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Implementation of Energy Management in Solar PV Powered EV Charging Station

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ABSTRACT - It's great to hear that countries are pushing for electric vehicles and renewable energy-based charging stations to tackle the issue of global warming. The use of renewable energy to power electric vehicle charging stations is an important step towards reducing greenhouse gas emissions from the transportation sector. The combination of a solar-powered electric vehicle charging station and a Battery Energy Storage System (BESS) is an excellent approach to ensure continuous power supply and efficient use of renewable energy. The use of a bidirectional grid connection allows for the excess energy generated by the solar panels to be stored in the BESS or exported to the grid when the demand for power is high. The use of a MATLAB Coding to Control power flow in a fixed direction voltage-controlled Maximum Power Point Tracking (MPPT) algorithm is a promising approach to optimize the power generation of the solar panels and improve the overall efficiency of the charging station. Function block can adjust the voltage of the solar panels based on the weather conditions and the power demand of the EVs to ensure maximum power generation. The MATLAB/Simulink platform is an excellent tool for designing and evaluating the performance of the charging station. The simulation can help to identify the potential issues and optimize the design of the charging station before it is implemented in real-life scenarios. Overall, the development of a solar-powered electric vehicle charging station with a BESS and bidirectional grid connection, MPPT, is an excellent initiative towards a sustainable future.

Keywords - Electric Vehicles, Battery energy storage system, Function Block, Current Controller, Full-Wave Rectifier with LC Filter MPPT, PV.

I. INTRODUCTION

Global warming and the perilous climate changes associated with it are on the rise, largely due to the increasing demand for modern transportation systems. The harmful environmental pollutants emitted by internal combustion engine vehicles (ICEs) are major contributors to air pollution and greenhouse gas emissions. Therefore, IC-enabled automobiles are the main culprits behind these negative environmental consequences. However, electric vehicles (EVs) offer a potential solution to the world's current dependence on gasoline-powered autos.

Electric vehicles are gaining popularity due to their highly efficient electric motors, which surpass the capabilities of internal combustion engines. As a result, this mode of transportation conserves energy in comparison to traditional ICE vehicles while also mitigating noise and pollution. Furthermore, they offer an opportunity to reduce reliance on oil for transportation, provided that the electricity is sourced from non-oil fuel sources like renewable energy (1,2).

As electric vehicles become more prevalent on the road and rely on the electric grid for charging, the task of charging these vehicles can become increasingly difficult (3). When numerous electric cars are connected to the grid, it can lead to operational and control difficulties for the grid. Additionally, charging EVs with conventional energy sources offers no benefits to the environment. Therefore, to facilitate efficient charging infrastructure for EVs, renewable energy sources must be used. Implementing a battery energy storage system (BESS) that can act as a buffer between the EV charging station (EVCS) and the utility is a promising solution (4-7). However, despite the relief provided by BESS on the utility grid, the expected rise in the number of EVCSs in the future remains a concern.

A promising solution for efficient charging infrastructure for EVs is the integration of a battery energy storage system (BESS) with solar PV, as discussed in (8). To further optimize the use of renewable energy, the implementation and control of power flow in a wind energy conversion system (WECS) and PV array for EV charging is discussed in (9). Another approach is to create an efficient, adaptable, and cost-effective EV charging station based on environmental data and PV technology, as explored in (10). Charging EVs using solar and battery in the workspace is discussed in (11). Additionally, (12) presents a method for maximum power point tracking of a standalone PV array using P and O MPPT.

This study proposes a Control of power by using MATLAB coding for the efficient power management of a solar-powered electric vehicle charging station that is connected to an AC grid and utilizes a battery energy storage system. To optimize the power output from solar panels under varying irradiance and temperature, Current Controller is used to protect equipment's from high currents, Rectifier circuit is used to convert ac to dc in grid, MATLAB coding is employed to management of power in particular direction.

The proposed system employs a MATLAB Code that utilizes both solar power output and the state of charge (SOC) of the battery energy storage system (BESS) to manage the power output of the AC grid. Solar PV is the primary source of energy, with excess power from the panels used to charge the BESS and supply power to the AC grid during periods of high irradiance. At night or when there is a lack of solar energy, the BESS can be utilized to charge the EV. Both solar and BESS power generation are critical for charging electric vehicles, and in situations where the power supply is unstable, the AC grid may also be used to charge the EV and BESS for an uninterrupted power supply. The proposed system has been simulated using MATLAB/Simulink.

II. MODEL OF ELECTRIC VEHICLE CHARGING STATION

A schematic diagram of a solar-powered charging station with energy storage in the form of a battery and AC grid is presented in Figure 1. The proposed system utilizes a 120V DC bus and can charge one EV battery at a time. Technical specifications for all components are provided in Table I.

A. PV ARRAY WITH BUCK CONVERTER

In the proposed design, a 6394.5W PV panel with an open circuit voltage of 363V is modelled in MATLAB/Simulink. To achieve the required DC bus voltage of 120V, a buck converter is utilized to decrease the voltage

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the PV array. An MPPT is used to maximize the power output of the PV array.

The PV Array is configured into 10 series connected modules and 3 parallel connected modules combine together form the 6394.5W power is maintained the PV panel .

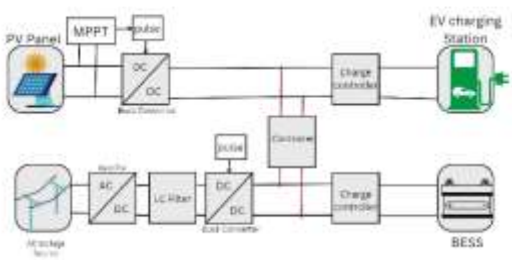

Fig. 1. Block Diagram of EV Charging Station

Module Data	
Number of cells	60
Open circuit voltage	36.3V
Short-circuit current	7.84A
Voltage at MPPT	29V
Current at MPPT	7.35A
BESS Data	
Nominal voltage	120V
Rated capacity	100Ah
Battery type	Lead-Acid
EV Battery Data	
Nominal voltage	120V
Rated capacity	50Ah
The initial state of charge	10%
Battery type	Lead-Acid
Buck Converter Data	
Switching frequency	100kHz to 1MHz
capacitance	5.920833e-5F
Inductance	0.00211118H

Table I. Charging Station Data

B. (BESS) Battery Energy Storage System with Bidirectional Boost DC – DC converter

Extrasolar electricity is collected and stored in a battery energy storage system, which is then used to charge electric vehicles at night. The charging and discharging of the BESS are controlled by a Current Controller. A 120V 100Ah BESS is utilized for the charging station. BESS is anticipated to discharge when it's SOC is greater than 20%.

C. Grid System

It appears that there may be a missing sentence or two in the text you provided. However, based on what is currently written, it seems that a Function Block Simulink model is being used to generate switching (0 or 1) to the switch to operate, with the PV array output power and the state of charge (SOC) of the BESS used as input data for the MATLAB Code. The AC grid is connected to the 120V DC bus through the connectors. The AC grid is operating at a frequency of 50Hz and a voltage of 230V.

D. EV Battery

A 120V, 50Ah Battery is considered for the charging station, The incoming EV's battery is expected to have a minimum of 10% SOC for simulation purposes. The energy required.

(Eev) for charging of the EV battery can be calculated from the nominal voltage (Vn), remaining % state of charge ($SOCr$) and Ampere-hour rating (Ah) of the battery.

$$E_{ev}=\frac{V_n*SOC_r*Ah}{100} \qquad (1)$$

III. CONTROL METHODOLOGY

A. Full-Wave Rectifier with LC Filter

A capacitor-inductor filter is often employed to enhance the filtering capability of rectified voltage and current. As we discussed earlier, using just a capacitor or an inductor alone may not provide sufficient filtering, as capacitors are better suited for low-power applications and inductors for high-power applications. However, when combined, these two components can produce a high-quality DC voltage and current. The capacitor smooths out

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voltage variations, while the inductor smooths out current variations, resulting in a steady flow of current. Due to its ability to maintain a consistent current, the capacitor-inductor filter is widely used in high-power applications. Figure illustrates a full-wave bridge rectifier with a capacitor-inductor filter.

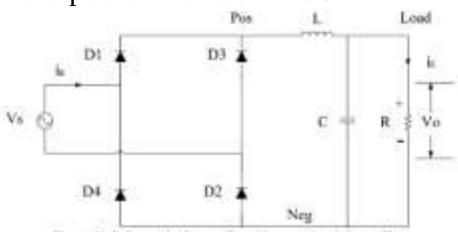


Figure 4a. Full-wave bridge rectifier with a capacitor-inductor filter

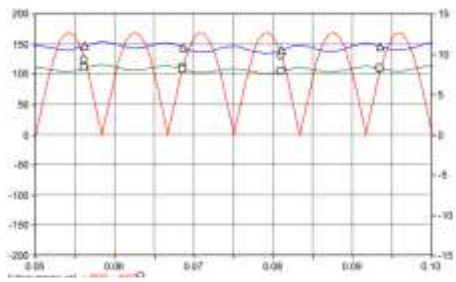
By using this rectifier circuit, we will convert the AC supply into the DC with zero crossings and further we will implement the LC filter circuit to maintain a constant Dc voltage rating.

We can use the following formulas to calculate the DC supply.

They are,

Ripple percentage = (Vrms/Vo) x100

percentage = (Irms/Io) x 100



B. Maximum power point tracking

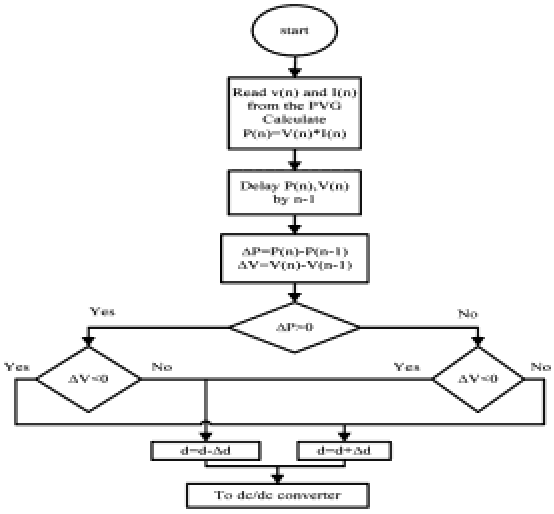


Fig. 4. Working Flow Chat Of MPPT

Maximum power point tracking (MPPT) or sometimes just power point tracking (PPT), is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions. Although it primarily applies to solar power, the principle applies generally to sources with variable power: for example, optical power transmission and thermophotovoltaics.

C. Buck Converter

The fundamental structure of a buck converter is illustrated in Figure 1, which depicts the switch being integrated into the chosen integrated circuit (IC). In some cases, synchronous converters substitute the diode with another switch integrated into the converter. In such instances, all equations in this document hold true, except for the power dissipation equation of the diode.

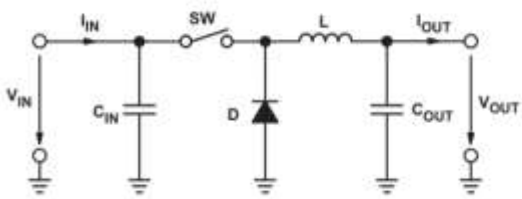


Figure 1. Buck Converter Power Stage

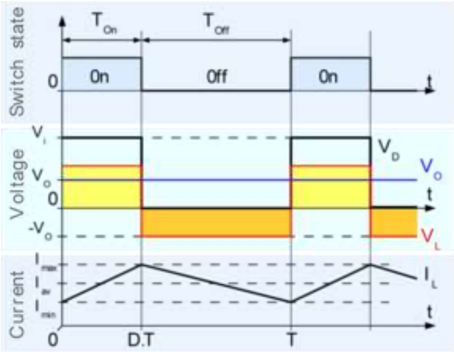
We will calculate three types of formulas to buck the voltage.

They are,

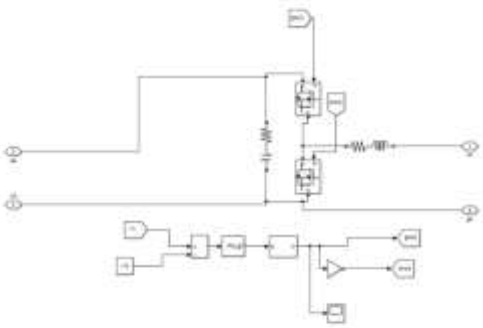
Max Duty Cycle D = $\frac{V_{OUT}}{V_{IN(max)} \times \eta}$

$$\text{Inductance } L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{\Delta I_L \times f_S \times V_{IN}}$$

$$C_{OUT(min)} = \frac{\Delta I_L}{8 \times f_S \times \Delta V_{OUT}}$$



D. Current Controller



Battery charging/discharging Control implemented in a case study that involves a DC bus (with a constant voltage), battery, a common load, and a bidirectional two-switch Buck-Boost DC-DC converter.

The control of battery charging and discharging is based on two PI controllers:

1- one is for reference current generation (dependent on mode of operation: charging or discharging)

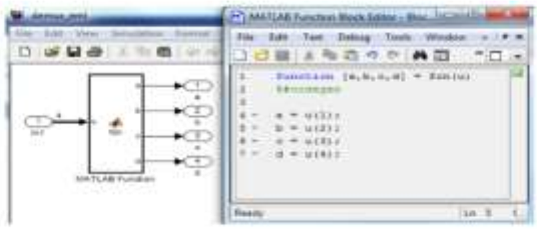
2- the other is for Current control of battery.

Here the safest current to charge the battery as fast as possible is assumed as 15A. So, while changing and discharging the current of the battery must maintain 15A. To achieve this a PI controller is used. The current flowing through the battery is measured and compared with the desired value if the error value is negative the PWM increase to increase the current and if the error value is positive the PWM decrease to decrease the current flow from/to the battery. So that the charge controlling is obtained.

E. MATLAB Function Block

By Programming the MATLAB Function Block we will control the overall charging station by taking the input values of solar irradiance, battery SOC's and Grid system power.

Inputs can be processed by using the code we write in function block, and we operate the circuit breaker whether it takes power and which source is turned into closed one. By using this method, we successfully done of energy management of power in critical conditions also and it leads to the continuous charge of EV battery in all conditions.



F. Charging Time Calculator

By using programmed MATLAB Function Block we will calculate the time required to charge the battery is displayed on the board.

G. Grid Support

The Grid is the support for overall system, whenever the PV panel power is low, or the external battery source (BESS) is low in that time we fetch the power from the grid source and in some cases like energy is wasted in system is supplied into the public service.

IV. OPERATION

Irradiance	EV SOC	BESS SOC	BESS	EV	Grid
<=250	<100	<20	Charging	Charging	Delivering
	<100	>20	Discharging	Charging	Idle
	100	<80	Charging	Idle	Delivering

	100	>80	Idle	Idle	Taking
<=500	<100	Any value	Idle	Charging	Idle
	100	<80	Charging	Idle	Idle
	100	>80	Idle	Idle	Taking
<=1000	<100	<80	Charging	Charging	Idle
	<100	>80	Idle	Charging	Taking
	100	<80	Charging	Idle	Taking
	100	>80	Idle	Idle	Taking

Table II. Operating Modes

Depending on the irradiance on the solar panels the whole process divided into three categories. Further these modes divided based on the SOC present in EV and BESS.

Mode 1: (0<Irradiance<250)

Based on the SOC's of BESS and EV this mode further divided into 4 types.

Mode 1.1: (BESS SOC<20 and EV SOC<100)

BESS and EV are charging and Grid and solar are delivering the power.

Mode 1.2: (BESS SOC>20 and EV SOC<100)

BESS and solar charges the EV. In this case Grid is open circuited

Mode 1.3: (BESS SOC<80 and EV SOC=100)

Grid and solar supply the BESS, and the EV is disconnected.

Mode 1.4: (BESS SOC>80 and EV SOC=100)

Now solar delivers the power into Grid and the BESS and EV are disconnected.

Mode 2: (250<Irradiance<500)

Based on the SOC's of BESS and EV this mode further divided into 3 types.

Mode 2.1: (EV SOC<100)

Solar charges the EV but the BESS and Grid is open circuited.

Mode 2.2: (BESS SOC<80 and EV SOC=100)

BESS is charging by solar power at that time Grid and EV is disconnected.

Mode 2.3: (BESS SOC>80 and EV SOC=100)

The power obtained from the solar is delivered to the Grid.

Mode 3: (500<Irradiance<=1000)

Based on the SOC's of BESS and EV this mode further divided into 4 types.

Mode 3.1: (BESS SOC<80 and EV SOC<100)

The power obtained from the solar is delivered to the BESS and EV.

Mode 3.2: (BESS SOC>80 and EV SOC<100)

Grid and EV is supplied by the solar.

Mode 3.3: (BESS SOC<80 and EV SOC=100)

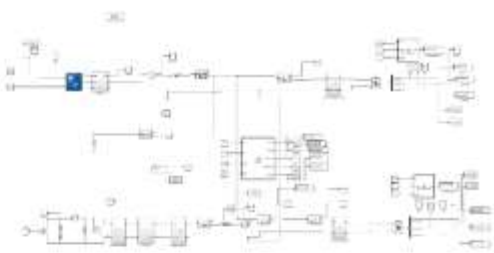
Solar power is used to charge the BESS and to supply the Grid.

Mode 3.4: (BESS SOC>80 and EV SOC=100)

All the power obtained from the solar panels are delivered to the Grid.

V. SIMULATION RESULTS

Circuit diagram



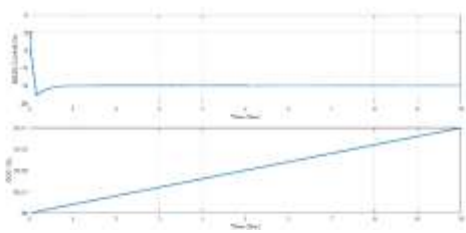


Fig. 6. Current and SOC graphs of BESS when charging.

Fig Charging Station.

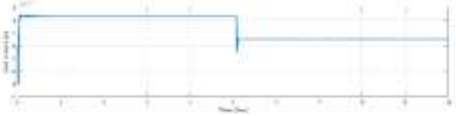


Fig. 9. Current graph of Grid when delivering power.

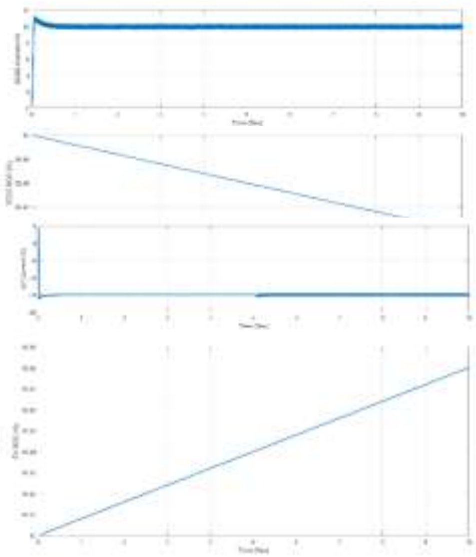


Fig. 8. Current and SOC graphs of EV when charging.

VI CONCLUSION

With the increasing popularity of electric vehicles, one of the major challenges is providing adequate charging infrastructure. A possible solution is to install charging stations that use a combination of photovoltaic (PV) arrays and battery energy storage systems (BESS), which can be further improved with grid support. To ensure that all connected EVs receive sufficient charging, a variety of control strategies such as MATLAB Code, PI controllers, can be used. By maintaining a constant DC bus voltage, the desired power output can be achieved, and the station's power management can be optimized in five different modes. To accommodate a larger number of EVs, the proposed model can be scaled up with higher power ratings and power supply capacities, making it suitable for installation at workplaces or parking lots. The proposed system has been validated using MATLAB/Simulink simulations.

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