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# Optimal Economic Dispatch of Hybrid Distributed Generators with Battery Energy Storage System using a Modified Meta Heuristic Algorithm

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**Abstract.** A battery energy storage system (BESS) is commonly embedded when designing a power system. It provides stability and improves the reliability and overall capacity of the system. Unmonitored depth of discharge (DOD) results in multiple problems in the microgrid, such as increasing battery's operational cost and lower life cycle count in which economic and reliability issues arise. This study proposed a modified meta-heuristic algorithm to solve the economic dispatch problem of a hybrid distributed IEEE 9-bus system by integrating a BESS. The hybrid energy system consists of diesel generators (DG) and photovoltaic (PV) farms with the uncertainty of solar irradiance and temperature variability. This study focuses on minimizing the operational cost of distributed generation by monitoring the battery's DOD. The researchers considered a DOD configuration of 0.660 with an incremental of 2% until it reaches the maximum of 1.000. The researchers implemented the hybrid system and the proposed algorithm in MATLAB software. The result shows that the proposed algorithm reduced the system's operational cost to a maximum of 73.62% and increased the maximum life cycle expectancy of the battery by 11.67% by having a DOD configuration of 0.660.

**Keywords:** Distributed Generation, Hybrid Energy Source, Battery Energy Storage System (BESS), Depth of Discharge (DOD), Economic Load Dispatch, Microgrid Optimization

## 1. Introduction

Global reports state a roughly 5% increase in electricity demand last 2022. The traditional power plants alone may not cope with the continuously increasing load shortly, especially when power losses are imperishable. Batteries are commonly used to provide power when the generators cannot fulfil the demand to sustain the power system's reliability.

Economic load dispatching is a method to determine the power dissipated by each generating unit considering the minimum cost [1]. However, using traditional sources that release high carbon footprints threatens the environment [2]. With that, optimization of the distributed generation that concentrates on using hybrid renewable sources has a growing recognition in the grid.

Recent methods, e.g., Mixed-Integer Quadratic Programming (MIQP), Particle Swarm Optimization (PSO), and Cuckoo Search Algorithm, solve the economic dispatch problem of the system [3-5]. However, only two of the stated studies considered a hybrid source, and only one considered the battery's optimal DOD but did not monitor it. Unmonitored DOD increases the battery's internal resistance, reducing its expected life cycle count and, in effect, much higher overall cost. As such, problems in the economic and reliability aspect arise.

The main objective of this study is to achieve the optimal economic dispatch of a hybrid distributed power system that includes DG and PV farms with the integration of BESS with uncertainties using a proposed modified meta heuristic algorithm. This study aims: (1) to model the IEEE 9-bus system incorporating hybrid distributed generators (2) to develop the modified meta-heuristic algorithm for the economic load dispatch problem (3) to monitor the DOD of the battery (4) to integrate cost-health analysis table for the hybrid power system (5) to evaluate the proposed modified meta-heuristic algorithm using t-test statistical treatment.

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# 2. Methodology

Fig. 1 illustrates the process flow of the study to ensure that the methods aligned with the objectives of this research. The study started by gathering the parameters of the hybrid sources to model the 9-bus system and calculate its output power in MATLAB. The modified meta-heuristic algorithm was implemented to monitor the battery's DOD and then evaluated using a statistical treatment.

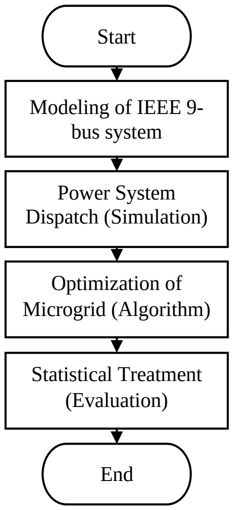


Fig. 1: Process flowchart.

## 2.1. System implementation

Table 1 shows the DG parameters, including loss coefficients α, β, and ϒ and output power capacity for constraints [5]. The parameters were used in modelling and calculating the output power of DG in MATLAB as shown in Fig. 2.

Table 1: Parameters for Diesel Generators (DG) [5].

| **Diesel Generators** | **α** | **β** | **ϒ** | $\mathbf{P_{min}}$ | $\mathbf{P_{max}}$ |
|---|---|---|---|---|---|
| DG 1 | 0.0001 | 0.0417 | 0.2 | 0 MW | 30 MW |
| DG 2 | 0.0001 | 0.0438 | 0.3 | 0 MW | 20 MW |
| DG 3 | 0.0001 | 0.0469 | 0.3 | 0 MW | 5 MW |

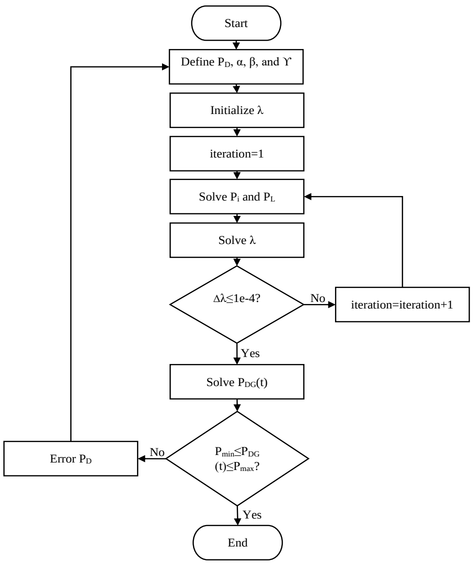


Fig. 2: DG output power simulation process [5-6].

Table 2: Parameters for Photovoltaic (PV) Farms [7].

| Parameter | Value |
|---|---|
| Cost Coefficient ($K_{PV}$) | 0.006$/kWh |
| $P_{max}$ | 30 MW |

| | |
|---|---|
| $P_{min}$ | 0 |
| Temperature | 25.1-32.5 °C |
| Solar Irradiance | 0-0.67 $kWm^{-2}$ |

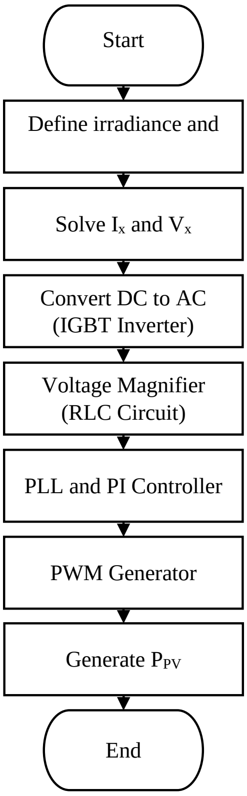


Fig. 3: PV farms output power simulation process [8-9].

Table 2 shows the parameters for PV farms, including the cost coefficient $K_{PV}$ power output capacity for constraints, temperature, and solar irradiance [7]. The parameters were used to calculate the output power of the PV farms in MATLAB as shown in Fig. 3 [8-9].

Table 3 shows the parameters of the BESS including the capital cost, rated capacity, and storable energy [5]. They were used to develop the proposed algorithm as shown in Fig. 4.

Table 3: Parameters for Battery Energy Storage System (BESS) [5].

| **Parameter** | **Value** |
|---|---|
| Capital Cost ($C_{BESS}$) | 250 $/kWh |
| Capacity | 50 kWh |
| $ES_{max}$ | 0.95*Capacity |
| $ES_{min}$ | 0.15*Capacity |

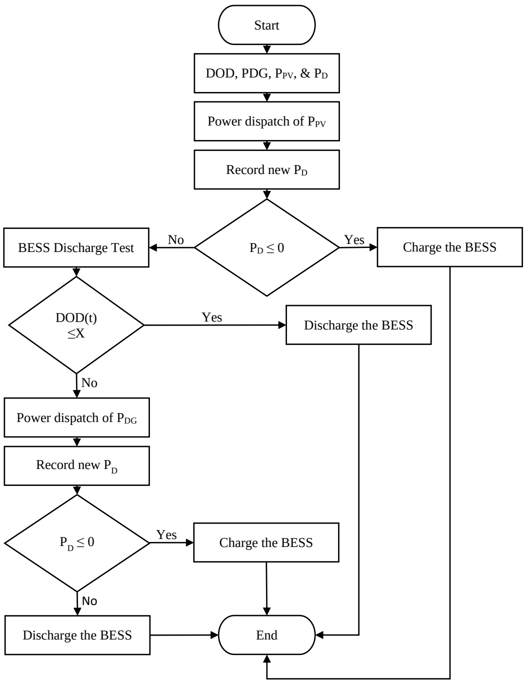


Fig. 4: Proposed modified meta heuristic algorithm.

## 2.2. Results and discussion

Fig. 5 illustrates the average output power of the 9-bus system simulated in MATLAB, supplying the daily load demand for one year. DG manages to fit the load with 88.91% accuracy. The PV farms provide high power during peak, 8:00 to 13:00, which allows the BESS to charge rapidly.

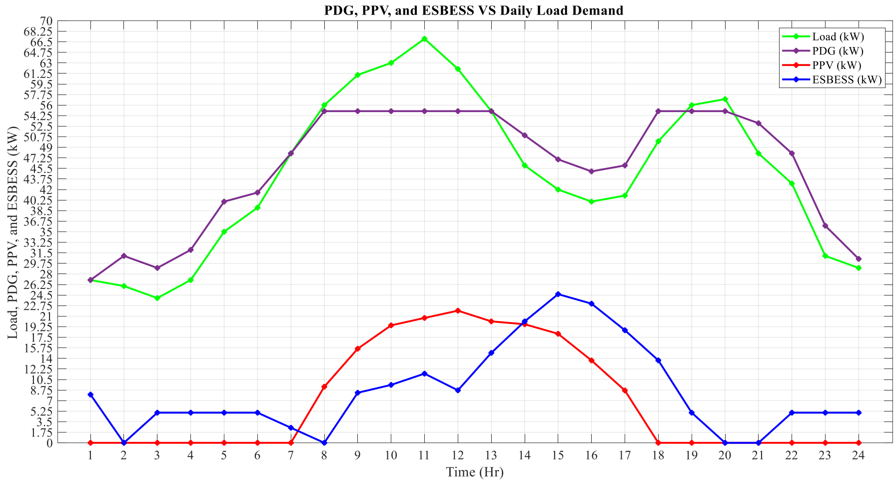


Fig. 5: Hybrid distributed IEEE 9-bus system simulation results in MATLAB

Fig. 6 illustrates the different DOD monitoring of the battery using the proposed modified meta-heuristic algorithm. It shows that the program accurately limits the DOD of the battery depending on the configured value from 0.660 with a 2% decrement.

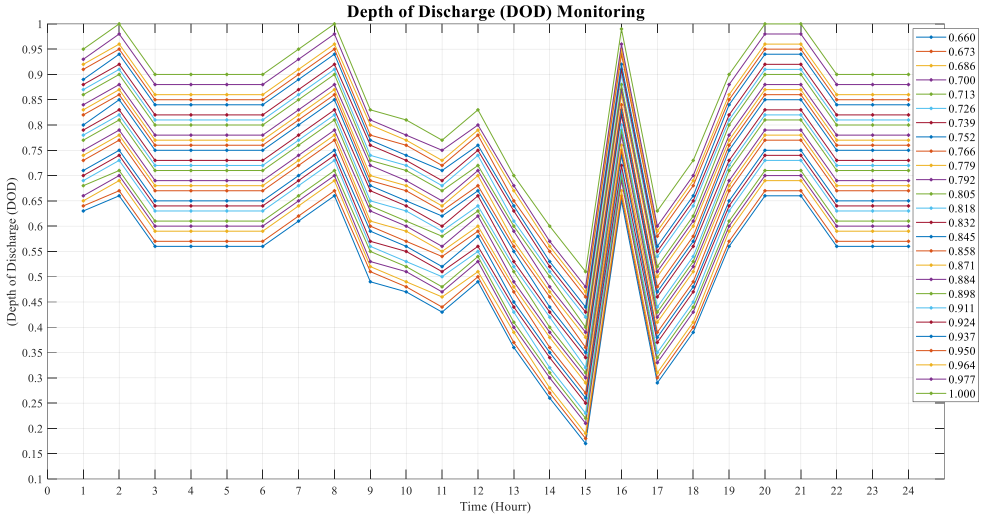


Fig. 6: DOD monitoring results

Fig. 7 illustrates the cost-health analysis having different DOD configurations for the battery. The graph shows that the DOD is directly proportional to its operational cost but inversely proportional to its life cycle count expectancy with a slope of 0.0632 and -794.37, respectively. Consequently, the cost of the hybrid sources was not affected by configuring the DOD of the battery.

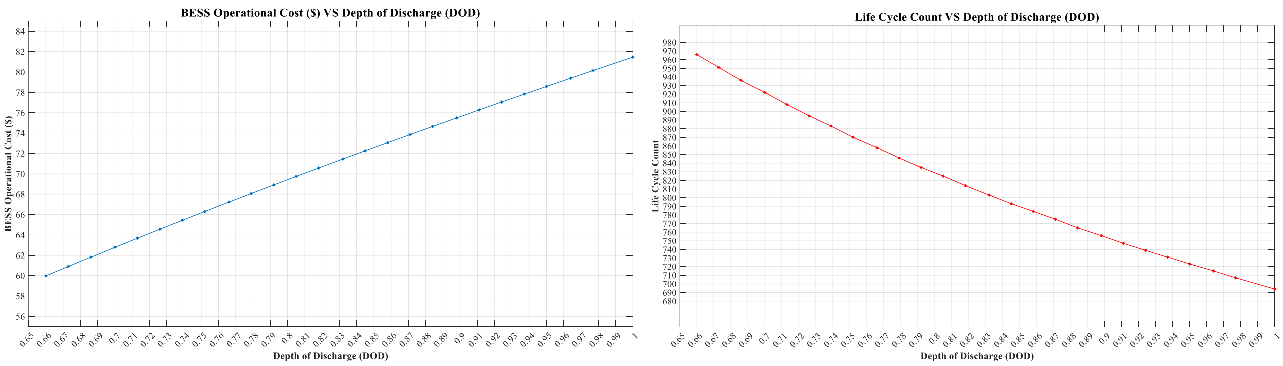


Fig. 7: Cost-Health analysis of different DOD configurations

Fig. 8 illustrates the t-test statistical treatment analysis to evaluate the proposed algorithm. It shows that there is a significant difference in terms of lowering the battery's cost at a DOD configuration of 0.660 to 0.911 compared to 1.000 having a significance level of less than 0.05.

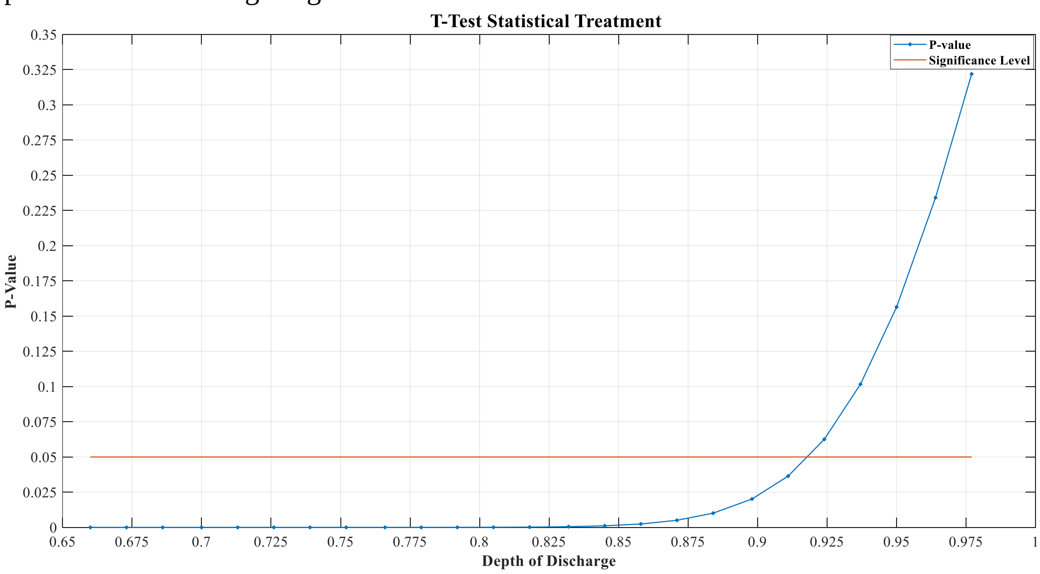


Fig. 8: T-Test statistical treatment

## 3. Conclusions

The results presented satisfied the main objective of this study which is to achieve the optimal economic dispatch of the 9-bus system with BESS by monitoring the DOD using the proposed algorithm. Specifically, the sub-objectives of the study were achieved:

The 9-bus system was modelled in the MATLAB Simulink. DG fits the load demand curve by having an accuracy of 88.91%. The PV farms provide power during peak hours, which offers more power to charge the BESS. The proposed algorithm shows accurate monitoring results from 0.660 to 1.000. The operational cost of the battery was reduced to 73.62% and increased its life cycle to 11.67% without affecting the cost of the 9-bus system. The optimal dispatch of the system was obtained at a DOD of 0.660 to 0.911.

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