Battery Management System for Standalone Solar System

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Abstract: Nowadays, due to the decrease of conventional energy sources, renewable energy sources are playing a big role in producing electricity. Among them solar and wind are popular renewable energy sources, that have gained more attention. A standalone solar system is off grid connected having a battery connection for the storage of energy. This stored energy can be used whenever needed at the night or during the cloudy day. In this paper a simulation model of battery management system for standalone solar system is designed in MATLAB Simulink. By applying limits to charging as well as discharging and using two quadrant chopper which acts as a high speed switch which connects and disconnects the load from source at high rate to get variable or chopped voltage at the output. With the help of BMS model battery is prevented from overcharging and over discharging.

***Index Terms* - Battery Management System, Standalone Solar System, Battery, MATLAB.**

I. INTRODUCTION

Electrical energy is the most essential sort of energy we use in present society. Electric energy is often described as energy stored in charged particles moving in an electric field. It's easy to transmit and when electrons move through a conductor they produce current. Hence, when electrons are forced to move through a conductor they produce electricity. We use different sorts of energy to do this. Generally, electric energy is produced by converting other sorts of energy (coal, nuclear, solar, wind, hydroelectric etc.).

Energy may be a burning issue within the present world since all non-renewable sources are getting extinct thanks to our overuse. Hence, we should always depend upon renewable energies among which solar power is the most plentiful source. If we could store solar power for each day everywhere in world it'll be enough to offer electricity for a year but it's very difficult to store the generated energy. A crucial component to be used is the solar cell which converts solar power into electricity at the atomic level. When light falls on these cells they absorb photons from the sunlight and release electrons. If these electrons are collected they form an electrical current flow which may be used as electricity. Hence they're also referred to as solar cells. These cells are made from semiconductor materials like silicon. A silicon wafer with positive charge on one side and negative on the opposite side is often said to act as a diode electrically. When photons strike the wafer, electrons are emitted and if we create a loop between the positive and negative sides of the wafer then the electrons flow from negative to positive creating an electrical current. This current are often filtered and amplified to supply enough power to charge any device.

Solar energy is the most abundant source of energy. Solar power can also be used to generate electricity by using the photovoltaic effect. For this an electronic component called the solar cell is required which absorbs photons from the daylight and breaks electron pairs which make charged particles move. They are converted into DC by using this effect. Photovoltaic cells are made of semiconductor materials. Solar power is out there everywhere, but photovoltaic cells are very inefficient. Constructing solar plants requires a huge amount of investment, hence solar power plants are limited. About 4% of the world's electricity is generated from solar power.

II. STANDALONE PV SYSTEM

Where a utility power grid is not available or cannot afford at reasonable costs, a standalone PV system can be used to generate the needed electric energy. Best examples for such cases are solar-powered water pumps, cabins in remote areas, emergency telephones, and also for boats or recreational vehicles. It is an off-grid electricity system and also known as remote area power supply (RAPS). As the solar modules produce electric power only during the daytime, it is very much necessary to store the energy for the night or for cloudy days. In renewable applications like solar and wind, such storage system mostly uses rechargeable lead-acid batteries due to their low cost, availability in large size and ability to accept with high efficiency for any input voltages. Mainly, a battery regulator is used to prevent overcharging and a load shedding circuit is used to prevent deep discharges. Sometimes also fuel cells are used as the storage element in PV systems. In this type of system an inverter is used to generate AC voltage, in which more typical appliances can be used.

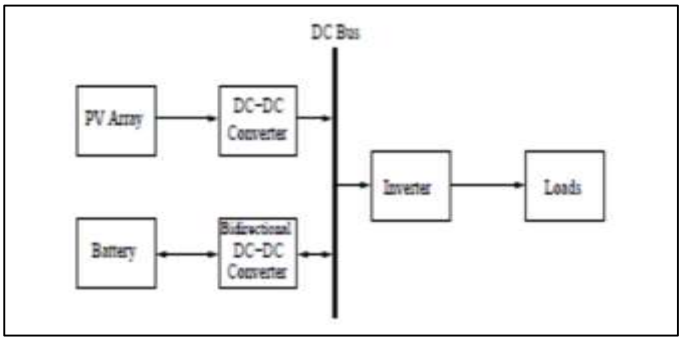

Fig1. Basic diagram of Standalone PV system with battery.

III. BATTERY MANAGEMENT SYSTEM

Three terms apply to the implementation of monitor and control functions within the energy chain. These terms are battery management, power management and energy management. As a rough indication, battery management involves implementing functions that ensure optimum use of the battery in a portable device. Examples of such functions are proper charging handling and protecting the battery from misuse. Power management involves the implementation of functions that ensure correct distribution of power through the system and minimum power consumption by each system part. Examples are active hardware and software design changes for minimizing power consumption, like reducing clock rates in digital system parts and powering down system parts that aren't in use. Energy management involves implementing functions that ensure that energy conversions in a system are made as efficient as possible. It also involves handling the storage of energy in a system. An example is applying zero-voltage and zero-current switching to scale back switching losses during a Switched-Mode Power Supply (SMPS). This increases the efficiency of energy transfer from the mains to the battery.

It should be noted that the implementation of a particular function may involve quite one among the three management terms simultaneously. A definition of the essential task of a battery Management System is often given as follows:

The basic task of A battery Management System (BMS) is to make sure that optimum use is formed of the energy inside the battery powering the portable product and that the risk of damage inflicted upon the battery is minimized. This is often achieved by monitoring and controlling the battery's charging and discharging process.

The basic tasks of BMS are often achieved by performing the following functions:

1) Control charging of the battery, with practically no overcharging, to make sure an extended lifetime of the battery.
2) Monitor the discharge of the battery to stop damage inflicted on the battery by interrupting the discharge current when the battery is empty.
3) Keep track of the battery's SOC and use the determined value to regulate charging and discharging of the battery and signal the value to the user of the portable device.
4) Power the load with a minimum supply voltage, regardless of the battery voltage, using DC-DC conversion to realize an extended run time of the portable device.

IV. SIMULATION MODEL

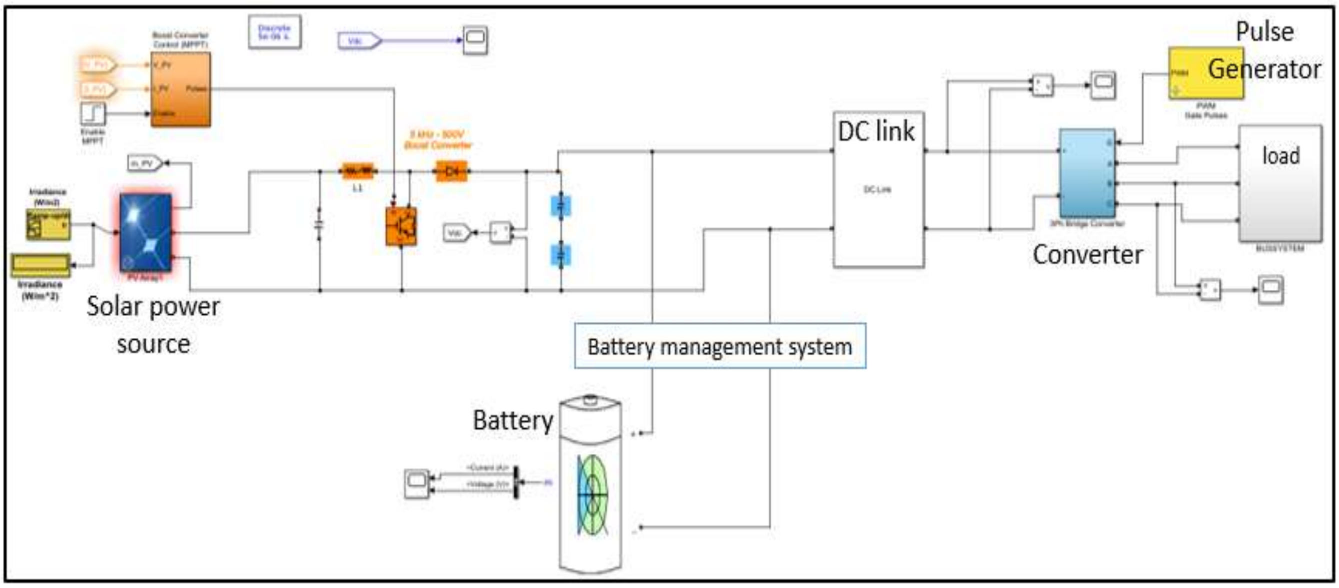

Fig 2. Simulation model for standalone solar system.

A Simulation model is designed in MATLAB Simulink as shown in Fig. 2 is a simulation model for a standalone solar system. Where the battery is powered by a solar power. We have used a dc link, converter to connect the source to the load. The purpose of a converter is to convert the DC voltage to another level. The DC link is a connection which connects a rectifier and an inverter. The DC link usually has a capacitor known as the DC link capacitor.

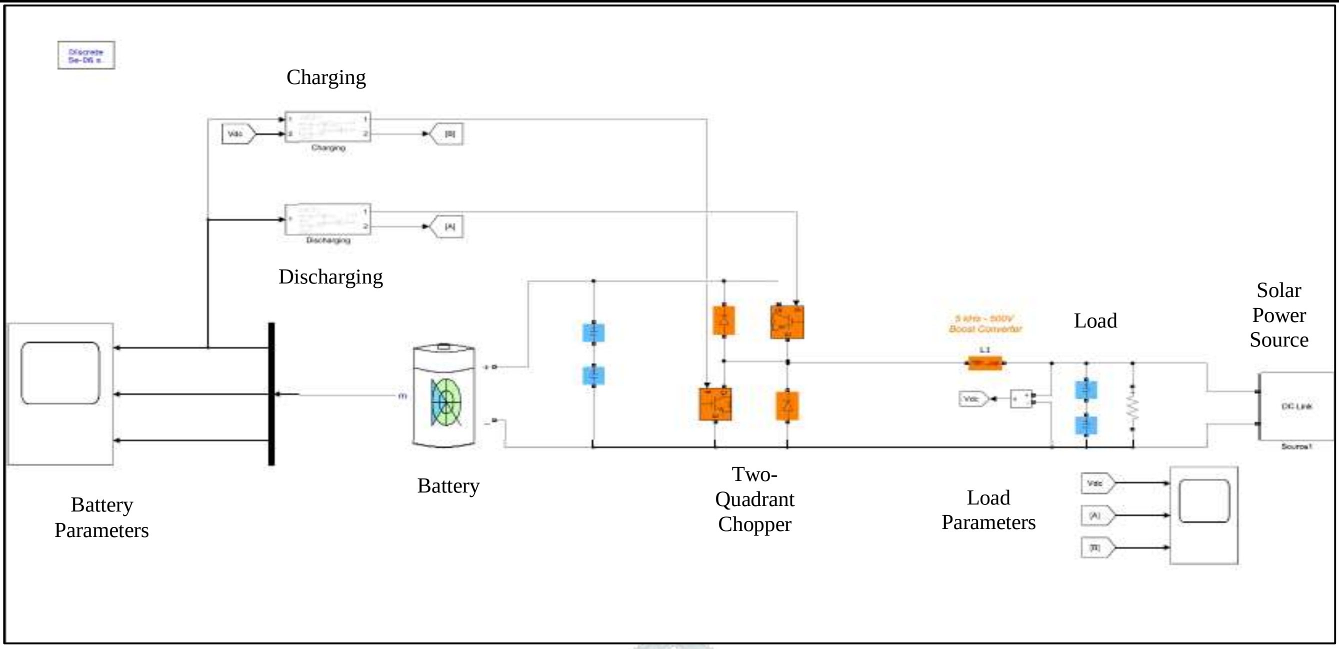

Fig 3. Simulation Model for Battery Management System.

A Simulation model is designed in MATLAB Simulink as shown in Fig 3. A source is connected to a resistive load. We have used a Two-Quadrant Chopper between a battery and source. The pulses are generated for charging and discharging. In this way a Battery Management System is designed for Standalone solar system.

MATLAB was used to create this simulation model. A battery can be protected by a BMS that prevents it from running outside of its safe operating range. However, in this case, a battery management system (BMS) is employed to safeguard the battery from overcharging and over discharging. The battery is linked to a two-quadrant chopper in the model. The chopper's primary function is to immediately convert a fixed DC input voltage to a variable DC output voltage. Also, the chopper's devices are unidirectional, which means they only allow electricity to travel in one way.

Between the battery and the source lies a resistive load. A DC current is supplied to the battery by the DC source. As a result, the model is for a solar system that is self-contained. So the source should be a solar power system that uses its energy to charge the battery, and instead of a resistive load, we may connect a bus bar system. However, for the sake of simplicity, we've utilized a dc supply and a resistive load in simulation model. A pulse generator is used in the charging and discharging subsystem. The subsystem's inputs include load voltage and Battery State of Charge (SOC). As a result, we'll look at battery characteristics like SOC, voltage, and current. Load voltage Vdc can be observed as a load parameter. We can also see the charging and discharging pulses on the graph in Simulink's Scope.

V. RESEARCH METHODOLOGY

Renewable energy sources are energy sources that are always being replenished. They can never be depleted. Some examples of renewable energy sources are solar energy, wind energy, hydropower, geothermal energy, and biomass energy. Solar energy refers to capturing the energy from the Sun and subsequently converting it into electricity. A stand-alone solar system the solar panels are not connected to a grid but instead are used to charge a bank of batteries. These batteries store the power produced by the solar panels and then your electrical loads draw their electricity from these batteries. A battery converts chemical energy into electrical energy by a chemical reaction. A battery management system (BMS) is any electronic system that manages a rechargeable battery. A battery needs to be protected from overcharging and over discharging.

Solar power produces solar energy to charge the battery and provide energy to the load. However, this system uses a DC source and a resistive load for simplicity of work. The battery is used to store the energy and use it when there is no source available. A two-quadrant chopper is connected between the source and the battery. Allows energy to flow in only one direction. The chopper also converts a fixed DC input to a variable DC output. The Battery State of Charge (SOC) is provided to the pulse generator. Where battery charging and discharging conditions is applied. The charging condition is that the 99% SOC limit must not be exceeded. The discharge limit must not exceed the lower limit of 10% SOC. This will prevent the battery from overcharging and over discharging. Therefore, the charge and discharge pulses, SOC, and load voltage can be observed.

VI. WORKING

In the simulation model, we're regulating the battery's charging and discharging. There are three stages to the simulation. The initial charging and discharging of the battery is the first stage. The second stage is to prevent the battery from becoming overcharged. The third stage is to prevent the battery from over discharging.
The three stages of a simulation model's operation are detailed here:

First Stage:
The first step is the early stages of the simulation. Here is to look at the charging and discharging of the battery. Here, the state of charge (SOC) is 50% of the battery, which means that the battery is 50% charged. The source is connected to the load when charging. Therefore, the DC source flow moves the battery from the source. This means that the battery is now charging. This battery is for stand-alone systems, so in the absence of a solar energy source (for example, at night or on cloudy days), a charged battery will energize the load. Therefore, to discharge the battery, you need to remove the source from the load. The battery begins to discharge

energy to the load. This project is for a stand-alone PV system and requires PV instead of a DC source. But to make the job easier, I used a DC power source and a resistive load. Therefore, the SOC, charge and discharge pulses can be observed through the graph after simulation of the model.

Second Stage:
In the second stage, we can see the overcharging the battery and preventing it from exceeding its limit. The battery can be charged up to the upper limit of 100%. However, if the battery is fully charged and still provides energy, the battery can be damaged. Therefore, you need to protect the battery from overcharging. Here, we designed the charging block so that when the SOC reaches 99%, the highest limit, the battery will no longer charge. Therefore, it prevents overcharging. The source is connected to the load. The source provides energy to the battery for charging. Now if the battery State of charge (SOC) is 98.95%. The battery is then charged to the maximum limit 0f 99% enough and then will stop charging the battery further. The SOC, charging pulses and load parameters can be observed graphically after simulation.

Third Stage:
In the third stage, we will see the battery over-discharging and preventing it from exceeding its limit. Here, the discharge block is designed such that if the battery reaches the lowest charge limit, i.e. 10%, it stops further discharging the battery to avoid over discharge. We need to disconnect the source and load. Because when there is no solar energy to supply the load. The energy stored in the battery provides energy to the load. This will drain the battery. When the battery's state of charge (SOC) is 10.1%. Then the battery will discharge to the lower limit of 10% and stop continuing to discharge the battery further. Thus, it will prevent the battery from being over-discharged.

VII. RESULTS AND DISCUSSION

In this study, we simulated a model for controlling battery overcharging and over discharging. This simulation can be observed in three stages of operation. The first stage is the initial stages of charging and discharging. The second and third stage prevent overcharging and over discharging respectively of battery. The working and connection of the model is well described in the above chapters. Here we will observe various parameters of the battery system through graphs such as State of charge (SOC), charging and discharging pulses, load voltage (Vdc).

The first stage is the initial charging and discharging stage. Here, the state of charge (SOC) of the battery is 50%. So firstly, the battery is charged with the help of a source. We can observe the battery charge in the SOC graph. In other words, we can see that the SOC is increasing over time. Similarly, the battery discharge from 50% SOC is shown in the figure. For discharging, the source is disconnected. So the battery is supplying energy to the load. You can see the graph is decreasing from 50% SOC with time.

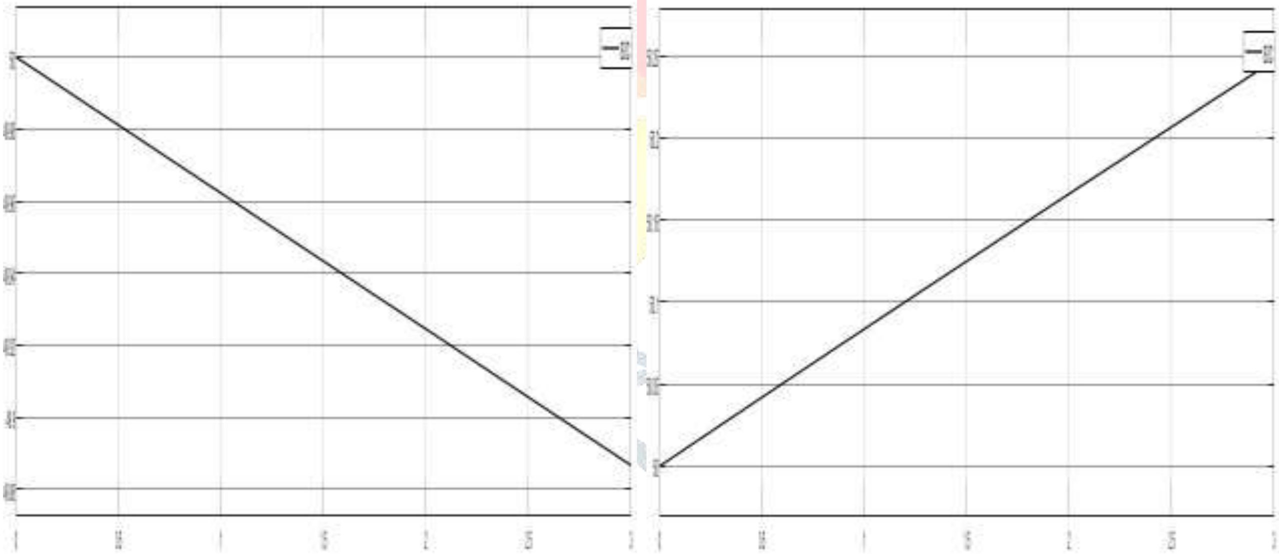

Fig 4. State of Charge of Battery for Charging and Discharging.

In the Fig. 5 and Fig. 6 for the charging and discharging of battery we will see the charging and discharging pulses respectively.

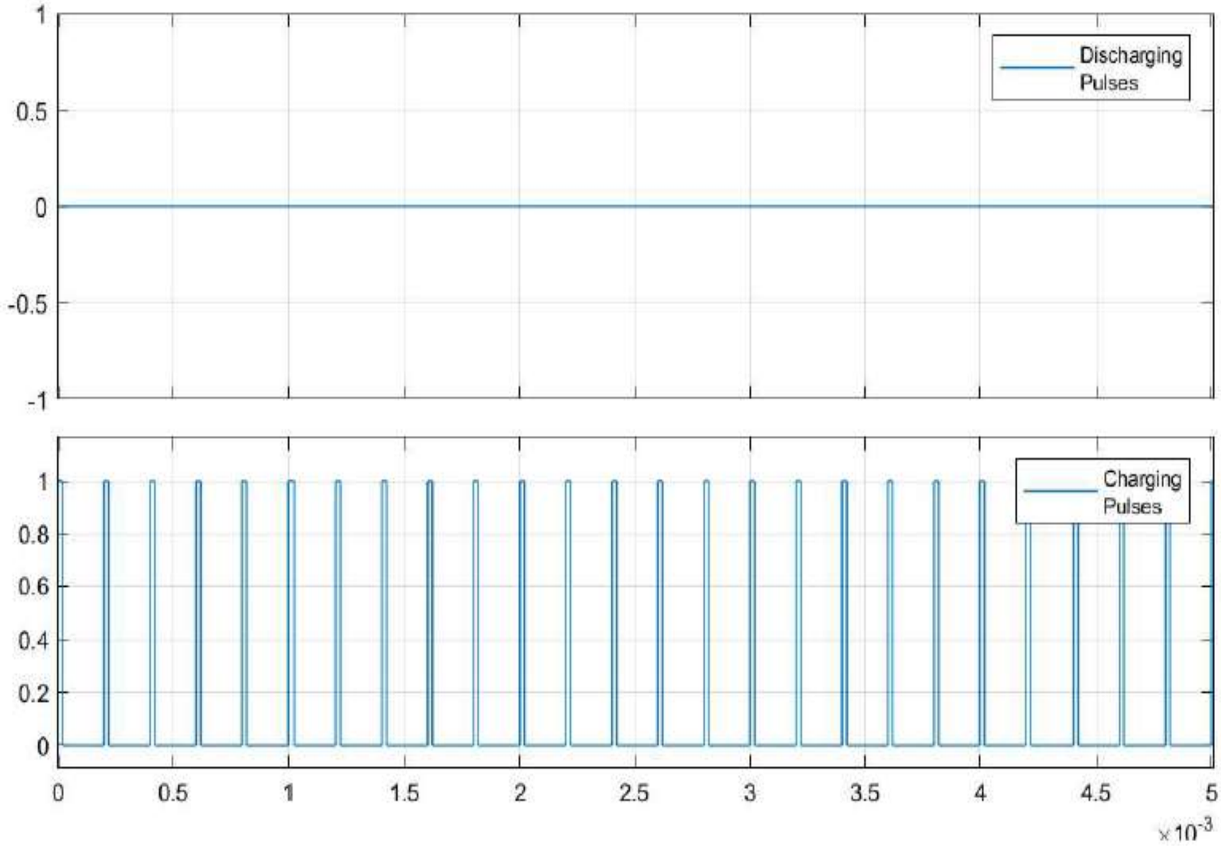

Fig 5. Charging pulses when charging the battery.

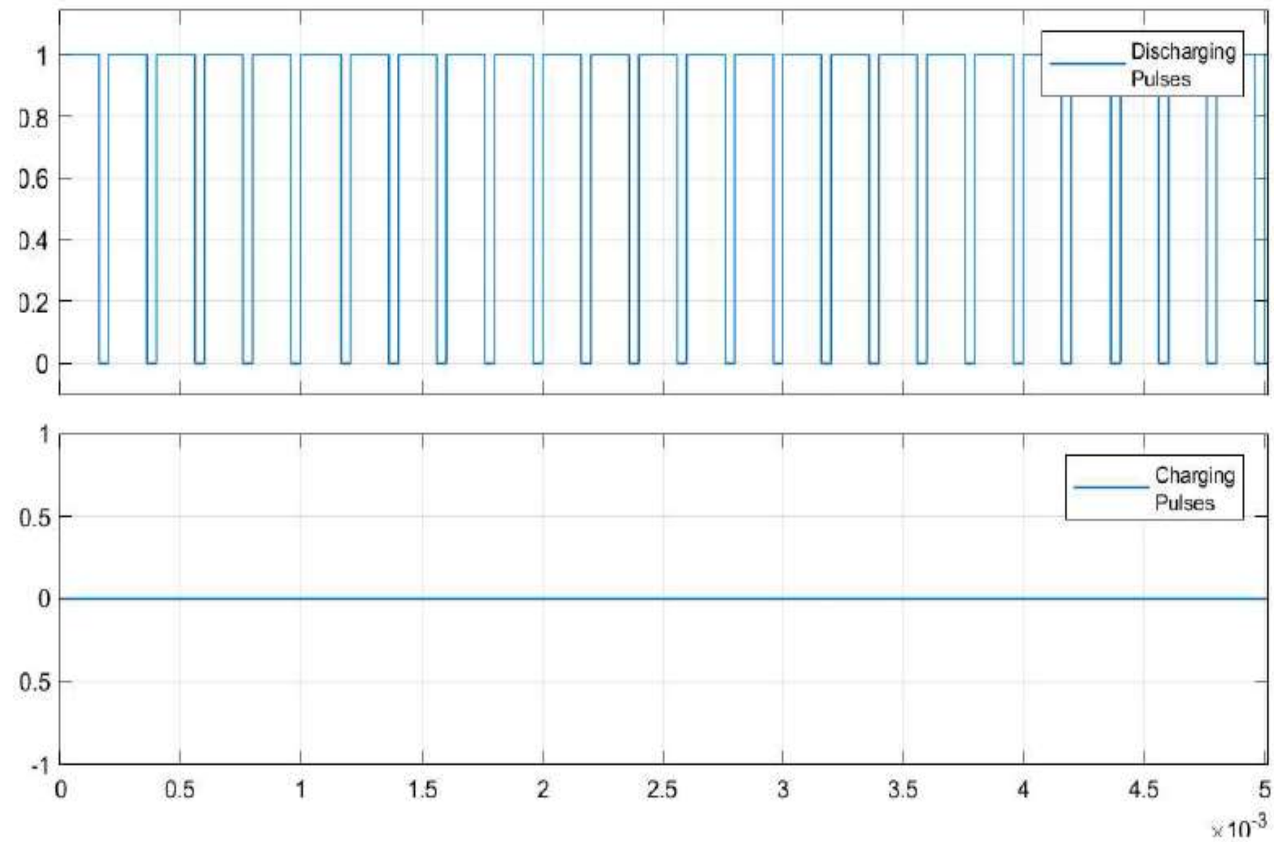

Fig 6. Discharging pulses when discharging the battery.

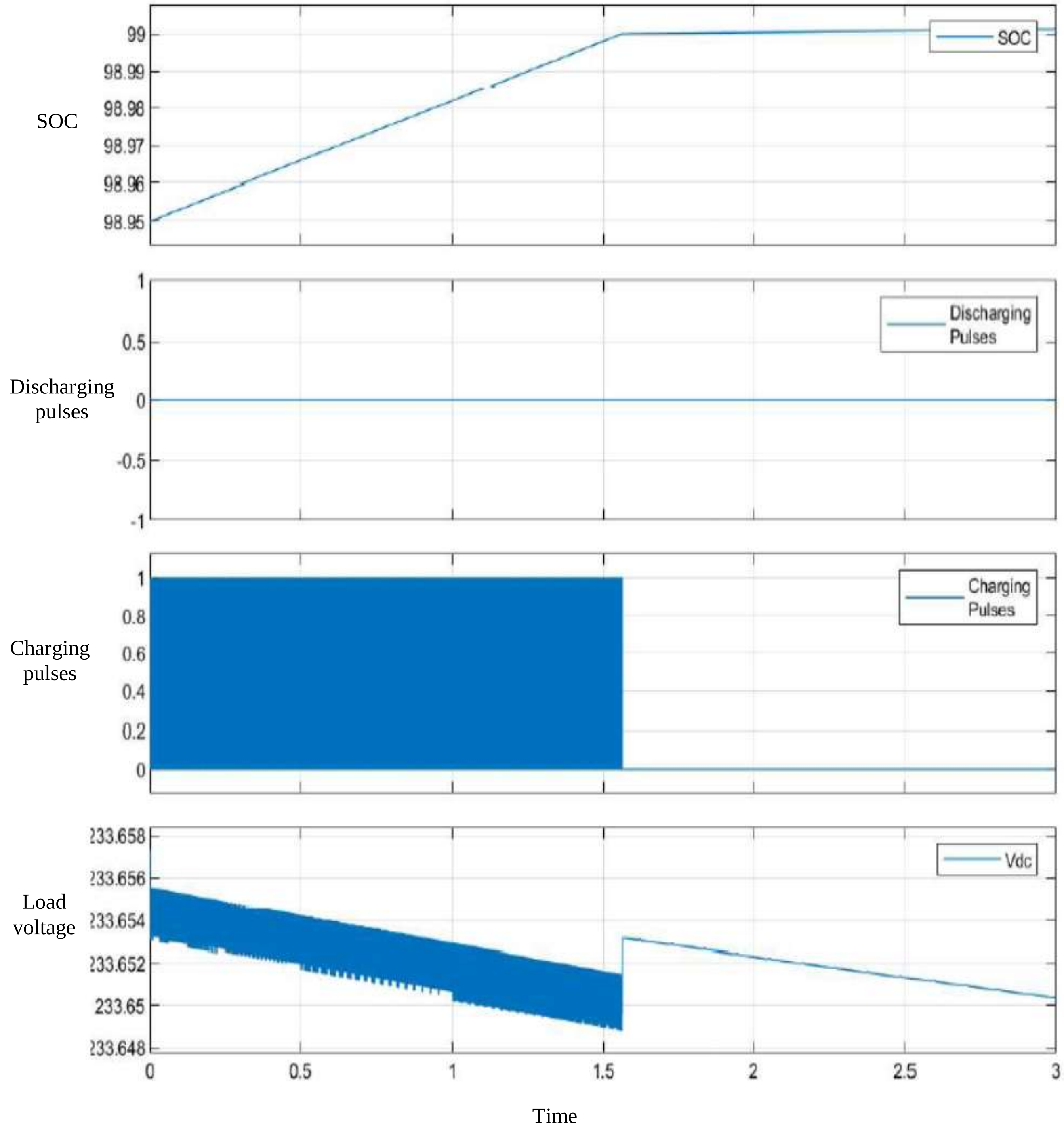

Fig 7. Prevention of battery from over charging.

We can observe from the above graph Fig. 7 of simulation for preventing overcharging of battery. We have applied a state of charge (SOC) which is limited to a maximum of 99%. Thus, the battery will not exceed the charge limit. So, preventing it from overcharging. In the first SOC graph, we can see that the graph goes up from 98.95% to 99% and then the charge becomes constant. As a result, the battery stops charging further. We can also see the voltage across the load in the graph. We can also observe the charging pulse up to the peak point and beyond the graph tends to zero. No discharging pulse were observed. Hence, from the fig. we can clearly see the charging of battery and prevention from overcharging the battery. This was the second stage of operation.

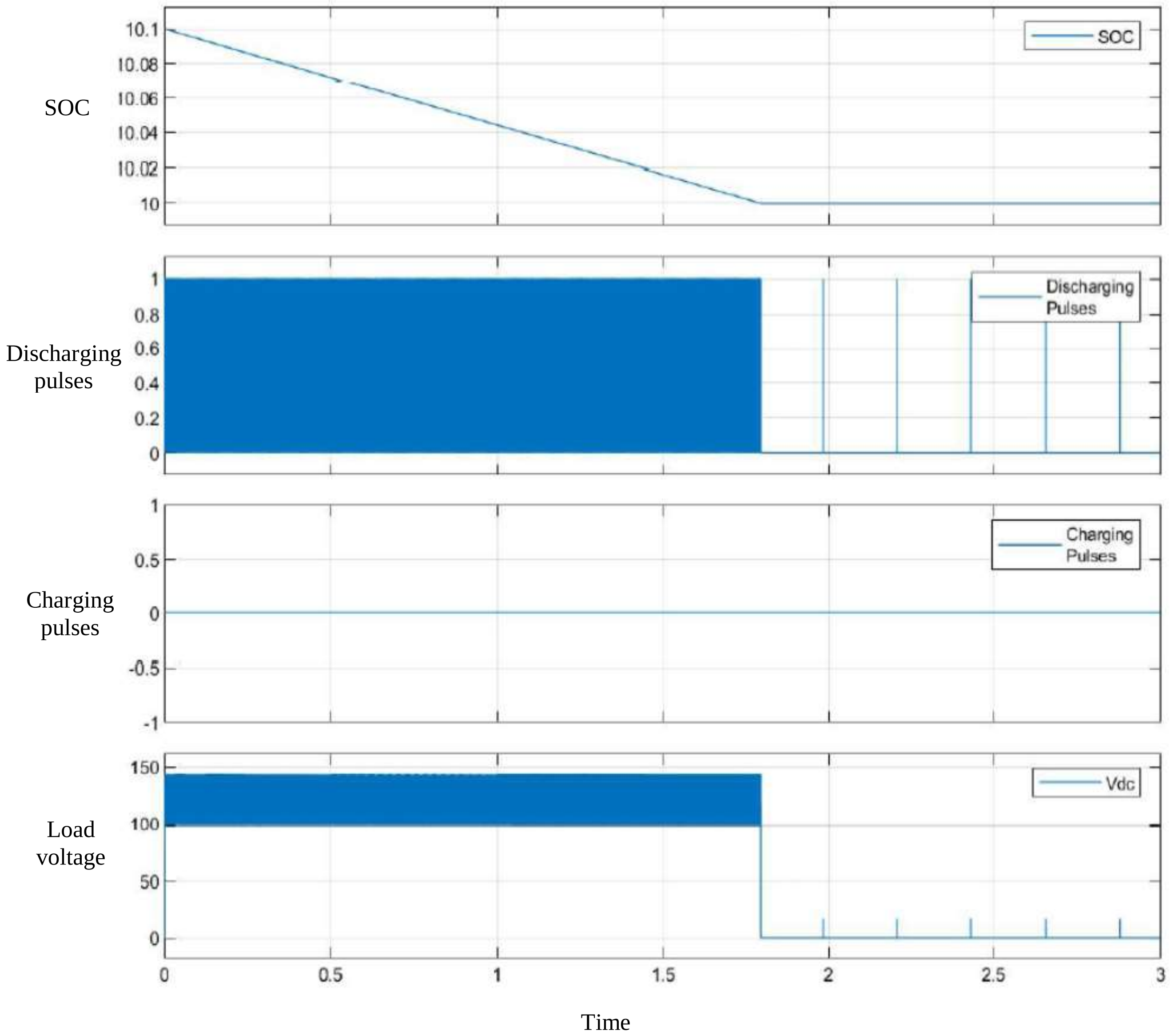

Fig 8. Prevention of battery from over discharging.

We can observe from the above graph fig. 8 the prevention from over discharging of the battery. For this the source is disconnected and the battery discharge itself to give energy to the load i.e. during the night or cloudy day when there is no solar energy. Here we have set a minimum State of Charge (SOC) limit to 10%. So that battery will not exceed its limit and will not over discharge it. From the first graph of SOC we can observe that the graph decreases from 10.1% to 10% and then it remains constant. Hence the battery is protected from over discharging. Also we can observe the voltage across load. Here we can observe the discharging pulses where as there is no charging pulses. The discharging pulses can be see till the break point after that the pulses get constant. As the further discharging of the battery is stopped. Therefore, from the above graph fig we can clearly observe the prevention of battery from over discharging. This was the third stage of operation.

In simulation model, the battery is linked to a two-quadrant chopper. The chopper's primary function is to immediately convert a fixed DC input voltage to a variable DC output voltage. Also the chopper's devices are unidirectional, which means they only allow electricity to travel in one way. Two-quadrant chopper used in this simulation model, which acts as a high speed switch which connects and disconnects the load from source at high rate to get variable or chopped voltage at the output. The subsystem's inputs include load voltage and Battery State of Charge (SOC). As a result, we'll look at battery characteristics like SOC and Load voltage Vdc can be observed as a load parameter. We can also see the charging and discharging pulses on the graph in Simulink's Scope. With the help of controlling limits for charging and discharging i.e. 99% and 10% we have successfully prevented the battery from overcharging and over discharging. Therefore, battery protected by a BMS that prevents it from running outside of its safe operating range can safeguard the battery from overcharging and over discharging.

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