panel
 system and ev vehicle discharging = $5w+9w=14w$

IV. GRAPHICAL REPRESENTATION



Project aims to design an efficient energy management system for an electric vehicle (EV) charging station. This system utilizes an ATmega 328P microcontroller, which acts as the central controller, managing the charging process and monitoring various parameters. A 16×2 LCD display is incorporated to provide real-time information on the charging status, power usage, and other system metrics. The system is powered by a 14W solar panel, which contributes to a sustainable energy model, promoting renewable energy use. A DC motor is used in the system to simulate or control aspects of the station, possibly related to adjusting the power flow. To ensure the microcontroller and other components receive stable power, an IC 7805 voltage regulator is employed, accompanied by filter capacitors to mitigate voltage fluctuations. The combination of these components enables effective energy management, optimizing power flow and enhancing the overall efficiency of the charging station. This project serves as an example of how renewable energy and efficient system management can work together in the context of EV charging infrastructure.

V. BLOCK DIAGRAM



The block diagram illustrates a renewable energy management system designed to integrate solar, wind, and grid power sources to supply energy to an electric vehicle (EV) load. The system incorporates CT (Current Transformer) and PT (Potential Transformer) sensors to measure the current and voltage from each energy source. These inputs are sent to a microcontroller, labeled 328p, which serves as the central control unit. The microcontroller processes the data and manages the flow of energy between the sources and the load, ensuring efficient utilization of renewable energy and grid power.

The 16x2 display is included as a user interface to present real-time data, such as the status of the energy sources

and the EV load. Relays (R1, R2, R3) are connected to the microcontroller, enabling it to control the distribution of energy based on predefined logic or priority. Another CT sensor (CT4) monitors the current flowing to the EV load for system regulation and safety.

A dedicated power supply is included to provide the necessary voltage and current for the microcontroller and other electronic components. The system prioritizes the use of renewable energy from solar and wind sources while incorporating the grid as a backup to ensure continuous power availability for the EV load. This setup highlights the integration of renewable energy sources with intelligent control and monitoring for sustainable and reliable energy management.

VI. ENVIRONMENTAL IMPACT

Wind or solar power cannot be the sole source of electricity in a stable base-load grid, but they can reduce the use of conventional energy sources. The environmental benefits of the wind-solar DC GRID system in this study were assessed in terms of avoided emissions. Given that a conventional thermal power plant emits a certain amount of pollutant per kWh of generated electricity, the wind-solar DC GRID system can be considered to cause an avoidance of emissions, since it generates the electricity with nearly zero pollutant emissions. Although there are many types of emissions related to electricity production, CO₂ emission was considered, sulfur dioxide and nitrogen oxides. CO₂ is the largest component of the emissions from conventional electricity production and may be considered as the greatest environmental impact caused by the established power industry. The amount of CO₂ produced by conventional diesel fuel is 0.6kg for 1kWh. Hence, the reduction of CO₂ from energy saving of 0.427GWh would be 331 tons/y, sulfur dioxide and nitrogen oxides would be 1.5 ,0.74 tons/y annually.

VII. EXPECTED OUTCOMES

1. Enhanced Renewable Energy Utilization
2. Reduced Operational Costs
3. Improved Energy Efficiency
4. Increased Grid Independence
5. Insights for Future Research and Development
6. Environmental and Community Impact

VIII. PROJECT SUMMARY

This project proposes a prototype of a Multi-Source Energy Management System (EMS) tailored for Electric

Vehicle (EV) Charging Stations, leveraging renewable and grid energy sources. The system employs solar energy, wind energy, and conventional grid power, functioning on a priority-based selection algorithm. When renewable energy is available, the system prioritizes it automatically to power the EV charging station. In the absence of sufficient renewable energy, the system seamlessly transitions to the grid source, ensuring uninterrupted energy supply.

At the core of the system lies an Arduino UNO (ATmega328P) microcontroller, which continuously monitors the status of energy sources using Current Transformers (CT) and Potential Transformers (PT). Based on predefined thresholds, the microcontroller activates relay modules to switch between sources. A 16×2 LCD display provides real-time feedback about the active source, energy flow, and system status. The DC motor and LED light strip serve as simulated loads to visualize the energy delivery process.

This architecture showcases how a low-cost, modular EMS can be implemented for sustainable EV infrastructure, especially in remote or semi-urban regions where grid reliability is limited.

IX. CONCLUSION

The present worldwide trends concern energy security and sustainable development across the globe. The role of renewable energy has therefore become ever more significant. The developed world is already on the track for walking out from the fossil fuel era and involving mainly the areas of renewable energy technologies and energy efficiency. Through this study an insight into the energy situation and renewable energy potential of India was given. It was identified that India has economically feasible power generation potential of wind and solar energy. Using HOMER simulation software, a grid tied wind-solar DC GRID power generation system was modeled for a selected location in the almarj area of India (MARJU), located on the coastal belt near Benghazi. Through the simulation process, installation of 10 numbers of 100kW wind turbines and 150kw solar PV array was identified as economically most feasible design to supply average load connected to grid where payback period of the design is 2.6 years.

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