Effective dispatch strategies assortment according to the effect of the operation for an islanded hybrid microgrid

Sk.A. Shezan [a,b], Md. Fatin Ishraque [c], S.M. Muyeen [d,*], S.M. Arifuzzaman [e], Liton Chandra Paul [c], Sajal K. Das [f], Subrata K. Sarker [f]

[a] *Dept. of Electrical Engineering, Engineering Institute of Technology, Melbourne, Australia*
[b] *School of Engineering, RMIT University, Melbourne, Australia*
[c] *Dept. of EECE, Pabna University of Science and Technology, Pabna, Bangladesh*
[d] *Department of Electrical Engineering, Qatar University, Doha 2713, Qatar*
[e] *Dept. of Business Administration, Canadian University of Bangladesh, Dhaka, Bangladesh*
[f] *Dept. of Mechatronics Engineering, Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh*

ABSTRACT

The optimized design of a freestanding hybrid microgrid for various distinct dispatch controls is assessed in this paper, which considers the optimal sizes of individual components, system response, and reliability analysis. The effective design and management of stand-alone islanded hybrid smartgrids are getting increasingly importance and influences as the prevalence of renewable energy in microgrids grows. Melville Island, off the coast of eastern Queensland, Australia, is taken as the test microgrid in this study. For the optimal sizing and techno-economic assessment of the intended hybrid microgrid system consist of of solar diesel generator, PV , battery storage, and wind turbine, four dispatch approaches have been unitized: load following, generator order, combined dispatch, and cycle charging strategy. The proposed off-grid microgrid's CO_2 emissions, total net present cost (NPC), and the Levelized cost of energy (LCOE) have all been optimized. In HOMER software, all the possible dispatch algorithms were analyzed, and the power system responses and reliability study were carried out using DIgSILENT PowerFactory. The findings of the study are useful for determining the optimum hybrid combination and available resources for the best performance of an off-grid microgrid employing various dispatch mechanisms. Following the simulation data, load-following is the best dispatch mechanism for stand-alone microgrid architecture since it has the lowest LCOE and NPC.

Introduction

Electricity is the modern world's driving power, and demand is growing swiftly in tandem with the rapid rise and development of the global industrialization and urbanization processes. Many hazardous greenhouse gases (GHG) are released by conventional fossil fuel-based power plants, posing a threat to the environment and humanity. As a result, there is a shift in attention in unconventional and renewable energy sources such as wind, solar, hydro, wave, geothermal, and biomass for obvious reasons. Wind and solar power technologies are more mature and widely available from other sustainable energy sources, and their participation in smartgrids and microgrids throughout the world is growing [1].

Solar and wind standalone microgrids could be a superior alternative for decentralized and remote distribution. The standalone microgrids operation using solar and wind energy, on the other hand, is difficult due to the stochastic nature of these resources. Some unforeseen factors can impair the performance of an off-grid microgrid due to the intermittency in wind speeds and solar irradiation. Because of power supply variations and demand responsiveness, power system dependability has always been a major problem in an off-grid renewable energy-oriented micro-hybrid grid system [2]. Furthermore, frequency and voltage dislocations can be noticed in the distribution network due to abrupt fluctuations in load demand, indicating system instability. When other DGs can run in PQ-controlled or grid-following mode in such mixed-inertia microgrids, the diesel generator often operates in grid-forming mode by taking responsibility for managing the voltage and frequency using an automated voltage regulator (AVR) and governor. When providing supplementary services, grid-following inverters can operate in grid-feeding or grid-

Nomenclature

Subscripts

Gen-1	Generator 1
IHMS	Islanded Hybrid Microgrid System
WECS	Wind Energy Conversion System
HOMER	Hybrid Optimization Model for Electric Renewables
NREL	National Renewable Energy Laboratory
COE	Cost of Energy
HRES	Hybrid Renewable Energy System
NPC	Net Present Cost
E	Electrical energy (kWh)
A	Swept Area (m^2)
P	Power from Wind turbine (kW)
P	Air Density
C_p	Power Co-efficient

V	Wind speed (m/s)
E_{prim}	Total volumes of principal freight.
$C_{ann,\ tot}$	Overall annualized price.
$E_{grid,\ sales}$	Quantity of energy vented to the grid.
E_{def}	Entire quantities of deferrable capacity.

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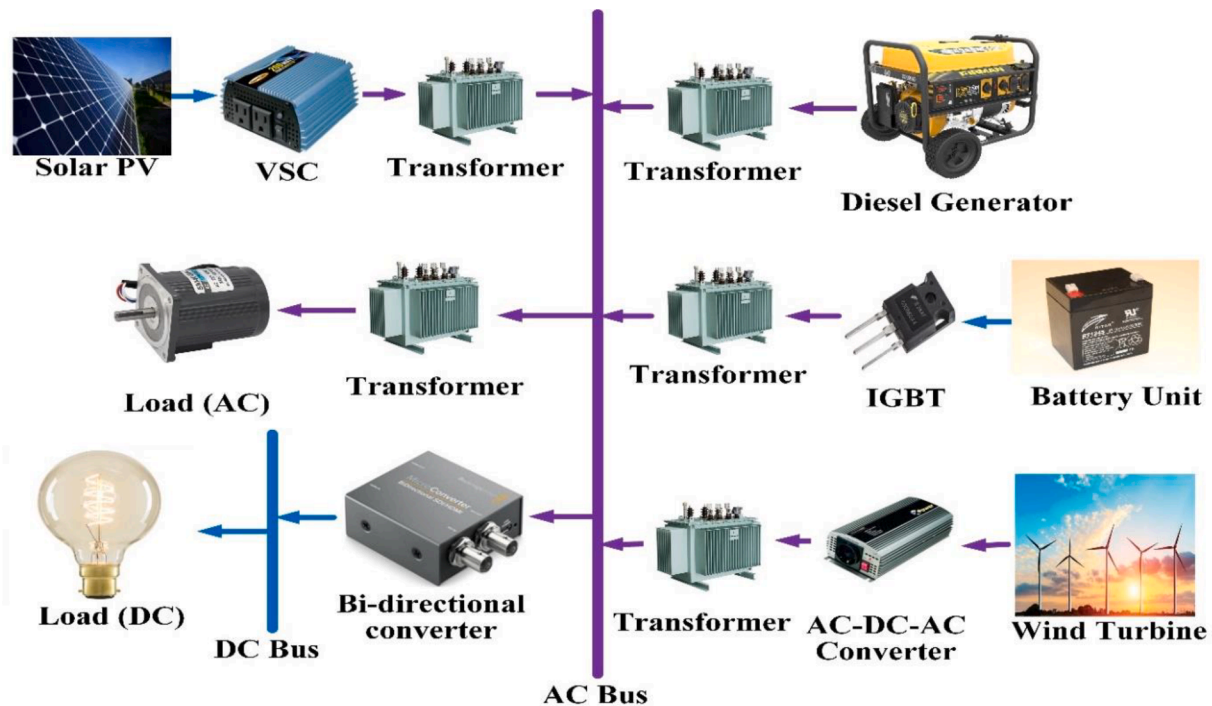|	
i	Annual real interest rate.
R_{proj}	Project lifetime.
$C_{ann,\ tot}$	Total annualized cost.
tCO_2	Amount of CO_2 emanations.
$CRF\ (.)$	Capital recovery factor.
HV	Petroleum boiler price (MJ/L)
m_f	Petroleum amount (Liter)
X_c	Corroded carbon portion.
CEF_f	Carbon production factor (ton carbon/TJ)

Fig. 1. Schematic block diagram of the off-grid PV-wind micro-hybrid grid system.

supporting mode. Battery-fed inverters can serve as grid-forming devices if the diesel generator is unavailable for whatever reason [3]. Researchers have shown an interest in evaluating islanded microgrid dispatch strategies and optimization algorithms [4–12]. Researchers evaluated a distributed economic dispatch technique for establishing a standalone microgrid [5]. Researchers discovered an optimum dispatch control for the standalone micro-hybrid grid by combining V2G (vehicle to grid) operation with suitable tariffs [6]. Scholars presented a two-level optimization strategy for dispatch algorithms suited for an off-grid microgrid system [7]. Researchers suggested a power dispatch approach to increase the generation stimulability for a wind-BESS system [6]. Researchers created a suitable energy management system on basis of multi-agent system (MAS) that takes real-time power dispatch algorithms into consideration [8]. The authors suggested a dispatch strategy for an integrated gas-electricity system based on the stochastic property of wind power [9]. The authors proposed a resilient energy

distribution strategy for a microgrid using a distributed economic dispatch mechanism to manage the high renewable access [10]. The authors utilized a hierarchical model predictive controller to introduce a dynamic active power dispatch control algorithm for the wind energy-oriented hybrid system, which increased network system stability [11]. Scholars proposed a technologically updated dispatch control algorithm for the standalone microgrid operation in order to keep the frequency within limits [12]. Researchers in [13] established an advanced optimal dispatch approach for an unbalanced 3-φ standalone microgrid using distributed technologies. Some research has focused on the stability of islanded hybrid microgrid systems and the reduction of voltage and frequency variations [14–19]. In [14], researchers offered a solution to the off-grid micro-hybrid grid's system stability with voltage fluctuation problem utilizing a static synchronous compensator (STAT-COM) and the genetic algorithm (GA) approach. Scholars evaluated numerous optimization strategies and control techniques from the
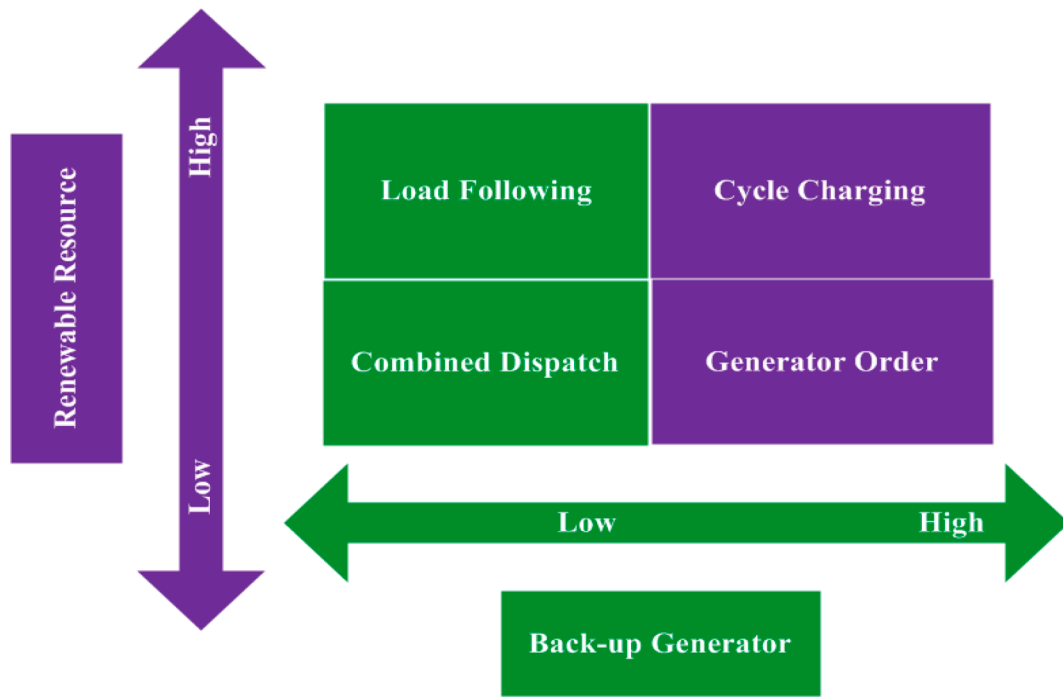
Fig. 2. The impact of renewable resources and diesel engines upon four dispatch mechanisms.
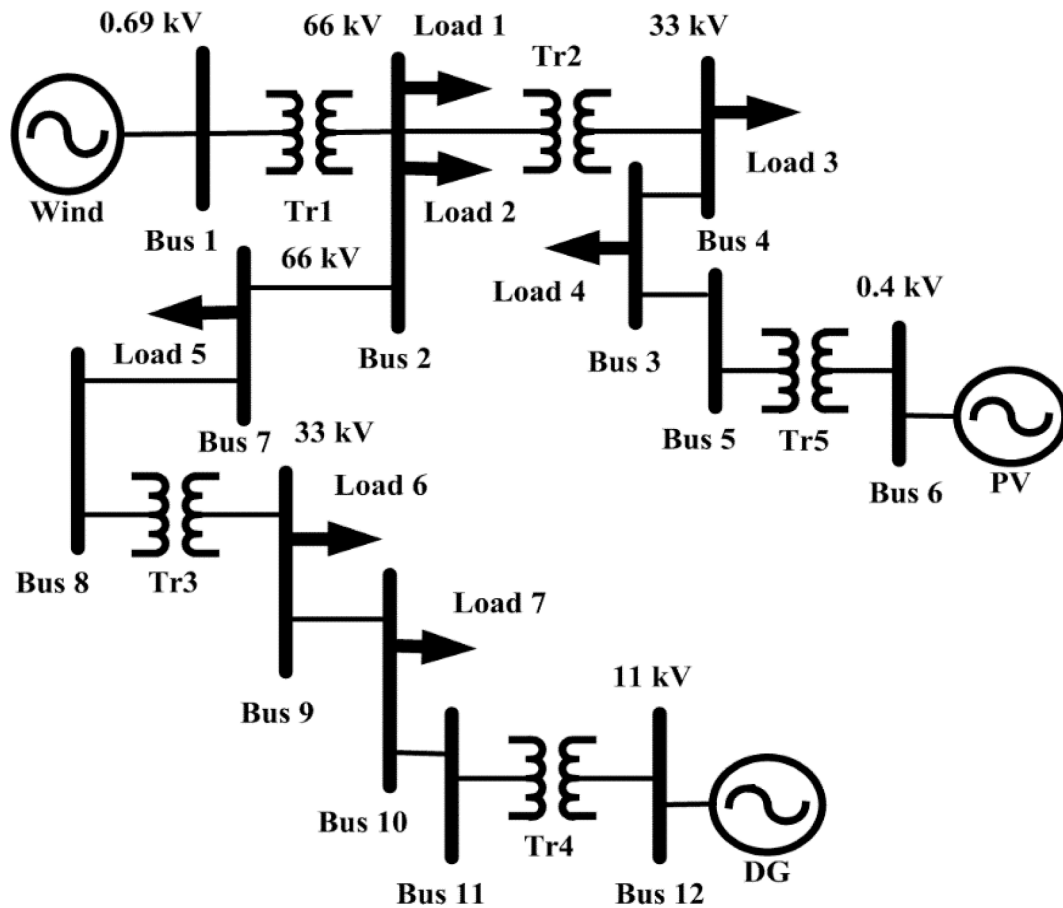

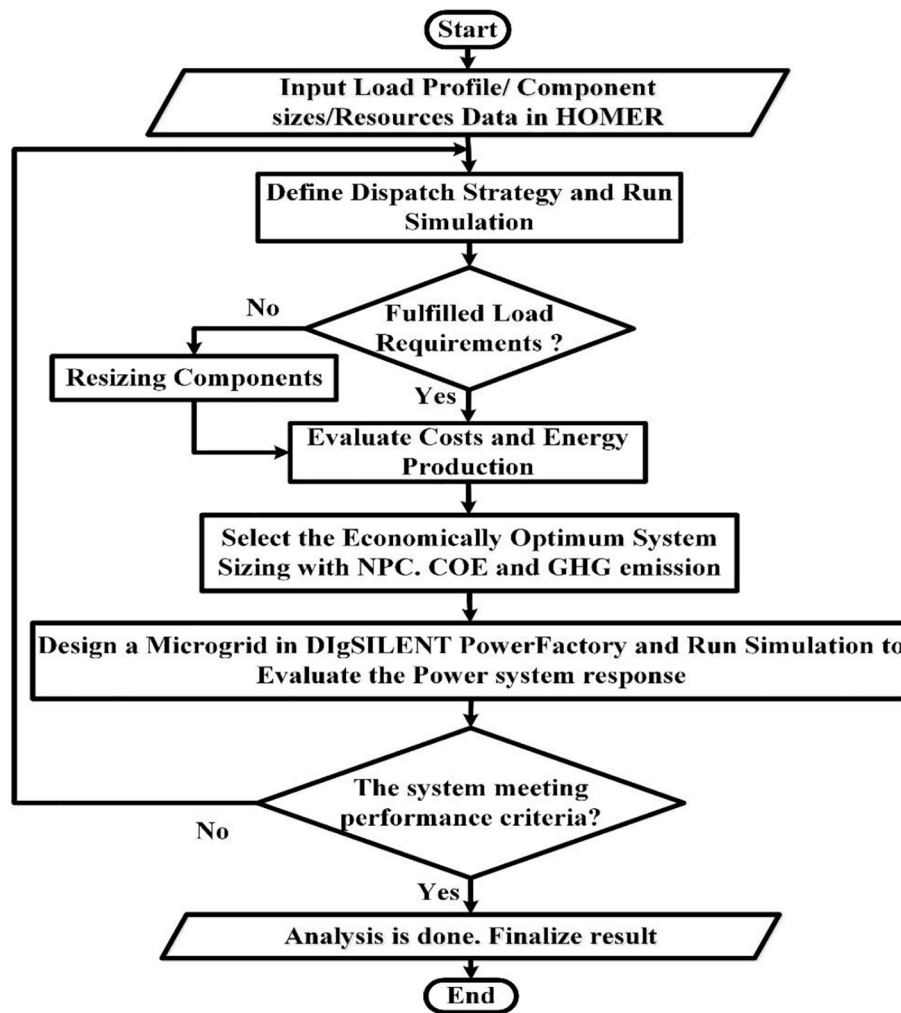**Fig. 3.** Line model for proposed Melville Island hybrid microgrid.

Fig. 4. Flow diagram for the proposed research work.

perspective of reducing various parameters such as environmental pollutions, NPC, voltage, and frequency instability in [15]. The authors proposed a control technique for output voltage optimization utilizing a modified PI controller and the genetic algorithm (GA) in [16]. By considering the bidirectional interlinking converter (BIC), researchers established a unique control algorithm for improving the power system responses of standalone microgrid networks [17]. To alleviate voltage and frequency stability, the authors proposed a multi-agent distributed control approach suitable for the off-grid hybrid system [18]. Researchers in [19] developed a multi-level frequency and voltage management technique suitable for an off-grid microgrid that takes into account the virtual inertia control co-efficient.

Furthermore, certain research [19–29] emphasizes the long-term planning and operational elements of islanded hybrid microgrid systems in terms of system resilience. Using a short-term stability and outages model, Scholars showed a reliability index calculation for the standalone hybrid system [19]. For the feasibility analysis of the system, researchers showed the reliability evaluation of the distribution system of the off-grid microgrid [20]. Researchers assessed the reliability of a standalone solar-battery-diesel system designed to accommodate Nigeria's typical decentralized and rural areas [21]. To ensure the viability of the distribution network, Scholars performed a transient component-based reliability study applicable for the off-grid microgrid [22]. By considering load voltage and converter dynamics, scholars designed an innovative independent energy management system to maintain system reliability [23]. Authors [24,25] proposed an upgraded

reliability evaluation and an improved islanded microgrid that took into account power electronic device operation failures. Improved reliability-based independent standalone microgrid with renewable-rich resources was proven by researchers in [26,27]. By examining the bandpass filter-based droop control approach, researchers developed a reduced-order design for the off-grid microgrid's reliability and dynamic stability [28,29].

The absence of proper correlation between techno-economic study and optimal designing of the microgrid with the suitable power system and system reliability assessment is one of the major gaps in the above-mentioned literature. Three core requirements have to be met to make the off-grid microgrid operate properly: (1) feasibility in techno-economic aspects, (2) reliability, and (3) stability in system performance. A suitable combination and correlation of these three requirements for an off-grid microgrid design could be a practical solution to the research gap. Melville Island was chosen for this study to demonstrate the research approach.

Melville Island, Australia's northern territory, is rich in renewable energy sources such as wind and solar electricity. The main goal of this study is to build an off-grid PV/wind/diesel generator/battery-based micro-hybrid grid system that will work with the existing Melville Island distribution network [30]. The core contribution of this research work can be described as the following:

- first, using the HOMER software platform to determine the suitable dispatch algorithms for the optimal operation of the off-grid micro-
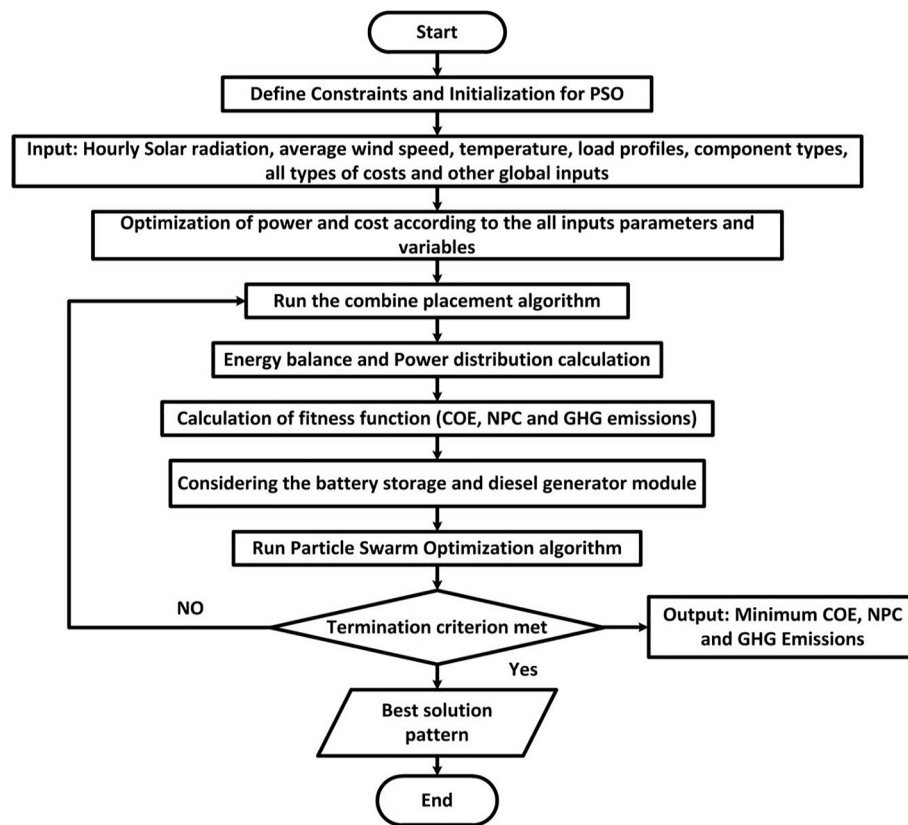
Fig. 5. Flowchart of PSO Algorithm [40].

hybrid grid which will result in the lowest COE, NPC, and CO_2 production;

- second, with the power system performance study, conducted in the DIgSILENT PowerFactory platform, ensuring stable, efficient, and reliable operation of the proposed design.

The remainder of the paper has been embellished as follows: Section II contains a block diagram model for the proposed stand-alone micro-grid, as well as the system equipment and power transformation strategy; Section III contains the simulation algorithm and methodology as well as a discussion on dispatch strategy; and Section IV contains the findings, as well as the necessary graphs to differentiate between four dispatch controls based on COE, CO_2 production, NPC, the system reliability index, and power system performance. Finally, the final section of this study summarizes the simulation findings and highlights the major contributions.

Construction of the proposed microgrid

In Fig. 1 a stand-alone solar PV-wind turbine micro-hybrid grid with the system equipment is shown in a block diagram. The designed and simulated off-grid microgrid is built with solar PV, diesel generator, wind turbine, battery unit, converter module, and load profile. Battery storage and solar PV supply DC (Direct Current) power. Before being connected with the AC busbar, this DC supply needs to be converted to AC (Alternating Current) power using an AC/DC bidirectional converter module. On the other hand, as AC power is directly generated by the diesel generator unit and wind turbine, these powers can directly be supplied to AC busbar after a simple voltage level correction (Stepping up or down).

The combined AC bus bar energy then will be used to satisfy the demand of the load. For the AC/DC bidirectional converter unit, a Voltage Source Controller (VSC) has been added [31].

Methodology

A. **Dispatch Strategies**

The optimization techniques can be analyzed according to various dispatch methodologies based on power sources, meteorological conditions, and load demand. *Dispatch strategy or control* can be defined as a set of regulations which is used for the control of the generator(s) and the storage bank(s) operation whenever there is not enough supply of renewable energy to provide the load [31]. Four dispatch techniques have been discussed and implemented in this study, which is: load following, combined dispatch, generator order and cycle charging.

When a generator is needed, the Load Following (LF) approach ensures that just enough electricity is provided to the load. In order to keep the system stable, demand should have been fulfilled utilizing renewable sources [32].

In Cycle Charging (CC) approach, the generator unit works at the rated capacity whenever it is needed, and in this mode, the surplus power from the source charges the storage bank. In general, this strategy will be ideal in power system networks having practically no or zero renewable power [32].

The Generator Sequence (GO) strategy chooses the generator combinations which satisfy the demand first among the other combinations [33].

In the Combined Dispatch (CD) technique, the upcoming net-load assumptions are avoided by utilizing the net present load to decide on charging the battery unit using the generator. In the CD strategy, the generator is not used when the load demand is low. The combined dispatch (CD) technique selects the cheaper option to make CC or LF in each time step [33,34]. The influence of renewable energy and the backup generator on various dispatch controls is depicted in Fig. 2. Following the study and observations, it is observed that the LF approach has the highest influence upon the majority of renewable
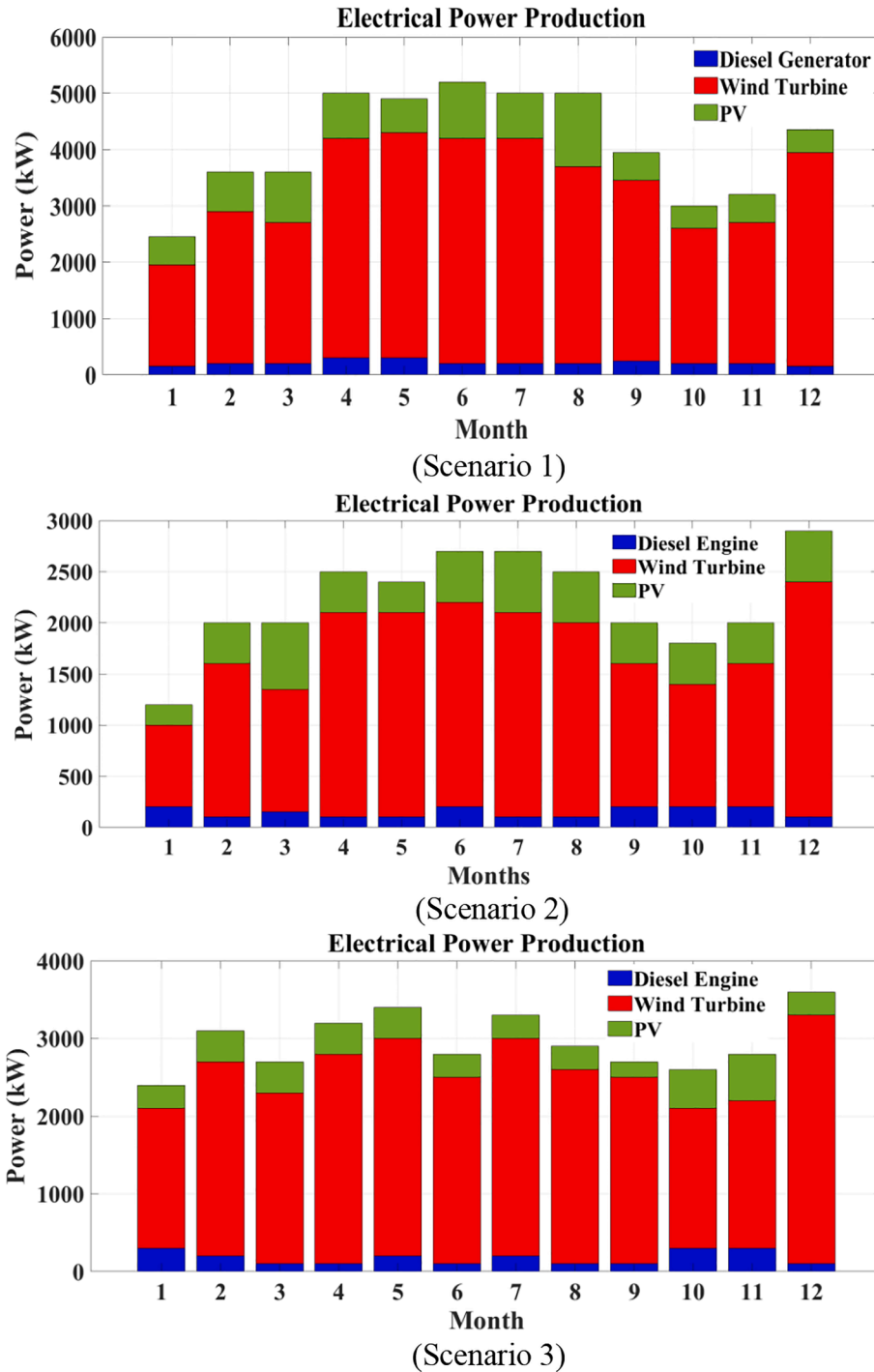
Fig. 6. Electrical Power generation for the designed IHMS throughout 12 months.

resources, while the generator has the greatest impact on the majority of backup generators.

In the islanded microgrid, dispatch techniques provide guidelines for power management and appropriate size requirements. It is vital for all four dispatch systems how they employ backup diesel generator when the load demand is extremely high, as well as the availability of renewable resources and variations in load demand.

B. **Optimal Sizing and Cost Function Minimization:**

To achieve the ideal sizes and necessary number of each power producing unit, the following optimization problems (Eqs. (1) to (4))

must be solved. a, b, c, and d are the respective sizes of various microgrid components, while f1, f2, and f3 are weights used to represent the relevance of each component. The terms LCOE and NPC refer to the associated component's levelized cost of energy, net present cost, and greenhouse gas emissions, respectively, while $e.CO_2$ refers to the quantity of CO_2 emitted by the Diesel Generator. Then, we can write,

$$\frac{\min}{a, b, c, d, f_1 \in N^\circ} (f_1(a.LCOE_{PV} + b.LCOE_{WT} + c.LCOE_{DG} + d.LCOE_{BT}))$$

(1)

Table 1
Comparison among different parameters for three cases for four dispatch Control.

HOMERController	NPC (million USD)	COE (USD/ kWh)	CO_2 Emission (kt/yr.)	Operating Cost (million USD)
Load Following (LF) 1	17	0.04	0.53	0.42
LF2	16.8	0.04	0.4	0.35
LF3	19.1	0.05	0.51	0.42
Cycle Charging (CC) 1	19.4	0.05	0.52	0.43
CC2	19	0.05	0.48	0.4
CC3	20.9	0.05	0.71	0.55
Generator Order (GO) 1	25.9	0.07	0.98	0.65
GO2	28	0.08	0.89	1.1
GO3	29.5	0.09	0.76	1.12
Combined Dispatch (CD) 1	18	0.05	0.45	0.38
CD2	17.4	0.04	0.4	0.35
CD3	20.3	0.05	0.65	0.51

Table 2
Simulation results for the Islanded microgrid by using PSO algorithm.

Optimization Technique	NPC (million USD)	COE (USD/ kWh)	CO_2 Emission (kt/yr.)	Operating Cost (million USD)
Particle Swarm Optimization	28.3	0.09	0.9	1.3

$$\frac{min}{a,b,c,d,f_2 \in N^\circ}(f_2(a.NPC_{PV} + b.NPC_{WT} + c.NPC_{DG} + d.NPC_{BT})) \quad (2)$$

$$\frac{min}{e,f_3 \in N^\circ}(f_3(e.CO_{2_{DG}})) \quad (3)$$

$$\frac{min}{f_1f_2f_3 \in N^\circ}(f_1LCOE_{Total} + f_2NPC_{Total} + f_3GHG_{Total})) \quad (4)$$

Each source generated power, P gen(i) must be less than or equal to the maximum capacity of the source:

Subject to P gen(i) $\leq$ $Pgen.max(i)$ (5)

The total power losses (P_{losses}), total load demand (P_{demand}) and storage power ($P_{storage}$) are being used.

$\Sigma iP\ gen(i) \geq P_{demand} + P_{losses} + P_{storage}$ (6)

C. Equations related to calculating the COE (Cost of Energy)

Optimum COE for a stand-alone system is calculated by HOMER using the formula below:

$$COE = \frac{C_{ann,tot}}{E_{prim} + E_{def} + E_{grid,sales}} \quad (7)$$

Here, *Cann, tot* = Annualized total cost, *Eprim* = Total primary load, *Edef* = total deferrable load, Egrid, sales = energy sold to the grid (per year).

D. Equations related to calculating Net Present Cost (NPC)

The total NPC is calculated using the equation below:

$$C_{NPC} = \frac{C_{ann,tot}}{CRF(i, R_{proj})} \quad (8)$$

Here, *Cann, tot* = Annualized cost. *i* = Interest rate (Annual). *Rproj* = Project lifetime. *CRF (.)* = Capital recovery factor.
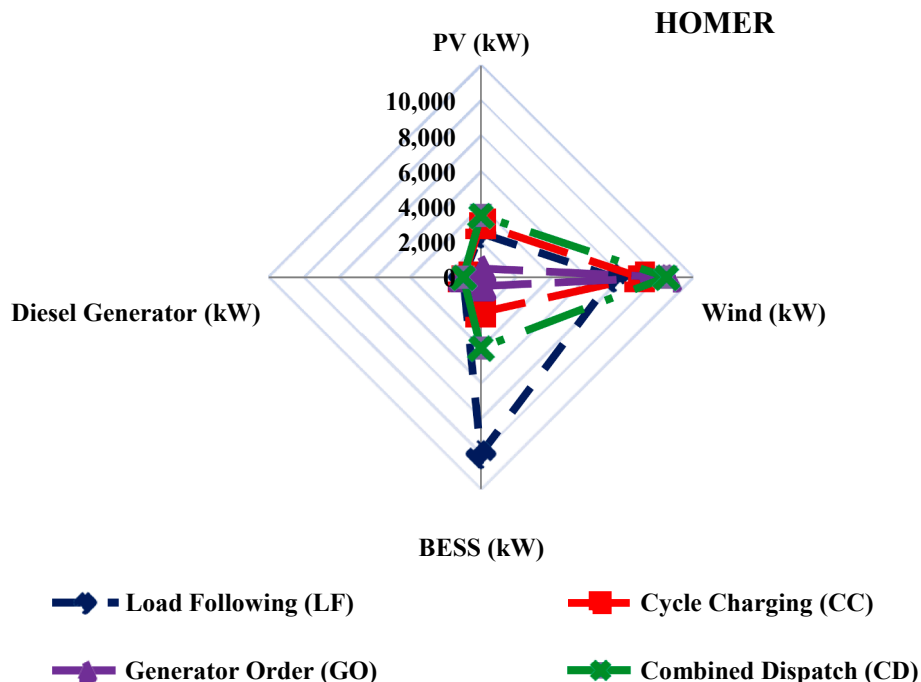
E. CO2 Emission related Equations

Fig. 7. Optimal sizes of each module according to the various dispatch strategies for a proposed islanded hybrid microgrid in the HOMER platform.
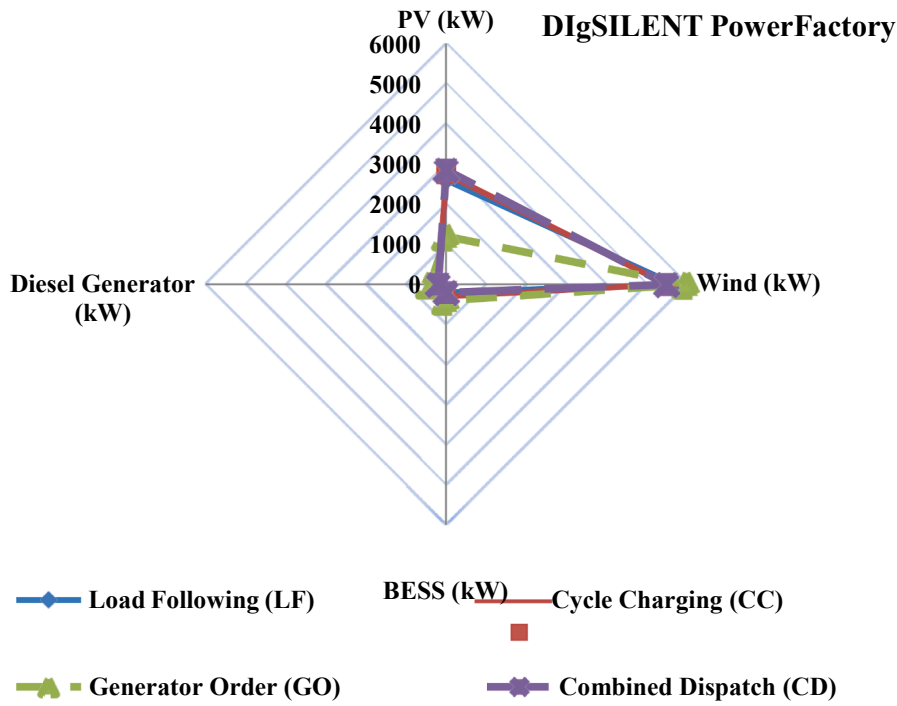
Fig. 8. Optimal sizes of each module according to the various dispatch strategies for a proposed islanded hybrid microgrid in the DIgSILENT PowerFactory platform.
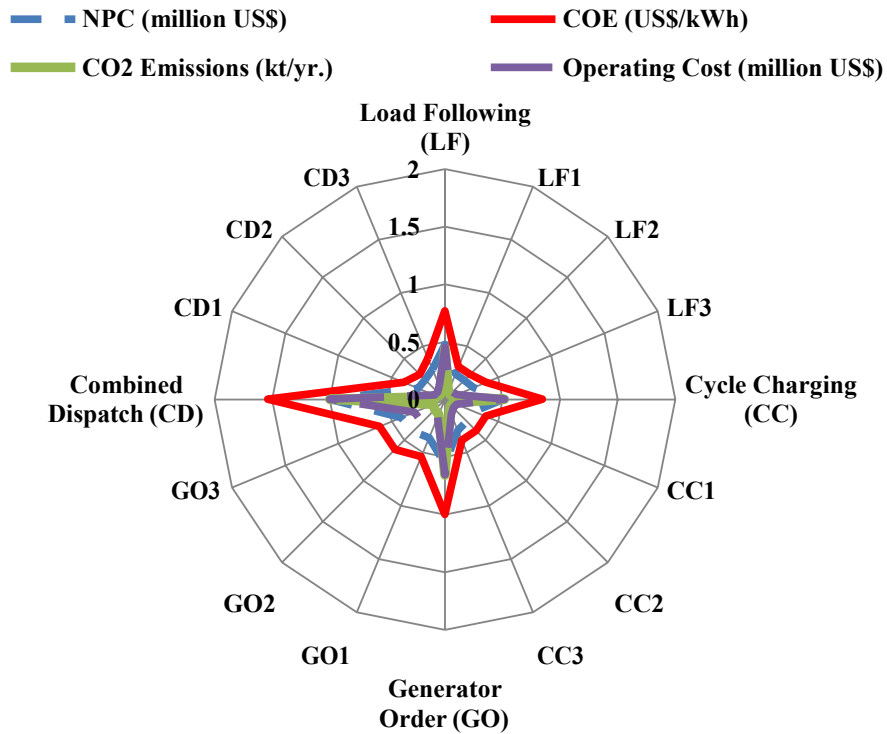

Fig. 9. The difference in various parameters for three cases for four strategies.

To find the amount of CO2 emission from the proposed hybrid system, the equation below have been used:

$$tCO_2 = 3.667 \times m_f \times HV_f \times CEF_f \times X_c \quad (9)$$

Where, tCO_2 = Total CO2 emission. m_f = Quantity of Fuel in Litre. HV_f = Heating value of Fuel in MJ/L. CEF_f = Emission factor of Carbon in ton carbon/TJ. X_c = Oxidized carbon fraction. Another factor is needed to be considered and that is 1 g of carbon is contained in 3.667 g of CO2.

F. Economic Dispatch:

Equations (10), (11) and (12) demonstrate the economic dispatch problem as an optimization problem:
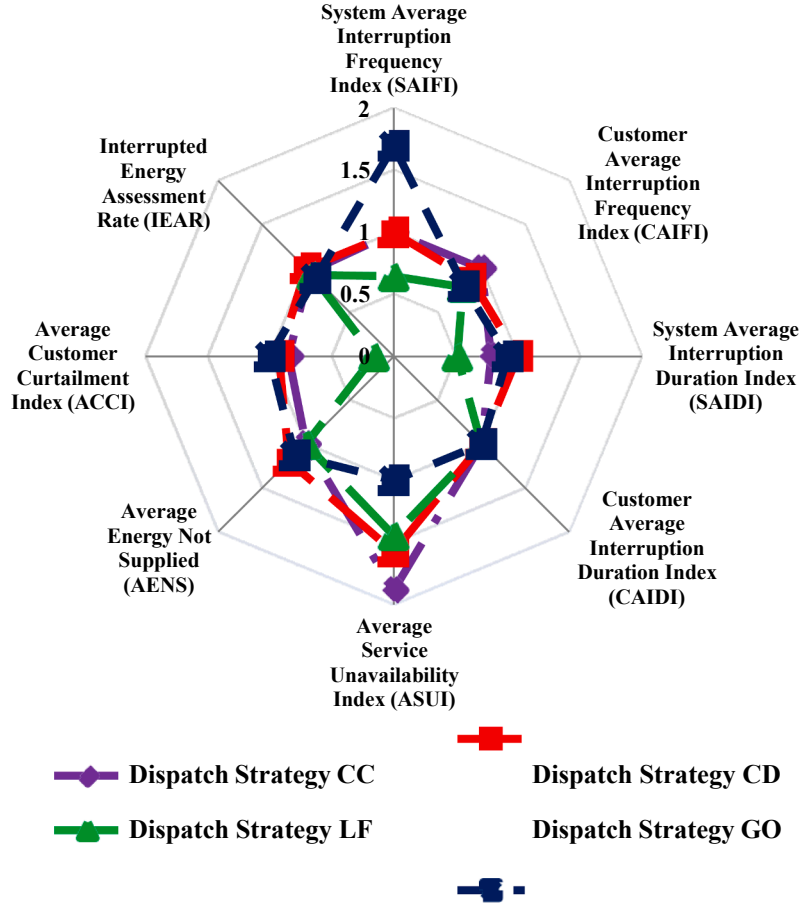
Fig. 10. The reliability index for the designed off-grid microgrid.

$$\underset{P_{G_i}}{min} \sum_i C_{G_i} P_{G_i} \tag{10}$$

Subject to:

$$P_{G_i}^{min} \le P_{G_i} \le P_{G_i}^{max} \tag{11}$$

$$\sum_i P_{Gi} = P_D \tag{12}$$

G. **System Design**

The objective function (10), where C_{Gj} defines the marginal cost for each generator unit and P_{Gi} defines the quantity of power it generates, minimizes the overall power generating cost. The generators have to maintain their maximum and minimum limitations, according to equation (11), and all generated power must be equal to the electricity demand P_D, according to equation (12).

Fig. 3 depicts the operational single line diagram for the proposed Melville Island hybrid off-grid microgrid [28]. The distribution network contains a total of 12 busses, 5 transformers, 7 loads, a diesel generator, 1 solar PV module and 1 wind turbine module. The network is connected to the 7 loads at various nodes having 11 kV, 33 kV and 66 kV voltage levels. The diesel generator unit, wind turbine module and solar PV unit are connected to the system network from three different points having 11 kV and then the voltage is stepped up to 33 kV by using transformers.

For the PV module, diesel generator module, and wind turbine unit, an initial voltage of 575 V is set [25].

The whole system flow chart is illustrated in Fig. 4 to describe the proposed off-grid hybrid microgrid's assessment and optimization process. The process of optimization begins with the nomination of various components and modules, as well as their sizes and input parameters,

and then moves on to the technical and economic restrictions, load profile assessment, and finally the various dispatch techniques. DIgSI-LENT PowerFactory simulation program uses the optimal sizes from the simulation results to perform a power system study to verify the technical correctness of the specified model.

The mandatory criteria of the reliability indices are Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Average Energy Not Supplied (AENS), Customer Average Interruption Duration Index (CAIDI), Customer Average Interruption Frequency Index (CAIFI), and Average Service Unavailability Index (ASUI) [32]. Microgrid system reliability assessment involves reliability indices that relay feasibility information of the system.

H. **Simulation Scenarios**

To verify the robustness of the proposed strategy, the system simulation technique was used with three different sets of data. The results of these three sets of data are presented in order to assess design alternatives and select the optimum microgrid despatch strategy. The data sets analysed are (1) NASA surface metrology data, (ii) Real Dataset 1, and (iii) Real Dataset 2. (ii) and (iii) were given by the Bureau of Meteorology (BOM) [40, 41].

(1) Data Scenario 1: (NASA Data) - For a year, wind speed [33] and solar irradiation data [34] are typical data with a 30-minute data resolution. The load data for Melville Island was obtained from [39]. The alternative data collected by NREL to justify the feasibility and consistency of the data.

(2) Data Scenario 2: (Real Dataset 1) - The second set of Melville Island representative data consists of a year's worth of solar
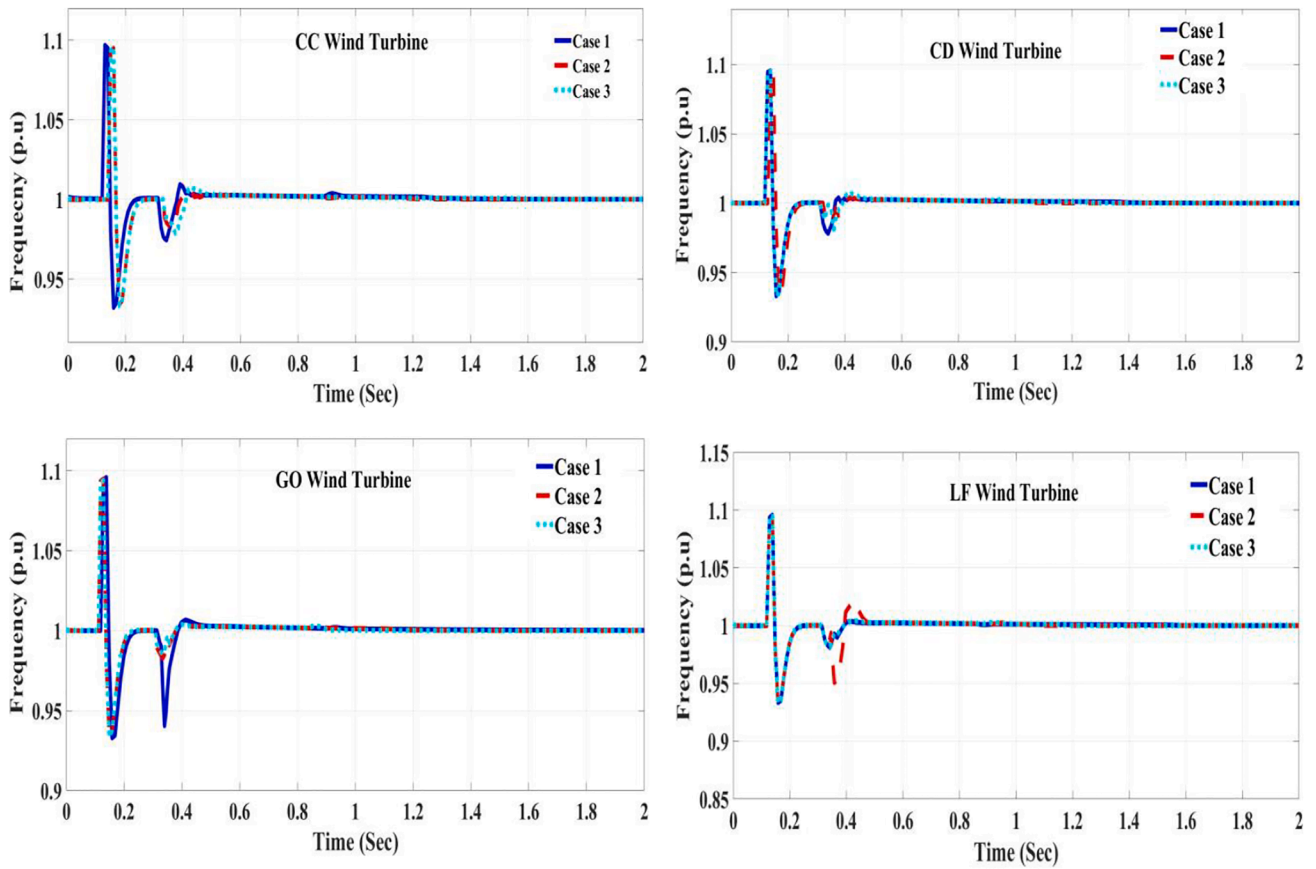
Fig. 11. Frequency responses for wind turbine modules according to the four dispatch strategies.
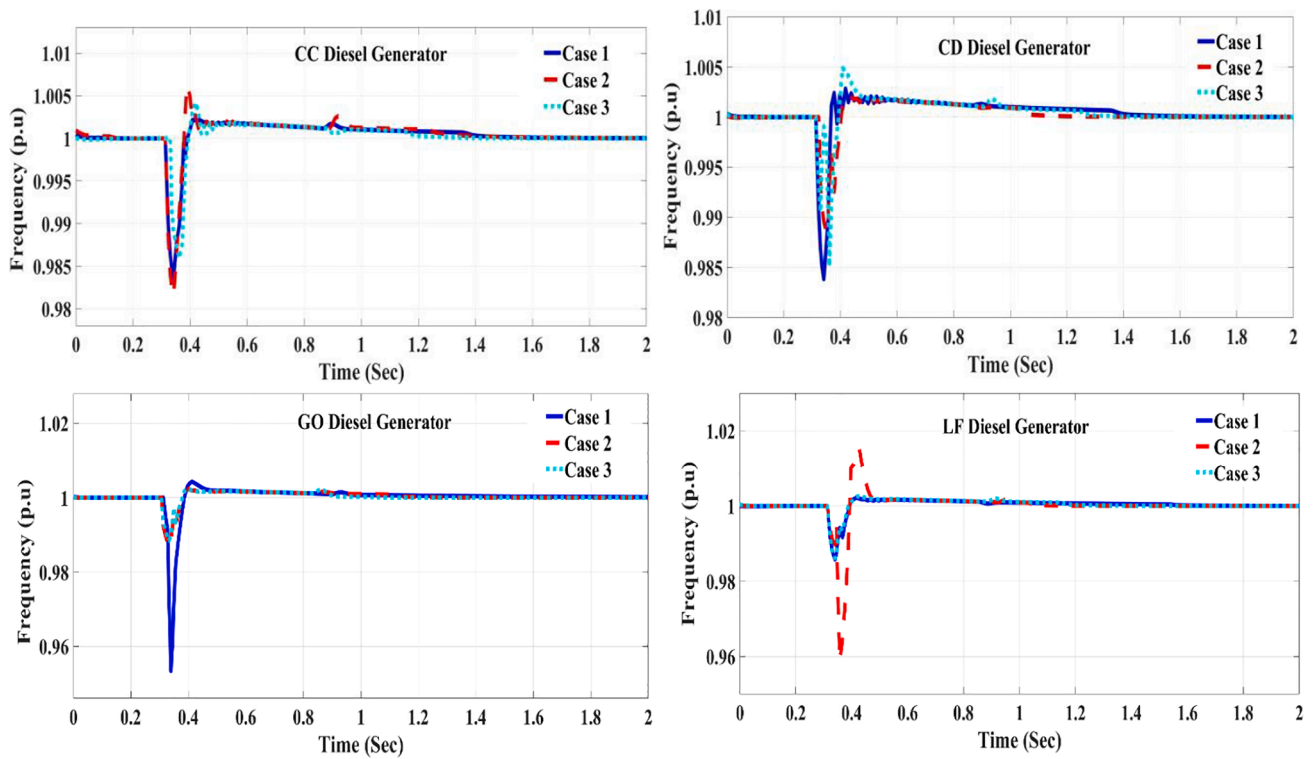

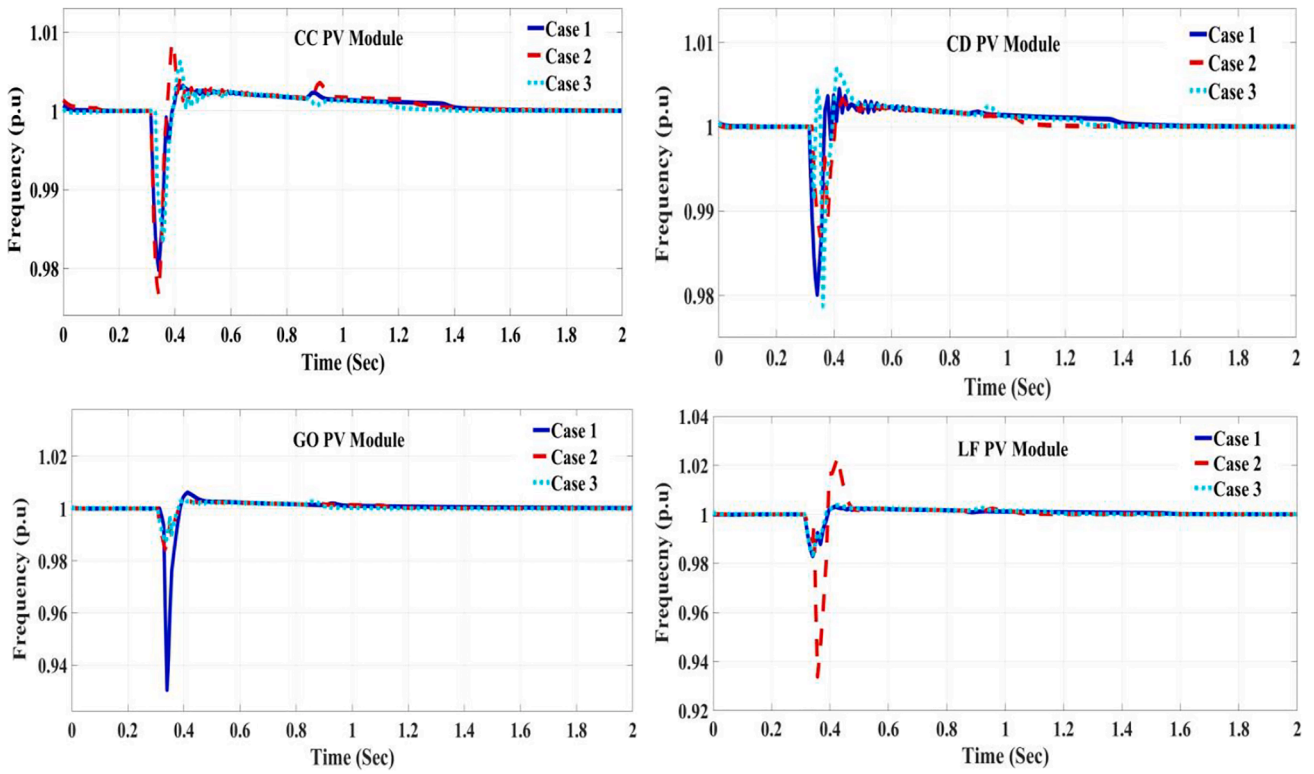**Fig. 12.** Frequency responses for diesel generator module for the four strategies.

Fig. 13. Frequency for PV module according to the four dispatch strategies.
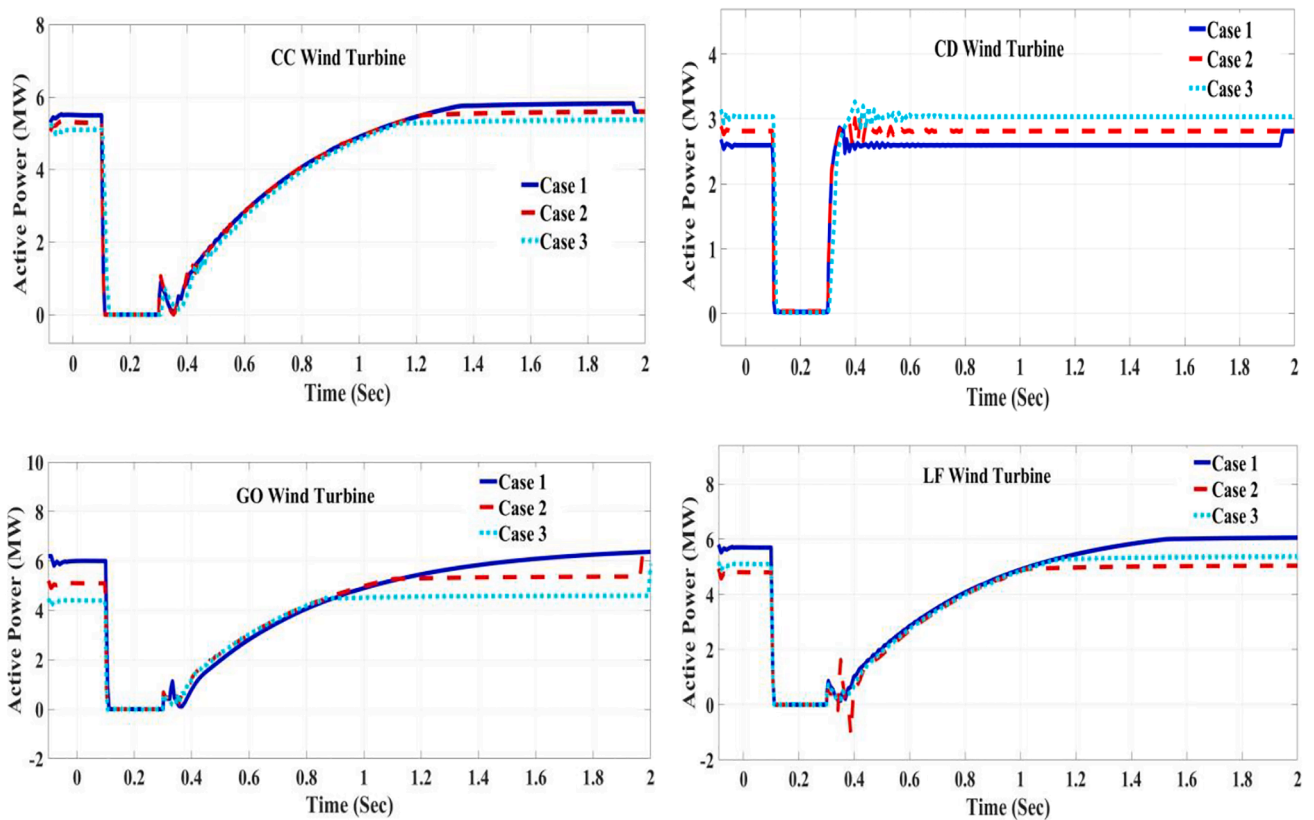
Fig. 14. Active power from wind turbine modules according to the four dispatch strategies.
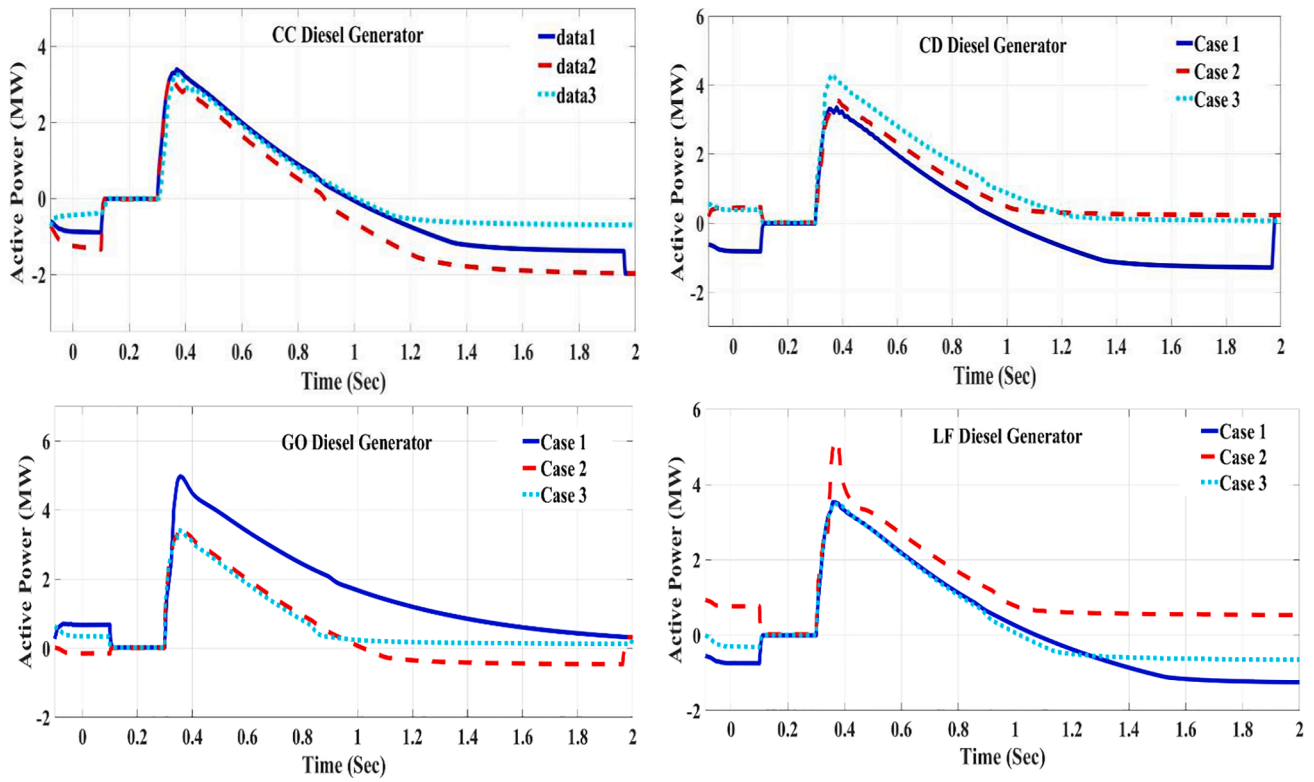
Fig. 15. Active power from diesel generator according to four dispatch controls.
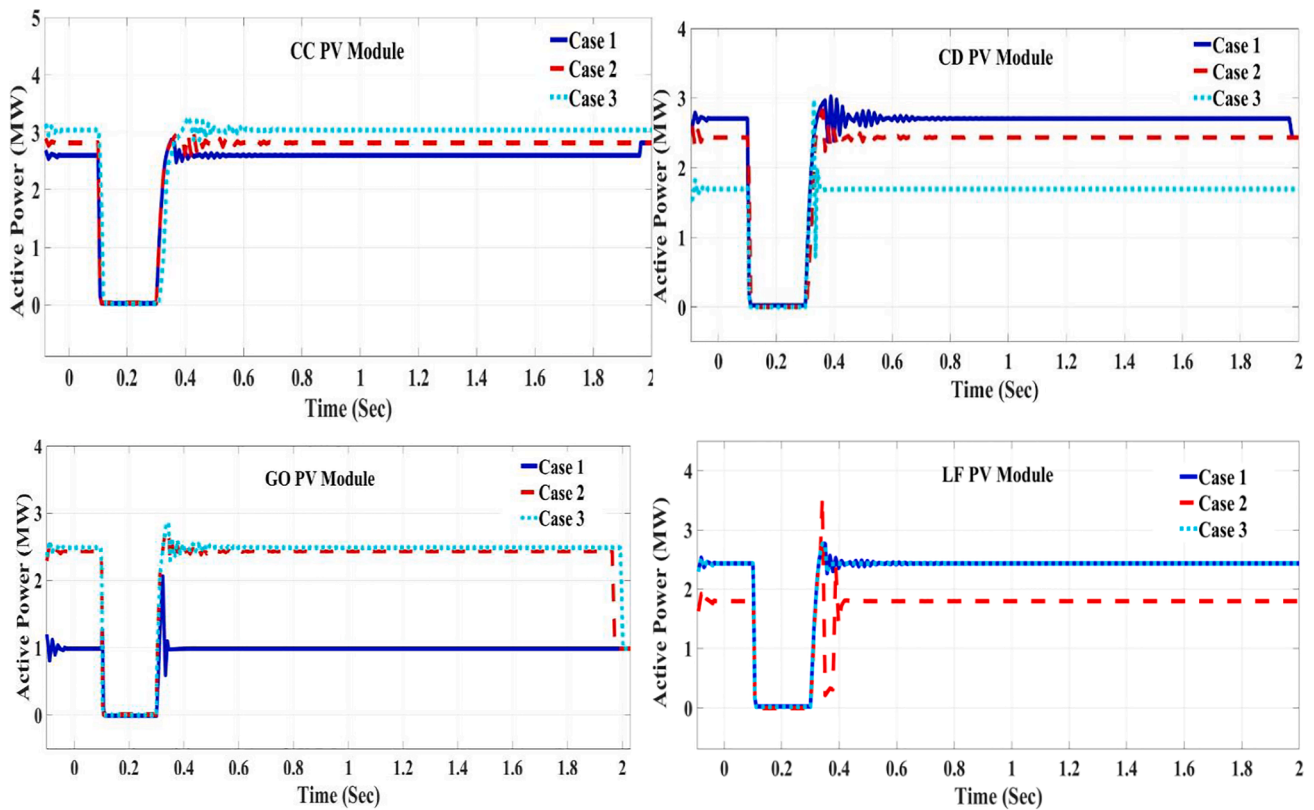

Fig. 16. Active power from PV module according to the four dispatch strategies.
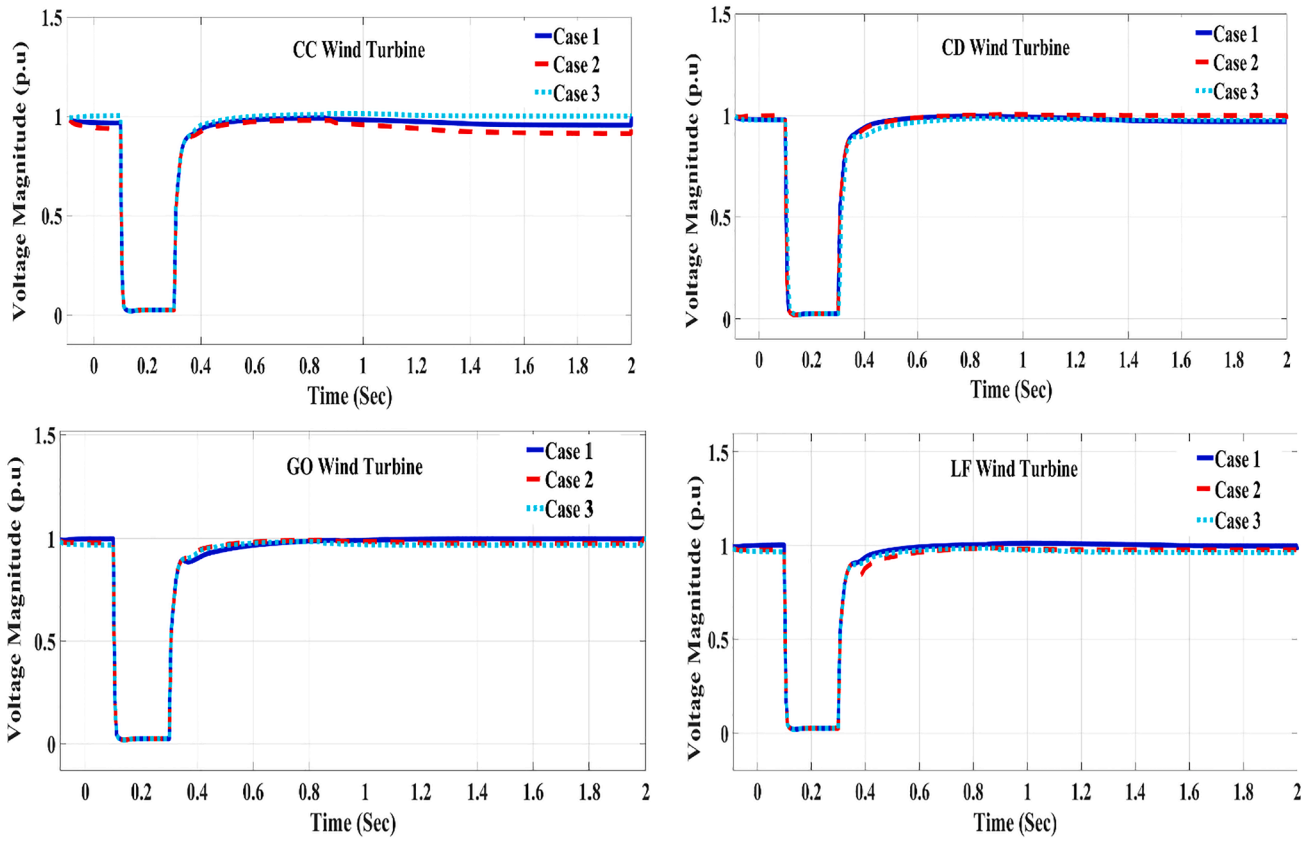
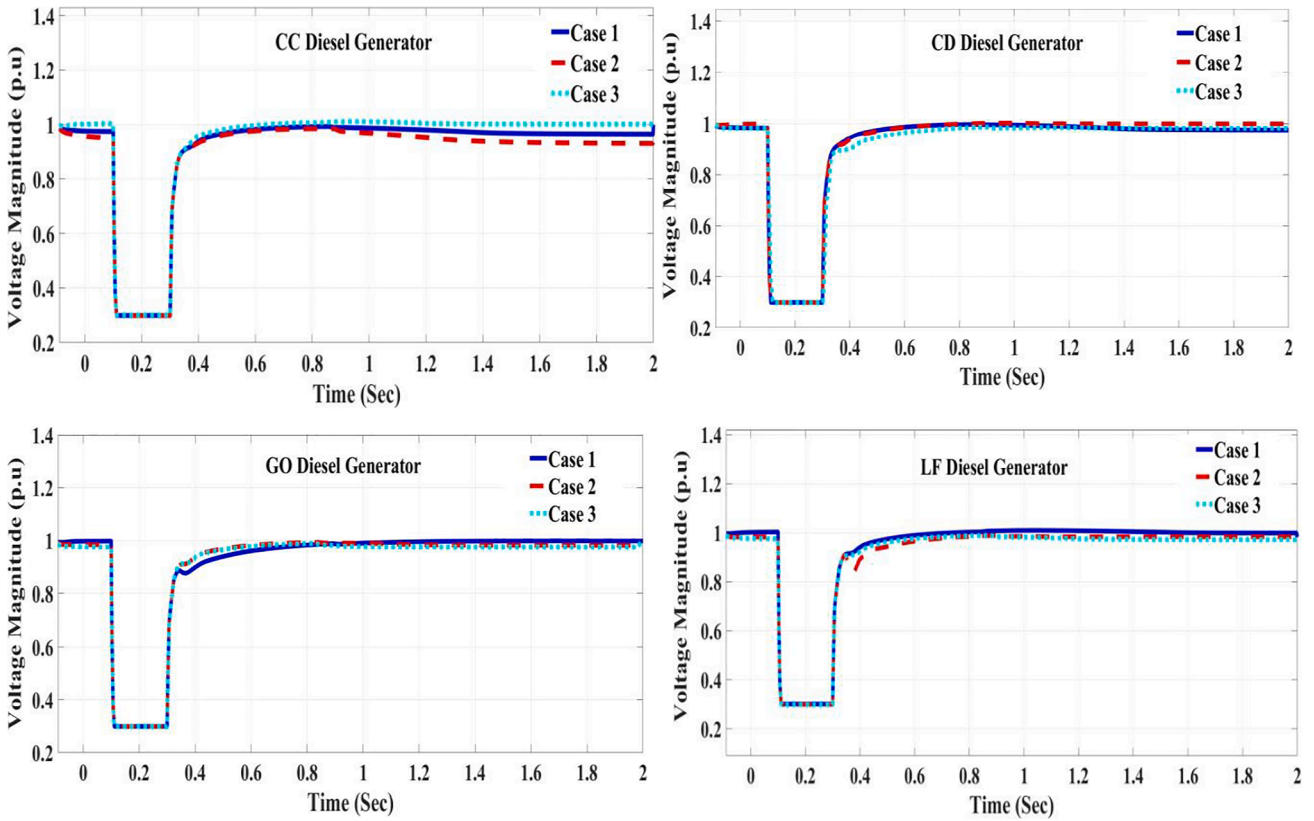**Fig. 17.** Voltage magnitudes from wind turbine module for four dispatch strategies.

Fig. 18. Voltage magnitudes from diesel generator module for four dispatch strategies.
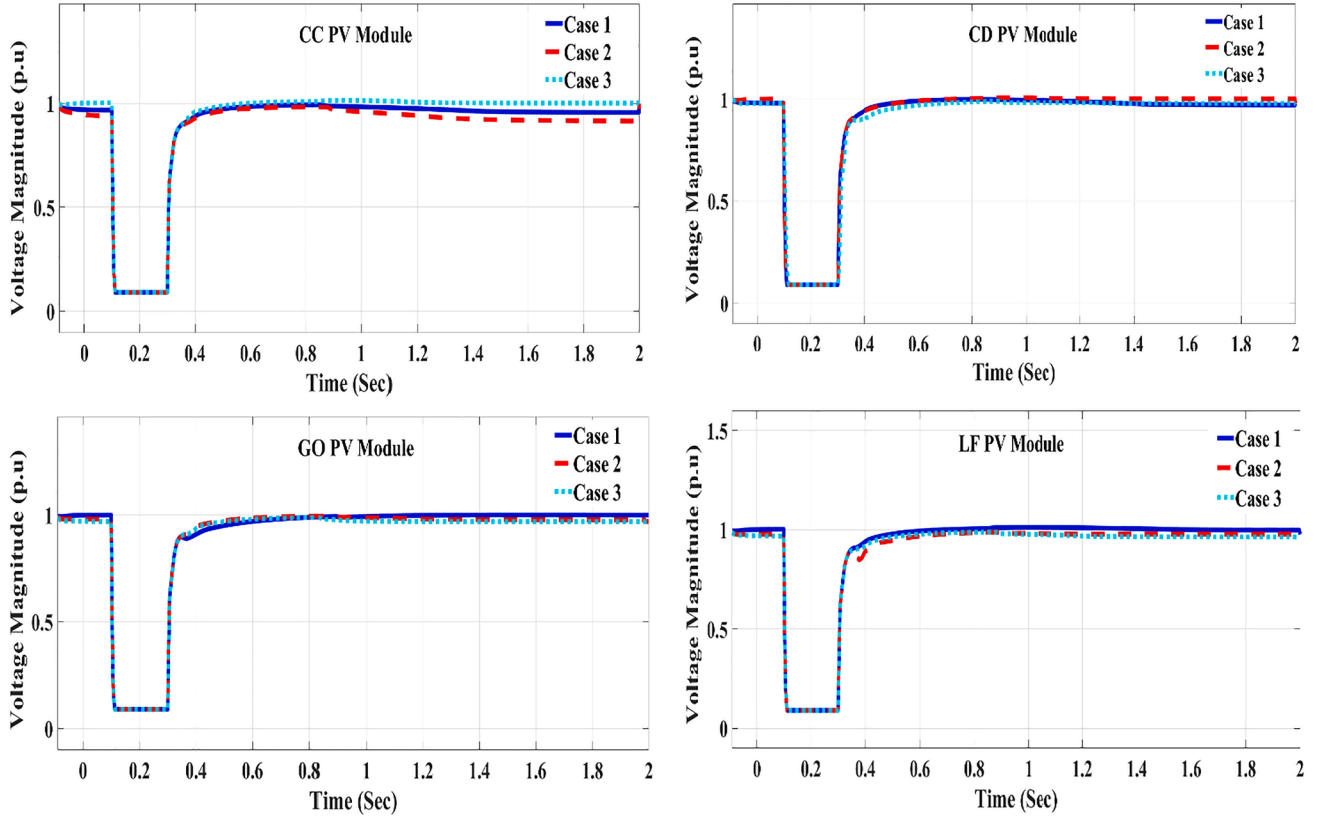
Fig. 19. Voltage magnitudes from PV module for four dispatch strategies.

Table 3
Comparison of different criteria between the designed and other HRES.

Criteria	Other HRES [35]	Designed IHMS
CO_2 Emersion/Year (Kt)	198347.984	0.4
Operating Cost ($)	19,516	0.4
NPC/Year ($)	288,194	16.8 M
COE ($/kWh)	1.877	0.204

Table 4
Comparison of different criteria between the designed and Traditional Plant.

Criteria	Traditional Power Plant [35]	Designed IHMS
NPC/Year ($)	297,000.00	16.8 M
CO_2 Emersion/Year (Kt)	198,348.00	0.4
COE ($/kWh)	0.380	0.204

irradiance, temperature, and wind speed data [35] with a 30 min data resolution. [35] was used to get the data for the representative load.

(3) Data Scenario 3: (Real Dataset 2) – The Melville Island representative dataset [36] contains annual data on solar irradiance, temperature, and wind speed, with a data resolution of 30 min, similar to 2. [38] provided the load information.

According to the three different scenarios, the results replicated and compared to justify the technical and economical feasibility of the system.

I. **Particle Swarm Optimization**

The PSO algorithm comprises three principle ventures as follows:

- Evaluate the wellness of every molecule
- Update individual and worldwide best finesses and positions
- Update speed and position of every molecule

Every molecule recollects the best wellness esteem it has accomplished during the activity of the calculation. The molecule with the best wellness esteem contrasted with different particles is additionally determined and refreshed in cycles [36,37]. The cycle is rehashed until some halting measures, like the quantity of emphasis or predefined target wellness esteem, are met. The situation of every molecule in the multitude is refreshed utilizing the accompanying equation [38]:

$$x_{k+1}^i = x_k^i + v_k^i \tag{13}$$

where x is the unit position and v is particle velocity in reiteration k. The velocity calculated as follows:

$$v_{k+1}^i = K \times \left[v_k^i + c_1 r_1 \left(p_k^i - x_k^i \right) + c_2 r_2 \left(p_k^g - x_k^i \right) \right] \tag{4}$$

where

$$K = \frac{2}{2 - \phi - \sqrt{\phi^2 - 4\phi}} \tag{15}$$

$$\phi = c_1 - c_2 > 4 \tag{16}$$

p^i is the best individual unit location and p^g is the best global position, c_1 and c_2 are cognitive and social parameters, whereas r_1 and r_2 are random numbers between 0 and 1.

v_k^i is called inertia, which brands the unit interchange in the identical course and with the same velocity.

$c_1 r_1 \left(p_k^i - x_k^i \right)$ is called the reasoning factor, causing the particle to return to a previous position in which it has experienced high separate fitness.

$c_2 r_2 \left(p_k^g - x_k^i \right)$ is called the social component, causing the particle to

return to the best section the swarm has originated so far and to follow the best neighbour's direction. If $c_1 \gg c_2$ then each particle is much additional involved to the individual best position, while on the contrary, if $c_2 \gg c_1$, then particles are more attracted to the global best position [39]. The flowchart of the PSO algorithm is provided in Fig. 5 [40].

Results with necessary discussion

This section examines the Melville Island hybrid microgrid system's performance. The power, voltage, and frequency responses of Melville Island's microgrid are described using various dispatch strategies after a study to explore the design of an optimal size microgrid system for Melville Island is exposed. As a result, a specific comparison is included in this part to investigate the microgrid system's best performance. A detailed study of this experiment is considered in the next part.

I. Optimal Sizing

In Fig. 6 the total power generation (electrical) based on the meteorological conditions, for 12 months a year is shown. Production of energy from different sources is dependent on the available solar and wind resources. Also, the location of the data affects power generation. Also, the load profile is a factor in electrical power production. In LF strategy, the size of the Battery unit is the highest of 10 MW as the amount of power generated from the wind turbine and solar PV module is more than the load demand, as a result, for future usage, the surplus electricity is stored, and thus larger storage is needed. In GO strategy, the optimal sizes of each module like solar PV, converter etc. is the lowest among other dispatch techniques. The reason is in the GO strategy, the size of each piece of equipment is chosen based on the total demand of load and the sequence of the power generator. GO uses the first generator combination in the list that fulfills the operational capacity, following a predetermined sequence of generator combinations.

Table 2 demonstrates the simulation results from the PSO algorithm. From the simulation results it can be observed that the results are very similar to the generator order results what we performed in HOMER. Those results have been treated as the worst-case scenarios in comparison to other dispatch strategies listed in Table 1. In terms of convergence rate, it can be easily said that HOMER is faster that PSO is a metaheuristic algorithm on the other than HOMER follows deterministic method which much faster. According to the comparison of techno-economic analysis it is also said that HOMER shows better results in terms of cheaper NPC, COE and operating cost and least GHG emissions. The code of PSO algorithm has been submitted as a supplementary document.

In Fig. 7 a comparison of the optimal sizes of every piece of equipment used in designing the proposed microgrid is shown for the four dispatch strategies by HOMER. With the same load, the comparison in the figure demonstrates fluctuations equipment sizes. Because of the variation in the dispatch strategy, the optimal size of the Wind turbine, solar PV, converter and Battery is different from each other.

Fig. 8 shows the optimized module sizes according to the four dispatch strategies for a stable system in the DIgSILENT PowerFactory software platform.

The NPC can differ with different lifetime, fuel cost, maintenance-operation cost, and component costs. According to the analysis done in this work, it can be found that the NPC for the designed off-grid Microgrid has been considerably reduced compared to NPC for the conventional power plant. Table 1 and Fig. 9 show a comparison among COE, CO_2 emission, and NPC for the three cases for the four strategies. The LCOE, CO_2 emission, and NPC are the lowest for LF as 0.04 \$/kW, 16.8 M\$, and 0.4 kt/year respectively. On the other hand, NPC CO_2 emission, and LCOE, are the highest for GO as 0.08 \$/kW, 29.5 M\$, and 0.76 kt/year respectively.

II. Power system performance and reliability assessment

Fig. 10 shows the reliability index for the designed microgrid to illustrate the reliability condition as well as to show the comparison among all the dispatch techniques. From the comparison, the load following (LF) strategy can be declared as the best among others based on system reliability.

In Figs. 11 to 13, the frequency response for the steady-state condition for wind turbine module, diesel generator module, and PV module for all four dispatch strategies for 0 to 2 s is shown respectively which is expressed in the p.u. system. A three-phase short circuit fault has been implemented in the network to observe the changes of the frequency in the network from 0.1 to 0.3 s. That is why at 0.3 s the frequency response deviated and fallen from 1 to 0.98 but it was recovered on the next second by injecting an extra active power.

According to the comparison of all frequency responses from the PV, wind, and diesel generator for the four dispatch strategies it can be observed that under LF dispatch strategies for all the modules the frequency response stabilizes in a faster time than others.

The active powers from the wind turbine, diesel generator, and PV according to four dispatch techniques are shown in Figs. 14 to 16. Due to the CC's operating concept, the active power response of the diesel generator for the CC is very different from the other three. For CC, the diesel generator normally charges the BESS, and additional generating modules subsequently provide the demand. PV and wind active power are the greatest among others in LF, indicating that the system's maximum power comes from renewable resources rather than a diesel generator. There is a 3-φ short circuit fault introduced in the network to observe the changes of the frequency in the network from 0.1 to 0.3 s. That is why at 0.1 to 0.3 s the active power response deviated and fallen down from 1 to nearly 0 but it was recovered on the next second just before 0.4 s by injecting an extra active power.

According to the scheduled and dedicated load demand, the required energy can be covered by renewable generation as the solar and wind resources are strong and feasible enough to produce enough power to supply.

The voltage magnitude responses for Wind turbine, Diesel Generator, and PV module for all four dispatch strategies are shown in Figs. 17 to 19 respectively. The voltage response for the BESS module is nearly null as the renewable generation is producing enough active reactive power input into the system to keep the stability of the system and ensure operational flexibility. According to the comparative studies among all the cases, dispatch strategies for all three modules (PV, wind and diesel generator) it can be observed that the voltage started falling at 0.15 s as the 3-φ short circuit fault was introduced then at 0.3 s it started rising and stabilized. But in most of the cases under the LF dispatch strategy, the stabilization of the voltage was smoother than the other three dispatch strategies.

A three-phase short circuit fault has been introduced in the network to monitor variations in the network's frequency from 0.1 to 0.3 s. As a result, the voltage response diverged from 1 to nearly 0 between 0.1 and 0.3 s, but it was recovered the next second, just before 0.4 s, by injecting extra active power. The system frequency is set to 1p.u., and a comparison of several dispatch mechanisms has been carried out. According to the load deviations, the overall system frequency has been kept within the range. However, the authors primary objective for this study was to present a comparative analysis of different dispatch algorithms for individual generators such as wind, diesel, and PV. Because there is a three-phase short circuit defect in the network, it has been developed to monitor the frequency variations in the network from 0.1 to 0.3 s. As a result, the frequency response diverged and fell from 1 to 0.98 at 0.3 s, but it was regained the next second by injecting additional active power. When a three-phase short circuit problem is implemented in the network, it's critical to keep track of the bus-to-bus frequency between generators and loads to ensure that the system frequency stays within the acceptable range. The active power responses of all generators

according to the four dispatch strategies show that the voltage variations in the LF and CC strategies are mitigated in a shorter period than the other two. The three-phase short circuit problem had a significant impact on CD and GO since the generator order is determined by the availability and greatest renewable resource from a list of options, with CD selecting a combination of GO and CC while the GO step is repeated most of the time.

III. System Comparison

The comparative analysis among the designed islanded microgrid and other researchers' works have been articulated in Tables 3 And 4. The comparison tables demonstrate the differences between designed offgrid microgrid and other HRES where it can be observed that the CO_2 emission has been decreased by 99%, NPC reduced by 88%, COE reduced by 92% and the operating cost reduced by 99%. On the other hand, in comparison to conventional power sources the CO_2 emission has been decreased by 99%, NPC reduced by 90%, and COE reduced by 40%. All these stats conclude the significance of the designed islanded microgrid with system stability and reliability.

Conclusion

In this research work, for optimal resource utilization and dependable operation, an off-grid hybrid microgrid comprising diesel generator, solar PV, battery storage devices, and wind turbine has been constructed. The load following (LF) strategy is the best dispatch strategy based on least NPC, LCOE, and CO_2 emersion, and the generator order (GO) methodology is the worst dispatch strategy based on the highest NPC, LCOE, and CO_2 emissions, according to simulation results for various dispatch methods. The LF dispatch approach has the lowest LCOE, NPC, and CO_2 discharge at 0.04 \$/kW, 16.8 M\$, and 0.4 kt/year, respectively. The GO dispatch approach, on the other hand, has the highest LCOE, NPC, and CO_2 emission, with 0.08 \$/kW, 29.5 M\$, and 0.76 kt/year, respectively. This study presents the voltage, frequency, power performance, and reliability index of the simulated microgrid. According to the results of a comparison of dispatch techniques based on power system performance and reliability study, LF is referred the best in terms of system reliability and stability. The developed IHMS addresses three crucial criteria as techno-economic feasibility, system dependability, and system stability to assure a continuous power supply for a remote island such as Melville Island. This specifically built hybrid off-grid energy optimization model will be ideal for islanded and isolated areas.

CRediT authorship contribution statement

Sk.A. Shezan: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft. **Md. Fatin Ishraque:** Conceptualization, Data curation, Resources, Visualization, Investigation, Software, Data curation. **S.M. Muyeen:** Supervision, Funding acquisition, Visualization, Validation, Writing – review & editing. **S.M. Arifuzzaman:** Validation, Investigation, Data curation. **Liton Chandra Paul:** Validation, Investigation, Data curation. **Sajal K. Das:** Supervision, Investigation, Data curation. **Subrata K. Sarker:** Validation, Investigation, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecmx.2022.100192.

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