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A Novel Idea of Balanced Super Capacitors with Fuzzy Control Using Renewable Energy Harvesting System

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Abstract: Energy is one of the crucial element to all the discoveries from single led blinker to advanced satellites energy is essential. What if the energy can be extracted from our primary source the sun, such energy is infinite in space and free of cost. Even though the solar energy is not dependable due to the un-stability with respect to time. If we can balance and control the passage of electron flow in a secured manner the energy can be used for electronic applications, even for the impossible ones. With the help of active balancing and a superior fuzzy based control system the model can be developed. Several tests should be planned to test the model for different surroundings.

Keywords: Active Balancing; Fuzzy Logic; Python; Solar Inverter System; Super Capacitor

I. INTRODUCTION

In an electronic system energy is an essential part where all the dependable components extract from the source. The energy is the result of electron flow, so a perpetual energy source is required to drive multiple components. Several elements possess the electrons where they can emit on different scenarios. Commonly used energy source is the solar energy where the sunlight is directly converted into electron flow results in required power. Once we enhanced such energy the next step is to store or use. According to instrumentation theory the energy can be neither used nor recorded. The source to store such energies are Supercapacitors, Batteries, and Semiconductors. The SC are developed to store energy for more than casual capacitors can hold. Now a days SC is replacing several BMS due to low charging time and low radiating energy. Before storing the energy, it must be balanced and stored in a controlled manner. Several methodologies are available for the same procedure but here explained an optimum methodology with the help of fuzzy logic and active balancing.

A. Control system

End to end controlling is essential for every digital circuitry. Fuzzy logic is introduced which gave high accurate output and python supported [2].

B. Crisp Logic

Every idea or thought by a human being has two stages either yes or no. the result action depends on the answer. Such a way of thinking is explained as crisp logic. The probability is limited into 0 and 1, so the result may or may not be accurate.

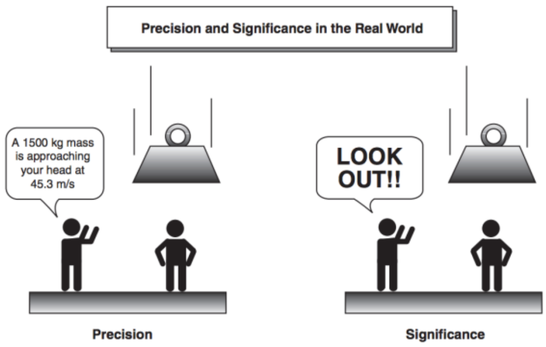

Fig 1. Example of crisp and fuzzy logic

Fig 1 explains two way of thought where the result of accident. The precision is optimum solution but not adaptable for a situation like in the Fig. So in such cases crisp logic is profitable, sudden actions result in avoidance of accidents. But for a system crisp logic is not enough the options should be accurate to provide accepting results which can be expressed as fuzzy logic.

C. Fuzzy Logic

Fuzzy logic is the optimum result of a classical logic, where the result is expressed in probability where the value stands between 0-1. The design of such complex method is done using MATLAB or python platform. The fuzzy logic implementation is complex so several attributes have to consider. The result is determined by using several rules which are designed by user itself before designing the fuzzy controls. Fig 2 explains the structure of fuzzy logic system.

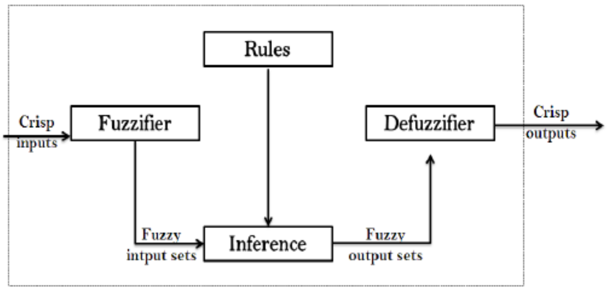

Fig 2. Structure of fuzzy logic

In the Fig 2, the fuzzifier extracts the crisp input into several stages where the inputs are controlled using the rules designed by the user itself. The rules can change the features of the crisp input. After fuzzy procedures it tis the de- fuzzified into crisp outputs where the value is more prominent and accurate.

II. LITERATURE REVIEW

Changhao Piao, et.al [3] proposed that in battery management system, it surely need a balanced design for proper charging and discharging. In this proposal using outlier detection algorithm approach battery bank is balanced and controlled. The battery is an unavoidable component for every electronic system so balancing it is essential. In this paper, an approach named outlier detection is used for unbalanced cell recognition. In this system, several mathematical approaches have done for deciding respect outputs, which are named ECE+EUDC tests. These tests are based on previously proven theories such as the Z-score standardization method, Euclid distance method. These calculations will helps the user to decide which cell shows unbalancing characteristics. Concerning the outcome of the above paper, in this thesis work, the tests that do can be a useful technique to monitor and increase the efficiency of the model. It helps to provide a simple idea about designing the control area.

Michael Helmlinger [4] proposed in his research that the energy can be stored with a proper balanced manner either in battery or in a capacitor. In this thesis he proposed a buck-boost converter can be used to protect from the interruptions of main supply. The glitches occurred by the load can cause severe variations at the output. The balancing circuitry is fed by the buck-boost converter, it supports energy transfer from the input to the output, as well as from the output to the input. TPS63020 charges and discharges the backup capacitor in an efficient and controlled way. The usable energy stored in the backup capacitor is limited by the maximum voltage of the buck-boost converter. The charging has been done via programming and corresponding output in a programmed level. This will helps to predefine the required output and design the structure for it. The purpose of the circuit is to charge the backing capacitor to a user defined voltage level and provide continuous backup power in case of a main power failure at the load. Smart eFuse with integrated back-to-back FETs and enhanced built-in protection circuitry. Designing such circuitry provides following benefits.

Murata Manufacturing Co. Ltd [5] proposed a thesis representing that a balanced storage unit can be used with low power consumption. By doing such a system availability of power won't be a problem. Today, every system is trying to develop under low power, because of the unavailability of power. As before explained that a storage unit can be designed for storing energy. In a battery charge can be held for a long time but required charging time is very high and discharging is done very fast. Such a device is not recommended for a 24-hour working area. Instead using batteries capacitors will be used as a replacement, a capacitor is a storage device where the requiring charging time is small and discharging will be done slowly. The above thesis explains that it can drive two cells at the same time which requires low power and provides faster response. The capacitor which has high capacitance and long cycle life in a miniaturized and low profile body is used as main power supplies or auxiliary power sources (for backup or peak power assist). Generally, several super capacitor need to be connected in series and the applied voltage for each cells should be controlled by voltage balance circuit when higher voltage is required. In this thesis it explains various methodology for balancing and a concluded system to generate required output within low cost and low power consumption.

Yuan bin Yua, et.al [6] proposed a model by combining both battery and super capacitor for an extended output. A hybrid energy system (HESS) introduced of a battery and super-capacitor (SC) that can make full use of advantages in energy and power density, which can be used for electric vehicles [2]. In this thesis redeveloped the energy management strategies (EMS) for HEVs passing from battery energy storage to HESS. An equivalent fuel consumption during parallel-charging of a semi-active HESS is designed in a series-parallel manner for HEV under rule-based EMS. For the control system, fuzzy logic is installed [4]. The control system will develop required voltage transfer under user defined rules. This is done by analyzing the membership functions which can develop a Parallel-charging of a semi-active HESS. This thesis explains the theoretical structure to a balanced with controlling capability equipment. Cao and A. Emadi explained in practical such a device using Battery and capacitor is far-fetched. The DC/DC can regulate the voltage of the battery and SC at the same time, results in controls over the power flow.

III. MATHEMATICAL MODELLING

This proof consists of scientific calculations which results the needed current and charge values. Before calculations various parameters are taken as constant, here capacitance is taken as 500F and resistor chosen as 1 Kilo-ohm.

Calculating charge.

$$Q = C * V \quad (1)$$

Calculating current.

$$I = {}^{V}/_{R} \quad (2)$$

Mathematical approach towards voltage

$$V(t) = \frac{1}{C}\int_{0}^{T} i(t)dt \quad (3)$$

i.e., $V(t) = {}^{i}/_{C} * T$ (4)

Apply (3) in (1)

i.e., $Q = C * {}^{i}/_{C} * T$ (5)

Therefore, (5) becomes

$$Q = i * T = V(t) \quad (6)$$

Therefore, (6) becomes

$$Q = {}^{dv}/_{dt} \quad (7)$$

The value of Q is the different attributes of fuzzy inputs, where expressed as low, medium and high.

IV. METHODOLOGY

A. Balancing technique

The identification of unbalanced cells in a bank of circuitry is impossible, there is a chance of distortion or leakage between these cells. So a balanced manner of charging and controlled sharing is required. The balancing methodology here used is the active balancing it is done using several active components which promises more accurate than previous forms. The active balancing is costly and complex than the passive balancing. The Fig 3 is an active balancing technique which is done by the help of bipolar transistors which delivers fast switching without heavy leakage. While implementing in real- life diodes are used to avoid any ripples on the output side. The diodes act as dc to dc convertors where only dc components are transmitted. Which also provides the shortage of unbalanced cells, results in optimum balanced system [2]. After proper balancing the output voltage is introduced with fuzzy logic where the fuzzy logic checks the voltage whether it is secure to share or not. If it is secure the fuzzy control enables the I\O pins which results in sharing the energy between the cells. This will avoid the unbalanced cells and develops stable and high power to the load.

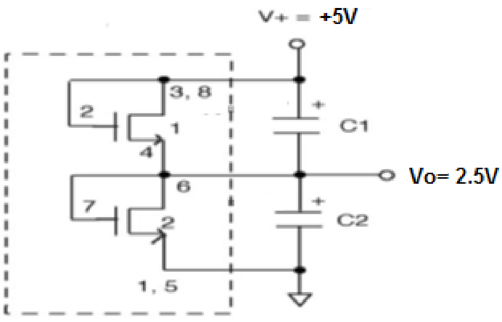

Fig 3. Active balancing

B. Block diagram of proposed model

The proposed model develops a stabled and extended power at the output. This can be generated by combining several stages such as energy harvesting stage, active balancing and fuzzy control stage. The fuzzy control is programmed in raspberry pi 3 because it has the suitability to run complex operations. The fuzzy rules are prewritten into the raspberry using python fuzzy controls. The output is connected from the stack of supercapacitor to the load. The block diagram is shown in Fig. 4.

The active balancing is done using active components were the bipolar transistors clips the voltage into equal amounts which can be used for protective charging.

V. FINDINGS AND RESULTS

Table 1 is the collection of values which is calculated from a 1F capacitor and various resistors. With these values the required attributes for fuzzy logic is designed.

No.	Resistors	Voltage	
		V_{low}	V_{high}
1	0 ohm	0.2	2.8
2	100 ohm	0.35	2.78
3	470 ohm	0.2	2.69
4	1 k-ohm	0.25	2.68

Table 1. Calculations for Fuzzy Input

Table 1 is the calculation of voltage across different resistors using the Ohm's law. In such manner current and charge is calculated using (1) and (2).

Attributes	Low	Medium	High
Voltage	0.2	1.35	2.75
Current	0.0025	0.045	2.85
Charge	8	1300	1800

Table 2. Attributes of Membership Functions

Table 2 represents the membership functions values which is used in fuzzy logic code. In this proposal Gaussian membership function is introduced which provides high accuracy. Fuzzy rules were designed by the help of this parameters, which is then controlled in python fuzzy logic code.

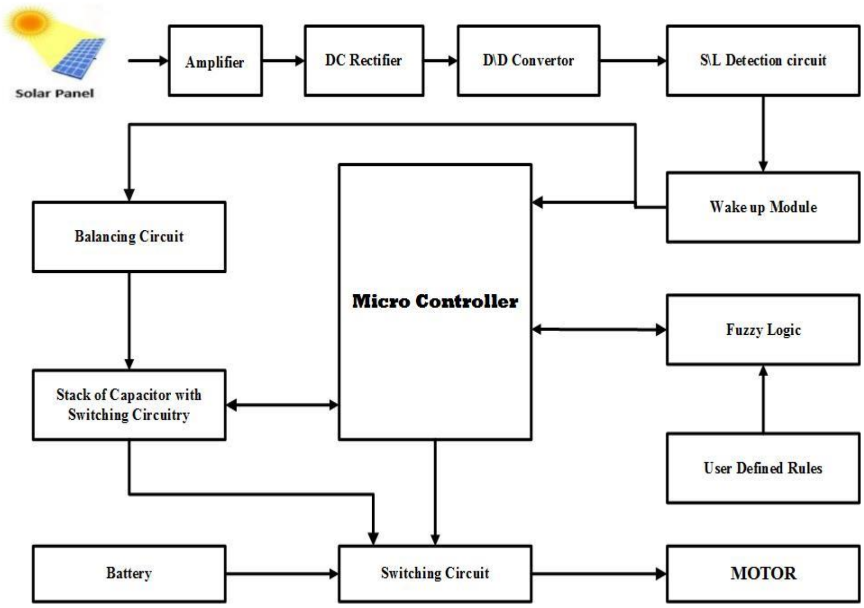

Fig 4. Block diagram of proposed system

A. Power supply analysis

One of the objectives is to install a solar panel with supercapacitor circuitry. From the study, the solar panel voltage varies with time and develops an unstable current flow, so the system should not fluctuate at this situations. So a balanced voltage distribution is necessary, with the help of active balance circuitry an undisturbed model is implemented.

Time	Solar voltage(V)	Super capacitor voltage
10:25	21.9	2.734
11:25	22.5	2.736
12:25	22.8	2.741
1:25	22.4	2.737
2:25	21.93	2.734
3:25	21.81	2.734

Table 3. Voltage distribution between solar panel and supercapacitor at different time instances

Table 3 shows solar panel and supercapacitor voltages at different time instances the capacitor voltage is determined using the equation given below. The solar panel is the primary source of supply, where the panel is kept in a height so the sunlight can directly fall on it. Table 1 is the collection of data which is collected on various time instances the SC low voltage and max voltage is calculated and difference of these two values is recorded. From the value it is clear that at any variance of time or any fluctuating voltage the SC can withstand without failing.

B. Testing on 12V dc motor

In this section charged balancing circuitry is interfaced with serially connected two 6V DC motor. Discharging due to the motor load is noted and plotted. The motor requires 6A at start and 0.24A for operating it and also achieves a power of 72W at primary stage and a 2.88W while operating.

Time (min)	Voltage(v)
0	4.6
2	3.78
4	3.00
6	2.88
8	2.66
10	2.46
12	2.22
14	1.96
16	1.74
18	1.56
20	1.26
22	1.12
24	0.88
26	0.72

Table 4. Discharging of SC on 12V dc motor at different instance of time

The motors are powered using two supercapacitors of voltage 2.75V (2.75+2.75=5.5V). Table 4 shows the time and respective voltage drop across the dc motors which are connected in series. The time taken in minutes using a stopwatch and the voltage is measured with the help of a multi-meter. From table 4, a graphical representation has done to see the rapid decrease across the supercapacitor due to the high load.

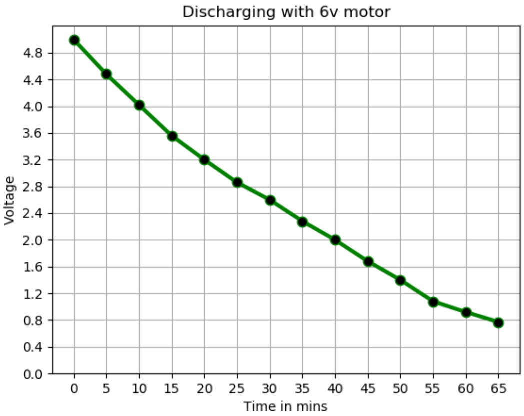

Fig 5. Discharging of SC on two 12V dc motor

Fig 5 shows the rapid decrease due to two serially connected 12V dc motor connected across the capacitor.

VI. RESULT AND DISCUSSION

This section discusses the performance and preliminary part of the proposed system. A model is developed as a balanced and control circuitry to perform the preliminary part. By the help of fuzzy logic required control operations were done. Balancing is designed on breadboard and using PI, control section of super capacitor is done. At the stage of preliminary section, it results an outstanding efficiency of balancing and delivered a stable output. Further improvements will result greater affect in the proposed model. Several work charts are pending and it will be completed in upcoming months.

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