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Multi LiFePO4 Battery Balancer for further Developing Effectiveness and Enhanced Capacity

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Abstract— Lithium-ion ($LiFePO_4$) battery can give various good features, for instance, more modest volume, higher security, cut down weight, without memory influence, higher release current, longer life cycle, recyclable and greater breaking point. In the proposed system, the battery structure will recognize the crucial factors of the lithium-ion (LiFePO4) battery module, including delivering or charging current, battery voltage, and temperature. Over current protection, overvoltage protection, cut off, over temperature protection, etc., are only some of the safety features that the battery management system may provide for the battery module. The employed battery management system IC is capable of controlling the uniformity of each cell. For this study, three-series-connected lithium-ion battery pack to test the suggested control method. Proteus has unparalleled performance by doing research and replicating its results, and then using the resulting replica diagrams to validate research hypothesis. With Proteus, result of battery management system will be obtained and analyzed.

Keywords— Lithium-ion Battery, Battery Management System (BMS), Charging Mode, Discharging Mode, Voltage Protection.

I. INTRODUCTION

Conventional fuel vehicles are the primary contributor to air pollution, and this is a growing problem as our understanding of the relation between carbon dioxide and the greenhouse effect. Electric automobiles (powered by the energy stored in a lithium battery) may be able to attain lower levels of pollution than conventional gasoline cars. There is a lot of effort being put towards finding ways to make all automobiles into electrical design. The alternative battery used by electric vehicles must meet strict requirements for energy density, cycle life, memory effect, and the capacity to supply high-flow, immediate power. As ongoing research has shown, the lithium-ion (LiFePO4) battery may provide a number of important benefits, including: compact size, light weight, high security, no memory effect, extended life cycle, high releasing current, high capacity, and the potential to be recycled [1]. The battery management system (BMS) is the most developed and secure way of extending the cycles of LiFePO4 batteries. Hence, lithium batteries are well suited as the electrical vehicles primary source of energy. The BMS (battery management system) for the large battery module is crucial for enhancing battery productivity, module lifespan, and battery life cycle [2].

The BMS, as its name suggests, controls and monitors the battery's charging current, discharging current, temperature, charge, as well as other factors. Basically, a BMS is a monitoring system that keeps an eye on your battery to ensure it lasts longer and performs better. In order to improve the efficacy of BMS before its deployed, researchers are always coming up with new scenarios and methods to study. The BMS may provide preventive security for the battery by monitoring and supervising its individual cell. Second, the qualities of the battery security circuit, including overvoltage, overcurrent, and over temperature protection, provide different protection of the battery [5], should be included into the battery management system.

Misalignments occur in a series of cells connected in a battery pack, decreasing the overall capacity and usual life expectancy of the normal power system. This is why the voltage balancing circuit in a battery is so important it keeps each cell in the battery working at the same voltage [13].

The battery balance circuit keeps an eye on voltage and load by fine-tuning them in a regulated manner using either active balancing methods or passive balancing methods [11-14]. In the event of a balancing system, several designs are possible, including inductive capacitive and transformer types.

While the initial amount and the difficulty of the project are both significant, the loss of energy is very low and makes it possible to increase the battery's capacity. Passive balance is a common term for the dissipative equilibrium. To the point resistance drains resources too quickly. To control the voltage of the cells contained in a battery pack, a device called a battery regulator or battery balancer is typically used. [16] In Lithium-ion battery packs used in portable electronic devices and mobile phones, the Balancers are frequently activated. Additionally, they are included in the battery packs of electric vehicles. In general, a battery's constituent cells can have somewhat varying limitations and states of charge (SOC) [15].

The cell with the lower voltage limit might become a major problem if nothing is done to fix it. That's what we mean when we talk about overburdening or over releasing while only slightly stacking the cells with high limitations. The pay circuit should allow the highest-capacity cells to be stacked/dumped completely, while the smaller cells be stacked/dumped properly, making for a radically different experience overall. A well-balanced battery is one in which the highest-capacity cell is charged without overburdening other cells (i.e., those that are weaker or less capacious) and is discharged during usage without excessively discharging other cells. The battery is fine-tuned by exchanging power between individual cells until the state-of-charge of the cell with the lowest threshold is equal to the battery's [16].

II. Management of battery System

Management of battery System is an electronic device that controls a rechargeable battery (battery or battery pack) in such a way that it provides battery security outside of safe operating region, status control, optional information estimation, reporting this information, taking a close look at the current situation, verifying and/or adjusting, and so on. [1] A smart battery pack has a battery management system built in and can transfer data to and from an external source. Intelligent battery packs require equally intelligent chargers.

An integral aspect of any lithium-ion battery architecture is the BMS (Battery Management System). Such a device maintains constant control over each battery cell, monitors voltage estimates, communicates with other devices, and calculates temperature and charge state, among other things. It is the BMS that determines the life and performance of the final battery. Various BMS types can be used depending upon different application and features. This type of BMS is particularly useful for medium-control situations (electric bicycles, etc.). There is also the option of using a battery management system (BMS) or a Master-slave version to manage permanently installed or extremely powerful batteries. This BMS was selected because of its high standards of quality and performance, its robustness and efficiency, and its low energy consumption [24].

III. Problem Statement, Objective and Literature Review

To minimize air contamination and shortage of fuel electric vehicle are presented now days. These vehicle use Lithium Ion Battery for energy consumption which need appropriate charging and discharging operation for their activity called Battery management system. In existing Battery Management System the cells of the batteries is charging in series which will lessen their quality and life pattern of the Battery.

1. To propose a system that can prevent the compromised cell effect of the overall performance of battery.

2. To propose a system that can continuously monitor the individual cell voltage and charge every cell individually.

3. To propose a system that can monitor the temperature of each cell and stop charging and discharging in case of overheating.

The growth of battery energy storage networks has increased demand for their potential in a variety of service roles. In particular, lithium-molecule battery-related network infrastructure has advanced rapidly due to the availability of several cell advancements and organizational structures.

With the goal of making lithium molecule based limit networks link with a specific organization application, this evaluation is meant to serve as a guide for the best choice of battery development, strategy, and endeavor by the organization. After providing a comprehensive review of lithium-molecule battery advancements and their qualities with respect to advancement and execution, this article explain in detail the limit network adventure, as evidenced by an analysis of activities in general. Normal purposes of the stockpiling network are assembled and described contrasted with the troubles posed with the battery organization. Demonstrating instruments straightforwardly available for Specialized and money related breaks down are shown. A compact examination of improvement approaches centers to highlights the hardships and conceivable game plan frameworks for situating, delivery and dimensioning the framework activity [26].

Abnormalities in battery packs may be traced back to two major and distinct causes: advances in manufacturing technology and accelerated deterioration. Variation in groups of cells with a same kind in terms of limit, internal obstruction, and a few different borders is caused by specific and material changes throughout the collection process. At the point when there are some cutoff contrasts in the re-energizing method, as far as possible cells will be completely energized to begin, while the battery re-energizing cycle won't be performed and an over-burden will happen.

In the event of release, the majority of the cells are still in a surface delivery condition; notwithstanding, cells with a little cutoff have recently been in a profound delivery condition, which caused an overabundance release. Where there are differentiations of interior check, the warm profundity delivered and the arrival of the cells will be unprecedented. Accordingly, these qualifications will likewise impact inside impediment. The greater the temperature, the less of an internal barrier it forms due to the increased cellular freedom, and the reverse is true for lower temperatures, when the internal resistance is more pronounced. The local temperature of a cell determines how quickly it may change directions in comparison to other cells. As the battery pack ages, its performance degrades and its lifespan decreases [14]. In conclusion, cell degradation will occur on several levels due to the primary problem of inconsistency across similar types of cells, in addition to the charge and cells delivery speed, the distribution depth, temperature that integrates, and many more external variables.

This is necessary because of the differences of various cells caused with collecting methodology. In any case, the first runtime checks to see if the battery pack's current cell use may be reduced. Even though cell (single) research has made significant leaps ahead and its performance has usually increased, constancy guaranteeing of the fundamental performance of cells, the pack of battery will similarly transmit differences because of the operating conditions and the earth. Consistency, not basic variances between cells, is the primary factor affecting battery pack longevity. Therefore, it is essential to utilize varying control to additionally improve the battery pack's consistency in the middle of the functioning system.

Several control strategies based on variation have been developed, including voltage modulation, Territory of Charging modulation, and control limits. Assault is made on and delivery of circuit. While adjusting the battery pack's voltage can help with voltage irregularities, this is not a sufficient metric for gauging the battery pack's performance. It's possible that a low cutoff cell's terminal voltage will be higher than that of other cells while it's charging or after it makes a choice. In cases when this way of change is implemented, the result of the change is that the most drained cells contribute vitality to the most drained cells, increasing the breaking point differences between all of the cells in the battery pack.

The method of ampere hour is for the most part an ordinary, direct, and strong technique for evaluating the Territory of Charge. The delivery current is protected and the negative values showed in charging current, the assessment condition is displayed as

$$SOC=SOC_{init}-1/CE \int_0^t \rho i(t)dt \qquad [2.2]$$

The underlying worth of CE shows the limit of a battery, SOC is given by SOCinit, and ρ is the productivity of coulomb.

It is demonstrated in [19], the temperature of battery is constrained by intensity created of inward resistance and by trading of intensity with encompassing circumstances. The intensity state protection comprises:

$$SOC=SOC_{init}-1/CE \int_0^t \rho i(t)dt \qquad [2.3]$$

To illustrate, let's say that Ta represents the ambient temperature, m represents the battery's mass, R represents the battery's internal impediment, hc represents the cell's coefficient of intensity trade, and S represents the battery's surface area.

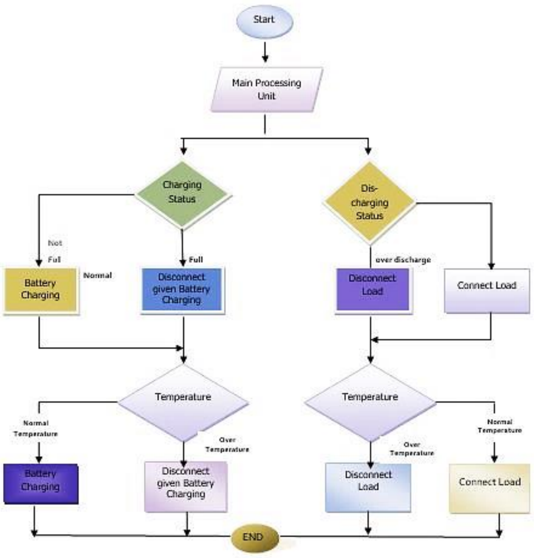

Figure 1 Flow Chart of System

The progress of batteries is crucial to the development of all future ideal energy vehicles, including as electric cars and modules in hybrid vehicles. The widespread use of this battery technology is crucial for a variety of uses, ranging from hybrid electric cars to consumer electronics [29]. Increased battery performance is dependent on the development of better materials for use in various battery subsystems [30]. Lithium battery technology has recently advanced for potential future uses. As a result, the anode will be in an ionic state of lithium, and the resulting battery will be called a lithium ion battery.

IV. Methodology and Implementation

For the purpose of design, a PC-based circuit simulator known as Proteus is used to model the proposed battery balancer framework. The solution provides us with a comprehensive library and run-time analysis of the framework to ensure the correct functioning of the proposed system. In figure 2 show the overall task outline.

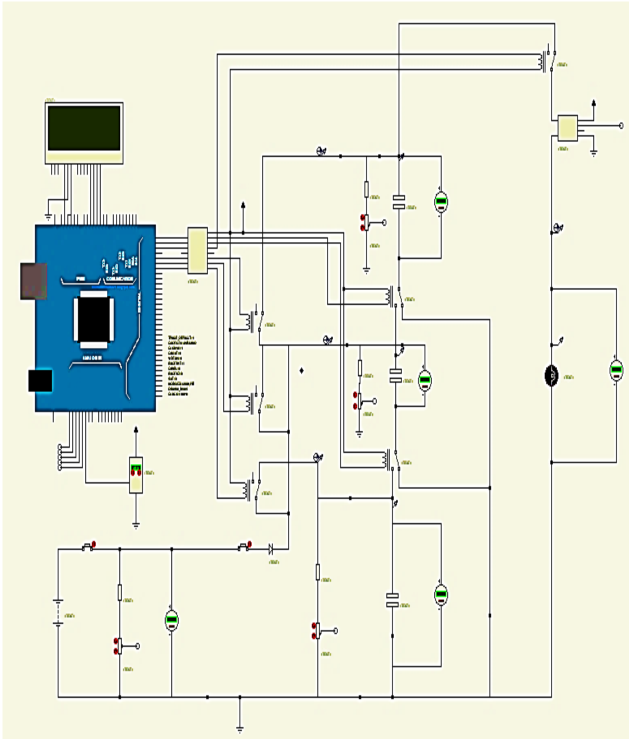

Figure 2 Battery Balancing overview System

Numerous components, such as resistors, capacitors, switches, a display, a microcontroller's direct current (DC) power supply, and a temperature sensor, make up the overall architecture. This section details the many components and the final method used to implement the framework, explaining how the design manages to fulfill all of the requirements listed in the project's goals.

A. *Microcontroller Arduino Mega 2560*

Because of their effectiveness, versatility, and speed, the Arduino Miniature regulators are finding widespread usage in a wide variety of electrical and gadget-related infrastructure. ATmega2560 is required for the board to function. The Arduino Mega 2560 has a lot of extras built right in, like a ton of I/O lines, greater RAM for sketches, and faster processing speeds for your code.

B. Relays

Electrical and mechanical uses are common places to see relay circuits in use. The mechanical assembly moves the metallic contact that interacts with or isolates the external circuit by simply energizing a coil inside the circuit.

C. Extra Components for Circuit

The power adjusting proposed framework likewise contains a few extra parts of utilized in the reproduction and also utilized for equipment execution. These extra parts are referenced beneath followed by a short portrayal of their job in the framework:

- A LCD display
- A power supply
- Variable Resistors
- Temperature sensor
- Current sensor

Battery charging should take place via a power source integrated within the structure. Another DC power supply is necessary when charging a DC battery with several cells. This power source's voltage should be somewhat greater than the calculated voltage of the battery being charged. The voltage of the second power supply being used to charge the battery, if its estimated value is 12 volts, should therefore be 13 to 15 volts. The charging battery is able to function as a stack because of the voltage difference.

This can either be another DC battery or a rectifier-based power supply. There are viable options for achieving the necessary goals. A 14-volt DC power supply is used to charge the battery. A 16x4 LCD is used in the simulation to display the current system state (Charging/Releasing Modes). This display makes sense and meets the basic need of displaying relevant data, such as the power, current and cells voltage while charging as well as discharging.

The LCD display may operate in either a 4- or 8-cycle mode. The 4-digit mode combines two separate 2-cycle pairs of data before sending it to the LCD for further processing

D. Overview of System Operation

Results from the reconstructed framework are analyzed in depth below. This section provides a high-level description of the proposed architecture and the instrument that drives it, so that readers may get a feel for how the circuit operates. Capacitors that have been captured are used to communicate with the battery cells in a replica. In earlier subsections of this section, the framework's components are explained. Three capacitors are used to fine-tune the battery for replication. Each capacitor is connected to a single battery cell.

The sensors, transfers, and variable resistors are all linked to the Arduino Mega2560 tiny regulator board so that its operation may be detected and shown. Initially, the voltage of all these cells is low, forcing the framework to go into charging mode. Whenever the charging mode is switched on, one of the batteries with a lower voltage than the other two will begin charging first. Cells keep charging until they reach their maximum capacity. Despite having a lower voltage than its neighboring cells, the undercharged phone will keep sucking power from the outlet. Anyhow, in the suggested framework, the regulator recognizes this flaw and prevents current from reaching that cell. However, during discharge, a damaged cell would continue to reduce its voltage below a certain level, altering the battery's overall performance. The system detects the high voltage of these cells and removes them from the stack. A properly functional battery, as measured by a battery activity analyzer, would still retain around 80% of its estimated voltage across its terminals after discharging to zero. If a battery discharges below that threshold, it has damaged at least one of its cells and will no longer function as intended. A continuous sensor is also used to monitor the rate of flow towards the pile. When the current being pulled by the heap is too high, the battery will be depleted quickly, and repeated charging and discharging might be harmful to the cells. Therefore, if the current in the stack becomes high enough, the system will trip, disconnecting the cells.

As can be seen in Figure 7, the battery cells are connected in series. In addition, the graphic displays the related variable resistors that are aligned with each cell in order to obtain a voltage value across them. This method allows the framework to monitor the voltages of each cells independently. The combination of switches, sensors and Arduino in this configuration not only ensures the system's health and safety by providing a stable voltage to all of the cells, but also ensures that all of the cells receive an equal amount of power.

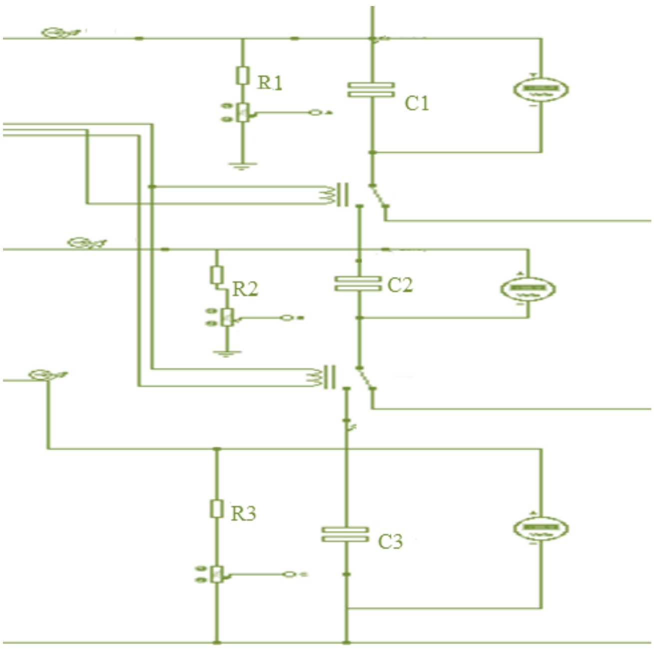

Figure 7 Battery Cell Arrangements in Proteus

RESULTS AND DISCUSSION

Results from implementing the suggested framework in the Proteus circuit test system are discussed here. In Section 4, the organization and central role of the various components are discussed. An important fact of the Proteus circuit test system is that it displays the reaction of the proposed circuit in real time, and that the simulation continues to run until forcefully stopped.

Proteus reproduction time is not a constant like MATLAB's. When the "play" button in the lower left corner is depressed, the underlying architecture is set into run as intended. The cells and power sources' start values are set in. To help make sense of the results shown in the proteus, we'll go through each one in turn here.

When the circuit is activated at the start of the simulation, the battery cells begin charging with their load disconnected. Two switches, connected to the primary power source and operated by hand, are featured for connecting and disconnecting the power supply. Figure 8 display the circuit's underlying boundaries. The battery's general voltage, individual voltage of cells, and temperature may all be viewed on the LCD display, providing insight into the framework's operation mode.

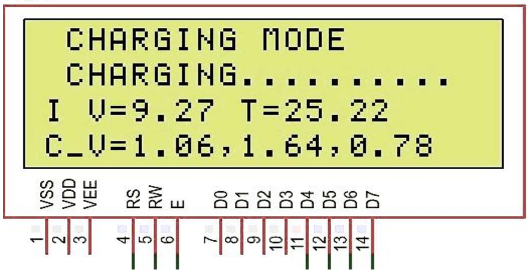

Figure 8 Initial System Parameters

In particular, the framework's limits at time t = 26 seconds are depicted in figure 9. As the framework kicks off, the power source begins supplying capacity to the cells to charge them from the low underlying voltages. The top of the paragraph displays whether the framework is now charging or releasing. As seen, the temperature is valued at 25 degrees Celsius. During the simulation, we tested the effect of using a temperature sensor with a range of possible quality on the framework. The charging battery's individual cells are what a polar capacitor talks to. If you look closely at Figure 9, you can see the capacitors that were used to make the copy. The positive terminal of the capacitor is shown by the red plate, while the negative terminal is indicated by the blue plate. Three cells are connected in series, with their voltage and capacitance all set to 100 Farads and 12 V, respectively. Figure 4.2 suggests that one of the phones has a lower voltage than the others. In such a scenario, battery voltage and power consumption are almost guaranteed to become unbalanced.

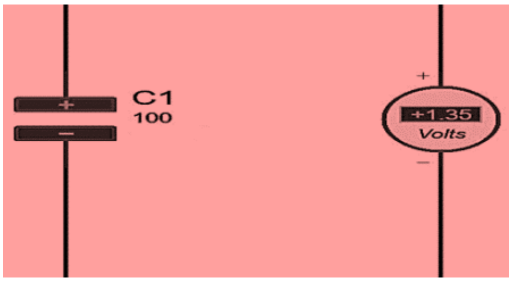

Figure 9 Battery cell in Proteus capacitor used

Turning off the modification to the primary power source initiates the framework's releasing procedure. When the electricity is cut off, the framework switches to release mode and begins supplying power. When the pile isn't initially linked to the battery's cells, the discharge occurs more slowly. The LCD panel (as seen in Figure 10) displays the current release mode.

The suggested management structure ensures the battery is being worked in a secure area that prevents damage to the battery and the load. A releasing mode is activated when the voltage of all the cells reaches a certain plateau.

Figure 10 Discharging Mode of the System.

As seen in Fig. 11, the framework's equitable pricing strategy is illustrated. When in releasing mode, cells' voltages are monitored to make sure none drop below a certain threshold, just as they are when in charging mode. To maintain a consistent voltage among the cells, it is important to turn off the battery's output and contribution when they are no longer needed. This not only improves the battery's performance and lifespan, but also prevents any unnecessary energy use.

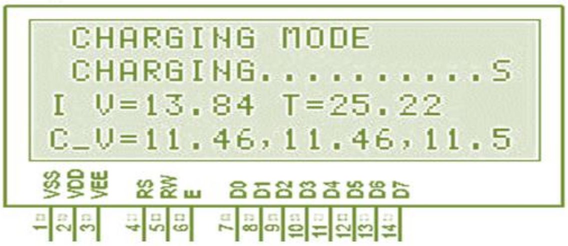

Figure 11 The Process of Balancing Battery cell

According to the figure above, the total voltage is 13.84 volts, while each cell voltage is also at roughly 11.5 volts maintained.

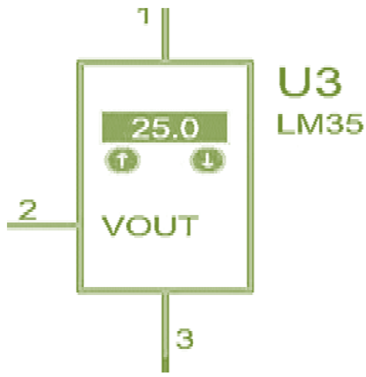

Figure12 LM35 Temperature Sensor

As may be seen in Figure 12, a sensor was used during the game. An ordinary LM35 temperature sensor will work here.

During operation, the sensor's temperature may be adjusted to study the system's response at varying temperatures. When the temperature rises beyond 50 degrees Celsius, the framework is programmed to shut down. As long as the temperature remains over the predetermined reference value, the display screen will continue to display the temperature insurance message. The temperature value used as a reference may be adjusted to work with different batteries and climates.

Using the bolt fastens shown in Figure 11, we increase the temperature being recorded by the LM35 sensor in order to test the framework for overvoltage. In figure 12, we can see the mode into which the system transitions after the temperature value reaches the preset limit. The figure suggests that the system's remaining attributes are being eliminated and that it will cease functioning unless the temperature value is lowered. As a result, the suggested framework can provide protection from excessive heat, which is detrimental to the battery and shortens its lifespan.

Figure 12 Protection of Temperature Display

The Proteus circuit test system can monitor and record the long-term response of the framework and display the resulting voltage and current changes. For your perusal, each cell's corresponding diagram is shown below. Every single figure represents the voltage and current of a single cell. Through analysis of these graphs, it may become clear that equal voltage is being applied to each cell of the battery.

This means that the voltage level remains constant after charging or discharging. In Figure 13 we see the voltage, and in Figure 14 we see the dynamic chart of the first battery cell.

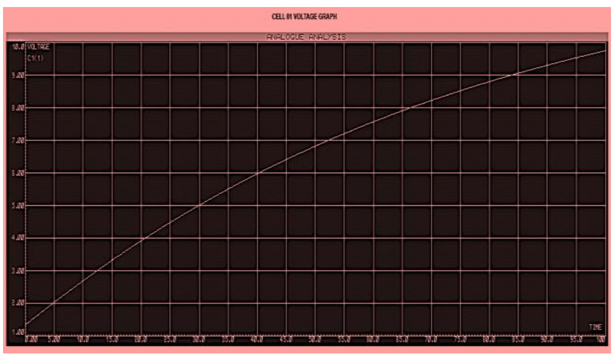

Figure 13 Cell 1 Voltage Graph

This graph demonstrates that the voltage of cells steadily rises over time.

However, the diagram will often settle down at the end, indicating that the voltage of the characteristics stops growing when a certain value is reached. When the power supply connected to the cell is 14 volts, the cell begins to charge, and the voltage across its terminals rises until it reaches the supply's voltage. In addition, the current causes the diagram to be inverted with respect to the one in figure 14.

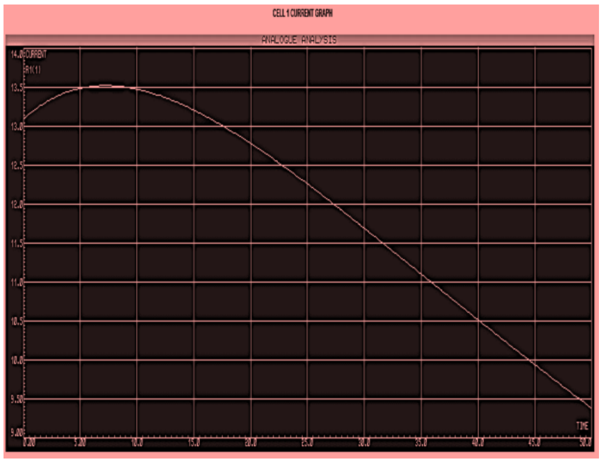

Figure 14 Cell 1 Current Graph

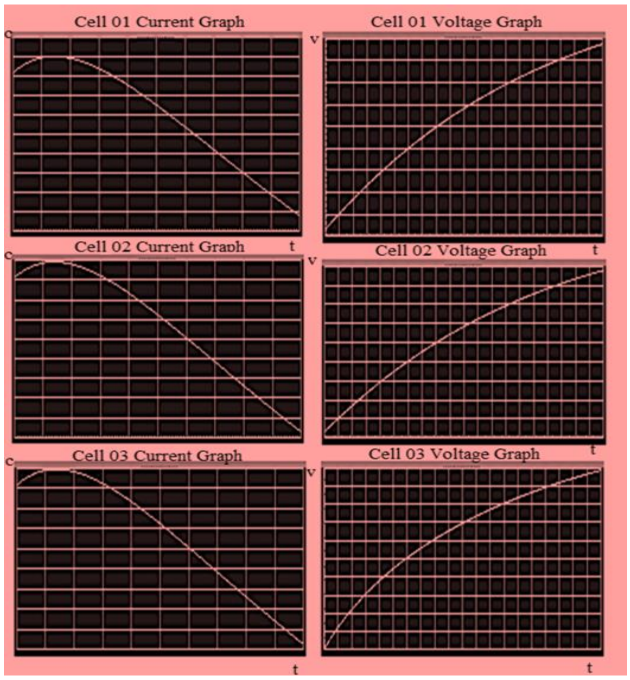

Figure 15 Voltage and current graph of all cells

Figure 14 is a schematic depicting the charging current in cell 1. For the first 100 seconds of the recreation, all such charts are repeated verbatim. When a battery is initially completely depleted, the voltage between its terminals will be low.

A 14 volt battery connected to a 6-volt or 12-volt cell at a greater potential and would start feeding current into the following component, as mentioned earlier. Figure 5.9 shows that initially the expected contrast between the power supplies is larger, leading to a higher continuing stream.

Charging a battery increases voltage between its terminals and reduces potential difference, resulting in lower current. When fully charged, the current in a battery drops to almost zero.

Figure 15 shows the continuous a voltage graphs for the three replica cells. Figure 15 displays current on the left and voltage on the right.

Voltage and Current readings for all 3 cells should look roughly the same, indicating that they are in a balanced condition.

Table 5.1 Battery Cell Charger Data

S. No	Voltage (Volts)	Current (Amps)	Time (Minutes)
1	2	13.5	5
2	2.73	13.48	10
3	3.3	13.23	15
4	3.94	12.75	20
5	4.53	12.27	25
6	5	11.6	30
7	5.5	11.1	35
8	6	10.5	40
9	6.4	9.9	45
10	6.8	9.4	50
11	7.23	8.87	55
12	7.61	8.26	60
13	7.95	7.69	65
14	8.17	7.12	70
15	8.50	6.55	75
16	8.83	75.04	80
17	9.08	4.47	85
18	9.33	3.88	90
19	9.57	3.03	95
20	9.89	2.43	100

Table 5.2 Battery Cell Discharger Data

S. No	Voltage (Volts)	Current (Amps)	Time (Minutes)
1	11	45	5
2	10.54	4.44	10
3	10.1	4.32	15
4	10.7	4.22	20
5	9.34	4.1	25
6	8	4.0	30
7	8.2	3.87	35
8	7	3.85	40
9	7.65	3.83	45
10	7.23	3.77	50
11	5.95	3.71	55
12	5.76	3.33	60
13	5.32	2.68	65
14	4.61	2.22	70
15	4.34	1.8	75
16	4.11	1.78	80
17	3.14	1.76	85
18	3.12	1.75	90
19	9.57	1.74	95

CONCLUSION

Examining the graphs and tables draw from the simulation one can reach to the conclusion that the suggested framework prevents the damaged cell from influencing the overall execution of the battery. In a real world setup, where the battery's balancer is not present, the low voltage of a down cell within the battery might create charging and discharging irregularities. The suggested balancer framework continuously monitors the voltage of each individual cell and cuts off power transmission when all cells have reached their nominal value.

1. The proposed framework can limit the compromised cell impact of the total consumption of battery.

2. The proposed system can continuously monitor the individual cell voltage and charge every cell individually.

3. The propose system can also monitor the temperature of each cell and stop charging and discharging in case of overheating. In addition to serving as a safety feature, the suggested framework may be used as a testing device to examine the health, lifespan, and damaged cells of a battery. It's also important to note that the suggested architecture has potential for extensive use beyond the realm of pure power applications. Power storage appears to be of paramount importance when considered the power needs of the modern world.

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