Performance of Fuel Cell and PV Integrated Hybrid DC/AC Microgrid Based on the Grey Wolf Optimization Algorithm

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Abstract. This paper presents performance of enhanced hybrid DC/AC microgrid system. Maximum active power possible to the utility grid can be delivered with renewable energy sources like PEMFC (proton exchange membrane fuel cells) and PV (photovoltaic systems). Mathematical modelling is used to characterize the MG system, which consists of a photovoltaic system, a PEMFC, and a power source inverter. In order to boost performance and improve PV module efficiency, GWO (grey wolf optimization) based on MPPT (maximum power point tracking) is proposed. A Digital PI controller is proposed to control the circuit in order to increase the PEMFC's efficiency. The direct-quadrature (dq) Axis control approach based on SRFT(synchronous reference frame theory) is used to control the suggested inverter. The performance of the MG system is evaluated under different loading and weather conditions. Based on the characteristics of fuel cells and solar panels, the results of MATLAB simulation demonstrate that the optimized MG system can generate and use active Power. The DC-bus voltage stabilization is accordingly better on the hybrid DC/AC Micro-Grid. Moreover, the MG's power output is enhanced via GWO tuning based on MPPT. It also produces respectable results to use GWO, which has a greater efficiency of 98.9% and an output current total harmonic distortion of 2.21%.

Keywords: grey wolf optimization · MPPT · PEM fuel cells · PV systems · direct-quadrature (dq) Axis control approach · synchronous reference frame theory

1 Introduction

The demand for renewable power is rising all over the globe. Numerous power companies are involved in power trading of the power market. New power flow techniques and creative network pricing models have been developed as a result of the distribution of power flow and network pricing gaining in importance. Demand Side Management, pricing, and the characteristics of different distribution load flow techniques have an effect on how well renewable energy is integrated into the actual distribution system. The electrical power network has been transformed into a trust worthy market in order

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to meet the demands of the most recent technological tendency [1]. In comparison to other sources like micro turbines and wind turbines which provide erratic AC output energy, hybrid microgrid power plants use the most RES (renewable energy sources) and DG (distributed generation units) such as photovoltaic (PV)/fuel cells (FC), in turn generate DC power o/p (output) directly [2–4]. With either method, connecting a DG to DC system network is usually simple, quick, and affordable. In addition, the energy storage device can be combined without the use of a converter (ESS). Many customers currently use modern electronics and DC-powered gadgets that are fed by energy tools with an AC-DC power converter. Additionally, the DC-based atmosphere is intended to be a simple and highly effective method of supplying energy to these loads [5–8]. Therefore, appropriate minimization techniques should be used to enhance the electrical system's power quality [9]. In comparison to other systems like PV cells or wind, the fuel cell type of PEM fuel cells is portrayed as a promising better efficiency, free, and renewable energy source [10]. Because it is thought of as an electrochemical source that transforms a specific molecular energy into electricity, the PEMFC is a static instrument [11, 12]. The only waste products when the FC is made of purified hydrogen are heat and water. According to a trustworthy [13], it is the most alluring source that can be discovered anywhere and is not limited by location or temperature. A PI (proportional-integral) controller has been used to regulate this source in order to keep the o/p voltage of the DC-to-DC boost-converter that is integrated with its o/p [14]. PV modules or arrays have grown to be one of the most common in recent years due to their affordable building costs and minimal working space requirements [15]. The PV modules or arrays must be run at their MPP (maximum power point to provide the necessary energy to the grid (or) load (MPP)). An MPPT Technique is performed to maximize electricity & consequently enhance overall system efficiency. This system is constructed using DC-DC converters that have an appropriate MPPT algorithm [16]. Artificial intelligence (AI), incremental conductance (IC), perturb and observe (P&O) and MPPT algorithms based on optimization are some of the MPPT methods or algorithms that have been investigated. Traditional MPPT methods, however, have a number of drawbacks, such as oscillation, power losses, and sluggish tracking rates [17–19].

On the other hand, due to their adaptability and controllability, power electronic interfaces are used to connect a significant portion of loads in common electrical distribution networks. As a result, they frequently reveal an irregular behaviour and introduce some harmonics into the electrical power system. As a result, these harmonic distortions may cause the electricity quality to degrade [20, 21].

The best control strategies for both PV and FC cells are proposed in this article as a PV/FC microgrid system to provide active power to the MG. Using the GWO based MPPT, the photovoltaic system was optimized, the power output was raised, and the PQ (power quality) of the MG was then upgraded. The research's main proposed contributions are as follows: A solid management strategy can be developed to ensure high PQ for the microgrid fueled by PV/PEMFC cells by modelling microgrid parameters [22]. This article has the following format. Section 2 introduces the MG's management strategies. Section 3 presents the results, while Sect. 4 presents the research's analysis and implications.

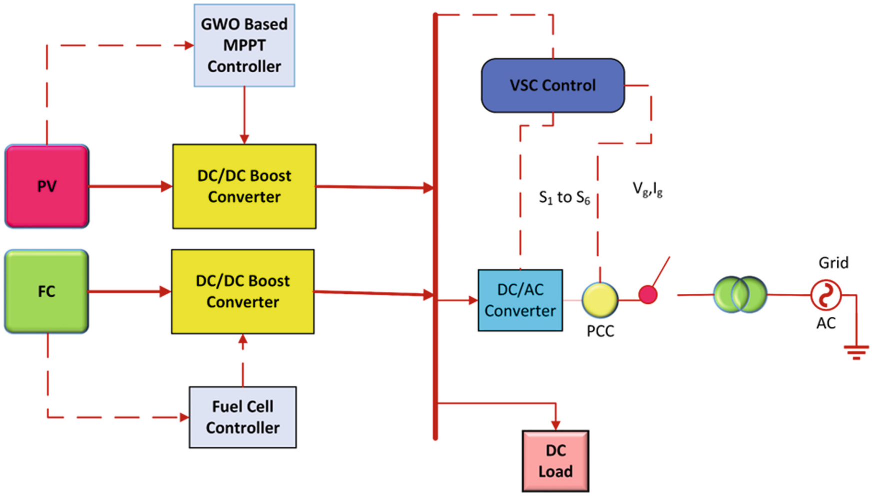

Fig. 1. Proposed hybrid Microgrid (DC/AC).

2 Control Schemes of the Proposed System

The designed system that was looked at for this research is shown in Fig. 1. The VSI, which implements at the side of AC power that suggested by system & provides the necessary o/p power at the grid, and the PV/FC sources, which stand in for the DC power side, are its main components. However, the utility grid and the DC/AC converter's voltage and frequency must be synchronized simultaneously in order to infuse the active power in DC. As a consequence, the dq Axis control technique is used to synchronize and control the VSI in AC bus. The PV & PEMFC sources both have not linear characteristics when it comes to producing energy. For both sources, a suitable control approach is therefore required. The management techniques employed in this research to control & enhance the PV cells and PEMFCs are discussed below.

3 GWO Optimizer Based MPPT Controller

To enhance the efficiency and effectiveness PV system, the boost DC to DC converter should be used in addition to the MPPT controller. However, the loss-of-power and oscillation issues with the traditional MPPT methods used in recent years have decreased the PV system's efficiency. Therefore, MPPT-based optimization, particularly the GWO optimization technique, is the best remedy for these problems. With this optimization, the PV system's effectiveness and efficacy will increase in all kinds of weather. The GWO optimization mimics the natural command structure and hunting strategy of grey wolves. The location of their search is a suitable technique for the grey wolves, who do not view it as random. According to Fig. 2, there are four different kinds of wolves: alpha, beta, delta, and omega wolves. These titles are used to mimic the hierarchy of authority. The following mathematical study can be used to examine how these grey wolves are hunted:

This **encircling** process can be achieved by using the following expressions:

$$\overline{D} = \left|\overline{C} \cdot \overline{X_p}(t) - \overline{X}(t)\right| \tag{1}$$

$$\overline{X_p}(t+1) = \overline{Xp}(t) - \overline{A} \cdot \overline{D} \tag{2}$$

where $\overline{X_p}(t)$ is the prey position vector

t is the current iteration.

$\overline{A}$ and $\overline{C}$ are coefficient vectors

the values $\overline{A}$ and $\overline{C}$ are given by

$$\begin{cases} \overrightarrow{A} = 2.\overrightarrow{a}.\overrightarrow{r_1} - \overrightarrow{a} \\ \overrightarrow{C} = 2.\overrightarrow{r_2} \end{cases} \tag{3}$$

where $\overrightarrow{r_1}$ and $\overrightarrow{r_2}$ are random vector in between 0 to 1

'a' linearly varies from 2 to 0.

GWO technique selects three best results and saves the data and the remaining search agents adjust their positions with respect to best values. In GWO algorithm, the wolf population is classified into four levels: α, β, δ, and ω. The top three best values (α, β, δ) changes their positions dynamically in a two-dimensional space are shown in Fig. 2.

Incorporate the best three results so far and make the calculations as per the following expressions are proposed in this regard.

$$\overrightarrow{D_\alpha} = \left|\overrightarrow{C_1}.\overrightarrow{X_\alpha} - \vec{X}\right| \tag{4}$$

$$\overrightarrow{D_\beta} = \left|\overrightarrow{C_2}.\overrightarrow{X_\beta} - \vec{X}\right| \tag{5}$$

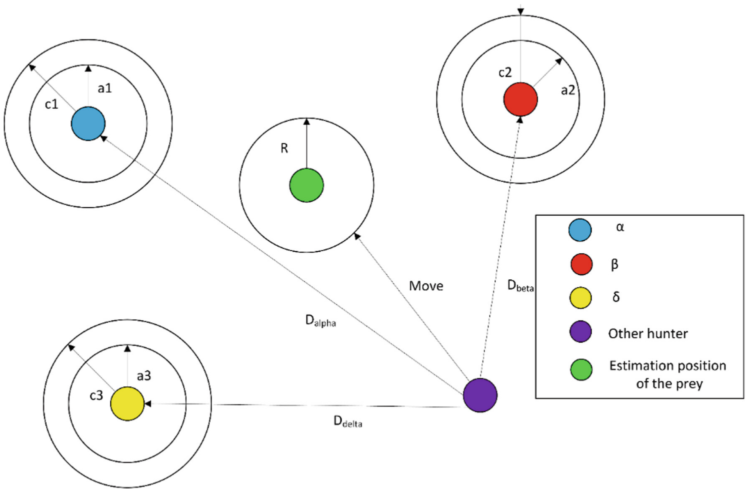

Fig. 2. Position updating in GWO

$$\overrightarrow{D_\delta} = \left|\overrightarrow{C_3}.\overrightarrow{X_\delta} - \vec{X}\right| \quad (6)$$

$$\overrightarrow{X_1} = \overrightarrow{X_\alpha} - \overrightarrow{A_1}(\overrightarrow{D_\alpha}) \quad (7)$$

$$\overrightarrow{X_2} = \overrightarrow{X_\beta} - \overrightarrow{A_2}(\overrightarrow{D_\beta}) \quad (8)$$

$$\overrightarrow{X_3} = \overrightarrow{X_\delta} - \overrightarrow{A_1}(\overrightarrow{D_\delta}) \quad (9)$$

$$\overrightarrow{X}(iter + 1) = \frac{\overrightarrow{X_1} + \overrightarrow{X_2} + \overrightarrow{X_3}}{3} \quad (10)$$

Using the above equations, a search agent randomly changes its position in a dimensional space nearby α, β, δ. The values of Coefficient vectors A and C can be changes as the range of $\overrightarrow{C}$ is 2 $\overrightarrow{C} \leq 0$, and when $\overrightarrow{C} > 1$, the result will be exploration. When $\overrightarrow{C} < 1$ and $\overrightarrow{A}$ value linearly decreases which results in exploitation. The GWO's performance has been improved using different techniques and arrives at the best solution.

4 Results and Discussion

The performance of the system for a step-change rate of DC load verifies the efficacy of the entire MG system. The suggested inverter supplies active power for grid with a great-power factor because of in phase voltage and current.

The effectiveness of the MG system is confirmed by doing simulation to the step-change at DC load. But because the in-phase current & voltage, the recommended inverter delivers high-power factor based real power to the grid.

Figure 3 displays the active and reactive power i.e., provided to the utility by PV and FC sources.

The outcomes of the actual electricity from sources, load, and grid are shown in Fig. 4. As can be seen, the reduction in power injected into the grid at this point is

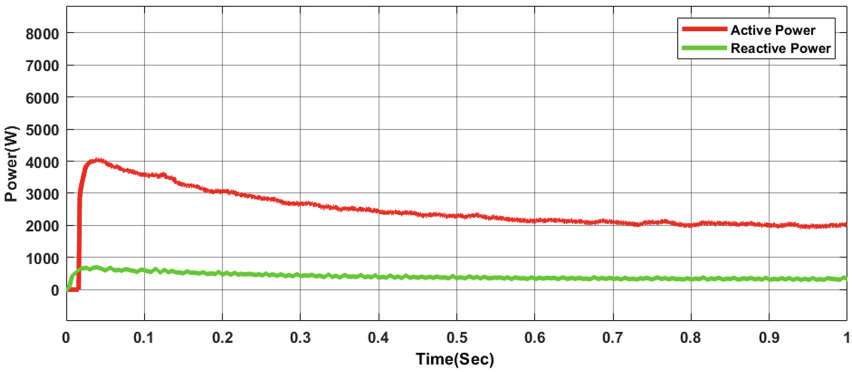

Fig. 3. 3-Ø active and reactive power delivered to the MG.

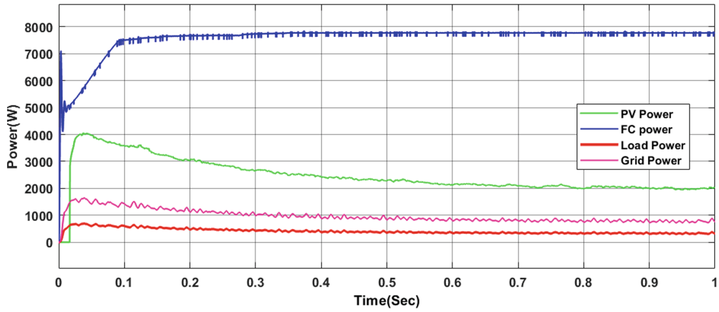

Fig. 4. The power delivered to MG system for a step-change in DC load.

brought on by the rise in DC load consumption. PV-generated power is 3 kW and 8 kW is the power of the FC system and 16 kW is the total operational power of the MG's.

The 3-level output voltage of the VSI inverter's steady-state results are shown in Fig. 5. It is predicted that this inverter will inject active power into the grid with a THD of 2.21%. The voltage profile of inverter under steady state is clearly smooth without disturbances.

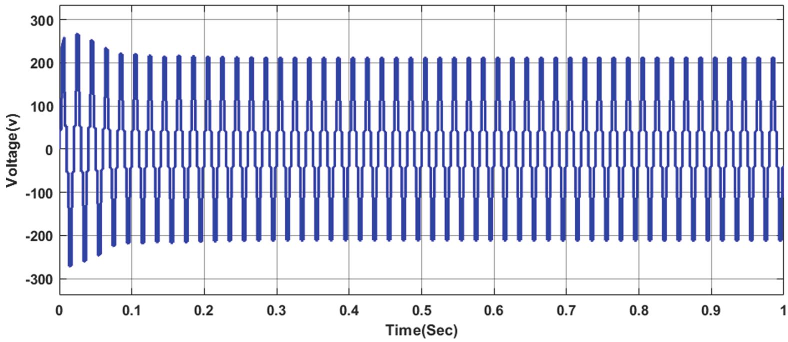

Fig. 5. Results for the inverter circuit under Steady-state.

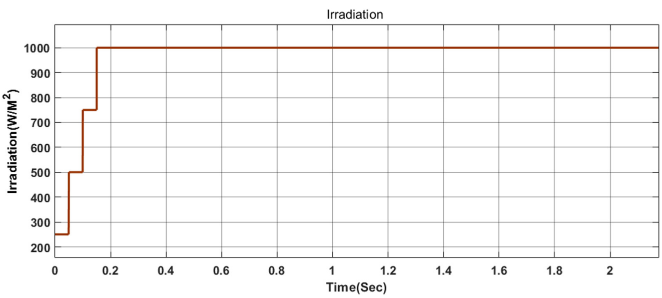

Fig. 6. Proposed solar irradiance profile.

According to Fig. 6, the suggested performance of MG system has been verified for the step change in irradiation. Additionally, the Photovoltaic system is managed by GWO optimization. As can be seen, the PV system's maximum power is thus accurately monitored. It is obvious that the GWO controller achieves optimum power under various irradiance values of 250, 500,750 and 1000 W/m_2.

As shown in Fig. 7, PV system Tracking is analyzed by using proposed GWO technique.

According to Fig. 8, MG system's power quality is enhanced by making use of the SRFT control approach with THD 2.21% (Table 1) for o/p current to stabilize the DC bus voltage.

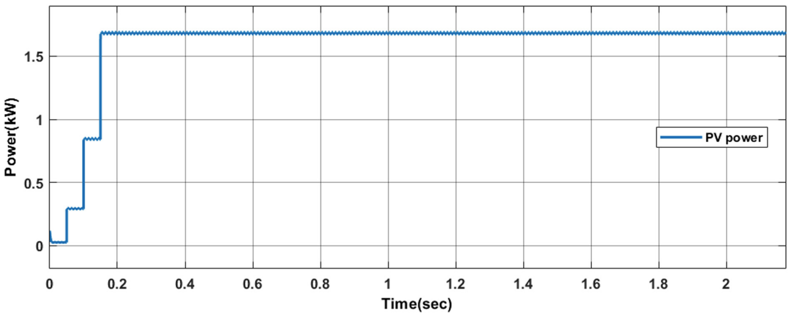

Fig. 7. PV power system Tracking with GWO optimization.

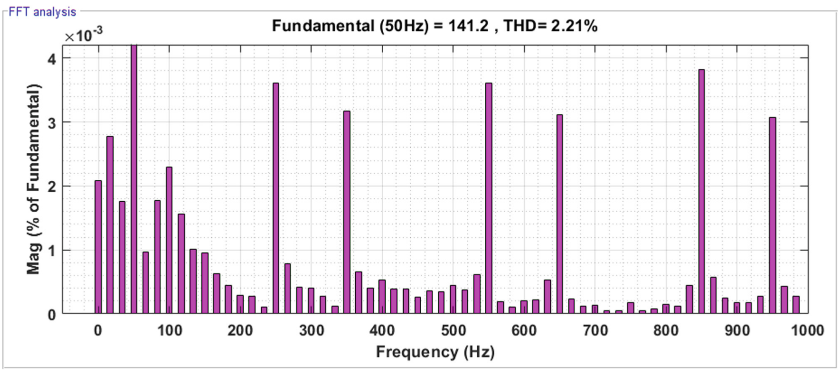

Fig. 8. FFT analysis for output Current

Table 1 Comparison between conventional MPPT and the Proposed GWO method

MPPT controllerfor Hybrid DC/AC Microgrid	Maximum Ripple Power (W)	Dynamic Response (SEC)	Efficiency (%)	THD of output current (%)
Conventional P&O	2950	0.45	96.9	5.6
Proposed Grey Wolf Optimization	1100	0.08	98.9	2.21

5 Conclusion

The PV/PEMFCs are utilised to supply active power to MG system. To provide improved performance of the MG system, FC/PV cells were used, especially for the PV system GWO algorithm is implemented. By implementing the GWO optimizer, dynamic efficiency of the PV system improves and minimises DC losses by this method. The electrical efficiency, is improved to 98.9% with proposed GWO optimization system and is more than conventional MPPT techniques. The MG system's power quality is enhanced by making use of the dq Axis control approach with THD = 2.21% for o/p current to stabilise the DC bus voltage.

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