International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 6, 2025
https://theaspd.com/index.php

Performance and Comparison of Cell Balance Techniques for EV Application

Gedela Sasikumar[1], Gembali Srinivasagupta[2], Venkata Padmavati S[3], Venugopal Dugyala[4]
[1]Department of EEE, VNRVJIET, Hyderabad, Telangana-500090, INDIA,2258sasikumar_g@vnrvjiet.in
[2]Department of EEE, VNRVJIET, Hyderabad, Telangana-500090, INDIA 2 srinivasagupta_g@vnrvjiet.in
[3]Department of EEE,Gitam Deemed to be University, Hyderabad, INDIA, vsatyava@gitam.edu
[4]Department of EEE, KITS, Huzurabad,Karimnagar,Telangana, INDIA, venufacts20m@gmail.com

Abstract:
The long life cycle, high in energy densuity and low in self-discharging rate made liathium-ion batteries popular However, when multiple cells are connected in series, inconsistencies in internal resistance, capacity, and self-discharge rates arise due to manufacturing and environmental factors. These inconsistencies can lead to overcharging or over-discharging of individual cells, reducing battery capacity, shortening lifespan, and posing safety risks. Balancing methods are essential to address these issues. Existing methods are categorized into: Dissipative balancing: Converts excess energy into heat, leading to energy loss. Non-dissipative balancing: Transfers energy between cells using capacitors, inductors, or transformers, offering higher efficiency. A bidirectional flyback converter topology with multiple winding input/output is suggested in the paper to get over the drawbacks of current techniques
Keywords: *Balancing method, resistor, inductor, state of charge, flyback converter, energy efficiency*

1. INTRODUCTION:

Batteries are the most widely used energy storage technologies in the new era of clean energy employing renewable energy sources and electric vehicles (EVs)[1]. The use of electric vehicles is one way to reduce air pollution on a worldwide scale. It also includes intermediate solutions like hybrid electric and plug-in hybrid cars (PHEV and HEV, respectively), which combine gasoline and electricity [2]. Since the weakest cell in the battery pack effectively drains the entire pack when it runs out of power, the battery pack's performance is restricted by that cell's capacity. The SOC measurement is used to evaluate the health of each individual battery cell in the pack by calculating the ratio of the cell's residual charge to its capacity. The SOC measures the battery's voltage, integrated charge and discharge currents, and temperature in order to determine the battery's charge level. BMS combines passive or active cell balancing with battery monitoring, including SOC measurements, to improve battery pack performance. Batteries are made up of cells arranged in series or parallel. Battery cells are always nearly identical in their traits., such as SOC, self-discharge rate, capacity, internal impedance, and temperature, even if they are from the same production batch. The cells have a slight voltage differential as a result of the change in these properties [3–4]. By preventing the imbalance between the battery cells, the BMS is crucial in extending battery life. By altering the SOC values of the individual battery cells and by utilizing cell protection strategies, BMS configurations are created to extend battery life. [5]. Battery management systems (BMSs) are electronic control circuits that keep an eye on and manage battery charging and discharge. The identification of battery type, voltages, temperature, capacity, state of charge, power consumption, remaining running time, charging cycles, and other features are among the features that need to be monitored To ensure that the charge is maximized and the battery can deliver the necessary amount of charge at all times, the BMS balances the battery cells [8][9], Otherwise, the imbalance may cause rapid degradation, lower charge, higher losses and/or heating effects, and/or higher heating effects [10].

2. SYSTEM MODELING

A. Types of Cell balance techniques

Without a balancing system, the voltages of the different cells will diverge over time, resulting in poor efficiency and even risks. Cell imbalance in battery systems is a critical issue in the system life of the battery. The cell equalizing is crucial for ensuring that, after a full charge, battery pack have the same voltage and SOC. dissipative and non-dissipative techniques are the two basic cell balancing strategies.

B. Types of cell balancing technique

Passive balancing dissipates the surplus energy of high SOC cells by parallel connecting shunt resistors[11]. This method makes it possible to balance the energy levels of cells and continuous waste power. Also, here the balancing speed is not fast enough. Only nickel-based batteries and lead-acid batteries continue to use this technique.[12].. The active cell balancing technique uses capacitive or inductive charge shuttling to move charge from the high-charged cell to the low-charged cell. In order to balance out differences between cells in series, active balance techniques move electrical energy from higher SOC cells to lower SOC cells.[15][16], with minimal damage.

3.MODEL AND SIMULATION OF BALANCER CIRCUIT

The switched resistor method, and the two-switch flyback converter method's circuit and simulation, together with their outcomes.

A Switched Resistor Technique

The switching shunt resistor cell balancing circuit [19] is seen in Figure.1, where V1, V2, V3, and V4 are the cell voltages that are connected in series, Q1, Q2, Q3, and Q4 are the semiconductor switches of each cell; and R1, R2, R3, and R4 are the fixed shunt resistors of each battery cell.

Table 1 Specified variables

variable	Specification
Cell Nominal voltage	3.7 V
Cell rated capacity	6.5A.h
Resistance	1Ω
Switches	4

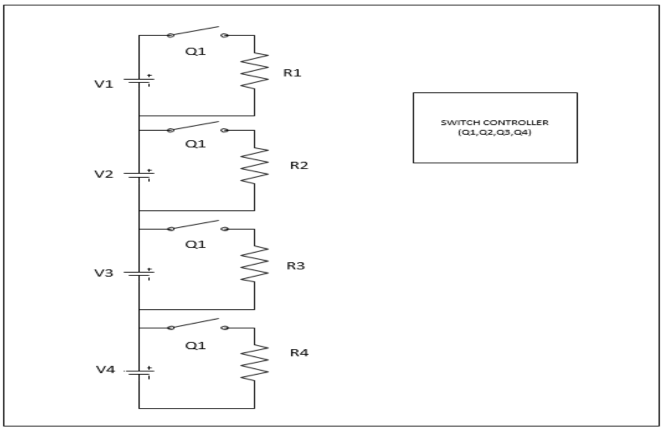


Figure.1: Switching shunt resistor cell balancing circuit

B Two switch Flyback convert balancing Technique

Flyback converters, which can be either unidirectional or bidirectional, are utilised in isolated structures. The unidirectional arrangement stores the energy of the highly charged cell in the transformer when the coupled switch is on and transfers it to the pack when it is off.When it comes to energy transmission, a bi-directional flyback converter is far more flexible because it allows for energy transfer from the pack to the cells.

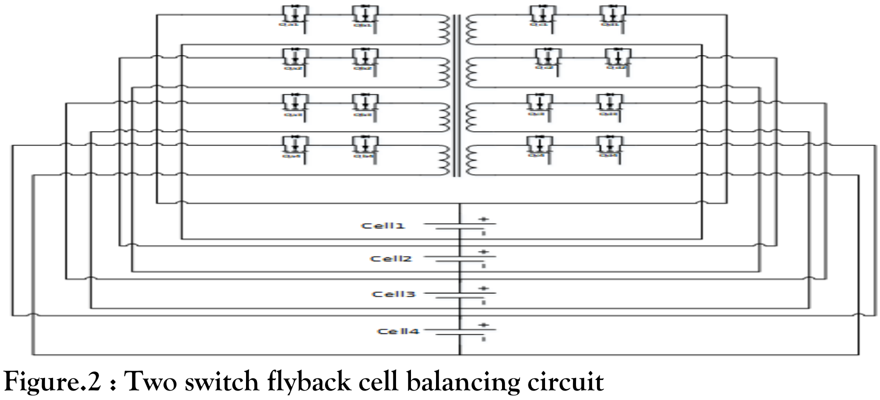
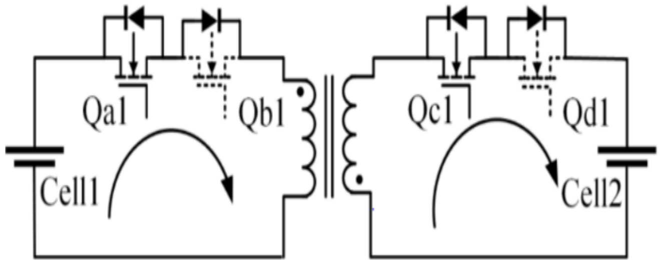


Figure.2 : Two switch flyback cell balancing circuit

Figure.2 depicts the multi-input multi-output (MIMO) based bidirectional flyback converter that makes up the balancing circuit. The SOC of a single cell is gathered, compared to the SOC values of other cells.. Each cell comes with two alternative transformer windings that are linked in series with two MOSFETs [20-21] on each winding. Assuming SOC1 > SOC2, and using Cell1 and Cell2 as an example, as shown in Figure.3, the equivalent circuit model transfers the energy Cell1 to Cell2. The main waveform of transfers energy cell1 to cell2 as shown in Figure 3.1. Through control the on-off combination of MOSFETs the bidirectional energy flow is made possible.



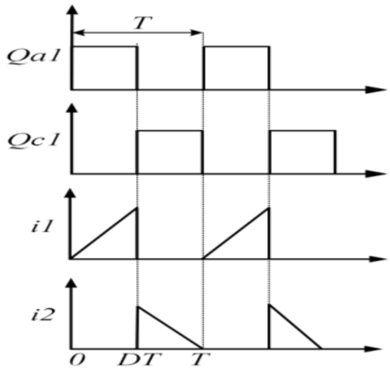
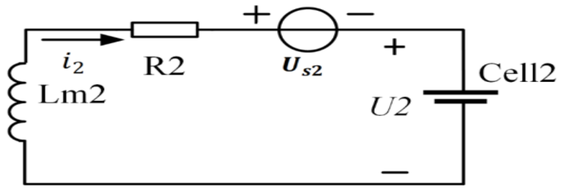


Figure.3 : Transferring energy from Cell1 to Cell2. **Figure 3.1: Balancing waveform**

Energy is transported utilising the transformer as an energy storage component. The primary and secondary loops of the transformer switches operated alternately during the equalisation period where T is the switching period and D is the PWM duty cycle.

Mode1[0 − DT], Cell 1 discharges while Qa1 is on, Qc1, Qb1, and Qd1 are off, the transformer's primary inductor stores energy, and the primary winding's upper and lower poles are both positive. Cell1 equivalent circuit discharging model is shown in Figure 4.



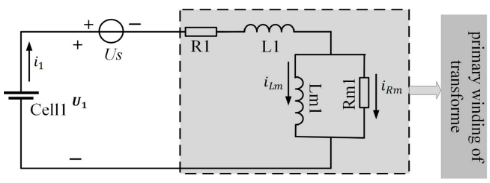


Figure 4 Cell 1 equivalent discharging circuit **Figure 5 Cell2 charging loop equivalent circuit**

The model uses U1 to represent the voltage of Cell 1. R1, L1, Lm1 & Rm1 to represent the primary winding of equivalent resistance , leakage inductance, magnetisation inductance and resistance respectively; and Us to represent the MOSFET voltage drop.

If we assume that the current in Figure.4 is flowing in a positive direction, Kirchhoff's law gives us the following results:

- $i_1R_1+U_s+L_1\frac{di1}{dt}+i_{Rm}Rm1=U1$
- $i_1=i_{Rm}+i_{Lm}$
- $E_{U1}=E_{Us}+E_{R1}+E_{L1}+E_{Lm1}+E_{Rm1}$

Figure 5 shows the voltage of Cell 2 which is represented by U2, the secondary loop inductance and resistance are represented by Lm2 and R2 respecitively, and the MOSFET's on voltage drop is represented by Us2. If the current direction is assumed to be positive, Kirchhoff's voltage law can be used to determine this

- $i_2R_2+U_2+U_{s2}=L_{m2}\frac{di2}{dt}$
- $E_{Lm2}=E_{Us2}+E_{R2}+E_{U2}$

C. **Balancing Controling strategy**

In the ideal scenario, each cell of the SOC is equal to the batter average SOC (SOCd) after equalisation is finished, ignoring the circuit loss. The equation 1 shows batteries' unbalanced states are divided as SOCd the reference value and related equalisation algorithms are developed based on various unbalanced states. In modern approach the specific differences are considered above and below the SOCd based on the electrical and component parameters.

$$SOCd=\frac{1}{n}\sum_{i=1}^{n}SOCi \qquad (1) \quad \text{Eq.1}$$

where n represents the batteries' cell count

Take four cells linked in series and define as SOCmax1 > SOCmax2 > SOCmin2 > SOCmin1.

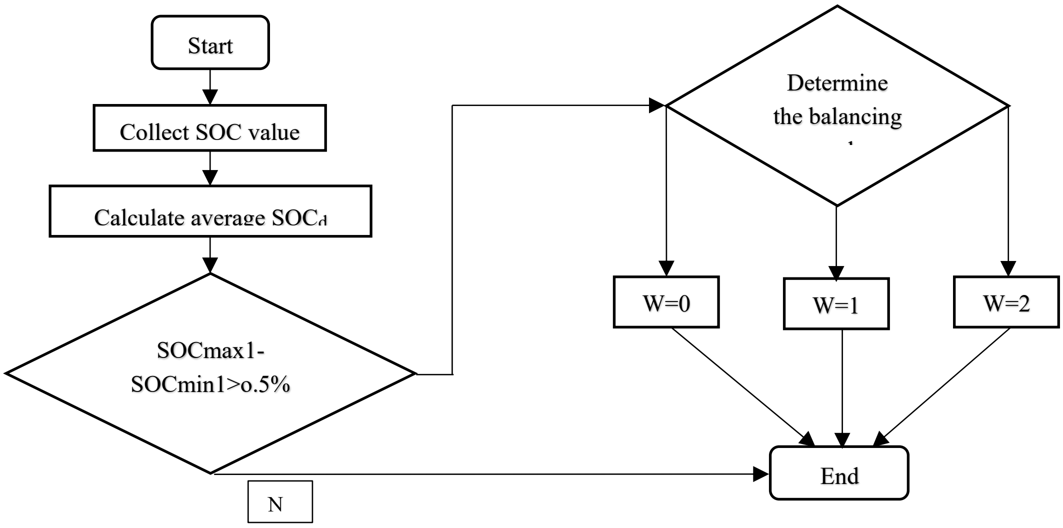
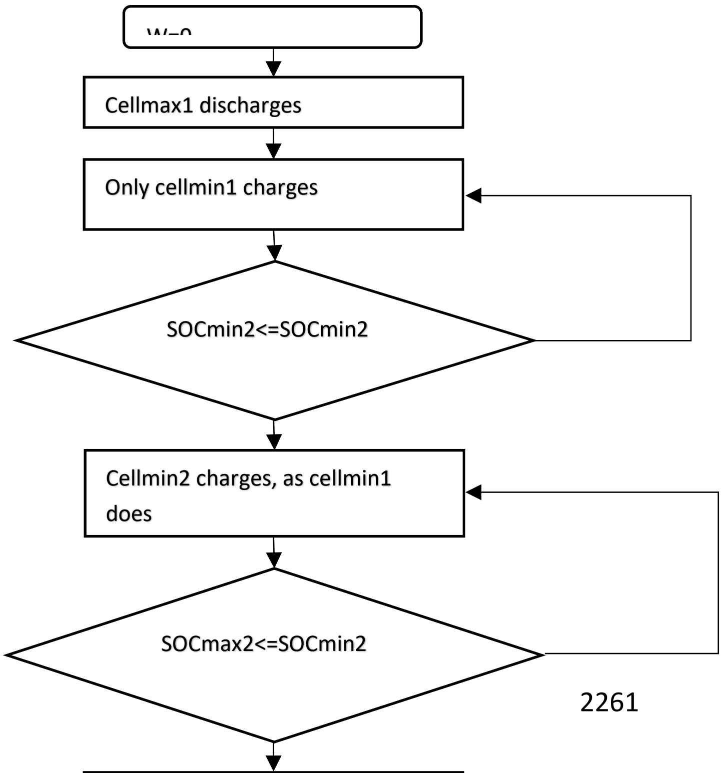


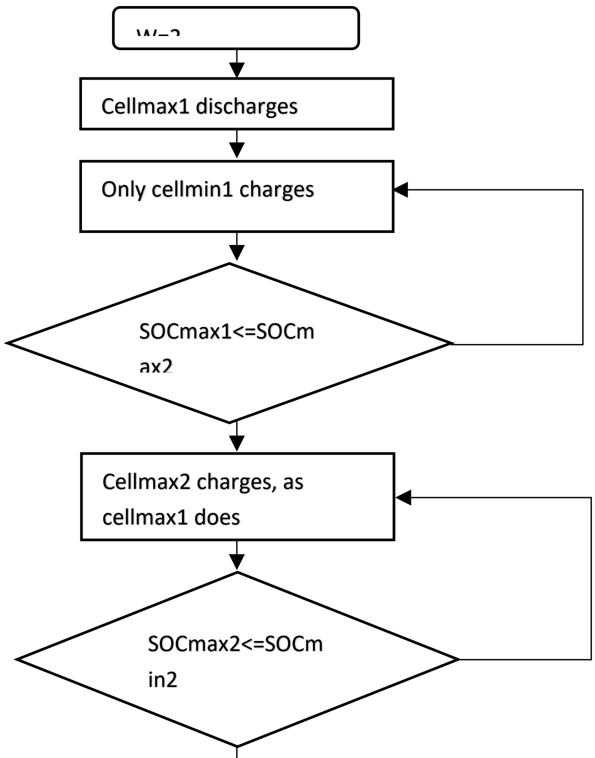
Figure.6: An overview of the balancing process

The entire flow chart of the balancing strategy is shown in Figure 6, where the highest balancing mode is denoted by 0, the second-highest by 1, and the lowest by 2.

W=0 means $SOCmax1 > SOC_d > SOCmax2 > SOCmin2 > SOCmin1$.
W=1 means $SOCmax1 > SOCmax2 > SOC_d > SOCmin2 > SOCmin1$.
W=2 means $SOCmax1 > SOCmax2 > SOCmin2 > SOC_d > SOCmin1$.
Based on the values of average SOC (SOCd), there are three possible modes which are Mode1,Mode2 and Mode3

Mode1: The W = 0 balancing mode is used when SOCmax1 > SOCd > SOCmax2 > SOCmin2 > SOCmin1. The Cellmax1 is connected to the transformer's primary side in this balancing mode, while the Cellmax2, Cellmin2, and Cellmin1 are attached to its secondary side. Cellmax1, Cellmax2, Cellmin2, and Cellmin1 exclusively absorb energy during this mode of energy balancing. MOSFETs energy-absorbing cells are progressively switched on. Cellmax1 first sends energy to Cellmin1 during the equalization process, while Cellmax2 and Cellmin2 are in a waiting state When SOCmin1 = SOCmin2, Cellmin2 begins charging at the same pace as Cellmin1, and as Cellmin1's SOC rises, the matching MOSFET of Cellmin2 turns ON. When the matching MOSFET for Cellmax2 is ON and SOCmin1 = SOCmin2 = SOCmax2, Cellmax2 begins absorbing the energy generated by Cellmax1 at the same rate as Cellmin2 and Cellmin1. The equalization process is complete when SOCmin1 = SOCmin2 = SOCmax2 = SOCmax1. Figure.7 depicts its control flow diagram.





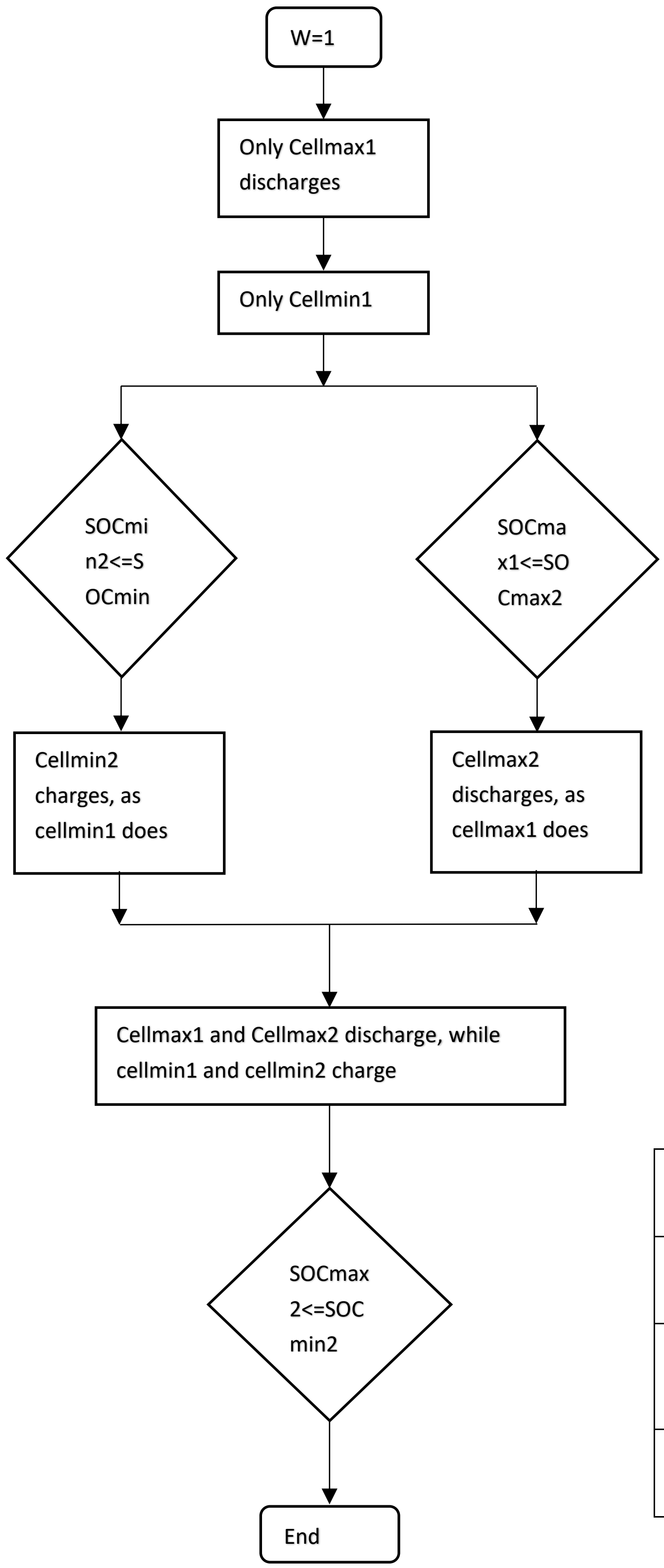


Table 2: change in SOC of cells				
	Cell 1	Cell 2	Cell 3	Cell 4
Initial SOC	85%	60%	45%	25%
Final SOC	24.59%	25.07%	25.57%	25%

Figure.7 depicts its control flow diagram. When w= 0 Figure.9 depicts its control flow diagram when w = 2

Mode2: The W = 1 balancing mode is used when SOCmax1 > SOCmax2 >SOCd > SOCmin2 > SOCmin1. Cellmax1 and Cellmax2 are connected to the transformer's primary side in this balancing mode, while Cellmin2 and Cellmin1 are attached to its secondary side. Cellmin2 and Cellmin1 only absorb energy during this mode of energy balancing, while Cellmax1 and Cellmax2 only release energy. Cellmax1 first sends energy to Cellmin1 during the equalization process, while Cellmax2 and Cellmin2 are in awaiting mode. The Cellmax1 SOC is continuously decreasing as its energy continues to transmit. When the equivalent MOSFET for Cellmax2 is ON and SOCmax2 = SOCmax1, Cellmax2 begins to release equal energy rate as Cellmax1. Concurrently, Cellmin1's SOC is still rising. When the equivalent

MOSFET of Cellmin2 is ON and SOCmin1 = SOCmin2, Cellmin2 begins charging at the same rate as Cellmin1. Cellmax2 and Cellmax1 transmit energy to Cellmin2 and Cellmin1 when SOCmin1 = SOCmin2 SOCmax2 = SOCmax1. The balancing process is complete when SOCmin1 = SOCmin2 = SOCmax2 = SOCmax1. Figure.8 depicts its control flow diagram.

Mode3: The W = 2 balancing mode is used when SOCmax1 > SOCmax2 > SOCmin2 > SOCd > SOCmin1. The Cellmin1 is linked to the transformer secondary side in this mode, while the Cellmax1, Cellmax2, and Cellmin2 are attached to the primary side of the transformer. Cellmax1, Cellmax2, and Cellmin2 only produce energy while Cellmin1 only absorbs energy in this balancing state. The matching MOSFETs for the energy-releasing cells are progressively switched ON. Cellmax1 first transfers energy to Cellmin1 during the process of equalization, while Cellmax2 and Cellmin2 are in a waiting state. When SOCmax2 equals SOCmax1, Cellmax2 begins discharging at the same pace as Cellmax1 as the SOC of Cellmax1 continues to drop. At this point, the matching MOSFET of Cellmax2 is ON. When the matching MOSFET for Cellmin2 is ON and SOCmax2 = SOCmax1 = SOCmin2, Cellmin2 begins energy releasing at the same speed as Cellmax2 and Cellmax1. The equalization process is complete when SOCmin1 = SOCmin2 = SOCmax2 = SOCmax1. Figure.9 depicts its control flow diagram.

Figure.8 depicts its control flow diagram when w = 1

4.SIMULATION AND RESULT ANALYSIS

1.Switched Resistor Technique Simulation model: Four cells are linked in series for the simulation, and the parameters are displayed in Table.1 with MATLAB/Simulink shown in Figure.10 The controller had been a MATLAB function that was embedded. Switches are controlled depending on the SOC of the battery cells. The switching algorithm follows: First, need to find the lowest SOC value among the battery pack. Then the remaining switches will keep on until all SOCs are the same, which means the remaining cells' SOC values are matched with the lowest SOC value of the cell. The simulation were seen in Figure.11 where cell 4 has a minimum SOC value of 25% and the remaining cell SOCs are 80%, 60%, and 45%, respectively.

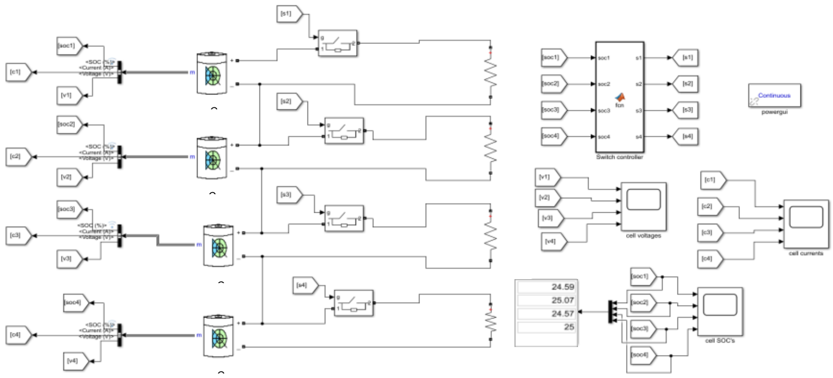


Figure.10: Simulation model

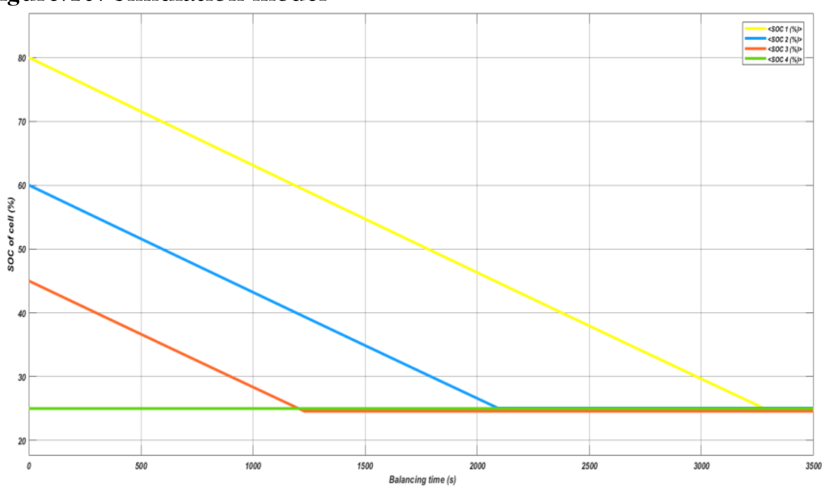


Figure.11: SOCs of cells

Table 2 shows the change in cell SOCs during balancing operation. Figure 11 depicts the variation of SOC in this method. Here, cell 4 has the lowest SOC, which is 25%. The remaining cell SOCs must all balance or equalize, but energy transmission is not possible in this situation, extra energy is dissipated

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 6, 2025
https://theaspd.com/index.php

using a shunt-connected resistor. The time total for this operation is 3500 s. The first 1200 s, cell1, cell2 and cell3 are uniformly discharging. In the periods of time from 1200 s to 2100 s, the cell2 and cell1 is discharging. Similarly, from 2150 s to 3250 s, only cell 1 is discharging. At last, all cells are balanced after 3250 s.

Figure.12 shows the cell balancing current during static conditions. Here, cell 4 has 0A, which means it has the least SOC value, which is why it is unlinked to the resistor. Cell 3 is linked to the resistor until its SOC matches the SOC of cell4, then the cell current will decrease gradually and become zero after 3250 seconds. Similarly, cell 3 and cell 2 gradually reached zero current after 1200 s and 2150 s, respectively. The voltage analysis during the balancing condition is seen in

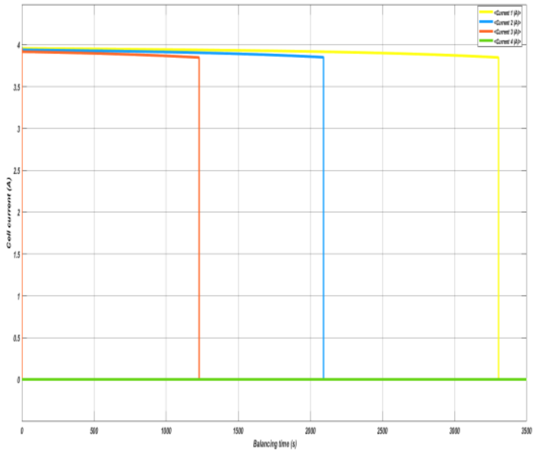


Figure 12 : Cell currents

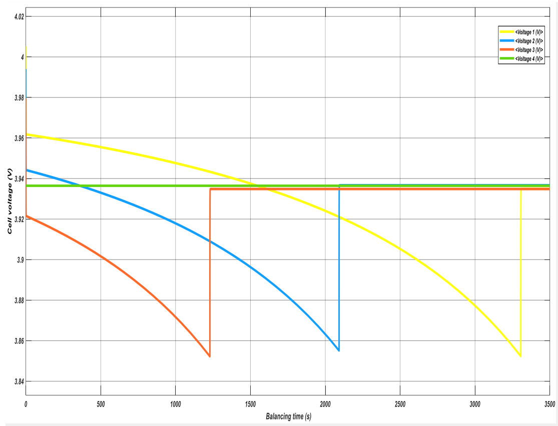


Figure 13: Cell voltages

Figure 13 It is known that cell voltage and cell SOC are directly proportional. In the first 1250 s, the first three cells are discharging uniformly, and the voltage is also decreasing. After 1250 s, cell 4 and cell 3 stopped discharging, which is why the voltage of those cells is constant. During 1250 s to 3250 s, cell 2 discharges up to 2150, and cell 1 discharges up to 3250 s.

2. **Simulation of two switch flyback converter method**

The simulation model for two switch flyback converter is seen in Figure 14 and parameters are seen in Table 2 [27].

Two switch flyback converter simulation model

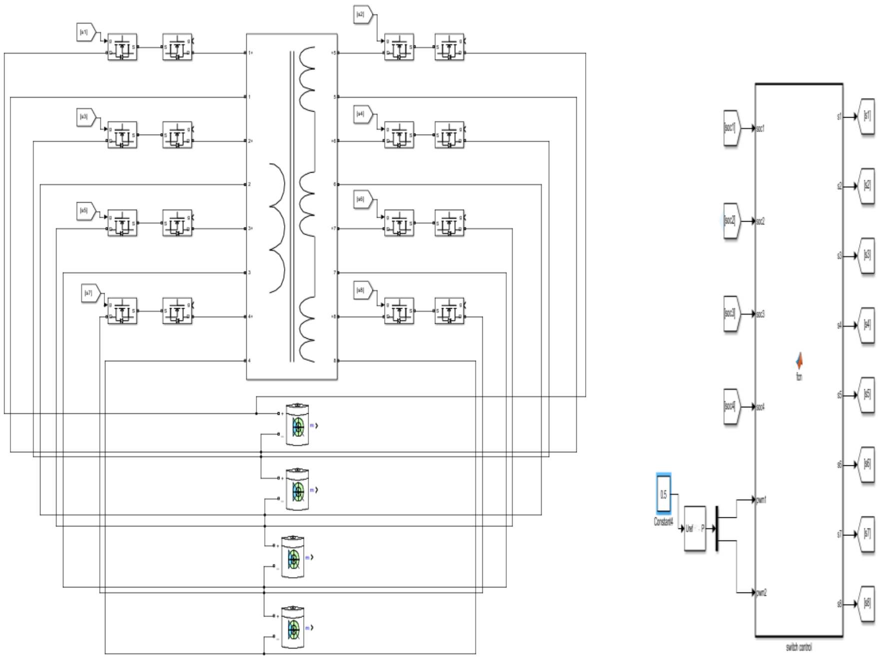


Figure 14 : Two switch flyback converter cell balancing simulation model

Table 3 Specified Variables

Variable	Specified value
Each cell Nominal voltage	3.7 V
Each cell rated capacity	6.5A.h
primary winding Inductance	48mH
secondary winding Inductance	48mH
Duty cycle	50%

Table 4: Change in SOC of cells

Case		Cell1 %	Cell 2%	Cell3%	Cell4 %
1	Initial SOC	92.76	84.49	83.46	85.52
	Final SOC	85.75%			
2	Initial SOC	92.76	83.46	89.66	85.52
	Final SOC	86.56%			
3	Initial SOC	92.76	91.73	90.69	86.52
	Final SOC	89.72%			

In this method we can vary the charging current based on the transformer parameter. The charging current range of battery is 0.2C to 0.8C. where C is cell capacity. In this simulation charging current is assumed to 2.2A [28]. The pack have four cells arranged in series with nominal voltage of 3.7V and capacity of 6.5Ah. All MOSFETs are controlled by a pair of comparable PWM signals, which significantly reduces the amount of control signals. Here simulation is carried for three different cases

3.Simulation Result

Figure 14 depicts the modelling for the two-switch fly back converter-based cell balancing technique. Simulation results are provided in Table 4 for a variety of chance scenarios.

Case 1

In this case, after observing all SOC values of cells, it is known that cell1 has the highest SOC value and the others have low SOC values. The average SOC is 86.55%, which lies between cells1 and4. Based on flowchart Figure 6, the W is 0. The balancing algorithm flows based on flowchart Figure.7, which means one cell is discharging and other cells are continuously charging step by step. In first 180 s, cell1 discharges with a +5.2A current, and cell4 charges with a -2.2A current. In the period of time from 180 s to 520 s, the SOC of cell4 and cell3 matches each other, therefore, both these cells charge parallel with a -2.2 A current. From 520 s to 630 s, the cell4, cell3, and cell2 charges with a similar current of -2.2A. During complete balancing operation, cell 1 discharges with +5.2 A current. All cells are balanced after 630 s. The balanced SOC value of the battery pack at the end of equalisation is 85.75%. The change in SOC, voltage, and current of battery cells are shown in Figure 14.1.a, Figure 14.1b and Figure 14.1c

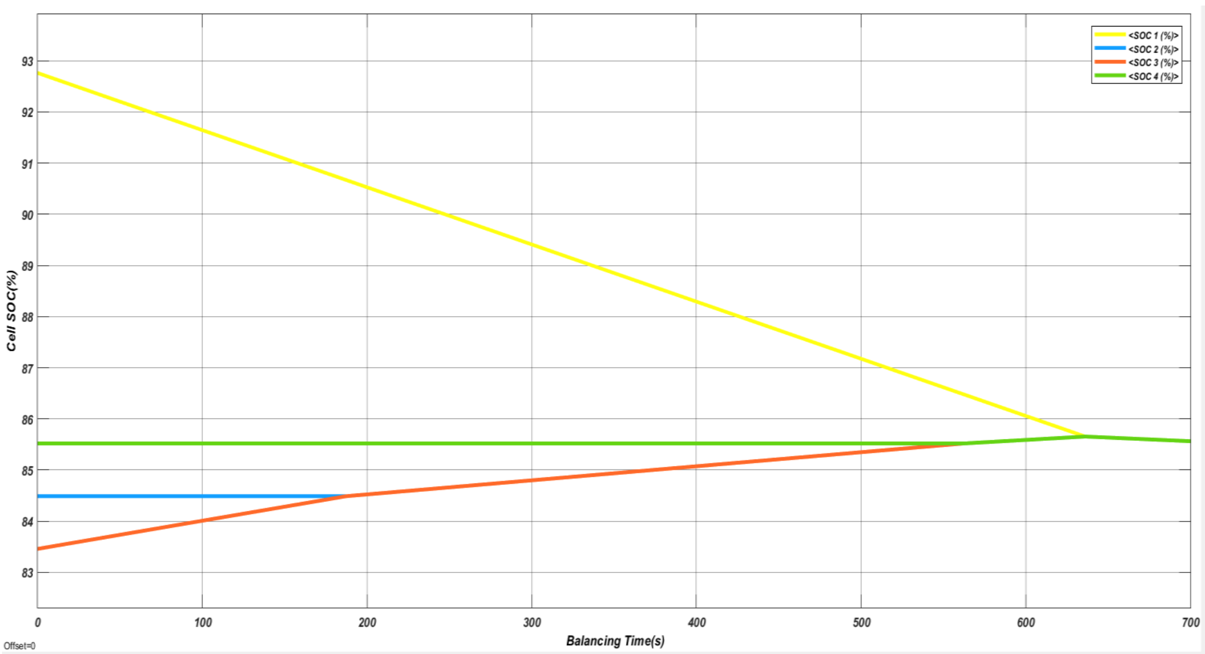


Figure 14.1a: cell SOC

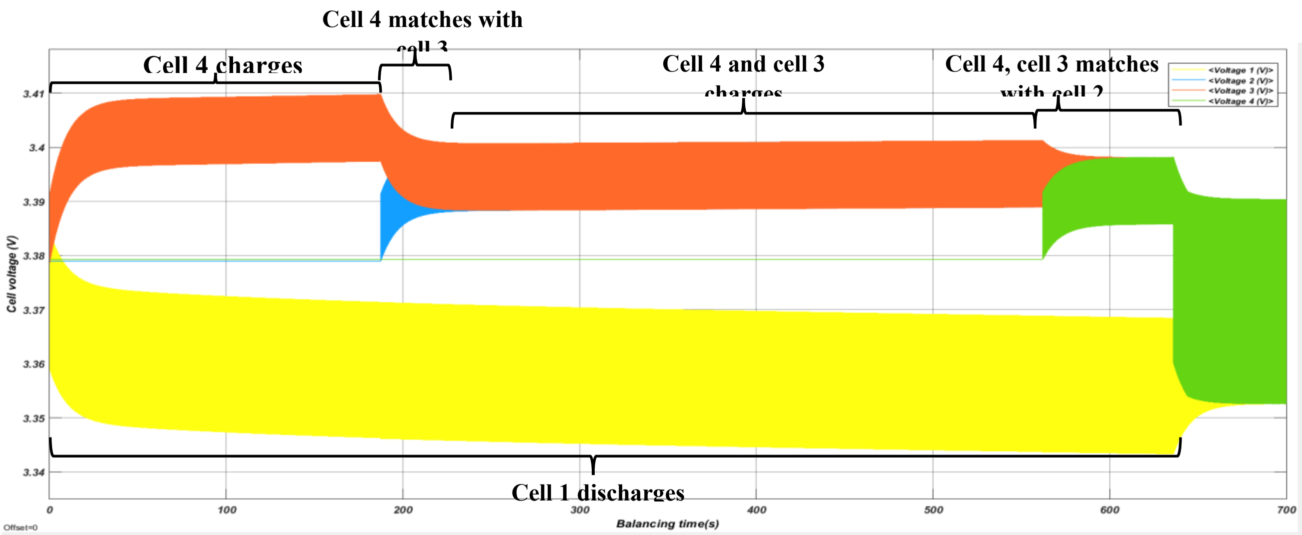
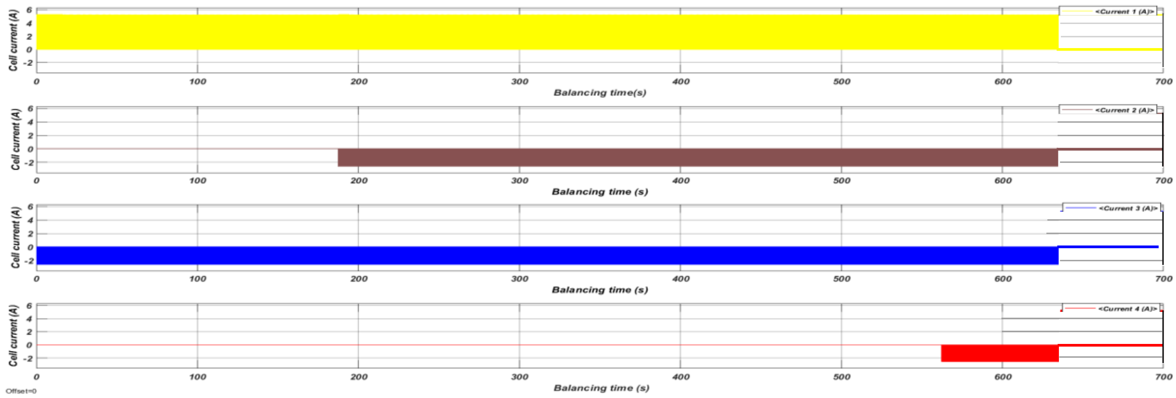


Figure 14.1b: Cell voltage



Case 2

In this case, after observing all the SOC of cells, it is known that, two cells have a high value of SOC and another two cells have a low value of SOC. The average SOC is 87.85%, which lies between cell3 and cell4. Based on flowchart Figure.6, the W is 1. The balancing algorithm flows based on flowchart Figure.8, which means two cells are discharging and other cells are continuously charging step by step. In first 280 s, cell 1 discharges with +5.2 A current and cell2 charges with -2.2 A current. And in the periods of time from 280 s to 370 s, the cell1 and cell3 SOCs matched each other, therefore, these cells charges with -2.2A current. During the time period from 370 s to 810 s, the cell1, cell3 discharges with +5.2 A current, and cell2, cell4 charges with -2.2 A current. The total period of balancing operation is 819 s. Figure14.2a, 14.2b, and Figure 14.2.c, shows the change in SOCs of battery, variation of battery voltage, and the change in battery current

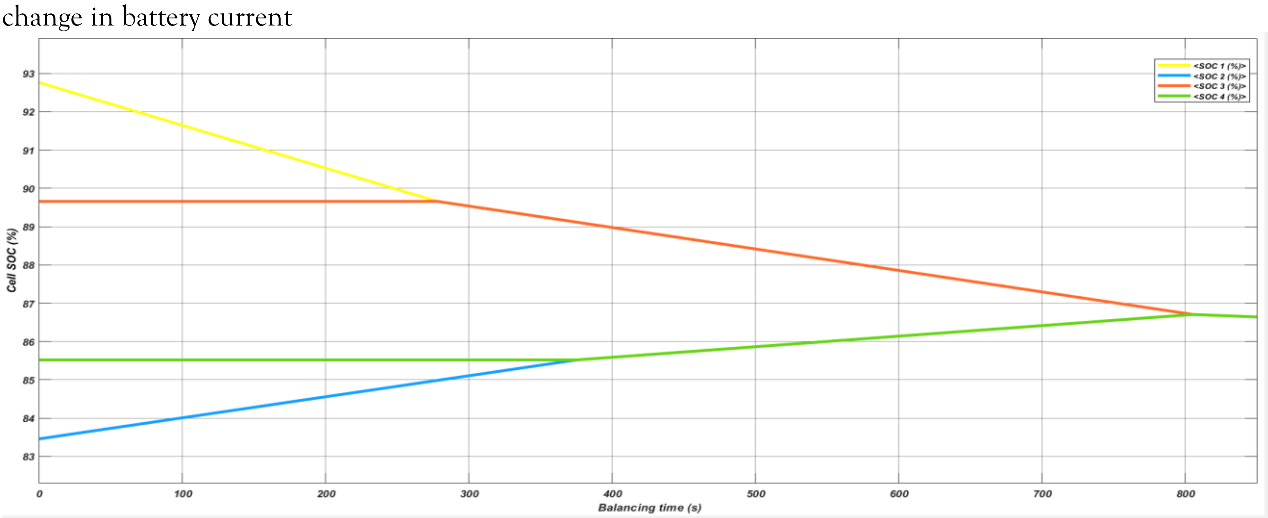


Figure 14.2a: cell SOC

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 6, 2025
https://theaspd.com/index.php

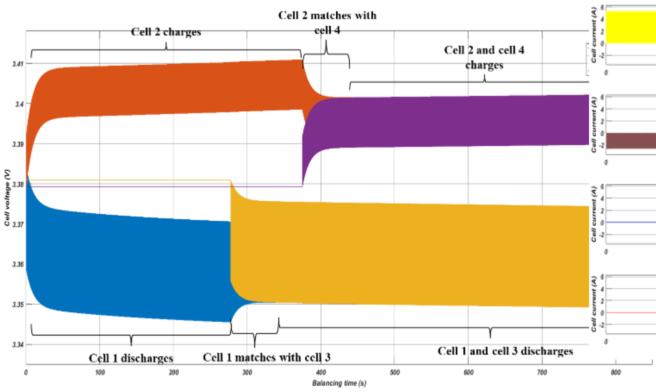


Figure 14.2b: Cell voltage

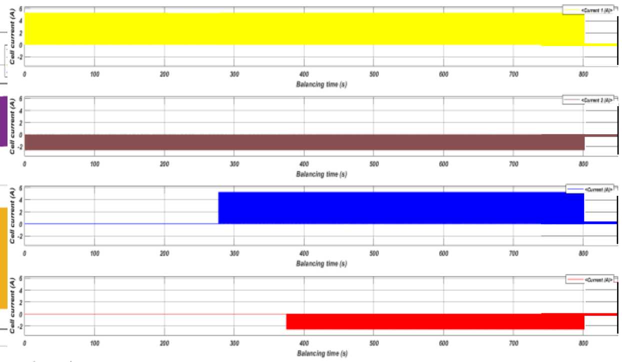


Figure 14.2c: Cell current

Case 3

In this case, after observing all SOC values of cells, after observing, three cells have close and high SOC values and other cell have low SOC value. The average SOC is 90.43%, which lies between cell3 and cell4. Based on flowchart Figure.6, the W is 2. The balancing algorithm flows based on flowchart Figure.9, which means three cells are discharging and another cell is continuously charging step by step. The first 90 s, cell 1, discharges with +5.2A current, and cell4 charges with -2.2A current. And in the periods of time from 90 s to 280 s, initially the cell 1 and cell 2 SOCs matched each other, therefore, these cells discharge with +5.2 A current. During the time period from 280 s to 570 s, the cell1, cell2 and cell3 discharges with +5.2A current and cell4 charges with -2.2A current. The total period of balancing operation is 570 s. Figure 14.3a, Figure 14.3b and Figure 14.3c, shows the change in SOCs of battery, variation of battery voltage and change in battery current.

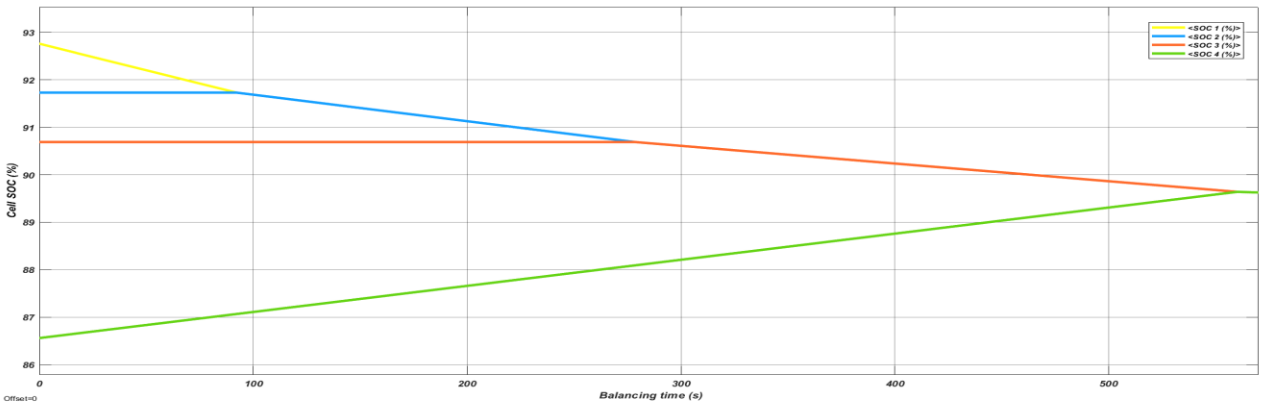


Figure 14.3a: Cell SOC

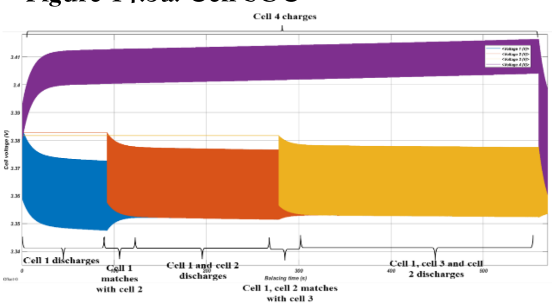


Figure 14.3b: Cell voltage

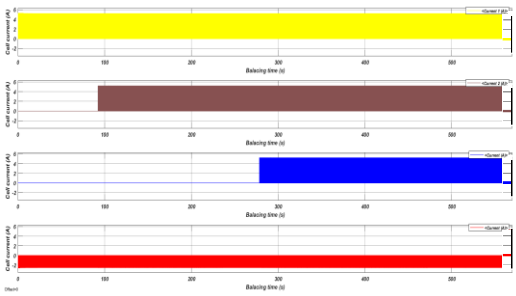


Figure 14.3c: Cell current

RESULTS AND DISCUSSIONS

This session describes the simulation conducted for the switch flyback converter, and switched register techniques. Simulink software and MATLAB are used to run the simulation and generate the findings

Table 4 comparison of balancing techniques

		Cell 1	Cell 2	Cell 3	Cell 4
		Switched Resistor method			

	Initial SOC	85%	60%	45%	25%
	Final SOC	24.59%	25.07%	25.57%	25%
		Two Switch Flyback Converter method			
Case 1	**Initial SOC**	92.76%	84.49%	83.46%	85.52%
	Final SOC	85.75%			
Case 2	**Initial SOC**	92.76%	83.46%	89.66%	85.52%
	Final SOC	86.56%			
Case 3	**Initial SOC**	92.76%	91.73%	90.69%	86.52%
	Final SOC	89.72%			

Contribution of the Work

The battery modelled in MATLAB Simulink is as seen in Figure.10, cell has a 3.7 V nominal voltage, and the 6.5 Ah capacity of each Li-ion battery is to be considered for simulation. Table 4 shows the change in the SOC of the battery cell

In switched resistor method, after observing the variation in SOC of cells, it is known that all cell SOC will be approximately equal to the lowest cell SOC at the last of the balancing operation. The battery will be balanced after a period of 3256 s. That means it takes more time to balance the battery pack. Here n = 4, the battery pack SOC after equalization (SOCe) is 25.45% and energy efficiency (η) is 48.47%. That is very low balancing efficiency, and there is complete energy wasted. It is basically a passive cell balancing method where energy is dissipated and has a high simulation time (3256 s) with a lower energy efficiency of around 48.47%. That's why it is suitable for low-rated batteries. This method continuously dissipates energy in the type of heat, which results in the cell reducing its light span.

In case of Single After observing the change in SOC of cells, it is known that all cell SOC will be balanced at intervals of 92 s. Compared to the switched resistor method, this requires minimum time to balance the battery. Another is balancing efficiency, i.e. η = 96.67%. Compared to switch register method, this method has decent energy efficiency, and there is a no repeating charging and discharging of cells during balancing operation. Compared to the switched register method, this method has a fast-balancing operation, around 92 seconds for 4 lithium-ion cells.

At last, in two switch fly back converter method, after observing the change in SOC of cells, it is known that all cell SOC will be balanced over a moderate period of time. This balancing period lies between the switched resistor method and the single inductor method. All three cases of battery pack will be balanced before the period of 800 s. The balancing efficiency of three different cases is calculated using Eq.1, and their results are seen in Table 5

Table 5 Energy efficiency

	[**n. SOCe**(%)]	∑ **SOCi**(%)	**η**(%)
Case 1	[4(85.75)]	92.76+84.49+83.46+85.52	99.00
Case 2	[4(86.56)]	92.76+83.46+89.66+85.52	97.41
Case 3	[4(89.72)]	92.76+91.73+90.69+86.56	99.48

The overall efficiency of the two-switch fly back converter method is 98.63%. Compared to both the switch method and the single inductor method, this has more energy efficiency or balancing efficiency, and one of the key features is the variation of charging current. The control strategy is based on time-sharing participation in equalization, which is the order of the initial SOC of cells.

CONCLUSION AND FUTURE SCOPE

In this project, lithium-ion battery, fundamental operation of BMS, and the importance of SOC are understood.

From the literature summary, objectives were drawn, most importantly equalization efficiency.

From simulation study of the balancing circuits, it is observed that the balancing time in single inductor has a lower balancing period compared to the switched resistor method.

A comparison between the switch resistor method, the single inductor method, and the two-switch fly back converter method revealed that the two-switch fly back converter has a variation in charging current with a proper transformer parameter and a decent balancing period.

According to the simulation study, the active cell balancing technique outperforms the passive cell balancing technique in terms of balancing period and energy efficiency.

Future scope

In the future work, cell balancing can be performed using lossless cell balancing method based on switching matrix

REFERENCES

1. G. Coppez, S. Chowdhury, and S. P. Chowdhury, "The importance of energy storage in renewable power generation: A review," in Proc. IEEE Int. Univ. Power Eng. Conf., pp. 1–5, 2010.
2. Electric vehicle battery technologies: From present state to future systems Sergio Manzetti, Florin Mariasiu c.
3. Z.-G. Kong, C.-B. Zhu, R.-G. Lu, and S.-K. Cheng, "Comparison and evaluation of charge equalization technique for series connected batteries," in Proc. IEEE Power Electron. Spec. Conf., pp. 1-6, 2006
4. M. Uno and K. Tanaka, "Single-switch cell voltage equalizer using multistacked buck-boost converters operating in discontinuous conduction mode for seriesConnected energy storage cells," IEEE Trans. on Veh. Technol., vol. 60, no. 8, pp. 3635-3645, Oct. 2011.
5. A.Jossen, V. Späth, H. Döring, and J. Garche, "Battery management systems (BMS) for increasing battery lifetime," in Proc. IEEE Int. Telecommun. Energy Conf., pp. 81-88, 2000.
6. M. Dubarry, A. Devie, and B. Y. Liaw, ''Cell-balancing currents in parallel strings of a battery system,'' J. Power Sources, vol. 321, pp. 36–46, Jul. 2016.
7. G. Qi, X. Li, and D. Yang, ''A control strategy for dynamic balancing of lithium iron phosphate battery based on the performance of cell voltage,'' in Proc. IEEE Conf. Expo Transp. Electrific. Asia–Pacific (ITEC Asia– Pacific), Aug./Sep. 2014, pp. 1–5.
8. M. M. Hoque, M. A. Hannan, and A. Mohamed, ''Voltage equalization control algorithm for monitoring and balancing of series connected lithium-ion battery,'' J. Renew. Sustain. Energy, vol. 8, no. 2, 2016, Art. no. 025703.
9. A. U. Schmid, L. Eringer, I. Lambidis, and K. P. Birke, ''Electrochemical balancing of lithium-ion cells by nickel-based cells,'' J. Power Sources, vol. 367, pp. 49–56, Nov. 2017.
10. W. Han and L. Zhang, ''Battery cell reconfiguration to expedite charge equalization in series-connected battery systems,'' IEEE Robot. Autom. Lett., vol. 3, no. 1, pp. 22–28, Jan. 2018.
11. N. H. Kutkut and D. M. Divan, "Dynamic equalization techniques for series battery stacks," pp. 514–521, 1996.
12. M. Daowd, N. Omar, P. Van Den Bossche, and J. Van Mierlo, "Passive and active battery balancing comparison based on matlab simulation," pp. 1–7, 2011.
13. A. N. A. N. Amin, Kristian Ismail, "Passive balancing battery management system using mosfet internal resistance as balancing resistor," 2017 International Conference on Sustainable Energy Engineering and Application, 2017.
14. L. Wei, L. Jie, S. Wenji, and F. Ziping, "Study on passive balancing characteristics of serially connected lithium-ion battery string," pp. 489–495, 2017.
15. M. Bowkett, K. Thanapalan, T. Stockley, M. Hathway, and J. Williams, ''Design and implementation of an optimal battery management system for hybrid electric vehicles,'' in Proc. 19th Int. Conf. Automat. Comput., Sep. 2013, pp. 1–5.
16. J.-C. M. Lin, ''Development of a new battery management system with an independent balance module for electrical motorcycles,'' Energies, vol. 10, no. 9, p. 1289, 2017.
17. J. C. Jonathan Carter, Zhong Fan, "Cell equalisation circuits: A review," Journal of Power Sources, vol. 448, 2020.
18. Omariba ZB, Sun D. "Review of battery cell balancing methodologies for optimizing battery pack performance in electric vehicles". IEEE Access. 2019; 7:129335-129352.
19. Amin, Kristian Ismail "Passive Balancing Battery Management System using MOSFET Internal Resistance as Balancing Resistor", International conference on sustainable energy engineering and application (ICSEEA), 2017.
20. Van-Long Pham, Thanh-Tung Nguyen "A New Cell-to-Cell Fast Balancing Circuit for Lithium-Ion Batteries in Electric Vehicles and Energy Storage System", 8TH International power electronics and motion control conference, 2016.
21. Rigvendra Kumar Vardhan, Selvathai Thavassy "Modelling of Multi Inductor based Balancing of Battery Pack for Electrical Mobility", Defence Science Journal, Vol. 69, No. 3, May 2019, pp. 266-273.
22. Guo Xiandwei, Geng Jiahao "Active balancing method for series battery pack based on flyback converter", IET Journals, Device & Systems, 2020, Vol. 14, PP. 1129-1134.
23. Jayasree K.S and K.R.M Vijaya Chadrakala "Active cell balancing technique for improved charge equalization in lithium-ion battery stack", 2021 4th International conference on recent development in control, automation and power engineering (RDCAPE), PP. 160-164.
24. Andrej Brandis and Denis Pelin "Active Li-ion battery charge balancing system based on flyback converter", 2020 IEEE 11th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), September 2020.
25. Kuzhivila Pannickottu Nivya and K Deepa "Active cell balancing for a 2s Lithium-ion battery pack using flyback converter and push-pull converter", International Conference on Recent Innovations in Engineering and Technology (ICRIET 2020) 4th - 5th December 2020, Tamil Nadu, India.
26. Ui-Jin and Sung-jun Park "New cell balancing technique using SIMO two switch flyback converter with multi cells", Energies 2022, Vol. 15, 4806.
27. Dakshina Murthy-Bellur "Two-switch Flyback PWM DC-DC Converter in Continuous-conduction Mode",2011 International Journal of Circuit Theory and Applications, Vol.39;1145-1160.
28. Yilin Cao and Kai Li "Balancing Method based on Flyback Converter for Series-connected Cells", 2021 IEEE open access journal, Vol. 9, pp. 52393-52402