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Super-Capacitor Overpowers Battery: An Overview

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Abstract- Adoption of renewable energy sources significantly increasing and has become the most preferred for upgrading and modernizing the energy sector across the world. Failure of energy system leads to the blackout on large scale applications, and security or personal losses on small scale. The need for maintaining the credibility and consistency of the energy system for its proper functioning along with the efficiency accompaniments of sources of renewable energy has led to the emergence of an intelligent battery management system. For hybrid energy sources, EMS must have some control units to monitor and sense the behaviour of hybrid energy sources and control accordingly. In this system, the super capacitor plays the role of supplementary energy storage, which supplies the over and uneven demands; whereas the role of the battery is still as a main energy storage device. The structure and performance of the super-capacitor in a hybrid energy system will be discussed analytically under various scenarios. Recently the role of super-capacitors has become more fascinating in areas of the transportation and other energy sectors. The one primary concern in HESS is the utilization of batteries with super-capacitor. In economic sectors too, renewable energy sources are becoming a major investment and growth in the global market.

Keywords: Battery, Energy Management System (EMS), Hybrid Energy Storage System (HESS), Super-capacitor, Maximum Power Point Tracker (MPPT).

I- INTRODUCTION

In the current scenario, at a global level, the accessibility to electricity has been steadily increasing over the last few decades. In 2000, around 43% of the world population had access; this has increased to 99.6% in India till 2019 [1].Recent shifting towards development of renewable energy resources because it provides low-cost electricity to consumers [2, 3]. Solar photovoltaic (PV) has become one of the most attractive renewable energy technologies in recent decades, owing to its claims as a clean, green, and silent source of electricity, as well as its modularity, ease of installation, mature technology, low operating costs, and free and inexhaustible resources. [4,5,6]. One of the significant difficulties is to address the developing worldwide energy interest and to sort out the approaches to satisfy this need by feasible and earth favourable energy arrangements. Because of the irregular electrical properties of PV cells and the intermittency of sun-powered photons, an intermediate Energy storage system (ESS) must be implemented in order to provide a consistent supply to the loads. [4]. Energy Storage (ES) technologies are becoming increasingly significant as electrification and sources of energy become more prevalent. [7, 8, 9, 10].The ESS goes about as a safeguard for surplus energy and provider of energy when framework required [11, 12]. The control trades are commonly divided into high and low-frequency aspects, such as a sharp uptick in power demand, and low-frequency aspects, such as day by day typical vitality use design. ESS elements with a fast response time are often based on high power frequency exchanges, whereas ESS elements with a high energy density are required for low-frequency power exchanges. [11, 13]. The mix of batteries and super-capacitors utilizes reciprocal qualities that permit the covering of batteries high energy thickness with a super-capacitor high force thickness. This crossover frame-work produces a straightforward benefit over either person framework by taking advantage of each characteristic [5]. Figures 1 and 2 show the usual layout of a standalone PV system, in which PV cells are coupled and encased into modules or arrays that convert solar energy into electricity with only battery-bank storage or with both battery and SC storage. [4].

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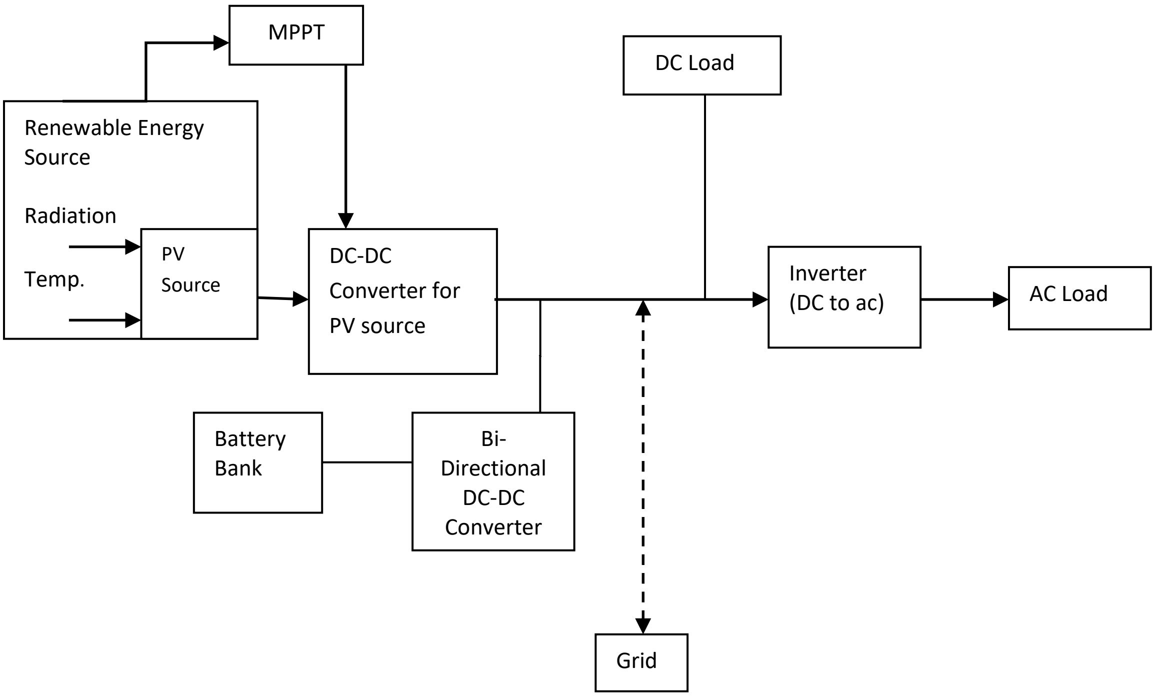

Fig. 1 Conventional PV-Battery Power System

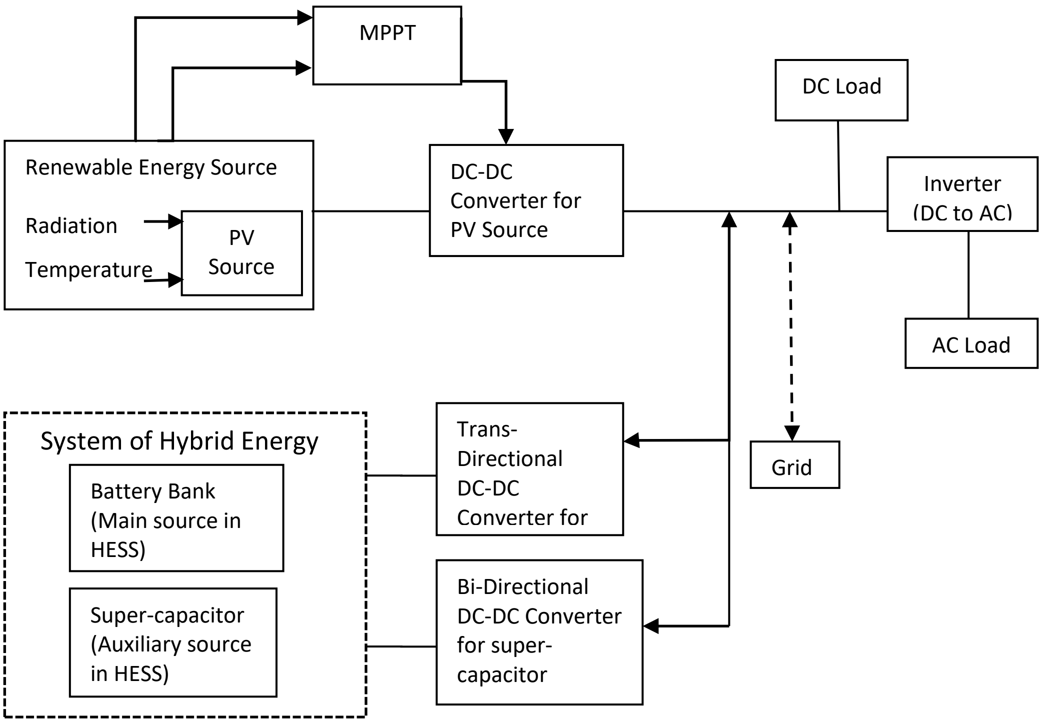

Fig. 2 PV-Hybrid Energy Storage System

Proposed system consists of subsystem, Power generation, Power conditioning, Hybrid energy storage system, Power conversion, Loads.

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Subsystem	Function
Power Generation system	• Generated by PV array. • Convert light energy into electrical energy. • Its output directly affected by radiation and temperature.
MPPT System	• Tracking maximum power from I (PV) and V (PV). • Controlling the switching actions of converter.
Power Conditioning system	• Conditioning by Multiple dc-dc converter. • Boosting the output of photovoltaic array. Controlling the flow of power. • Provide protection (from overvoltage& overcharging).
System of Hybrid Energy Sources	• Storing the conjunction of battery and super-capacitor. • Provide stable electricity.
Power Conversion system	• The Conversing process through inverter. • DC output of PV array into AC for AC appliances.
Loads and Grid	• DC loads. • AC loads. • Grid supply to load according to condition.

II-PROBLEM FORMULATION AND SOLUTION APPROACH:

Traditionally the energy storage device only consists of a battery. The formal problem in these storage systems is that it uses the PV power as a major source during the daylight, since the sunlight intensity effects the of output and cause fluctuations, also the batteries fails to respond accurately during sudden load variation. The Battery has a role to provide continuous load at a certain rate for different time variations and it also provides high energy density. Certain equipment require excessive current initially, e.g., compressor, certain motors, when the current reaches higher than the existing current demand [14]. In order to fulfil the increased current demand battery under certain breakdowns, i.e. inconsistent battery charging/discharging, reducing lifespan, intensify stress factor, and material degradation, mannerly causes' fire due to thermal runaway. Usually replaces in every 3- 5 years, usually requires a large number of batteries. Rising concern in this area is about how to advance battery lifespan and minimize its quantity. Presently the BESSs market is dominated by lithium-ion and lead-acid batteries. Table1 summaries difference between lead (Pb)-acid battery and lithium (Li)-ion battery.

PARAMETERS	LEAD ACID BATTERIES	LITHIUM-ION BATTERIES
Energy Density	Low	High
Temperature Range	-40 to 60 ^oC	-25 to 40^oC
Efficiency	Low	High
Cost	Low	High
Safety	Moderate	Low
Weight	Bulky	Light
Replacement Cycle	2-3 years	7-8 years
Safe Discharge	Down to 30-40% capacity	Down to 20% capacity
Charging Time	High(In hr)	Low(In hr)
Usable Energy	50%	80%
Self-discharging time	Weeks to few months	Hours to days

TABLE 1- Lead acid battery versus Li-ion battery.

Super-capacitor provides an ease while dealing in these situations. While hybridizing super-capacitor with high-energy batteries, we can discover a solution to satisfy the upraised situations [15, 16, 17, 18].
A super capacitor named electric double layer capacitors (EDLCs) is efficient-capacity capacitors. In EDL fabrication on electrode surface generally these generates a pair of electrons and holes which gives high capacitance and dielectric. Surface area and material of electrodes are the influencing factors of capacitance [19]. Super-capacitor neglects the issues involving chemical reaction since is store electricity in-state electric field. It provides high power density with quick burst of energy, due to lower internal resistance it provides a wide temperature range and higher load variations [15]. Super-capacitor also offers unlimited life cycles including higher charging & discharging efficiency with instantaneous response without any delay [5, 20, 21]. In order to overcome the increased DOD of battery, the super-capacitor decreases the damaging by reducing stress factors [5]. To ensure a greener ecosystem we can use super-

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capacitor to minimize the quantity of battery usage. While comparing with batteries it has no overcharging risk and maintenance free usage. Table2 shows differences between battery and super-capacitor. Super-capacitor helps to maintain power quality with stable power and uninterrupted power supply [22].

PARAMETERS	BATTERY	SUPERCAPACITOR
Power Density	Low	High
Charging/discharging efficiency	Low	High
Internal Resistance	High	Low
Charging time	Hours	Seconds/Minutes
Self discharging time	Weeks/Month	Hours/Days
Energy Density	High	Low
Cost	Medium	Low
Weight	Low	High
Lifetime	High	Low
Operating temperature	Wide	Limited
Power Delivered	Rapid over a short time period	Constant over long time period

TABLE 2-Battery versus Super-capacitor.

III-ASSORTMENT AND SIZE EVALUATION [7, 23].

The three primary types of super-capacitors are as follows. These are Electric Double Layer Capacitor, Pseudo Capacitor and Hybrid super-capacitor. These capacitors are specifically different from one another due to the materials used in electrode and mechanism of charge stored. EDLC basically use carbon elements like activated carbon, porous carbon and nano-tubes etc, PC use noble metal, layer-lattice intercalation host material metal oxide, p-doped polymers and HSC use coupling of EDLC and PC materials.

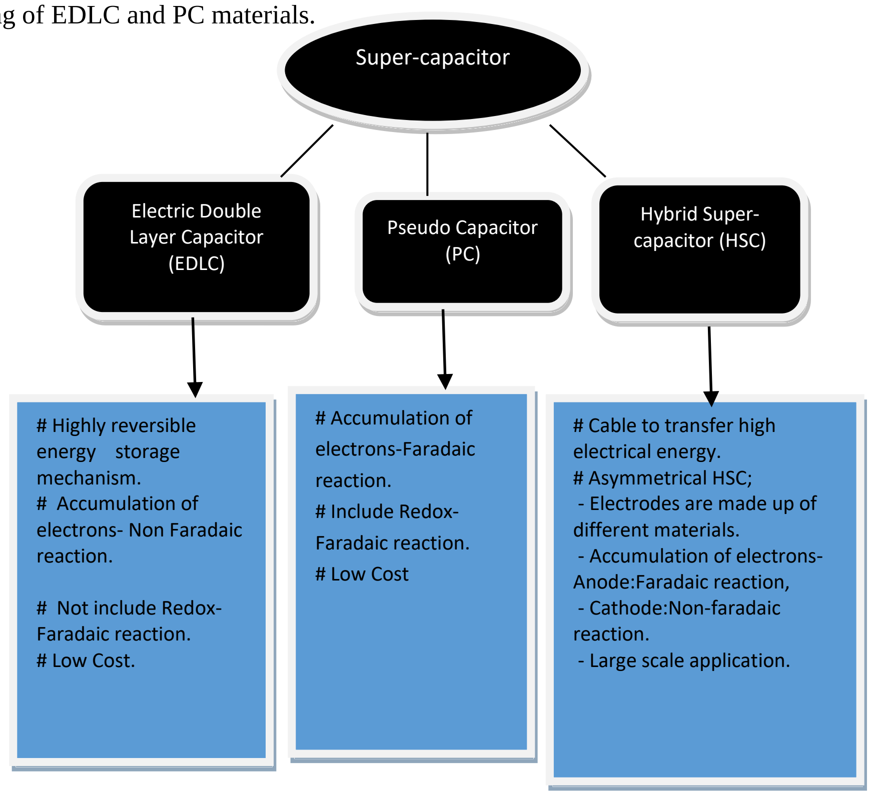

Fig. 3 Classification of Super-capacitor

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IV- SIZE CALCULATION [12]:

The capacity of the PV system, the quantity of backup required, and the radiation transients described in Table 3 all influence the size of the super-capacitor and battery. The cost of HESS is defined through the size and the performance needed from the stand alone PV system.

Battery Size Calculation	**Super-capacitor Size Calculation**
Power; $P = I \times V(B)$ (1) Current; $I = I(B) \times h$ (2) Battery capacity; Amp hours ; $Ah = I(B) \times h = I$ Replacing (I) value in (1), we get; $P = Ah \times V(B)$ Rearranging; $Ah = \frac{P}{V(B)}$	Charge; $q = V(SC) \times C(SC)$ (1) Current; $I(SC) = q / t$ (2) Putting (q) value in (2), we get; $I(SC) = \frac{V(SC) \times C(SC)}{t}$ (3) P is PV system power; $P = I(SC) \times V(SC)$ (4) Replacing (I(SC)) values in (4); $C(SC) = \{V(SC)\}^2 (t) \times (P)$

TABLE 3 – Size Calculation of Battery and Super-capacitor

P = Power.
q = Charge.
V (SC) = Voltage of super-capacitor.
I (SC) = Super-capacitor Current
I = Current (Amperes).
V (B) = Battery voltage (volts).
I (B) = Battery current (Amperes).
C (SC) = Capacitance.
h = Hours. t = time [12]

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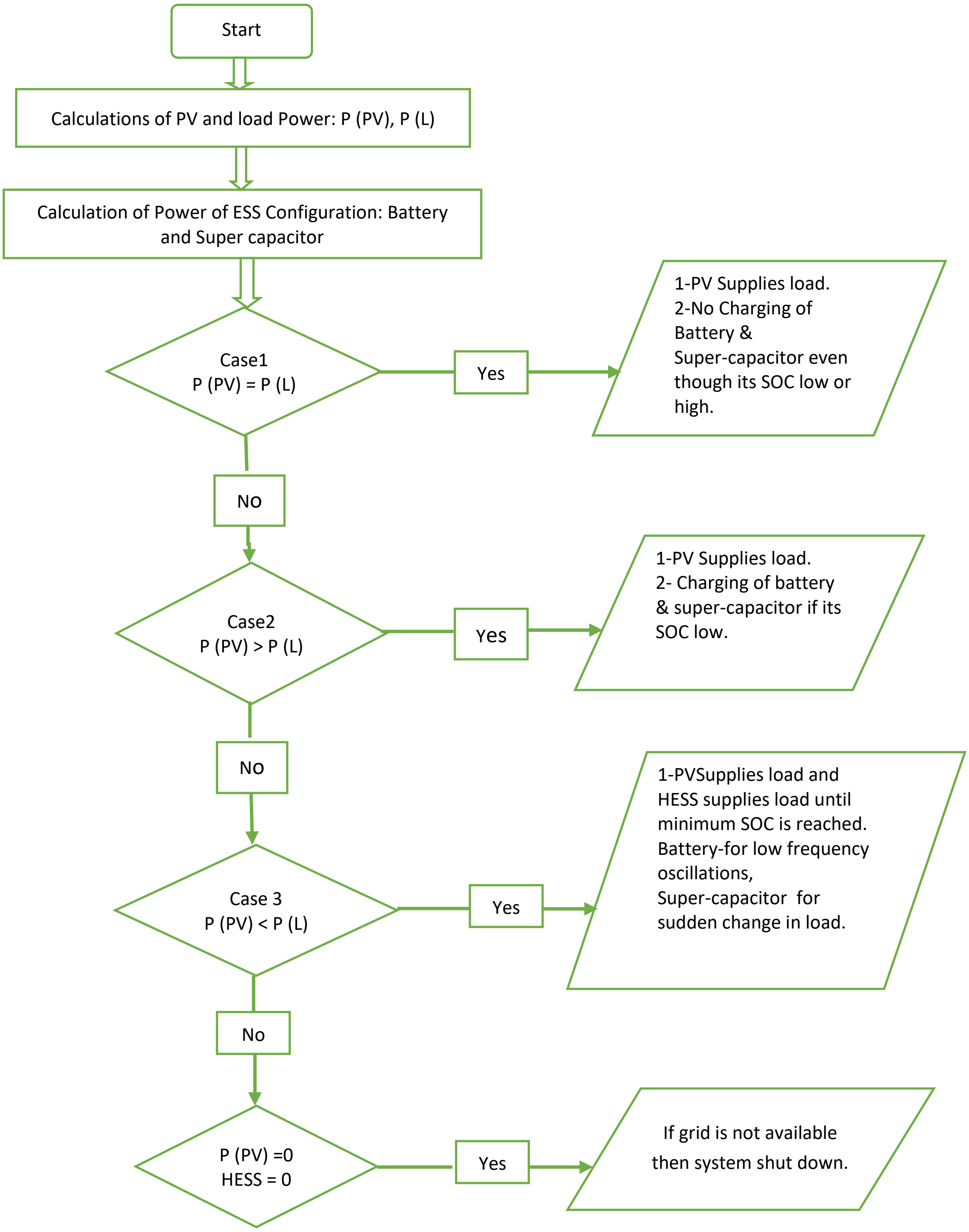
V- POWER ALLOCATION STRATEGIES: [2]



VI- Conclusion:

This review provides an overview of the System of hybrid energy storage. The super-capacitors have been classified including their size measurements and performance. There is a brief comparison of batteries and super-capacitor. In conclusive, super-capacitor overcomes the power upsurges and reduces high battery demand for energy, it has the advantage of high-power density and efficiency with which it can also the energy feedback from different loads With

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the use of many figures, a detailed comparison between a solar photovoltaic (PV) system and a hybrid energy storage system (HES) was explored. The condition and function of Energy storage system's performance according to load and power variations are also discussed this review. Discussions have been made elaborating the traditional problem of energy storage system, which of only consist of batteries and gave it a modern approach and solve it using the super-capacitors.

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