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DC-DC CHARGER CONTROL SYSTEM DESIGNING FOR SOLAR/FC BASED EV CHARGING STATION TO OPTIMISE THE POWER FLOW

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Abstract

Electric Vehicles (EV) have become a widely investigated field in an era where there is a greater emphasis on renewable energy sources. The majority of RE- depending charging architectures are being created to reduce grid dependence while also meeting the needs of EV battery charging points. This study concentrated on maximizing the flow of power to the battery by utilizing the energy of the solar cell as well as fuel cell. An Artificial intelligence relying controllable electronic DC-DC converter has been devised to assist in transforming the high power provided by solar panels to the appropriate EV battery voltage. Maximum Power Point Tracking (MPPT) is used by DC-DC converters to help Photovoltaic panels in operating at max power, with the recognition and monitoring procedure handled by an AI-based tool in MATLAB/SIMULINK. The proposed DC-DC converter connects the solar panel, fuel cell, as well as load to provide optimum power transmission with little los.

Keywords: DC-DC converter, Electric vehicle, Charging station, AI algorithm

Introduction

The power converter phase resulted in a drastic shift in the development of numerous innovations in the electrical field. Furthermore, conventional power converters have conventionally held a strong position due to their uses and distinct properties. The following section will assess converter categorization and applicability in Photovoltaic systems implementations.

DC-DC converters are segregated into two kinds: isolated and non-isolated converters. The isolation is defined as the existence of an electrical obstacle in between converter's inputs and the converter's outputs. This barrier can be provided by a high-frequency transformer. The main aspect of using this barrier is that it may be used in high voltage implementations. Additionally, these isolated converters can be set to be positive or negative in nature. Non-isolated conversions lack this barrier. Isolated converters include flyback, resonant, forward, push-pull, and bridge converters. Non-isolated converters which are commonly used include Cuk, boost, buck-boost, SEPIC, Ultra-lift Luo as well as positive-output super-lift Luo.[20]

Notwithstanding the structure, both the EVs as well as batteries are highly associated to a shared DC-bus via a DC/DC converter. The DC/DC stage connecting to Battery Energy

Storage System must obviously be bidirectional. The EV process, on the other hand, has no such requirement. The viability of employing EV batteries as local storage units is frequently addressed in the literature [22,23]. The goal is to store additional energy obtained by renewable in the Electric Vehicle battery as well as transmit it back into the grid whenever power requirement increases. The unique non-isolated bidirectional DC-DC converters are built on the basic bidirectional DC-DC converters and thus are developed to enhance the effectiveness of bidirectional DC-DC converters by impedance transformations in terms of enhancing the voltage conversion ratio as well as effectiveness, lowering the current ripple on the power supplier side as well as the voltage/current stresses of the device, as well as enhancing the input as well as output characteristics. This research drive innovation categorized available unique non-isolated DC-DC converter architectures based on diverse compositions of ESS devices.

A hybrid charge administration paradigm is essential for a charging point that incorporates simultaneous battery swapping as well as plug-in charging. This strategic system's only objective is to decrease charging queue duration as well as vehicle trip period while also maximizing charging performance improvements for the station. Zhang et al. [83] developed a hybrid charging management program for electric taxis that incorporates battery swapping as well as plug-in charging points. Depending on time-varying demands, the suggested work gives an optimum approach among battery charging point as well as battery swapping stations. The simulation outcomes confirmed the efficacy of the suggested effort. Regulation of optimal functioning is critical at battery interchange stations wherein charging, discharging, as well as battery exchange actually happen.

The numerous studies of multiple authors allow us to comprehend the fundamental framework of a solar-fed Electric Vehicle system. The investigation of the merits and applications of AI-based technologies and their many varieties has been included in recent EV systems topics of interest. Better approaches can be adopted for improved charging system effectiveness once the DC-DC controllers are better managed for more stable and dependable output. In regards to quality concerns and maintenance, the effects of integrating surplus energy resource must also be investigated properly. The study is aimed at the establishment of HES (Hybrid-Energy-Systems) that use solar and fuel cells to power EVs.

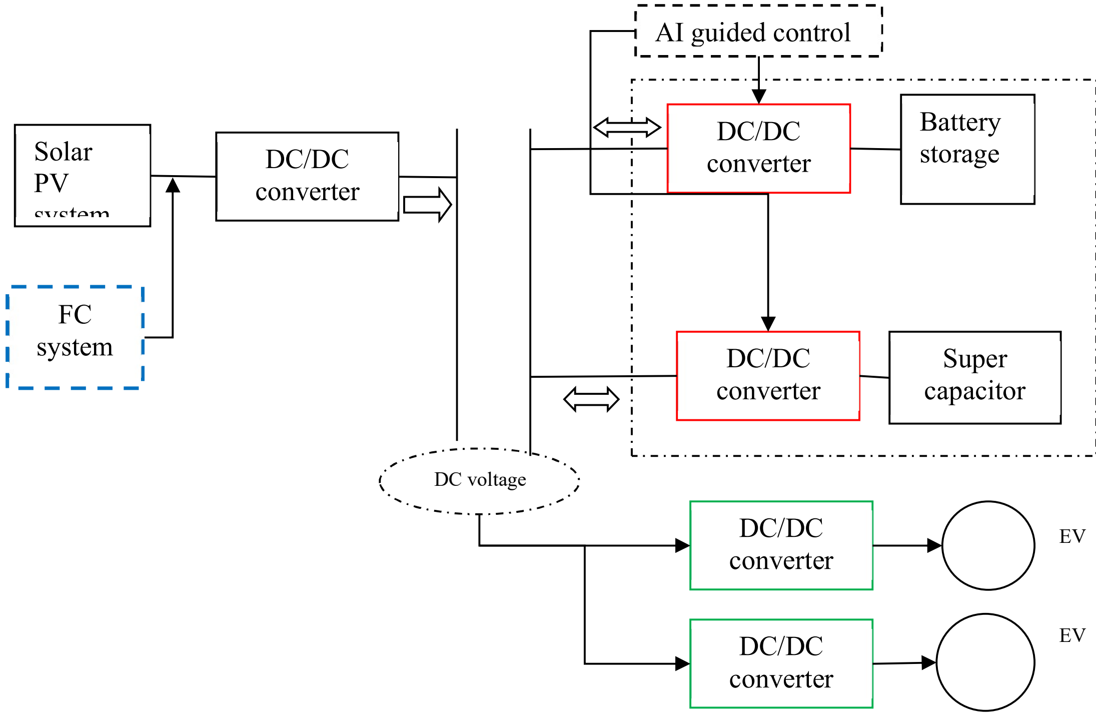


Figure 6.2: Generating unit integration with the system

An RL filter has already been explored among the charging station as well as loads in order to reduce outputs harmonics throughout the operation as well as switching procedures of converters. The control technique is primarily concerned with the DC/DC converters. Due to the choke in its architecture, super capacitors function as both ESS and converter isolation. As a result, noise interference is decreased as well as load protection is enabled. In a DC-DC converter, the feedback controller is primarily important for producing regulated power, preferably with no steady-state error, less overshoot, as well as fast dynamic response whilst preserving highest efficiency.

Personal transportation is critical in our society, and the 2020 epidemic scenario has strengthened this. Simultaneously, transportation adds to local emissions, that must be decreased in the context of global warming. Another feasible method could be to transition from ICE to compact electric automobiles. As a result, in order to develop widely approved sustainable transportation solutions, we must first study mobility behaviors and perceptions regarding E-mobility. An online questionnaire involving 432 participants from around Europe was carried out. Germany received the most responses, followed by Austria, Sweden and Italy. Cars are the most common mode of personal transportation. PTWs are utilized for both commuting and recreational activities. The driving experience, lesser maintenance, and ease of parking compared to vehicles are all compelling grounds for selecting a PTW. There were not any disparity among younger and older participants. E-PTWs are usually ignored because to high pricing, range concern, and anticipated charging infrastructure issues. These barriers must be overcome in order to promote long-term mobility. One problem that must be addressed is the supply of improved charging facilities or electric automobiles with higher range. As a result, given average journey lengths and goals, it may appear equally vital to address prejudices and enhance public awareness of E-mobility and all of its potential advantages [17].

Electric two- and three-wheelers are light electric vehicles (LEV), that account for the majority of EVs stock. These cars are going to be at the centerpiece of electrification initiatives in China, India, and certain other Asian countries, as they are favored for last-mile connection and as a cost-effective means of personal transportation. Furthermore, charging devices excluding active cooling systems may be challenging in Asian regions with high ambient temperatures. Because of the use of lead-acid batteries, these cars were conventionally sluggish to charge. Rapid charging becoming achievable with the use of new chemistries, although thermal management remains the most difficult task. Electric two- and three-wheelers are light electric vehicles (LEV), that account for the majority of EVs stock. These cars are going to be at the centrepiece of electrification initiatives in China, India, and certain other Asian countries, as they are favored for last-mile connection and as a cost-effective means of personal transportation. Furthermore, charging devices excluding active cooling systems may be challenging in Asian regions with high ambient temperatures. Because of the use of lead-acid batteries, these cars were conventionally sluggish to charge. Rapid charging becoming achievable with the use of new chemistries, although thermal control remains the most difficult task. Instead of using an AC charging converter, the DC charging technique utilises direct current power from the PV panels to charge the e-battery. bike's The e-bike may be wirelessly charged through inductive power transmission through the bike kickstand (receiver) and a specifically engineered tile (transmitter) at the charging station, providing greatest level of accessibility to the user.

MATLAB Implementation Algorithm and Work Flows

The method for modeling of PV module and PV cell are similar. It uses the exact same PV cell model. The model is made up of a series resistance (Rs), a diode (D), as well as a current source (ISC). Parallel resistance (Rp) has a relatively little influence in a single module, hence it is excluded from the model. To improve the model, it additionally adds influence of temperature on the short-circuit current (Isc) as well as reverse saturation current of the diode (Io). It uses a single diode having the diode ideality factor (n) chosen to produce the optimum current-voltage curve fit.

Vpv is the photovoltaic voltage of the cell and Ipv is the photovoltaic current of the cell. A series resistance (Rs) of the cell is linked in series with a parallel connection of the cell's photocurrent (Iph), shunt resistance (Rsh) as well as an exponential diode (D). It can be written as follows:

$$I_{pv} = I_{ph} - I_s\left(e^{q\left(\frac{V_{pv}+I_{pv}*R_s}{nKT}\right)} - 1\right) - (V_{pv} + I_{pv} * R_s)/R_{sh}$$

Where:

I_{ph}- Solar-induced current

I_s - Diode saturation current

n - Ideality factor (1~2)

q - Electron charge (1.6e^{-19}C)

T - Temperature ^{0}K

K - Boltzmann constant (1.38e^{-23}J/K)

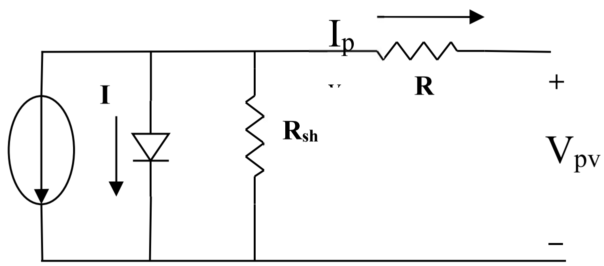


Figure 3.3 Solar PV cell's equivalent circuit

The relation between the solar irradiation and operating temperature induced current of the solar cell can be depicted by the equation presented below.

$$I_{ph} = I_{sc} - k_i(T_c - T_r) * \frac{I_r}{1000}$$

Where:

I_{SC} Short-circuit current of cell at STC

K_i Cell short-circuit current/temperature coefficient(A/K)

T_C ,T_r Cell working and reference temperature at STC

I_r Irradiance in w/m^2

2

As illustrated in Fig 4.4, an exponential relation among I and V may be seen in a PV cell, with the MPP happening near the knee of the curve.

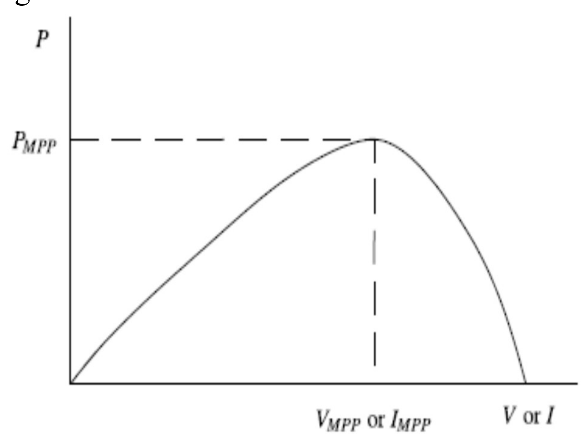
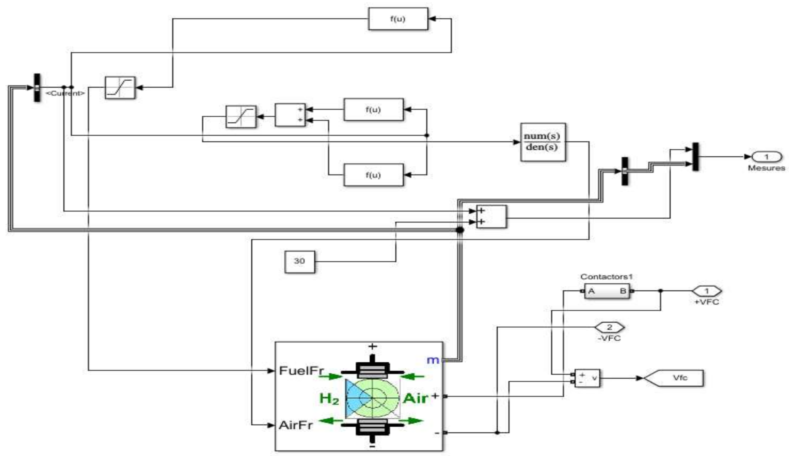


Figure 3.4 Characteristic PV array power curve



Implementation circuit of Fuel Cell in Charging Station

The load line's power needed signal is translated to the stack current necessary to produce power. Optimal pressures are chosen from a variety of values based on current requirements. The stack voltage, power, as well as mass flow rates of hydrogen and air are then calculated by the fuel cell. A compressor is also designed to accommodate for power dissipation while in use. The following formulas are used to compute the oxygen and hydrogen utilization.

$$O_2 \text{ consumption} = \frac{\text{current} * \text{air fuel ratio} * \text{no of cells} * \text{molar mass of } O_2}{4 * \text{faraday constant}}$$

$$H_2 \text{ consumption} = \frac{\text{current} * \text{no of cells} * \text{molar mass of } H_2}{2 * H_2 \text{ utility factor} * \text{faraday constant}}$$

For the computation of the stack voltage from the cathode pressure as well as current density, a cell polarization curve is employed. By using appropriate requirement of "I" from the fuel cell, the cathode pressure can be evaluated.

A:F (Air:Fuel) Ratio	2
Molar mass of O_2	32×10^{-3} kg
Faraday Constant	96485
Molar Mass of H_2	2×10^{-3} kg

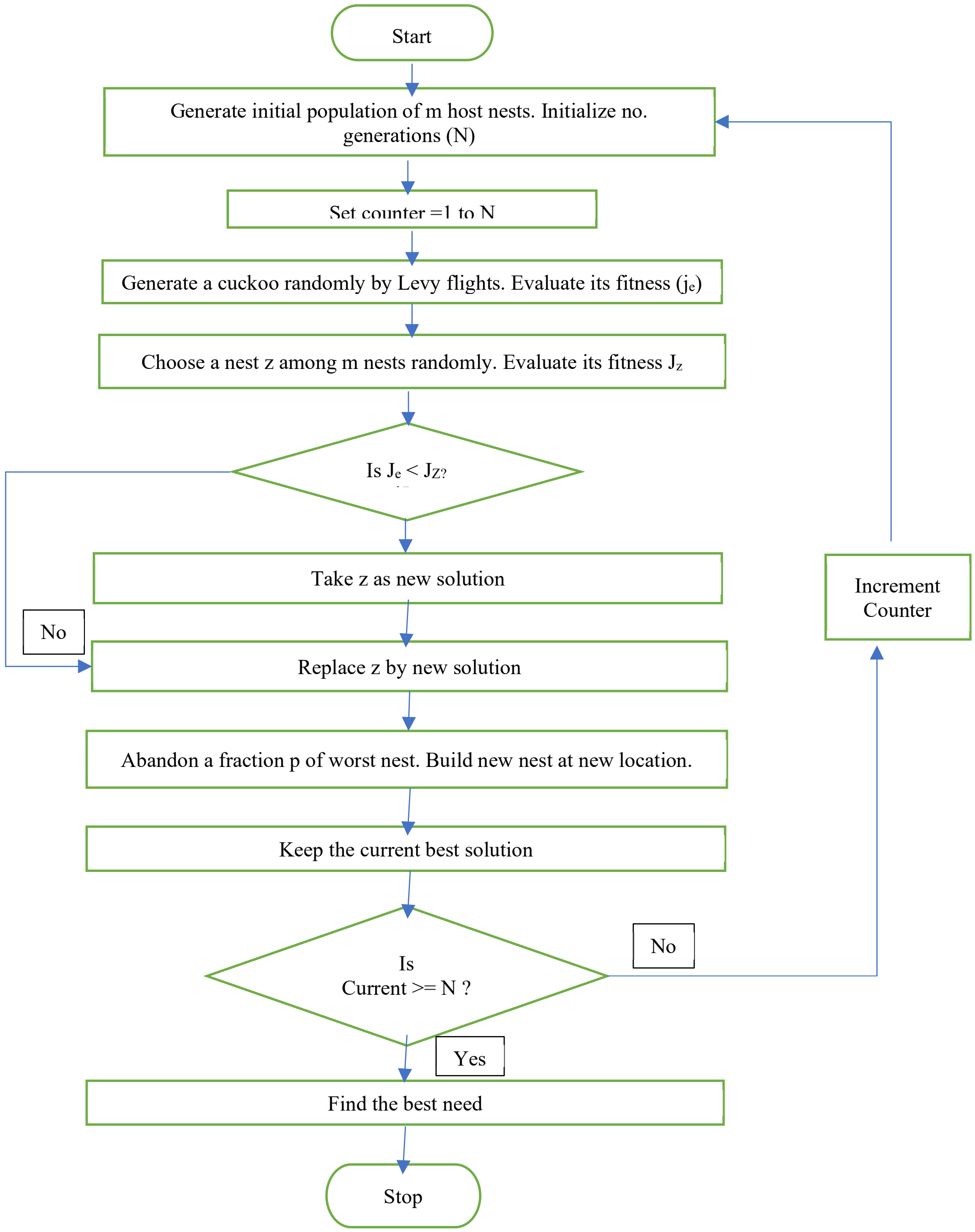
Supercapacitors can be an excellent energy storage solution for solar-based charging stations. They offer several advantages over other types of energy storage devices like batteries, including higher power density, faster charge/discharge rates, and longer cycle life. Supercapacitors can be charged and discharged at much faster rates than batteries. This makes them well-suited for applications that require quick charging or discharging, such as solar-based charging stations. The capacitors require careful charging control to avoid overcharging or undercharging, which can damage the supercapacitor or reduce its performance. Solar-based charging stations can use a charge controller that regulates the charging voltage and current to ensure safe and efficient charging of the supercapacitor. To achieve this Ai based algorithm is found to be best suited to avoid any disturbances. Here are some key equations involved when using supercapacitors in solar-based charging stations:

1. Capacitance equation: The supercapacitor's capacitance can be computed using the following equation: $C = \varepsilon A/d$ where C is the capacitance, ε is the permittivity of the dielectric material, d is the distance between the electrodes and A is the area of the electrodes.
2. Energy storage equation: The energy stored in a supercapacitor can be calculated using the following equation: $E = 0.5CV^2$ where E is the energy stored, C is the capacitance, and V is the voltage across the supercapacitor.
3. Voltage decay equation: The voltage across a supercapacitor decays over time due to the discharge through the internal resistance. This can be modeled using the following differential equation: $dV/dt = -I/C - V/R$ where V is the voltage across the supercapacitor, I is the current flowing through the circuit, C is the capacitance, and R is the internal resistance.
4. Equivalent series resistance equation: The ESR(equivalent series resistance) of a supercapacitor is the sum of the internal resistance and any external resistance in the circuit. This can be modeled using the following equation: $ESR = R_{internal} + R_{external}$ where $R_{internal}$ is the internal resistance and $R_{external}$ is any external resistance in the circuit.

These equations can be used to develop various types of supercapacitor models in MATLAB, such as equivalent circuit models or electrochemical models. However, the specific equations and parameters used will depend on the specific model and application.

AI algorithm development

The use of control strategies in the suggested system is critical because of the characteristics of inconsistent Photovoltaic power production, which can offer considerable changes in output over the day while maintaining an approximately constant voltage in the DC bus voltage. Hence, to assure incredible performance of the intended system, controls will be added to certain main sections of the suggested system, such as the boost employed MPPT to handle PV variations. Furthermore, the buck controller governs the charging process in an electric car, and the bidirectional controller maintains the sustainability of the DC bus voltage as well as manages the battery's charging process as well as discharging process.



A Cuk converter is a sort of DC-DC converter which is utilized to convert Voltage "V" and manage power flow. The Cuk converter is a two-switch architecture notable for providing galvanic isolation here among input as well as output circuits. To manage the power flow throughout the converter, the Cuk converter employs a specific control technique known as the Cuk control algorithm.

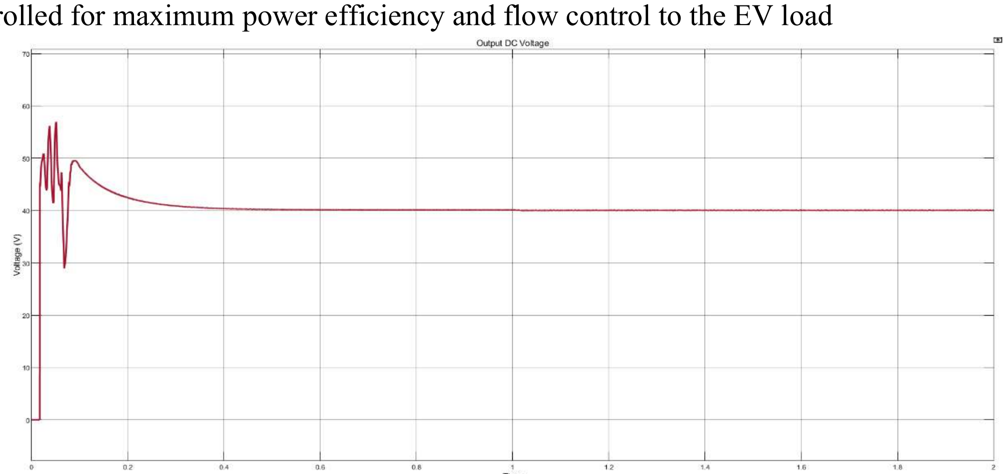
The Cuk control technique relies on a feedback mechanism that detects the output voltage as well as modifies the duty cycle of the switching to keep it at the correct level. The Cuk control algorithm's procedure for managing power flow throughout the DC-DC converter may be characterized in preceeding phases:

- Evaluate the output voltage: The foremost step is the utilization of a feedback loop to determine the final voltage of the DC-DC converter. This can be accomplished with the support of a voltage sensor or another appropriate device.
- Comparing the output voltage to the reference voltage: The observed output voltage is in contrast with the desired output value, i.e., the reference voltage. The difference between both the voltages is the error voltage.
- The error voltage is employed to establish a control signal, which is then utilized to alter the duty cycle of the switching devices in the converter. The duty cycle is defined as the ratio of the switch's on-time to the overall switching duration.
- Change the duty cycle: The control signal is employed to change the duty cycle of the converter's switching devices. Alleviation in the duty cycle lowers the output voltage, and raising the duty cycle raises the output voltage;
- Repetition: The operation is done indefinitely to retain the required output voltage. The feedback loop monitors the output voltage constantly and modifies the duty cycle of the switching devices to maintain the required value.

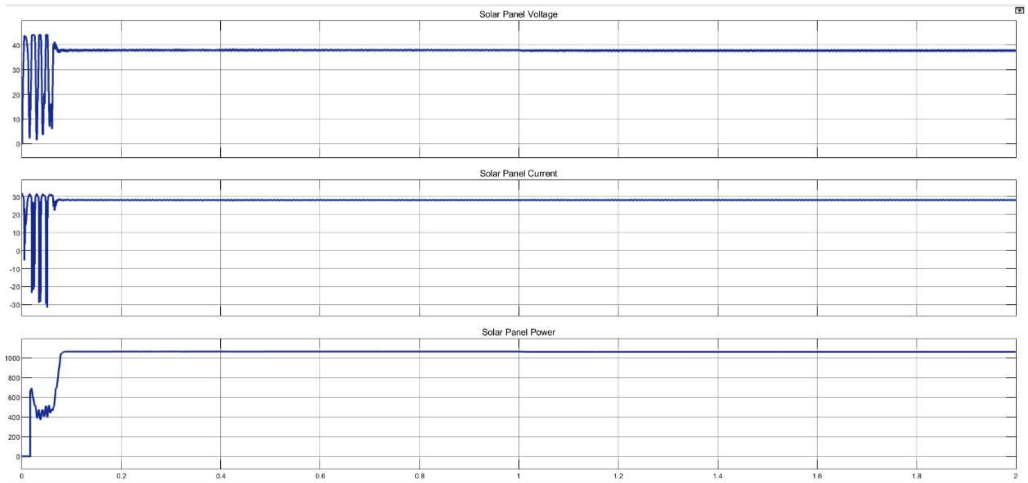
The Cuk control mechanism is a closed-loop control system that regulates the power flow throughout the DC-DC converter. The Cuk control algorithm assures that the converter functions efficiently and consistently by constantly monitoring and changing the output voltage.

Simulation and Outcomes

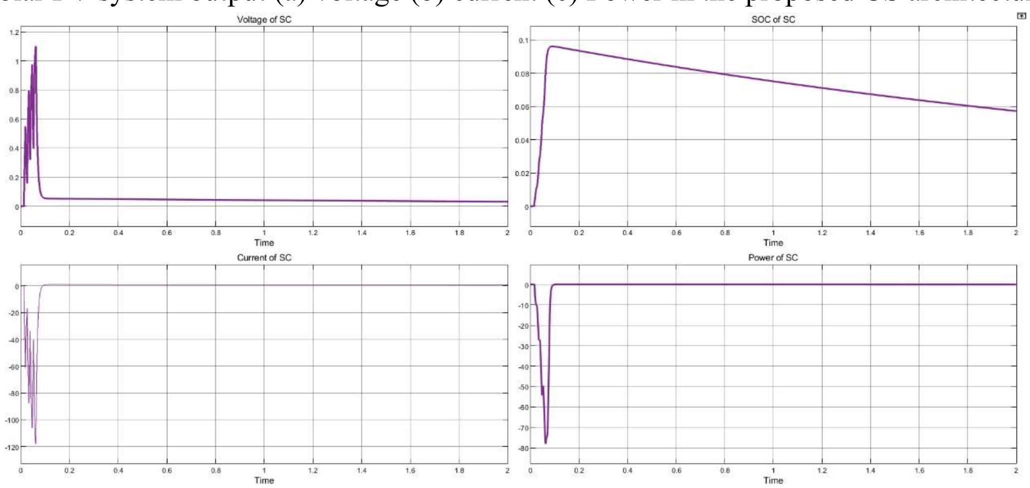
In this research paper, DC-DC Charger Control System is designed on MATLAB which is comprised of solar photovoltaic system, fuel cell-based system and dc-dc converter. also, the load is connected as a battery. The graphs are drawn to show the output parameters for the battery as energy storage device and super capacitor. These energy storage systems as controlled for maximum power efficiency and flow control to the EV load



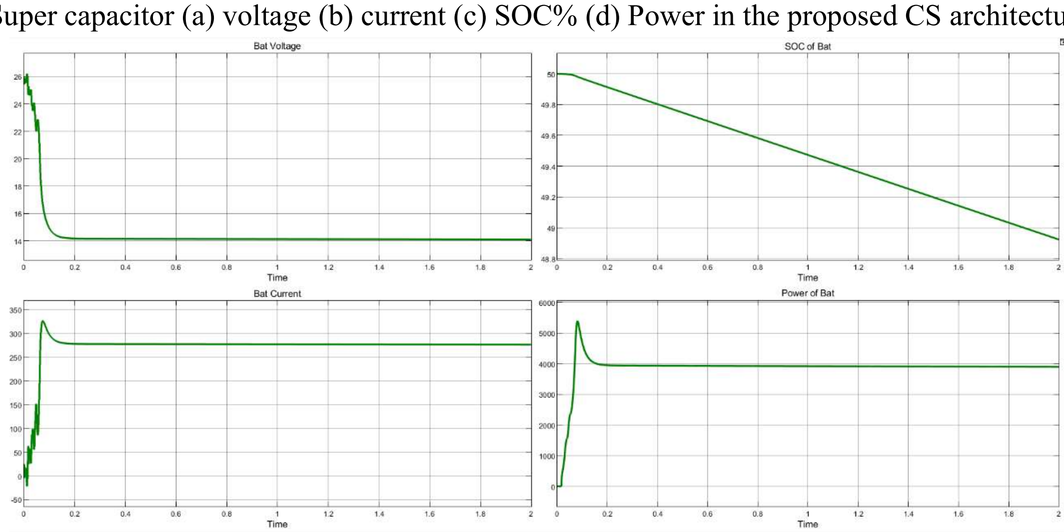
DC voltage output from the hybrid system



Solar PV system output (a) voltage (b) current (c) Power in the proposed CS architecture



Super capacitor (a) voltage (b) current (c) SOC% (d) Power in the proposed CS architecture



Battery storage system (a) voltage (b) current (c) SOC% (d) Power in the proposed CS architecture

This chapter defines a simulation run employing the model given above. The simulation characteristics are supplied first, which are specific to the vehicle and the FC used. The vehicle and fuel cell under evaluation were chosen mostly because of the availability of data.

In any case, what is essential to demonstrate here aren't the mathematical outcomes and the simulation input variables, but the category of outcomes that can be collected from the model, i.e., the quantities acquired and the trend of quantities displayed in the graphs of the upcoming sections, which are beneficial in particular to recognize the power split logic and hence the interaction among FC.

Conclusion

A self-contained EV charging station depending on a photovoltaic energy source in conjunction with a fuel cell is being proposed. The structure integrates a bidirectional converter, Energy-Storage-Sytems batteries, and EV batteries. The control system consists of four controllers: Maximum power point, Electric Vehicle charger, storage-converter control system, as well as an AI-assisted algorithm that regulates the battery current throughout charging and discharging functions, with the reference value of the current being positive for charging operational processes and negative for discharging operational processes. DC-DC converters are an essential element of charging stations that utilise DC power sources. They are designed to regulate voltage, convert power, improve performance, reduce weight and size, as well as ensure dependability.

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