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ENERGY MANAGEMENT SYSTEM IN BIDIRECTIONAL DC-DC CONVERTER FOR MICROGRID

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Abstract:

In microgrids and energy storage systems that use synchronised power delivery and operational stability, DC-DC converters are crucial components. This study proposes a closed-loop proportional-integral (PI) based energy management control technique to assess and solve unstable DC link voltage problems. In grid-connected mode, battery units and a hybrid energy storage system (HESS), such as a super-capacitor (SC), are charged by separate hybrid energy resources, such as solar and wind. The primary goal of this effort is to supply the grid with energy storage units (supercapacitor and battery) in the event that solar or wind energy supplies are unavailable. To meet the stability requirement, wind and solar power generation is first controlled by the energy management control. In order to increase system flexibility and compatibility with various PV cell and wind energy sources, the MPPT technique has been taken into consideration. The maximum power was effectively tracked by the suggested system, and the incremental conductance (IC) technique based on galactic swarm optimisation (GSO) is used to assess the data. GSO should be used in MPPT to obtain a high convergence rate and less steady-state oscillation. The MATLAB/Simulink platform is used to implement the entire project, and the suggested algorithm's performance is compared to that of the current ones.

Keywords — **Bidirectional DC-DC Converter, Battery, Supercapacitor, Energy management Control Algorithm, Small scale Micro Grid, and Hybrid energy resource.**

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I. INTRODUCTION

In order to serve a local loads network, the microgrid is described as a network of power conversion systems, communication systems, energy storage units, and local electric power sources that operate independently as a separate scheme (islanded mode) [1]. It is possible for a microgrid to operate in both grid-connected and islanded modes [2]. There could be a power outage, which would cause overloading in the islanded mode. By redistributing power between the grid and microgrid in grid-connected mode, the imbalance between load and power generation is balanced.

The microgrid system in this case needed a few DC-DC converters in order to maintain stability and improve system performance [3]. Various energy management control methods are offered for various energy-storage systems (ESSs), such as two ESSs and one energy resource, or one ESS and two energy resources [4]. Additionally, in order to enhance system performance, this article suggested an energy management control strategy [5]. a HESS with a battery and SC in it. In order to attach the SC/battery unit to the DC connection, a parallel dc-linked multi-input converter operation is used to select the converter [6].

In this approach, the DC-DC converters' insulated-gate bipolar transistors (IGBTs) are triggered by the PI controller. The PI controller sends a trigger signal to a converter by taking the output voltage value and comparing it with the necessary system output voltage [7]. Currently, the microgrid uses the majority of solar and wind power. In the event that frequency stability and AC loss become issues for the microgrid to function properly, reactive power regulation has the potential to connect to an alternate source [8]. This research proposes a bidirectional DC-DC converter based on GSO for microgrid energy management.

- Here, solar and wind are considered as inputs to provide continuous power to the microgrid.
- The HESS (SC and battery) units are charged from solar and wind. The MPPT technique has been considered here to make system flexibility and compatibility with different PV cell and wind energy.
- Using GSO in MPPT should reduce the steady-state oscillation and get high convergence rate.
- The results are improved by GSO based IC algorithm, which has successfully tracked the maximum power which is carried out in simulation.

The rest of the study is structured as follows; some similar studies are analysed in the next section. The PV, wind, and bidirectional DC-DC converter topologies, as well as the GSO-based incremental conductance algorithm, were all described in the third part. The research findings are presented in the final section, which also serves as an evaluation of the planned work through the Simulink implementation in the fourth portion.

II. PROPOSED METHOD

It is suggested to model and analyse a bidirectional DC-DC converter for a microgrid within the energy management system. Different hybrid energy sources, such as solar and wind, are used to charge the battery units and hybrid energy storage system (ESS). ESS and power requirements are stabilised by managing energy control, which is first utilised to control the power generated by solar and wind PV.

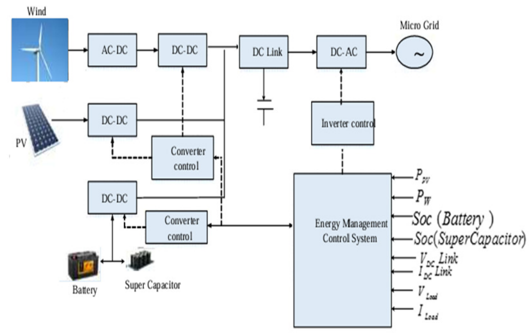

Fig. 1. Microgrid Structure

A. State of charge of energy storage system

Over The HESS structure is depicted in Figure 1. The state of charge (SOC), which is expressed in equation [1], is one of the important metrics to characterise the battery state.

$$SOC = 100[1+(\int Ibat\ dt)/Q]$$

Where, the battery charging current is represented by I ̅_bat and battery capacity is represented by Q. Depends on SOC, demand and available power of the battery will be charge discharge [1]. Depends upon the SOC limits, the energy limitations of the battery are resolute.

$$SOc\_min \leqslant SOC \leqslant SOc\_max$$

For the safety of battery, Where, SOc_min and SOc_maxare the minimum and the maximum acceptable positions respectively.

B. Wind energy conversion system topologies

The schematic of the simulation system is shown in Figure 2. A PMSG, rectifier, MPPT converter, grid, dump load, inverter, and incremental conductance algorithm are all parts of a wind energy conversion scheme. The MPPT boost converter creates the DC bus common voltage by tracking the maximum power points. The DC bus sets the particular value, and when the HESS's SOC exceeds 80%, the dumped load is enabled. Rather than attaching it directly to the DC bus, a controller and PWM generation units are used to achieve high precision control.

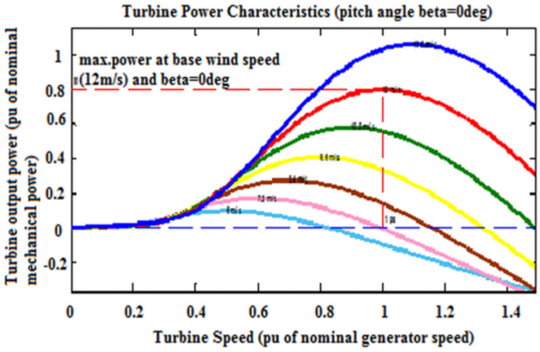

Fig.2. Characteristics of Speed of Wind Turbine

Figure 2 displays several wind turbine parameters, including speed, and shows a distinct pitch wind turbine model. The filter transfer function is,

$$|H(j\omega)| = \frac{1}{\sqrt{1+(w/w_C)^2}}$$

Here, the H (jw) represents the angular frequency transfer function, the angular frequency can be expressed by,

$$w = 2\pi f_c/f_s$$

$$w_c = 2f_s.tan(w\ /\ 2)$$

Where, fs represents the wind power sampling frequency and fc represents the cut-off frequency. For mathematical calculation, the variance equivalence can be increased that is needed for the time domain transfer function.

$$y(n) + \sum_{k=1}^{N} a_k\, y(n-k) = \sum_{k=0}^{N} b_k\, y(n-k)$$

For the system of battery-SOC energy storing, the reference power is represented by equation 8.

$$P_{ref=}P_{wf} - P_{perfect}$$

The super capacitor, which corresponds to the low-frequency band and a substantial portion of Pref, manages quick power variations while the battery maintains ideal power.

$$P_{ref} = P_{ref\_Battery} + P_{ref\_Supercapacitor}$$

C. GSO Based incremental conductance algorithm

The GSO offers the two levels. Stars make up the first level, and galaxies make up the second. Since each level was chosen using the first level's best metrics, every level—aside from the second level initial population is the autonomous search component. In GSO calculation, the multi-layered struck is expressed as,

$$s_j^i \in s_i\text{:j=1, 2 ,..N}$$

$$b_i \in s_i\text{: } b_i = \text{best}\ (s_i)$$

$$\text{G} = \bigcup_{i=1}^{M} b_i$$

Initial M subpopulation consists of N solutions which is randomly generated in the original GSO algorithm. Where Si represents the ith subpopulation, Sj i represents the jth solution of the ith subpopulation. The best solution of a subpopulation S_i is represented by bi (best (Si)).

$$G_i^t = d_i^t = [d_1, d_2, \dots d_{NP}]$$

Where, the number of iteration is represented as t, and the number of a particle is represented as NP.

III. PROPOSED CONVERTER SIMULATION RESULTS

The program Mat-lab/Simulink is used to implement the entire work. PV power, wind power, battery power, super capacitor power, DC current, DC voltage, active and reactive load power are all measured here, and our results are also compared to those of various other methods now in use. The methods currently in use are PSO, GA, and ACO.

D. PV power

Figure PV power performance using some of the current methods is displayed in Figure 3. By the different time, PV electricity will be consumed. PV power is defined as the sum of PV voltage and PV current. In this case, our GSO method outperformed the other available methods in terms of stable PV power. The PV power is constant for ranges greater than 0.1.

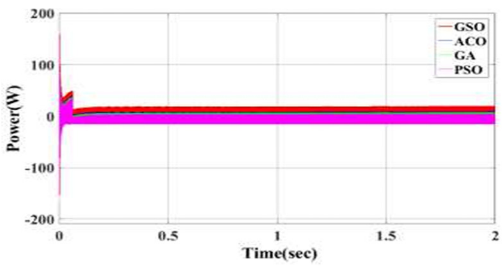

Fig. 3. PV Power Performance

This type of converter does not need any transformer clamping diodes or flying capacitors; each bridge converter generates three level of voltages (E; O, and YE). For a three-phase configuration, the cascaded converters can be connected in star or Delta. It has the following Advantages: It uses fewer components that the other types. It has a simple control, since the converters present the same structure. However, the main drawbacks is that it needs separate dc source for the conversion of the active power, which limits its use. Its configuration can be represented as.

E. Wind power

A PV Power Performance in Figure 3. Figure 4 illustrates the wind power performance using a few of the current techniques. The wind power will increase to 0.2 and then transition to a sinusoidal waveform.

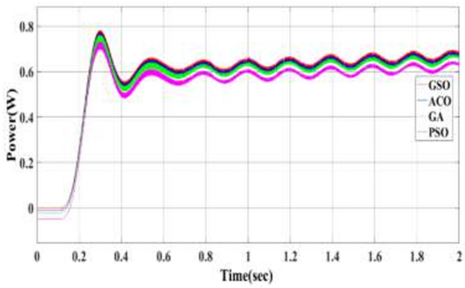

Fig. 4. Wind Power Performance

F. Battery power

Figure 5 displays the battery power graph's performance, both current and proposed. The battery's capacity serves as a representation of the conditions in which the maximum quantity of energy may be taken from it. The battery is charged when it is within range of 0.1 and significantly depleted when it is outside of range of 0.2.

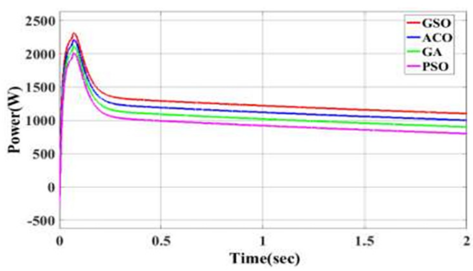

Fig. 5. Performance of Battery Power

Figure 6 displays the performance of the SC power graph. The sum of the SC voltage and the super capacitor current is the SC power. The SC power increases somewhat between 0 and 0.1 and decreases slightly between 0.2 and higher, at which point it gradually discharges before reaching stable power.

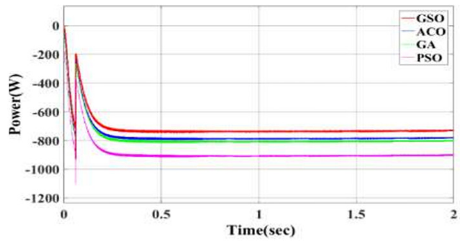

Fig. 6. Super Capacitor Power

TABLE I
COMPARISON TABLE

Algorithm	PV power	Wind power	Battery	Super Power (W)
PSO	15	0.62	900	-900
GA	22	0.64	950	-800
ACO	25	0.68	1000	-850
GSO	30	0.7	1200	-700

Table 1 compares PV power, wind power, battery power, and SC power with different values of PSO, GA, ACO, and GSO. Our GSO method achieved superior power as compared to previous algorithms, as the table illustrates.

CONCLUSION

This research proposes the use of a GSO based bidirectional DC-DC converter in microgrid energy management. In order to increase the reliability of the DC voltage connection, this article uses closed-loop PI technology in the microgrid, which is dependent on a bidirectional DC-DC converter-based HESS. Here, solar and wind power are regarded as inputs to give the microgrid constant electricity. Solar and wind energy are used to charge the HESS (SC and battery) devices. Here, the MPPT technique has been taken into consideration to increase system flexibility and compatibility with various wind and PV cell energies. The MATLAB/Simulink platform is used to implement the entire project. Our approach is contrasted with a few current algorithms, such as

ACO, GA, and PSO. The stability value is attained for power output from photovoltaic cells, wind turbines, batteries, and DC link current and voltage. In this regard, our suggested GSO technique outperformed other already available algorithms since it minimises power uncertainty from RESS in order to obtain the greatest power.

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