ELECTRIC VEHICLES

(EEE 4016)

PROJECT REPORT

PROJECT TITLE:

Cell Equalization Technique for Battery System

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INTRODUCTION

Cell balancing is a method to monitor the voltages and State of charge of individual cells connected in series in a module. When the battery is integrated, it is made sure that voltage of the cells is equal. When the battery pack is put together, the cells are made to have the same cell chemistry, but owing to the frequent charging and discharging, anomalies occur, leading to significant changes in the cells' health and other issues. This creates a scenario in which the voltages of the cells diverge at the same moment, resulting in cell unbalance. To combat this, cell balance is employed.

Techniques for cell balancing may be divided into four categories:

- **Passive Cell Balancing :** This is the simplest approach of cell balancing in which charges simply gets dissipated during the charging cycle.
- **Active Cell Balancing :** Excess charge from one cell is transferred to another cell with low charge to equalize them. This is accomplished through the use of charge storage devices such as capacitors and inductors.
- **Lossless Cell Balancing :** Lossless balancing is a newly developed approach for lowering losses by reducing the number of hardware components and increasing software control. This simplifies the system and makes it easier to design.
- **Redox Shuttle :** This is based on the chemical properties of the cell. In lead acid battery we don’t face 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.

OBJECTIVE

- EV's Battery system consists of a lot of cells which are charged substantially with a single source, and for charging, every cell must have identical voltage. Thus, Our Primary objective is to design a system which automatically equalize the cells before charging.
- Battery Management System (BMS) plays a crucial role, in order to achieve a reasonable life-time and best performance. So, we will tend to make No loss cell balancing system for better performance.
- Switching circuits are also needed to enable the equalization system. Following this, we would be adding the switch system to trigger the circuit as soon as the uneven voltages are detected.
- We would also be working with the more pairs of cells to test the system efficiency change with the number of cells.
- Reduction in Cell equalization time is also our concern after final testing.

BLOCK DIAGRAM

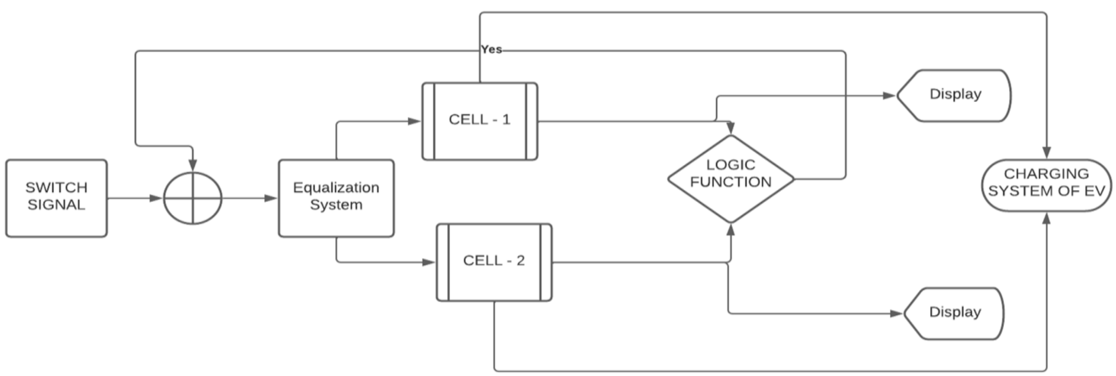

Fig.1 Cell Equalization logic Implementation

CIRCUIT DIAGRAM

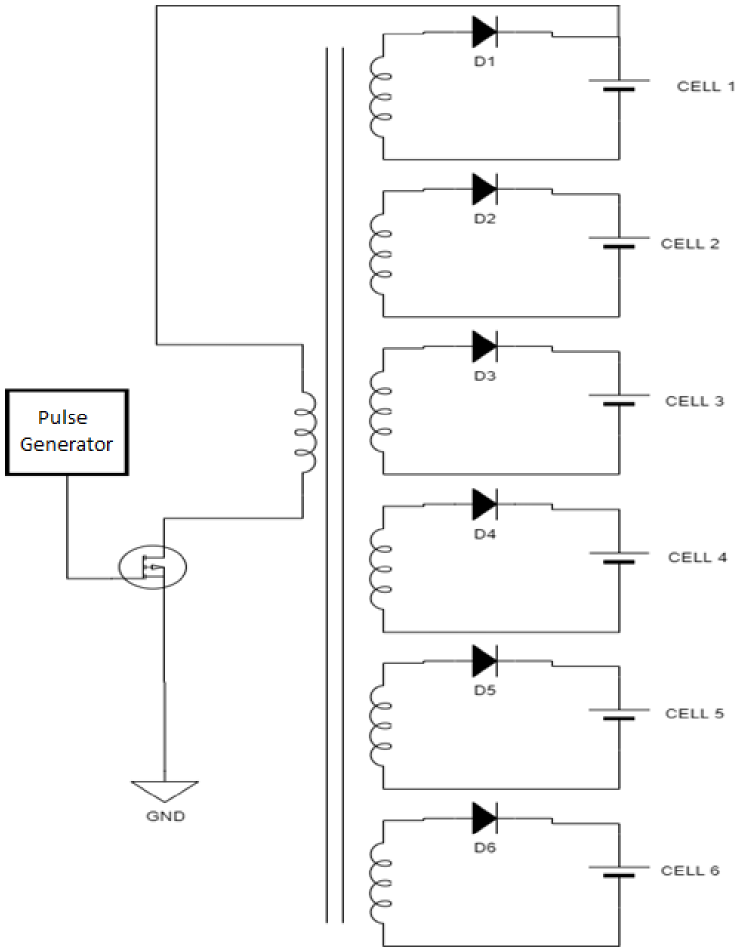

Fig.2 Circuit Diagram

WORKING PRINCIPLE

The primary winding in the circuit 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.

PROPOSED METHOD

Two- Winding Inductor Balancing Technique:

- With galvanic isolation between the input and any outputs, the two-winding inductor or flyback converter is employed in both AC/DC and DC/DC conversion. The flyback converter is a buck-boost converter with the inductor split to form a transformer, which multiplies voltage ratios while also providing isolation.
- The converter's capacity to produce galvanic isolation may be utilized to provide various outputs and positive or negative output voltage, as well as choosing equalizing voltage and state of charge among the cells.
- Based on the concepts listed, we are going to employ Inductance balancing method using linear transformer for cell balancing process.
- Here, we are going to apply logic function to trigger the equalization system which is equipped with the switching device.
- Thus, as the voltage level differs, Circuit is triggered, and cells are supplied with the equalized power, which results in the final balanced voltages for effective charging.
- Diode would be utilized here to make sure that no loss of charge occurs from battery towards balancing system.
- Both the cells would be equalized based on Active Cell Balancing Technique.
- Simulation results will show us the cell voltages and battery voltage variations during whole process, which is further used for equalization time reduction.

Design Equations

➢ MATLAB FUNCTION

TwoCellImplementation ▸ MATLAB Function

```
function y = fcn(a,b)
if(a==b)
    y = 0;
else
    y = 1;
end
```

Fig.3 Cell Banlancing function for 2 cells

FourCellImplementation ▸ MATLAB Function1

```
function y = fcn(u,v,x,w)
if(u <= v && u >= v &&  v<= w && v>= w && v <= x && v >= x)
    y = 0;
else
    y = 1;
end
```

Fig.4 Cell Banlancing function for 4 cells

SixCellImplementation ▸ MATLAB Function1

```
function y = fcn(u,v,x,w,a,b)
if(u <= v && u >= v &&  v<= w && v>= w && v <= x && v >= x && v <= a && v >= a && v <= b && v >= b)
    y = 0;
else
    y = 1;
end
```

Fig.5 Cell Banlancing function for 6 cells

➢ Design Logic

A single linear transformer is used to emulate the primary and secondary windings which were shown in previous figure. Each cell is connected to the secondary winding through the diode.

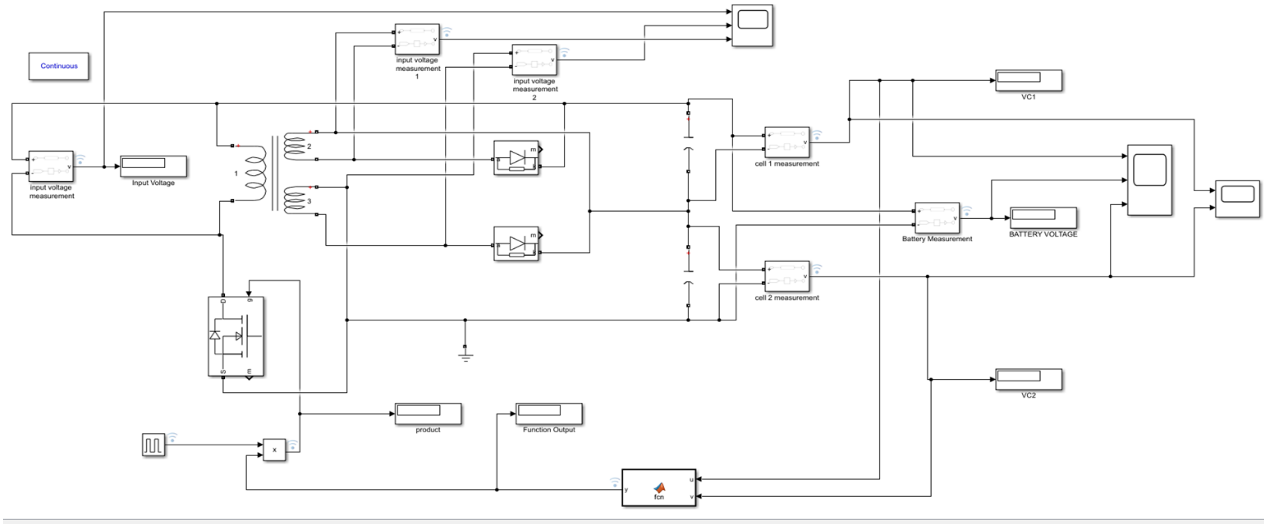

Fig.6 Simulation Diagram

The MOSFET or the switch is controlled by a MATLAB Logic function which compares the voltages of the two cells and yields a value which is multiplied with gate pulse to trigger the switch as soon as uneven voltages are detector.

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.

SIMULATION DIAGRAM

➢ For 2 Cell Setup

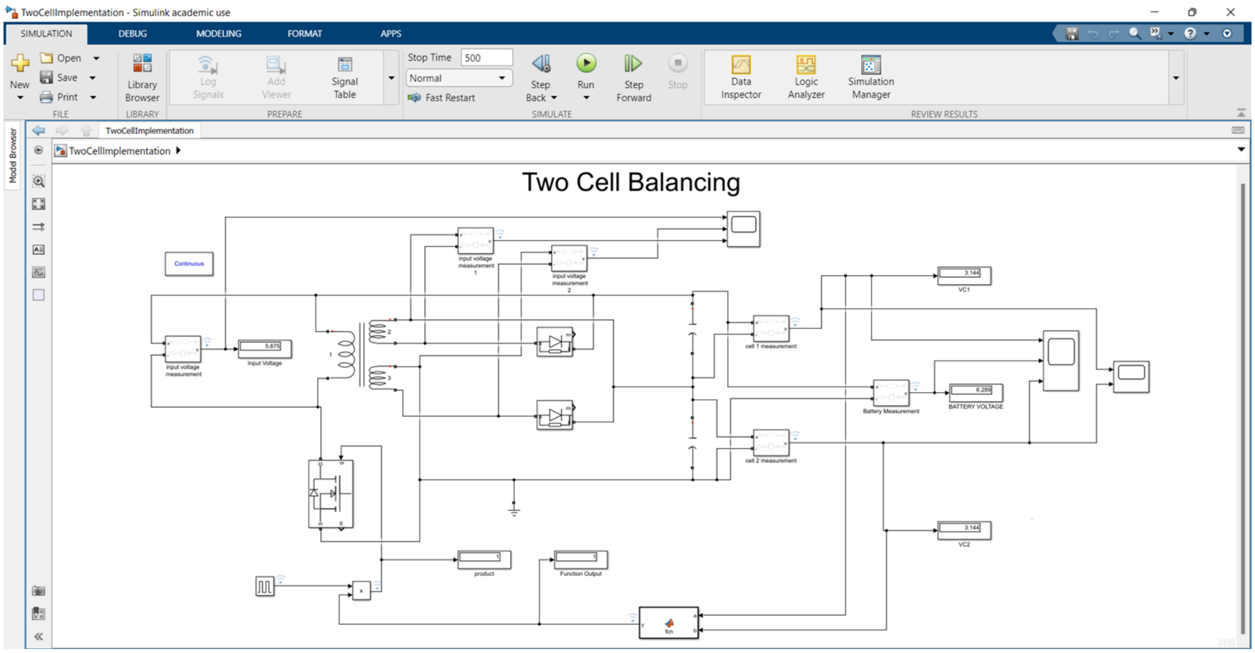

Fig.7 Matlab Simulation for 2 Cells

➢ For 4 Cell Setup

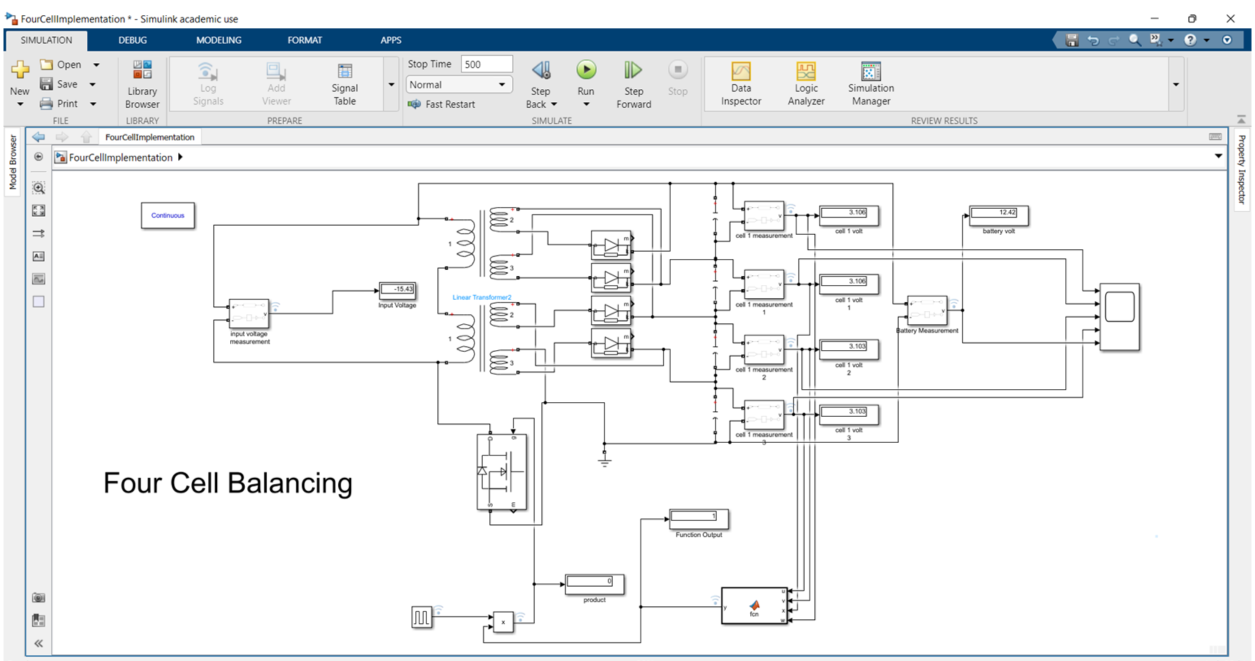

Fig.8 Matlab Simulation for 4 Cells

➢ For 6 Cell Setup

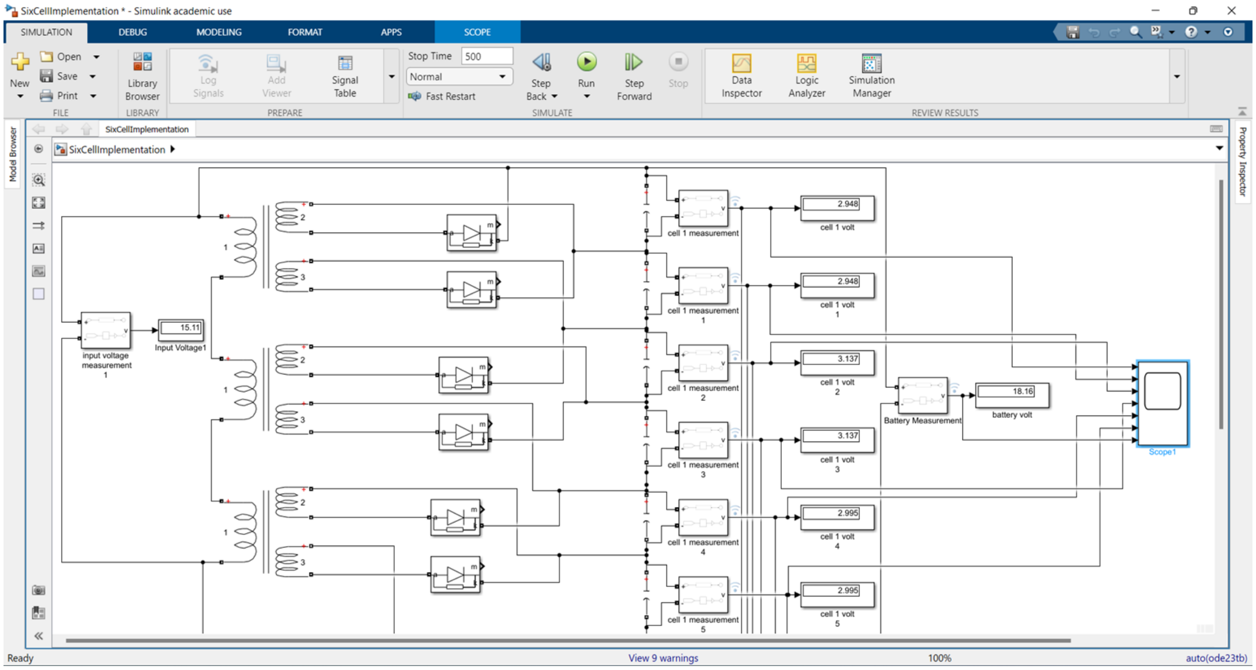

Fig.9 Matlab Simulation for 6 Cells

➢ N Cell Implementation

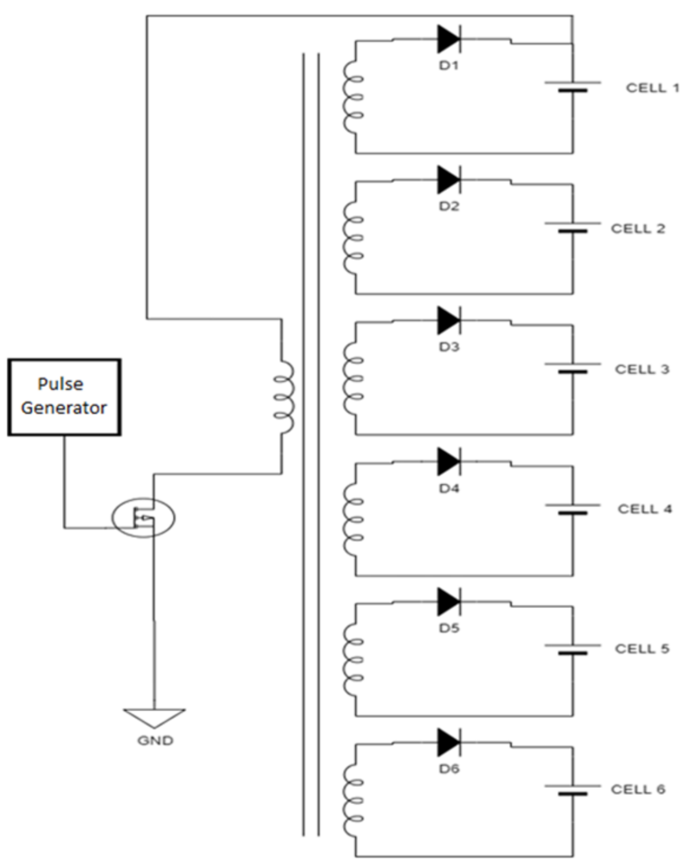

Fig.10 Simulation Design for N Cells

RESULTS / OBSERVATION

➢ For 2 Cells

1. <u>Cells with least significant difference</u>

We have tested two cells in series with variation in voltages of **3V and 3.4V** respectively. We found out that after simulation for **500 sec** , the battery system has equalized.

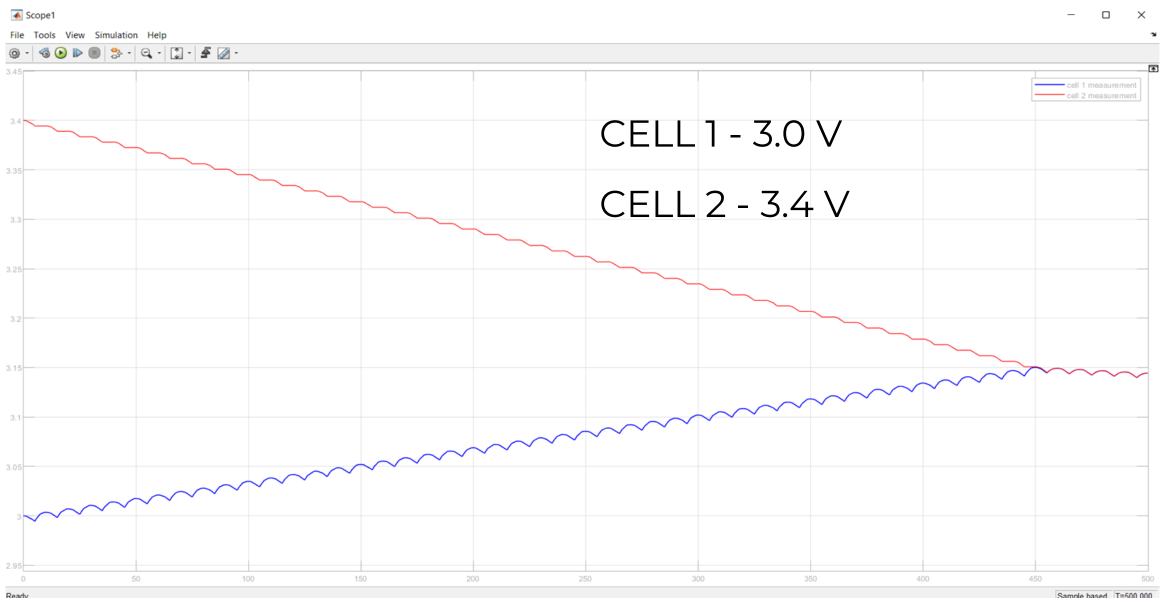

Fig.11 Simulation Results for 2 Cells (with least significant difference)

As shown in Fig.11, the Cells attained the same voltages after **450 sec** of equalization process.

Moreover, we can see that Voltages are **equalized to 3.144V** , which signifies that CELL 1 is charged and CELL 2 is discharged to yield a stabilized voltage condition.

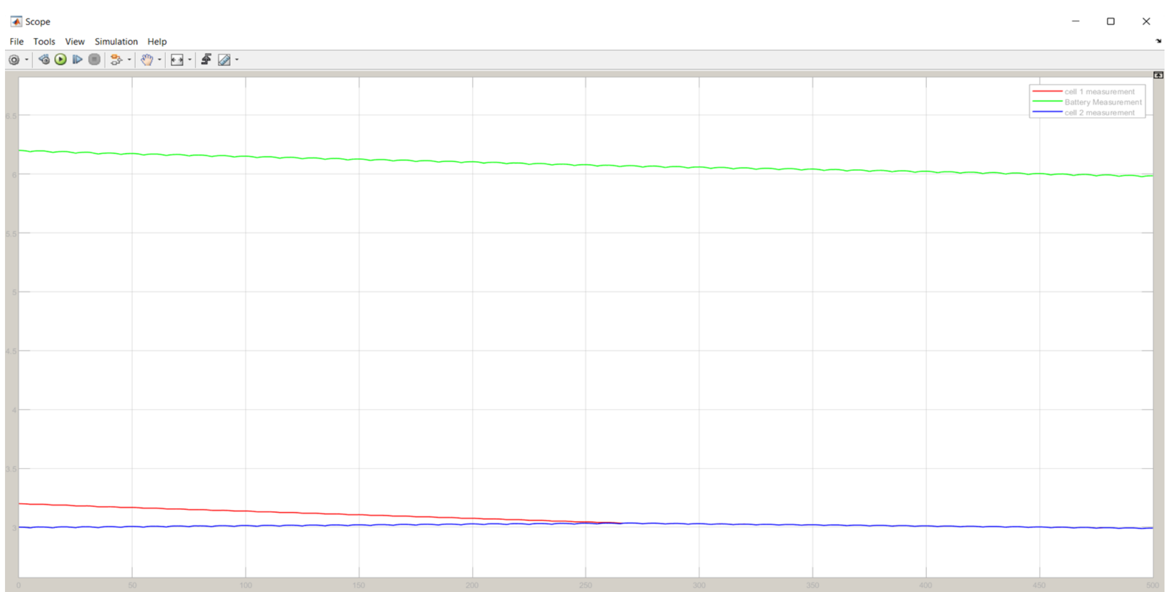

Fig.12 Simulation graph for equilibrium voltage (in 2 cells)

The batteries attain the equilibrium voltages, i.e , the overall voltage of the given battery system consecutively attain a equilibrium value after completing switched equalization process, as shown in Fig.12. We can confirm the results from the Voltage indicators displaying the corresponding results.

2. Cells with Large Difference in Potential

We have tested two cells in series with variation in voltages ranges from **2.5V and 3.5V**. We found out that equalization time for the battery system has altered significantly.

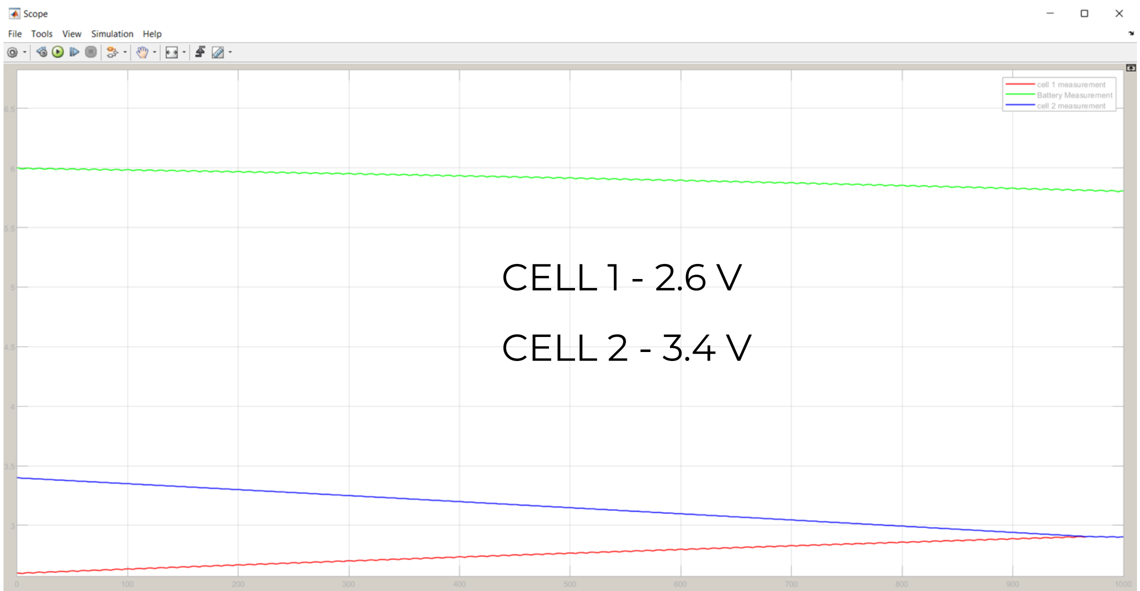

Fig.13 Simulation Results for 2 Cells (with large significant difference)

As shown in Fig.13, the Cells attained the same voltages after **950 sec** of equalization process.

Moreover, we can see that Voltages are **equalized to 2.904 V**, which signifies that CELL 1 is charged and CELL 2 is discharged to yield a stabilized voltage condition.

RESULTS

After testing the cells with large significant differences in the potentials, we have got a visualization which clearly signifies that Time Taken for Equalization has substantially increased. And we can also observe some discrepancy in voltages if potentials are too distant.

➢ For 4 Cells

1. Cells with least potential mismatch:

In this arrangement, the equalization process is tested for voltage mismatch for the least significant range of **3V to 3.3V**.

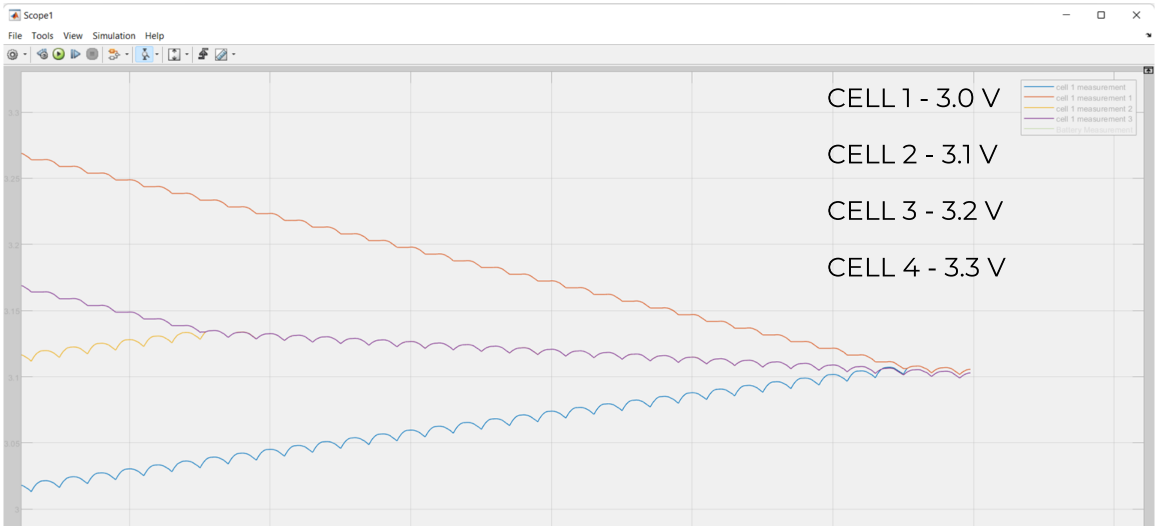

Fig.14 Simulation Results for 4 Cells (with least significant difference)

As shown in Fig.14, the four cells attain the equalized voltages after **400 sec time**. The crucial point to observe is that, Cells with a bit closer potential mismatch could be equalized in the **lesser simulation time.**

2. Cells with large potential mismatch :

In this arrangement we would consider the cells with large potential mismatch i.e., from **2.5V to 3.5V.**

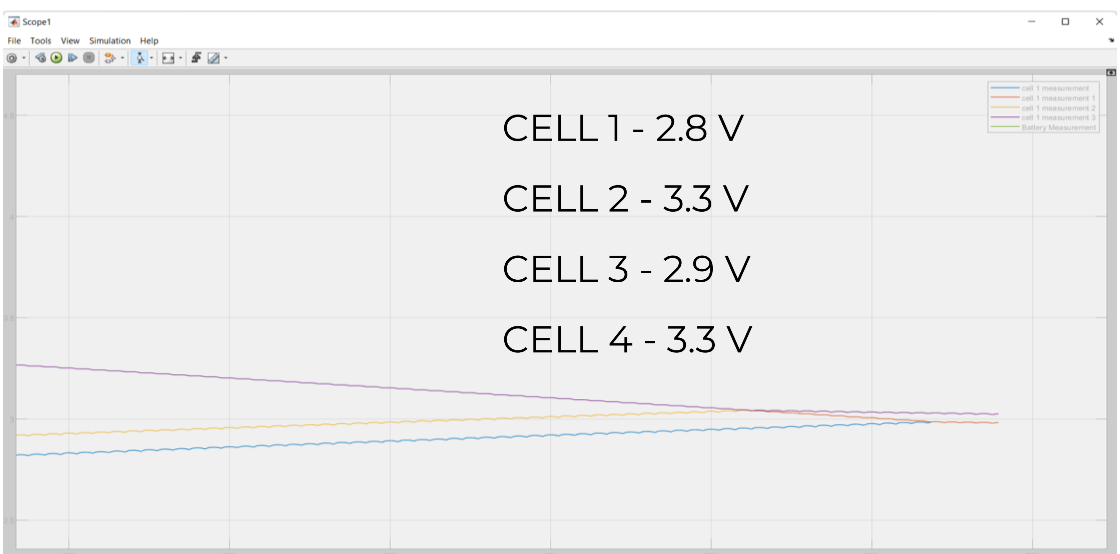

Fig.15 Simulation Results for 4 Cells (with large significant difference)

As shown in Fig.15, the Cells attained the same voltages after **680 sec** of equalization process.

Moreover, we can see that Voltages are **equalized to 3.0V**, which signifies that CELL 1&3 is charged and CELL 2&4 is discharged to yield a stabilized voltage condition.

RESULTS

Due to larger voltage mismatch between the cells, we could observe the increment in the significant time for equalization process.

➢ For 6 Cells

We have simulated the 6 Cells configuration system **for 500 sec** (As shown in Fig.16) and we can visualize the graph of cell voltages of all the cells, **converging towards equilibrium potential.**

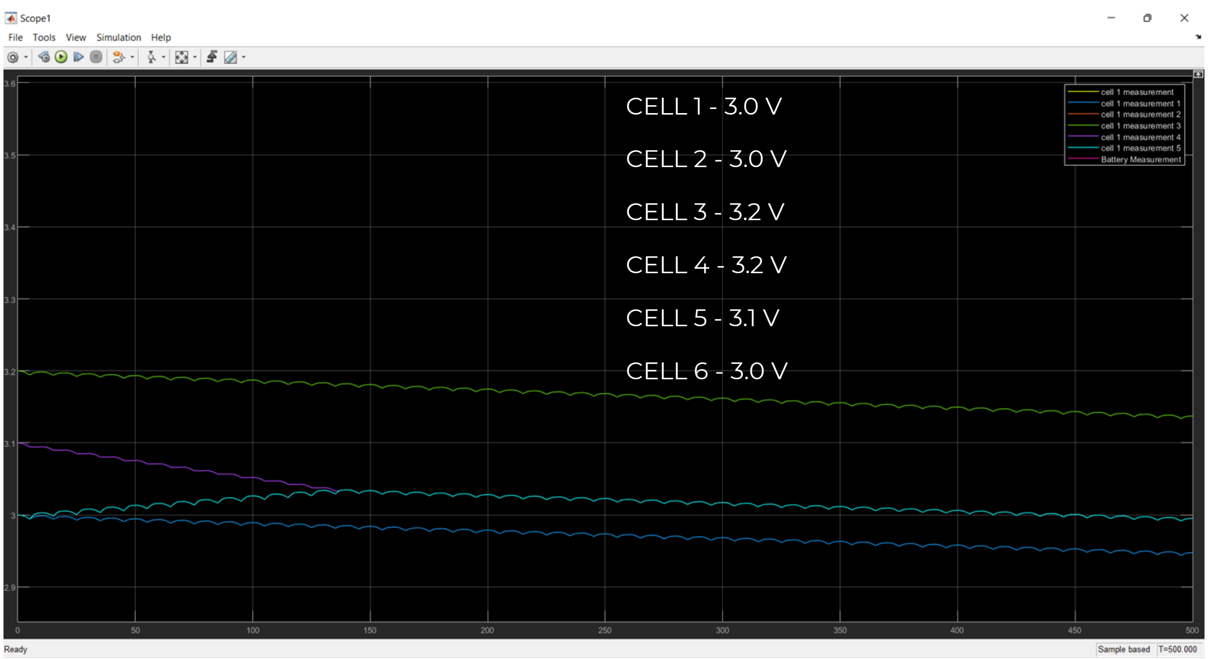

Fig.16 Simulation Results for 6 Cells

We can see that simulation is not sufficient for achieving the equilibrium potential.

Practically, EVs can stand still for hours , so this **equalization can be achieved** as more time is given to equalization process.

➢ For N Cells

- As we know that battery pack for any Electric Vehicle comprises of **Thousands of cells**. Thus these principle could be generalized for N no of cells.
- Moreover , Vehicles can **stand still for hours** , so in this resting time ,cell balancing could be achieved with time.
- As Li Cells sparks when charged or discharged suddenly, so we need a gradual procedural equalization, and thus it takes few minutes for balancing.

CONCLUSION

✓ We have simulated the active battery balancing technique for different cell configurations and with different range of voltage mismatch.

✓ We can infer that Equalization time can be reduced when we maintain the voltages within a minimal significant range.

✓ As we tend to increase the no of cells for equalization process, so as to get the brief analogy of whole battery pack, we observe that time taken is increasing with the increase in no of cells.

✓ One more inference can be done that cells with larger mismatching potentials take more time to equalize. Mostly it is difficult to balance this type of system.

✓ This circuit could be further rectified for second life battery packs or cells that are excessively overcharged or undercharged, despite the shortened duration.

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