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DYNAMIC POWER MANAGEMENT SCHEME FOR BI-DIRECTIONAL DC-DC CONVERTERS USING HESS

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Abstract—
Hybrid Energy Storage Systems (HESS) technologies are used to supplement batteries in systems such as electric/hybrid automobiles and islanded DC microgrids. To maintain constant DC grid, balance the energy flow between source and load. Energy storage is used to correct any mismatches between supply and demand. The battery-SC combination is the best suitable for managing the imbalance power between source and load demand. The modelling of HESS, design of converter, stability study are presented. The simulation results for traditional and suggested technique for step change in PV and load demand are all examined in this article. The effectiveness of traditional and proposed control strategies was evaluated.

Keywords— microgrid, Bidirectional converter, Battery, HESS, Super capacitor.

I. Introduction

Typically, alternative energy sources are evaluated to offer a sufficient proportion of the power based on available rather than effect [1]. Solar power generation is the best renewable energy source (RES) is still a relatively new technology. Combining a battery with a SC can give an amazing competition that has protected a wide range of power and energy sources in RESs, such as wind, PV, and individual power producers, which rely significantly on Energy Storage Systems (ESSs) [2]. Conservation of energy, power density and lifespan are requirements for ESSs [3]. Batteries frequently experience deep cycles and imbalanced charging patterns due to changing PV output and non-linear, high-power loads. These methods have the potential to shorten battery life and increase maintenance costs [4]. For optimum performance, the technological characteristics of the battery and a SC, such as power, response time, energy, and longevity, are especially important.

The HESSs can be inactive or active, depending on the power converter technology used in the structures [5]. In the active method, one or more DC/DC converters join the storage device and the dc-link [6]. Both an energy management plan and a power regulation element are necessary for a HESS. When using DC/DC converters in HESS, multi-input converters (MICs) should be used in order to fix the ESS settings in a sensible, useful, and practical manner [7]. These converters perform better when the circuit design is straightforward, the power flow to the storage component is controlled in both ways, there is high consistency, and the cost and manufacturing size are modest. For HESS to increase consumption and capabilities, a controller approach is needed [8]. This technique uses the battery to regulate the SC's power supply.

Section II describes the HESS configuration. Section III goes over the whole investigation of the suggested approach.

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Section IV evaluates the simulation results for the proposed structure. Section V concludes the paper.

II. HESS Design Configuration

The two-input bidirectional converter design for the HESS-aided RES is depicted in Fig. 1 of this part. Fig. 1 depicts a battery-supercapacitor bank design for off-grid RES with Solar and HESS. One of the most important RES for a DC microgrid is Solar producing. The DC microgrid is interfaced with and the PV panel's maximum power is extracted using a boost converter. HESS is configured using a battery-SC bank combination, and in the event that PV generation and load demand are out of sync, HESS reacts right away to quickly regulate DC grid voltage.

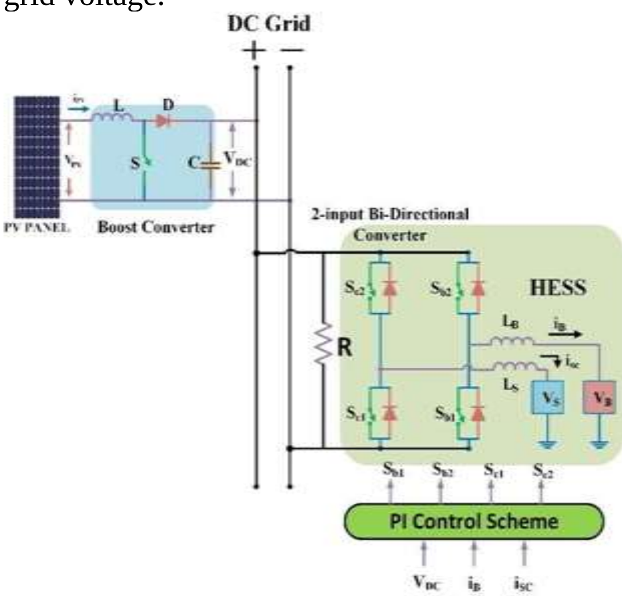

Fig.1. DC grid configuration fueled by PV and augmented by HESS

III. HESS Control Scheme Proposed

The control block diagrams for the suggested and conventional control techniques are shown in Figs. 2 and 3, respectively. Both systems compare the grid's reference voltage (VDC,ref) and actual voltage (VDC), and the difference between the two voltages is then applied to the proportional integral (PI) scheduler. The processor receives the necessary total reference current (itot) from the HESS, thereby minimizing voltage variations. As shown in Fig. 3, the typical method involves dividing the overall current into low and high frequency components, which are then applied to the battery and the SC, which serve as the respective reference currents. In the proposed control method, which is described in more detail below, the battery current has an error component, and the SC reference current has a high frequency component.

iBAT

which is depicted in Figure 3, in order to produce the PWM pulses that correspond to SC switches like Sc1, Sc2.

VB

$iSC,ref = itran + iBAT,err \cdot VSC$ (7)

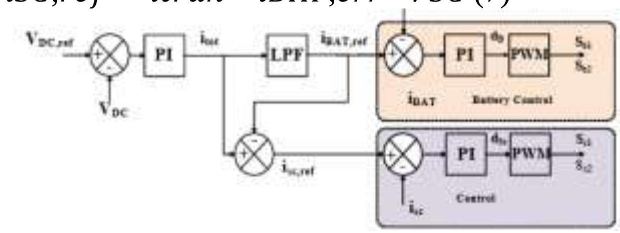

Fig 2: block diagram-1 (conventional)

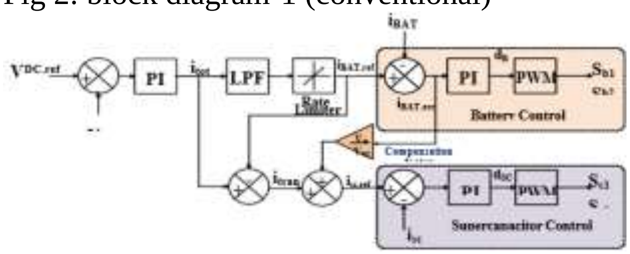

Fig 3 block diagram-2 (Proposed)

Where $iBAT,rr$: error current of battery is the Difference between battery standards and real is provided by

$iBAT,rr = iBAT,ref - iBAT$ (8)

IV. Simulation Analysis

This section illustrates the outcomes of four test conditions using typical and proposed control methods. Table 1 displays the nominal settings for the simulation research. MATLAB is used to implement the complete model. Battery-SC based multiple input converter used in these model.The boost converter is linked to the unidirectional PV array. The next sections go through the four operating scenarios for a significant increase in PV and load.

Table 1 Rated parameters for simulation Analysis

S. No	Speciication	Value
1	Peak Power (P_{mppt})	96 W
2	DC microgrid voltage (V_{DC})	48 V
3	Maximum Peak Power Current (I_{mppt})	4 A
4	Battery Voltage (V_B)	24 V
5	Maximum Peak Power Voltage (V_{mppt})	24 V
6	SC Voltage (V_{SC})	32 V
7	Resistance (R)	24 Ω
8	Battery inductance (L_B)	0.4 mH
9	SC inductance (L_S)	0.355mH

Itot is used to generate the component (ilfc) with low frequency in the manner shown below,

$ilfc = flfc\ (itot)$ (1)

Where,

flfc

(.)

: low pass filter (LPF), frl : battery

charge/discharge current rate limit as shown in Figure 3.

The rate limiter's output signal for battery reference current is created by ,

$iBAT,ef = frl(ilfc\ )$ (2)

Difference between reference and actual battery current (BAT,err) is provided to the PI controller. The controller creates the control signal (dB) to reduce the currents' differences. The switches (Sb1, Sb2) in the battery converter are connected to the pulse width modulator (PWM) generator, which generates the pulses with the duty ratio seen in Fig 4. Because of the battery system's electrical inertia and slow dynamics, the DC-DC converter might not follow the battery reference current ($iBAT,ref$) immediately. Consequently, the battery system's visible uncompensated electricity is provided by

$itra\ = itot - iBAT,ref$

(4)

$PB\_Uncomp = (iBAT,ef - iBAT\ ) \cdot VB$ (5)

A. Step PV change simulation results:

Figures 4 and 5 demonstrate simulation waveforms for PV change for traditional and proposed. At t=0.3sec in both management methods, the PV output varies from 96W to 192W as a result of atmospheric changes. At that point, the PV current jumps from 3A to 6A. The necessary electricity from the load is 96W. The DC grid raises more than 48V as Solar production rises above demand power.

Where PB_Uncomp

: is battery uncompensated power

The SC takes the surplus power of 96W for a brief period of time and battery provides at steady state to keep the DC

and itran is the transient component of current. PB_Uncomp is

employed in the suggested control approach to improve SC performance. As a result, the formula for the supercapacitor reference current (iSC,ef) is as follows,

grid voltage to 48V. According to the modelling findings, the suggested control technique settles in 100 ms and the traditional technique in 35 ms.

$iSC,ref\ = itran + (iBAT,ref - iBAT)\ VB\ VSC$

(6)

After comparing the references and real supercapacitor currents, the fault is communicated to the controller. The mistake is decreased when the PI processor generates the control signal dSC. This control signal is sent to the PWM

B. Step -fall simulation findings for PV generation

Figures 4 and 5, respectively, display the computer findings of the modelling for step decline in Solar production for the two variables. Due to meteorological variables, the

PV panel's power production fluctuates between 96W and 192W at t=0.6sec. The decrease in PV production causes the PV current to decrease from 6A to 3A. The DC grid's voltage drops as a result of the abrupt drop in PV production. For both systems, the settling period is 120 ms and 30 ms.

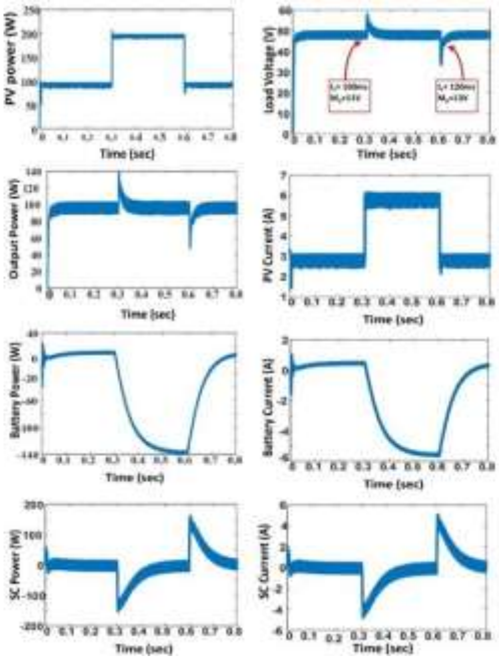

Fig.4 Step PV change for conventional control scheme

C. Load consumption is gradually increasing.

Figures 6 and 7 display the outcomes of simulations for two control systems for a step rise in load demand. The load power rise from 96W to 192W at 0.3sec. The PV current constant to 3A. At 0.3sec, load power is more than PV generation. There is supply load imbalance at that time. HESS reacts instantly, SC meets the short-term portion of the power requirement, and the battery meets the long-term portion of the power requirement. The proposed control system adjusts the DC grid voltage in 40 ms compared to the conventional control method's 100 ms.

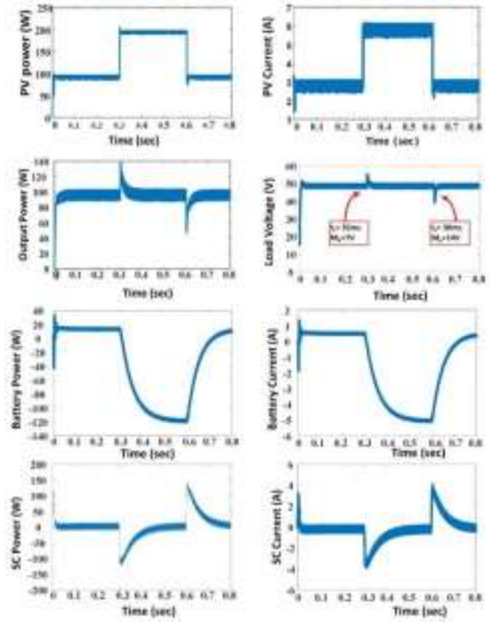

Fig.5 Step PV change for proposed control scheme

D. Simulation results for step fall in load demand

Figures 6 and 7 display the modelling findings for a step-down in capacity demand for two management methods. At 0.3sec, load power requirement fall from 192W to 96W.

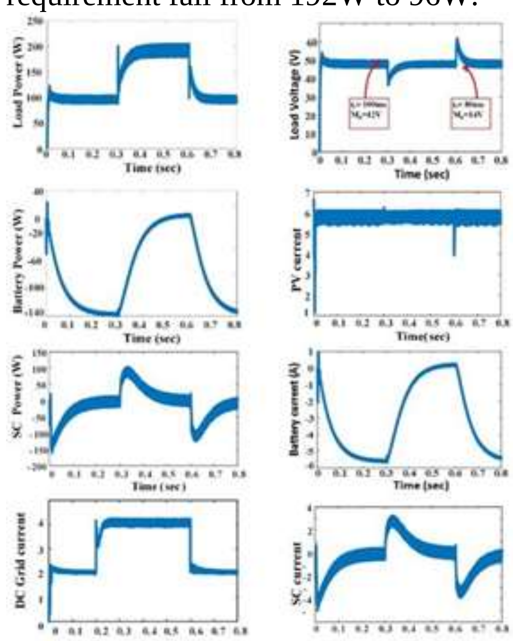

Fig.6 Step load change for Conventional control scheme

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The DC grid voltage is impacted by a sudden change in discharge power. HESS reacts quickly to these fluctuations in order to manage the extra electricity in the DC microgrid. In both management methods, the SC controls the transient power component while the battery controls the typical or steady state power component. The time it takes to reestablish voltage using the traditional and advised management methods is 80 ms and 30 ms, respectively. The findings show that the suggested control approach is quicker and has less peak overshoot DC grid voltage than the traditional control method.

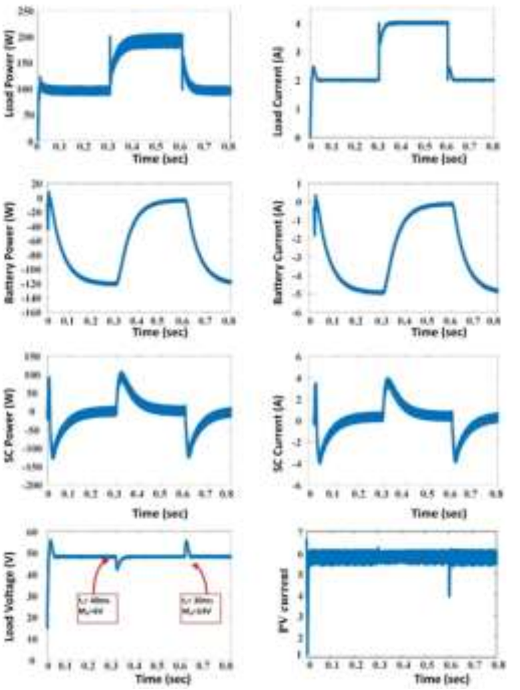

Fig.7 Step load change for proposed control scheme

E. Performance Comparison of Conventional and Proposed

Figure 8 compares the performance of the traditional and proposed strategies. According to the graphical depiction, the proposed approach is approximately three times faster than the standard method. In all four cases, the proposed control method reduces the maximum peak overshoot. The recommended control mechanism supports the HESS until it reaches steady state battery functioning. In terms of reliability and control proposed control technique having more advantages.

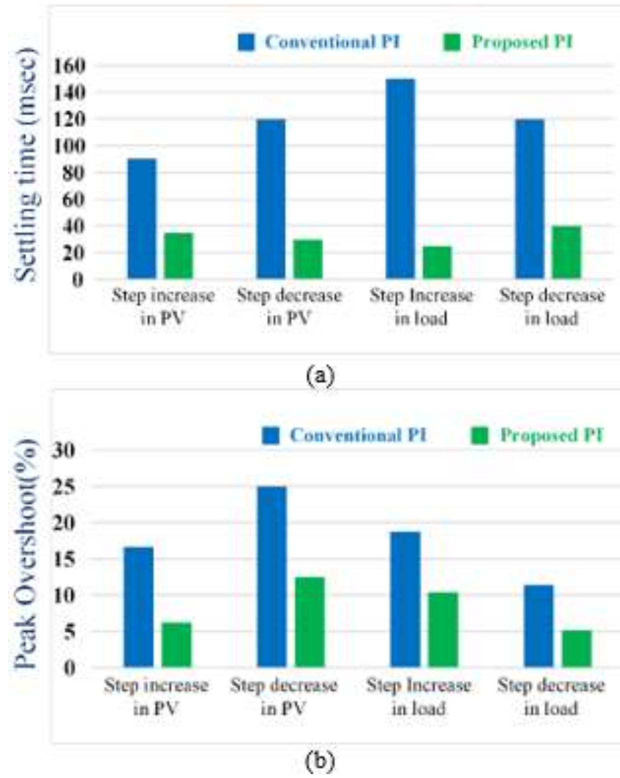

Fig. 8 settling time and peak overshoot of proposed and conventional control

V. Conclusion

Multiple input bidirectional converter with advanced controller using battery and supercapacitor storage system is built in this study. The results of the simulation are reported, together with the full HESS modelling, controller design, stability analysis, and bi-directional converter design. Comparisons of the conventional and proposed control schemes' performance have been shown. The traditional control strategy is predicated on the notion that although the SC can handle brief power variations, the battery can handle steady-state fluctuations. A unique management method that is speedier than the existing control scheme in regulating DC grid voltage is created to allay the concerns raised above. By using the battery error current, the proposed control technique overcomes the slow dynamics of the battery system. The key advantages of the suggested control strategy are as follows: The suggested control strategy takes use of uncompensated power from the battery grid to I increase overall system capacity. Less battery stress during fluctuations in PV generation and load demand.

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