ELECTRIC VEHICLES

(EEE 4016)

PROJECT REPORT

Project Title:

Battery Cell Voltage Balancing Techniques

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(CONTENTS IN DETAIL)

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CERTIFICATE

This is to certify that the project work entitled “ BATTERY CELL VOLTAGE BALANCING TECHNIQUES ” by Siddhartha Menon(17BEE0045), Ayan Sikdar(17BEE0244) and Soumya Ranjan(17BEE0134) submitted to Vellore Institute of Technology University, Vellore, in partial fulfillment of the requirement for J component of the course titled Electric Vehicles(EEE 4016) is a work carried out by us under my supervision. The project fulfills the requirement for J component as per the regulations of this Institute and in my opinion meets the necessary standards for submission.

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Acknowledgement

We would like to take this opportunity to thank VIT University for encouraging us and giving the opportunity to perform this project. We could never have proceeded with our project if we did not get the correct resources.

We would also like to thank our Project Guide, Dr. Chitra.A for guiding us through every step of this project.

Lastly, we would like to thank our family and friends for their unconditional support towards us.

INTRODUCTION

Cell balancing is a method to keep in check the voltages and SOC of individual cells connected in series in a battery pack. When the battery pack is assembled it is made sure that the cells have the same cell chemistry, but due to the constant charging and discharging anomalies arises which thereafter tend to various changes in the cells health and other factors. This develops a situation in which the voltages of the cells become different at the same time which causes cell unbalancing, So to counter this cell balancing is used. We can imagine a chariot which is being pulled by 4 horses. If any one horse is running slow then the others have to slow themselves down to match the slow horse or if one horse is running faster than the others then it will be dragging the chariot, thus, we need an equilibrium so that we can pull the chariot with maximum efficiency. Similarly, we also need cell balancing to make sure we run our BMS and battery pack at its maximum efficiency.

PROJECT OBJECTIVES

In electrical vehicles, Battery Management System (BMS) plays and important role, in order to achieve a reasonable life-time and best performance. A cell balancing circuit is essential to equalize each battery cell as the same voltage level in a series battery cells. Among cell balancing method, flyback converter balancing method has fast balancing time. It has N secondaries for N cells. It only requires one switch and N diodes at the output for each cell. Therefore, the number of active switches are reduced, resulting in less losses and more efficient. In this paper, eight cells are investigated to be equalized.

A BMS may monitor the state of the battery as represented by various items, such as:

- Voltage: total voltage, voltages of individual cells, or voltage of periodic taps
- Temperature: average temperature, coolant intake temperature, coolant output temperature, or temperatures of individual cells
- Coolant flow: for air or fluid cooled batteries
- Current: current in or out of the battery

DIFFERENT TYPES

Cell balancing techniques can be broadly classified into four groups-

Passive Cell Balancing :

It is the simplest method of them all and can be used in situations where cost cutting and simplicity is the main idea. But it is inefficient as excess charge is unused.

Active Cell Balancing:

In active balancing the excess charge form one cell is transferred to another cell of low charge to equalize them. This is achieved by utilizing charge storing elements like Capacitors and Inductors.

Lossless Cell Balancing:

Lossless balancing is a recently developed method that reduces losses by reducing the hardware components and providing more software control. This also makes the system simpler and more easier to design.

Redox Shuttle:

It is based on the chemical properties of the cell. In lead acid battery we do not a problem of cell balancing due to its eccentric property of releasing gasses which prevents it from unbalancing. a similar approach is being developed for the lithium ion battery cells which will remove the software and hardware components for cell balancing.

PROPOSED METHOD

Two- Winding Inductor Balancing Technique

The two-winding inductor or flyback converter is used in both AC/DC and DC/DC conversion with galvanic isolation between the input and any outputs. The flyback converter is a buck-boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation. The ability of the converter to provide galvanic isolation can be used for to provide multiple outputs and positive negative output voltage as well as selection equalising the voltage and the state of charge among the cells.

CIRCUIT DIAGRAM

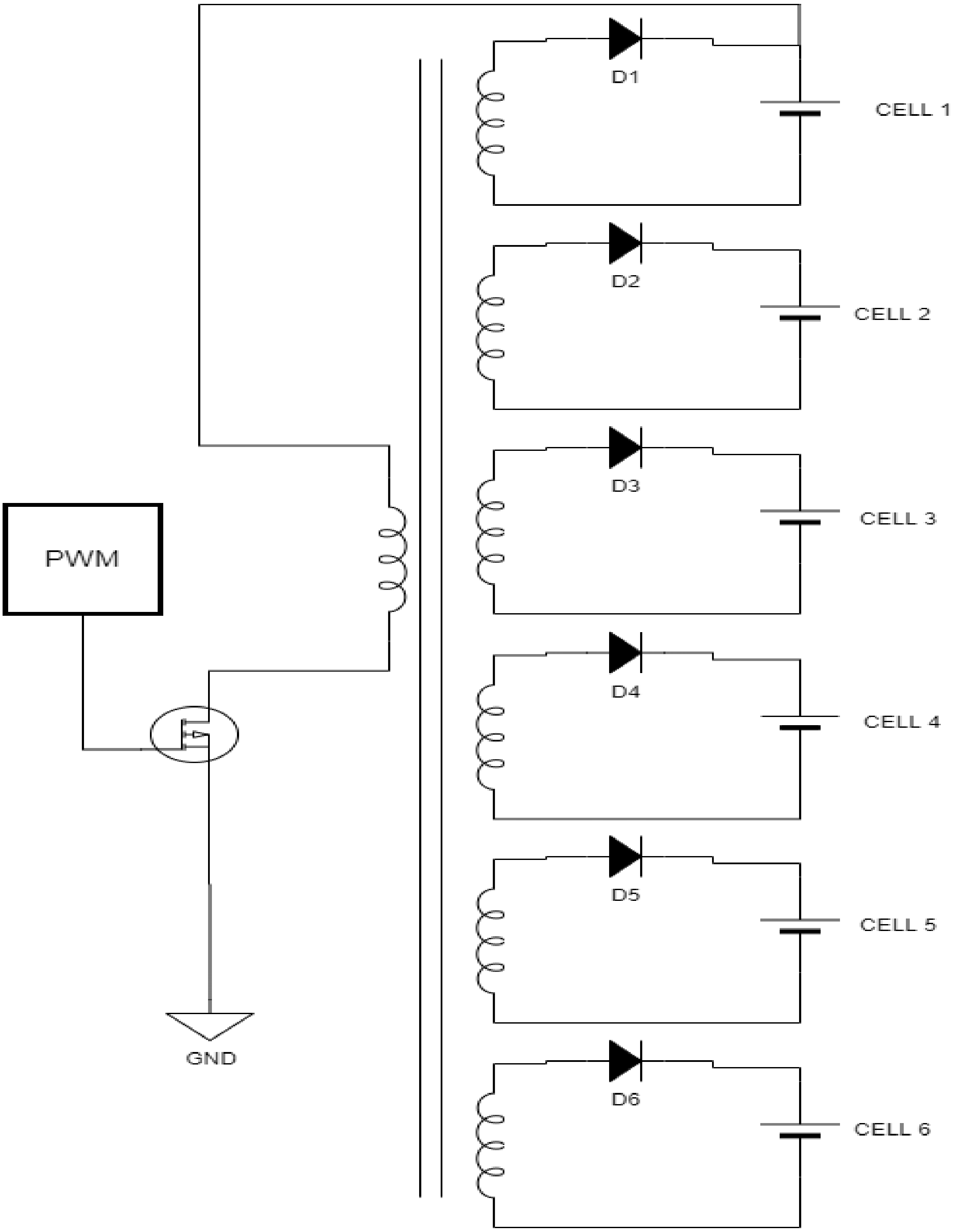

Figure (1) The Flyback converter balancing scheme

WORKING PRINCIPLE

The Figure (1) shows the circuit diagram used for this project. The primary winding is connected to the whole battery module, every cell in the module is connected to the secondary winding with a diode in between. The secondaries are placed in such a manner that their polarity is reverse to that of primary winding. When the N channel MOSFET, which is the switch is turned on, the energy is stored in the primary winding in the form of flux. As the diode is in reverse bias in this mode therefore the energy cannot be transferred to the secondaries. Now, when the switch/MOSFET is turned OFF the energy is transferred to the secondary windings. In this manner the individual cells are equalized. The main advantage of using a flyback converter instead of others is the low cost, simple design and high efficiency, and it is also widely used in power supplies. Moreover, the two sides- primary and secondary, are isolated from each other and they can also provide multiple output and positive negative output voltage selection.

EQUATIONS INVOLVED

$$Ton = D * Tp$$

$$i_{LP} = \left(\frac{V_{Battery}}{L}\right) * Ton$$

$$V_{LP} = V_{Battery}$$

$$Toff = (1 - D) * T_p$$

$$Ton * V_{LP} = V_{Battery} * D * T_p$$

$$Toff * V_{LP} = (-V_{cell\ m}/n) * (1 - D) * T_p$$

$$V_{Battery} = n * \frac{D}{1 - D} * V_{cell\ m}$$

$$P_{out} = V_{out} * I_{out}$$

$$I_{P,ave} = \frac{P_{in}}{V_{Battery}}$$

$$I_{P,ave} = \frac{1}{Tp} * \int_0^{Tp} I(t)dt = \frac{Area}{Tp}$$

$$Lp = \frac{V}{di} dt$$

$$Lp = \frac{V_{Battery}}{I_{Peak}} * Ton$$

$$V_{LP} = \left(-\frac{Vcell1}{n}\right) + \left(-\frac{Vcell2}{n}\right) + \cdots + \left(-\frac{Vcelln}{n}\right)$$

SIMULATION DIAGRAMS

Implementation of Figure(1) with two cells-

A single linear transformer is used to emulate the primary and secondary windings which were shown in figure (1). Each cell is connected to the secondary winding through the diode. The MOSFET or the switch is controlled by a MATLAB function which compares the voltages of the two cells and decides whether to balance them or not. Finally, each cell is connected to a voltage measurement device and the combined voltages of cell 1 and cell 2 are shown as the battery voltage. And all the signals are logged and voltages are plotted in the scope.

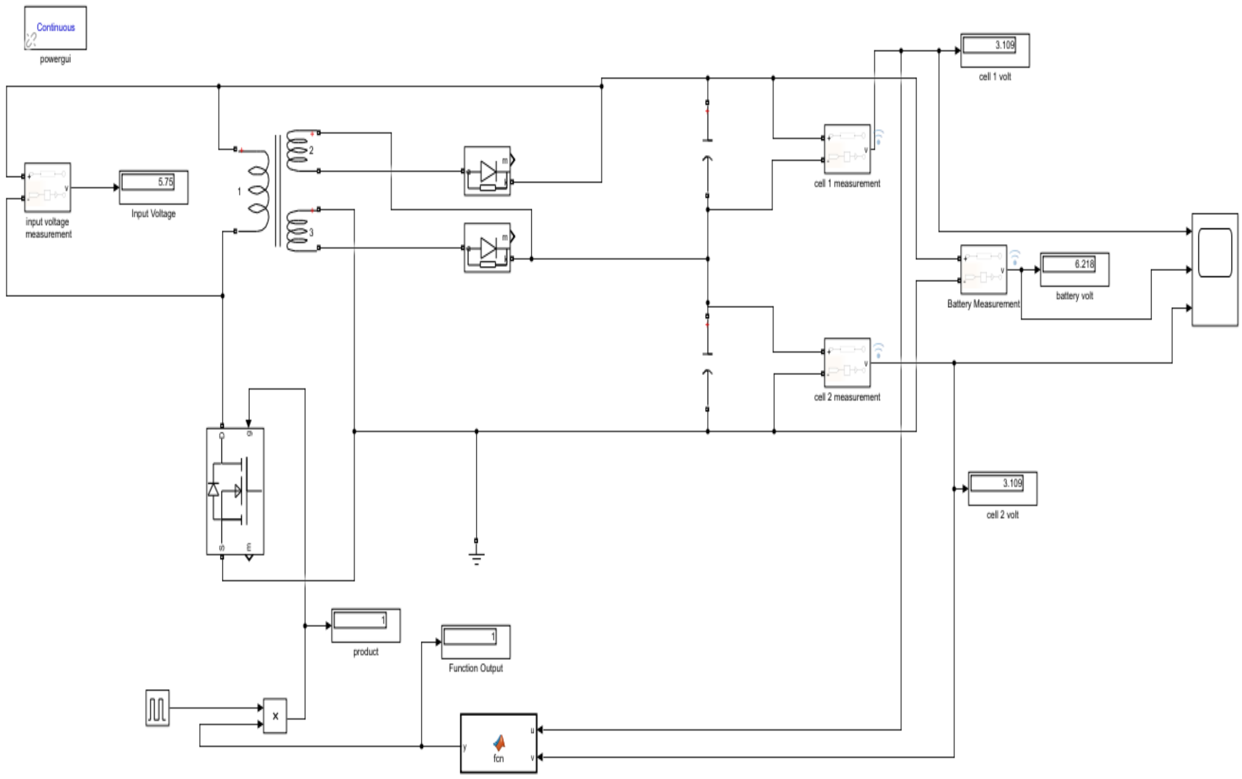

Figure (2) Two cells

Implementation of Figure(1) with four cells-

A double linear transformer setup is used to emulate the primary and secondary windings which were shown in figure (1). Each cell is connected to the secondary winding through the diode. The MOSFET or the switch is controlled by a MATLAB function which compares the voltages of the four cells and decides whether to balance them or not. Finally, each cell is connected to a voltage measurement device and the combined voltages of cell 1, cell 2, cell 3 and cell 4 are shown as the battery voltage. And all the signals are logged and voltages are plotted in the scope.

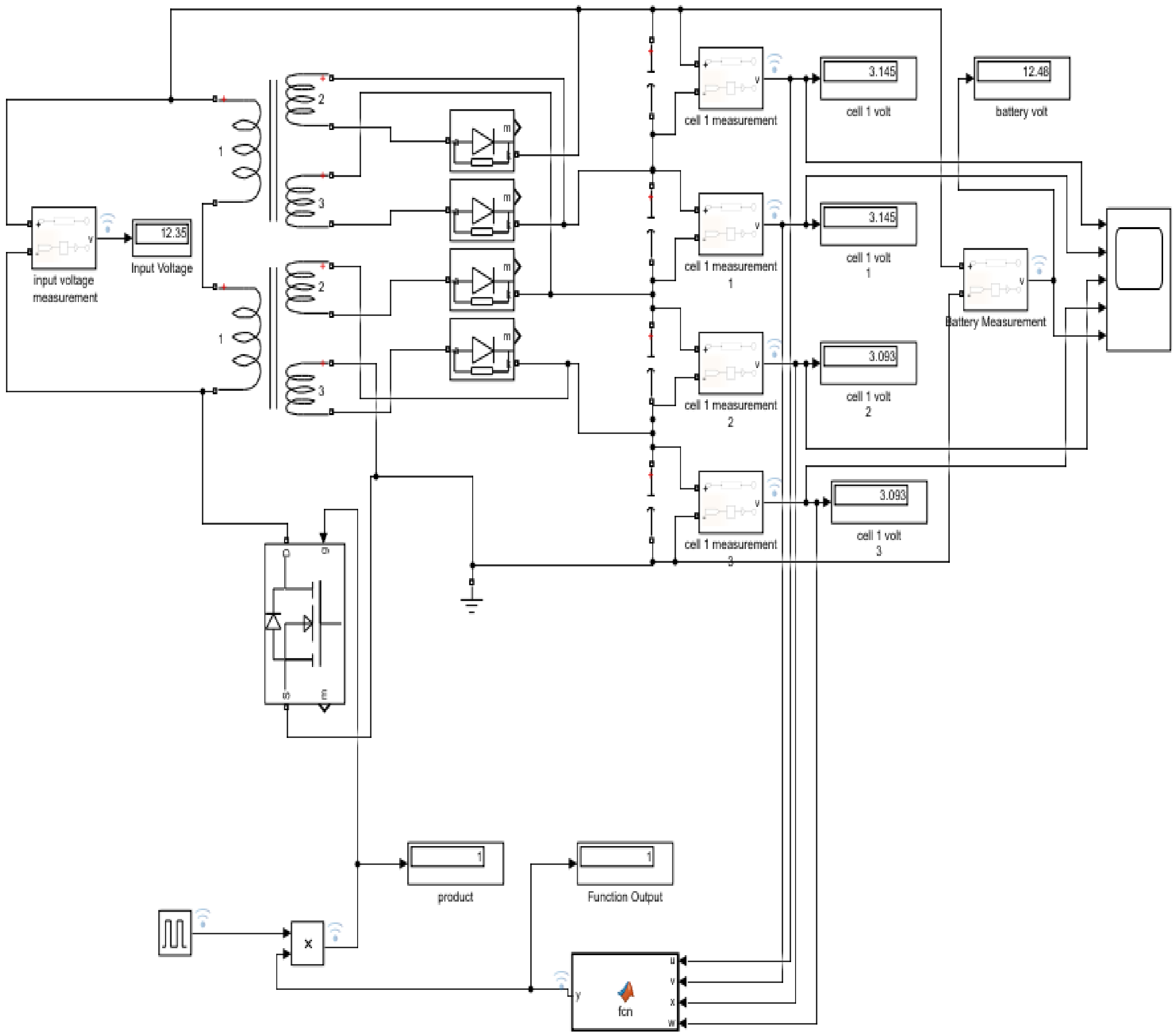

Figure (3) Four cells

Implementation of Figure(1) with six cells-

A triple linear transformer setup is used to emulate the primary and secondary windings which were shown in figure (1). Each cell is connected to the secondary winding through the diode. The MOSFET or the switch is controlled by a MATLAB function which compares the voltages of the six cells and decides whether to balance them or not. Finally, each cell is connected to a voltage measurement device and the combined voltages of cell 1,cell 2,cell 3, cell 4, cell 5 and cell 6 are shown as the battery voltage. And all the signals are logged and voltages are plotted in the scope.

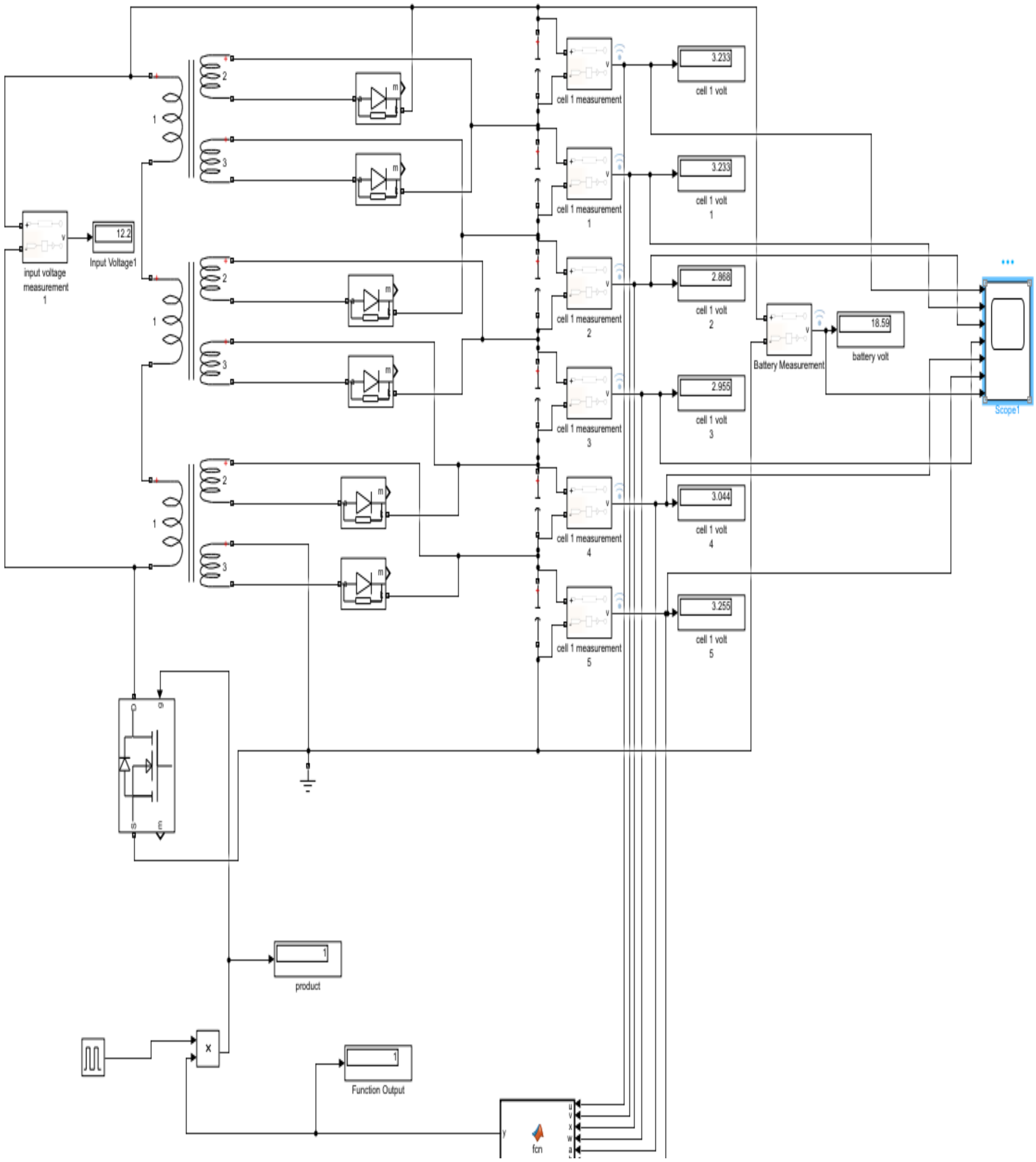

Figure (4) Six cells

SIMULATION RESULTS

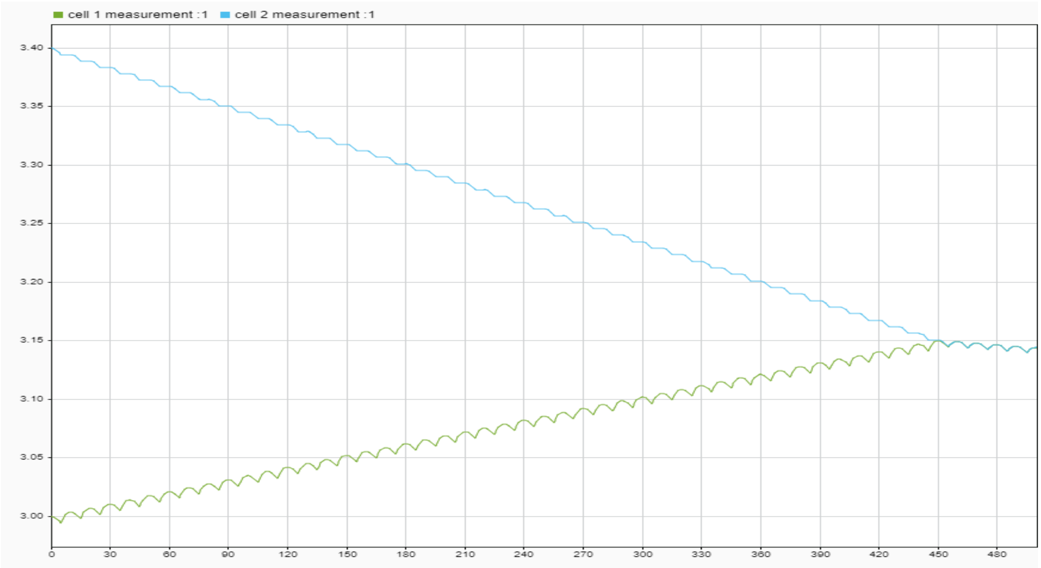

Figure (5)

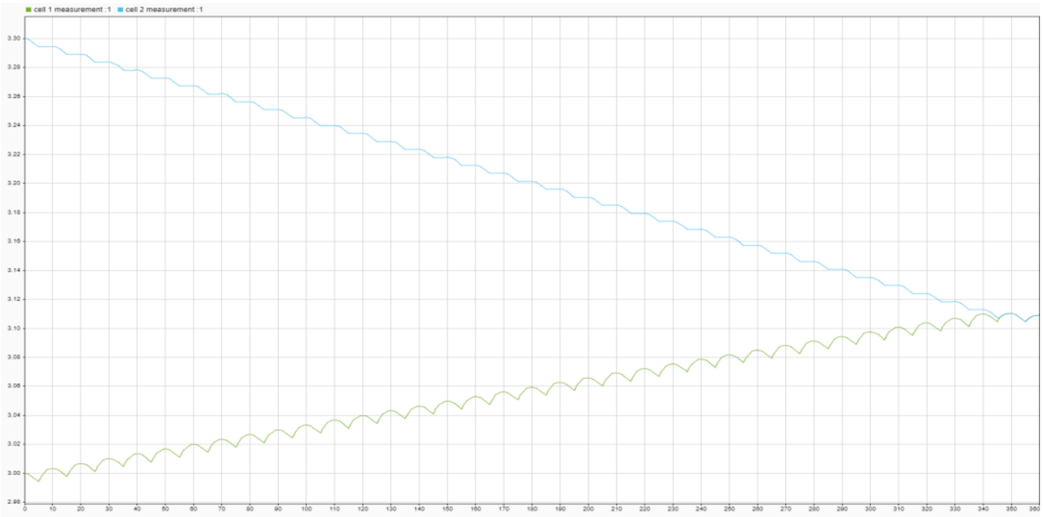

Figure (6)

The above figures 5 and 6 show the balancing time required when two cells are connected in series. The figure (5) uses older algorithm which is why the balancing time in it is longer than figure (6) which uses a new algorithm for balancing. The time was reduced by an amount of 100 seconds.

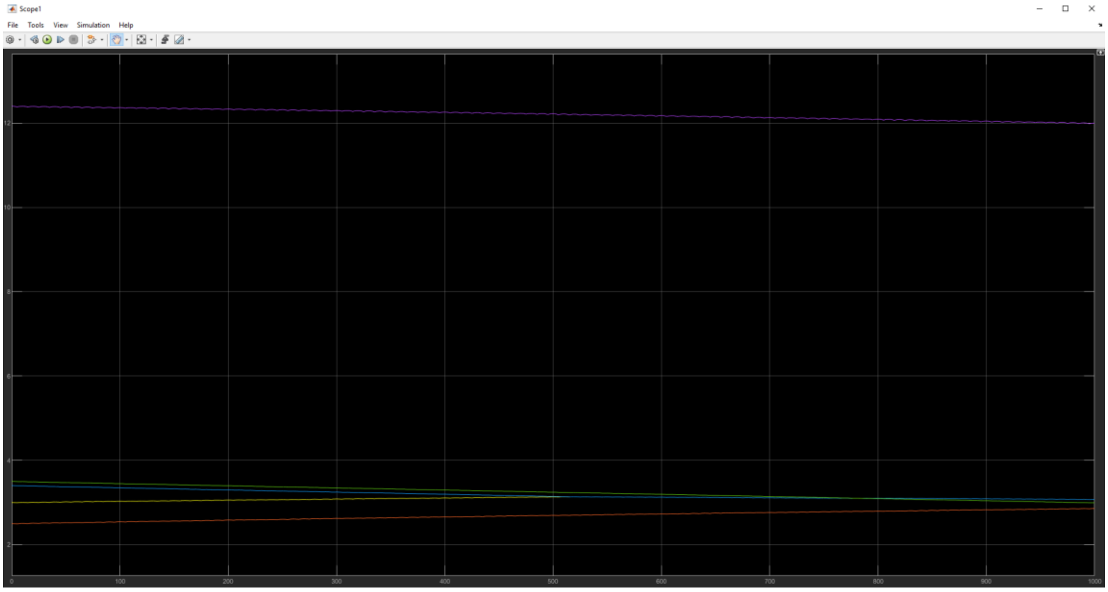

Figure (7)

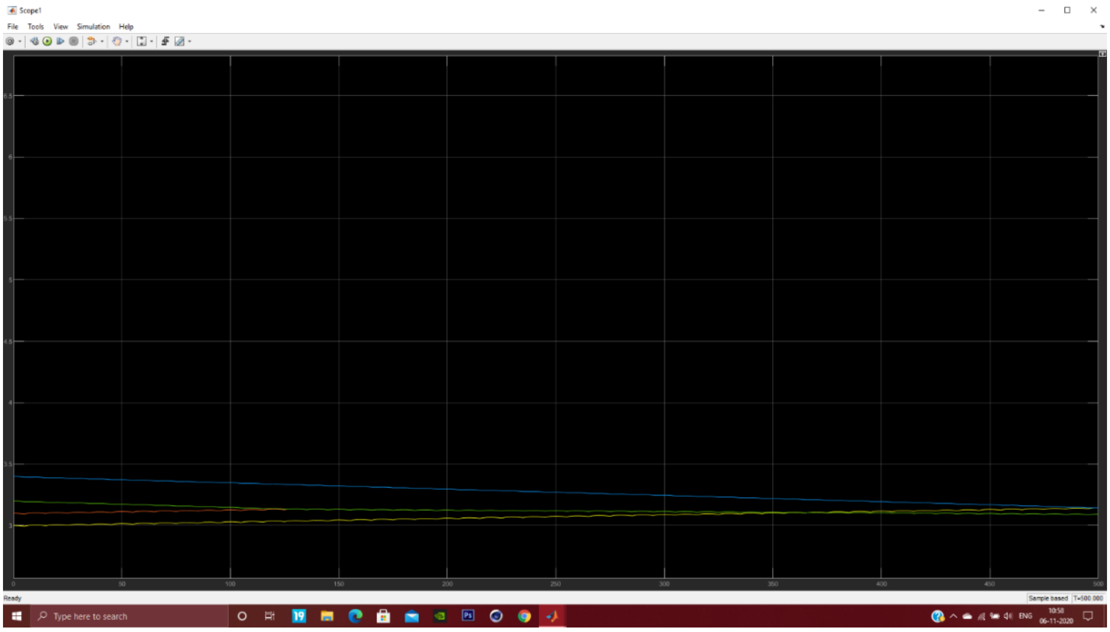

Figure (8)

Figures (7) and (8) are the ones in which four cells were balanced in series. The Figure (7) balances cells which have are less varying in their voltages, ranging from 3V to 3.4V. Whereas, Figure (8) is the balancing of four cells with much more varying voltages, ranging from 2.5V to 3.5V. Just by using cells which are a bit closer in voltages the simulation time was decreased substantially by 500 seconds. Which shows that using second-life cells and cells that are extremely undercharged and overcharged are challenging for the circuit to balance in a short span of time.

CONCLUSION

The simulation was conducted successfully for two, four, and six cells connected in series. There have been some tweaks in the original algorithm to make the balancing time shorter. This can be observed in the cell balancing diagrams shown for two cells in series. Although with reduced time this particular circuit is not suitable for second life battery packs or the cells that are extremely overcharged and undercharged. Which can be seen in the waveforms plotted when simulation was done for four cells in series. But, the overall time gets reduced dramatically by 500 seconds when the cells with less varying voltages were used, a similar thing can be seen for six cells connected in series,

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