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Maximization of the power delivered from permanent magnet synchronous generator wind energy conversion system to the grid based on using moth flame optimization

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ABSTRACT

In recent years, optimization techniques have been developed to improve accuracy and reduce execution time. The moth flame optimization (MFO) technique adapts to moth behavior. This design is based on the moth's transverse orientation. Over long distances, they maintain a fixed angle with respect to the moon at night. They spiral around the lights, however. Moths are trapped in a deadly spiral as the light approaches; eventually, they all converge on it. Furthermore, they are created by artificial light and fly similarly. To maximize the power delivered to the grid, moth flame optimization is used to optimize the controller parameters of the wind energy conversion system (WECS). A permanent magnet synchronous generator (PMSG) implements a grid-connected WECS a grid side converter (GSC) and a generator machine side converter (MSC) are used. A simulation package was used to model the proposed model. PSIM software was used to simulate power circuits and converters. Simulations were done in MATLAB. As a result, the obtained controller coefficients minimize both overshoot and steady-state error. Particle swarm optimization (PSO) and harmony search optimization (HSO) results were compared. MFO is a reliable method.

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1. INTRODUCTION

A renewable source of electrical power, wind power can be considered to provide a sustainable source of energy. Its advantage lies in its commercial potential. With the use of renewable energy sources increasing, it has been necessary to develop the integration of the grid and the use of inverters to control frequency, reactive/active power, and to provide grid voltage support [1], [2]. Control techniques have been applied to standalone and grid-connected wind energy coversion systems (WECS) [3], [4]. Machine controllers should be designed to maximize power conversion. Furthermore, grid operators should ensure that reactive power is delivered to the grid as well as active power [5], [6]. WECS utilizes a number of types of generators, including squirrel-cage induction generators, permanent magnet synchronous generators (PMSGs), double fed induction generators (DFIGs), high temperature superconducting synchronous generators (HTS-SGs), and wound rotor synchronous generators.

In order to maximize power extraction from variable speed wind turbines (VSWT), different control methodologies and converters have been implemented. Micro generators were installed, which consist of a wind turbine, an inverter and a generator. The turbines capture the energy and convert it into rotational mechanical energy. Variable speed turbines provide higher energy extraction than constant speed turbines [7]. The generator is responsible for converting mechanical energy into electricity. The benefits of VSWT are numerous, for instance, maximizing the extraction of energy, improving efficiency, increasing power quality, and maximizing power point operation [8], [9]. The use of a direct drive PMSG can improve system performance. This device may be considered as a market leader. It has the advantages of free maintenance due to the absence of brushes, the gearless WECS construction option, and the multi-pole design that provides slow speed operation. A number of reliable controllers have been developed to maximize the harvesting of wind energy [10]-[20], including hill-climb search (HCS), power signal feedback (PSF), and tip speed ratio (TSR). Wind turbine generators must have a variable speed in order to maximize power extraction from fluctuating winds. An inverter/generator control method was implemented. The system consists of two fully controlled 3-Φ converters, one for alternating current (AC)/direct current (DC) power conversion and the other for DC/AC power conversion for grid distribution. MFO [21] is a novel optimization technique that will be implemented to achieve the maximum power in comparison to harmony search optimization (HSO) and particle swarm optimization (PSO) [22], [23].

The paper is organized as follows: the system description is presented in section 1, and the mathematical model is presented in section 2. Section 3 describes the MFO technique. The results are presented in section 4. Section 5 provides the conclusions of the research.

2. SYSTEM DESCRIPTION

There are two controllers in the system. Specifically, one controller is located on the generator side converter in order to receive the maximum power from WECS as shown in Figure 1, while the other is located on the grid side inverter in order to transmit the energy. In this paper, four different optimization techniques are used to evaluate the performance of the controller in relation to various quantities. Several parameters must be considered, including power and average power (Po, Avg. (Po)), the wind turbine speed and mechanical torque (Nm, Tem), generator terminal current (Igen), and grid current (Ignd), and dc-link voltage (Vdc). This model consists of a wind turbine, a PMSG, a fully controlled rectifier, a DC link, a fully controlled inverter, and a transmission line to the grid. The PSIM pack simulation is used for the WECS response simulation. For the controller, MATLAB/Simulink was used along with the optimization algorithm simulation [24] as shown in Figure 2.

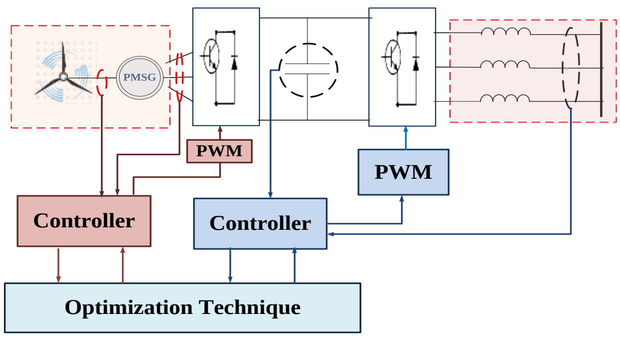

Figure 1. Illustrates Model

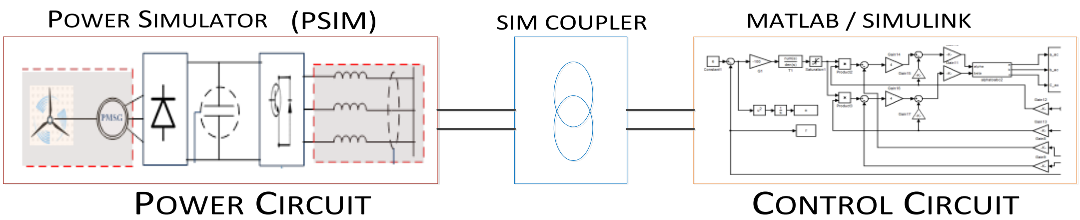

Figure 2. Illustrates model with simulated program

3. MATHEMATICAL MODEL OF WECS BASED ON PMSG

Presented in this section is a mathematical model for PMSG based on WECS. A wind energy conversion system consists of a wind turbine, a power management system, and a converter. In order to calculate the wind turbine power in (1) [25]: where wind power is, air density is, coefficient of performance is Cp, swept area is A, and wind speed is. The PMSG dynamic model can be expressed by (1) and (2):

$$P_t = \frac{1}{4}\rho A C_p v_w^3 \tag{1}$$

$$V_d = R_s i_d + \frac{d\lambda_d}{dt} - \omega_e \psi_q \tag{2}$$

$$V_q = R_s i_q + \frac{d\lambda_q}{dt} - \omega_e \psi_d \tag{3}$$

where, d–q axes stator voltage components are V_d and V_q, respectively, and the current components are i_d and i_q, respectively. The d–q stator linkage flux components are ψ_d and ψ_q, respectively. Electric angular rotor speed is ω_e (rad/s). Stator resistance is R_s.

The stator flux linkage components are:

$$\psi_d = L_d\, i_d + \psi_{Pm} \tag{4}$$

$$\psi_q = L_q\, i_q \tag{5}$$

where, the stator inductances of the d–q axes are L_d and L_q, respectively. The permanent magnet flux linkage is ψ_{Pm}.

Figure 3 depicts the relationship between the wind turbine speed of the generator (an independent parameter) and the power extracted from the generator (a dependent parameter), where the extracted power is affected by both mechanical and electrical factors. To clarify the relationship between the power extracted at various wind speeds, the parameters of this figure are set at constant values except for the wind speed. On the basis of the curve, the extracted power increased as the turbine speed increased until the maximum power point. After this, the power decreased as the turbine speed increased. The maximum power for each wind speed is different. Maximum tracking should be used when using PowerPoint.

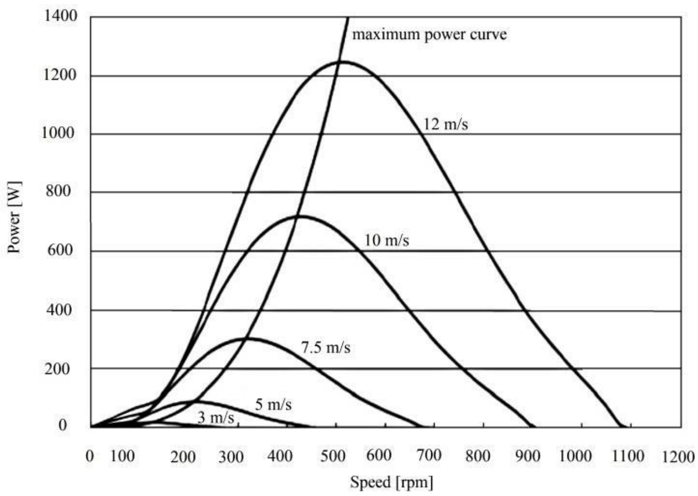

Figure 3. Speed power curve

4. MFO TECHNIQUE APPLIED

MFO is a nature-inspired technique that is based on the behavior of moths. A major source of inspiration for the design was the moth's transverse orientation. At night, they maintain a fixed angle relative to the moon, enabling them to cross long distances in a straight line. Nevertheless, they are typically observed flying in a spiral pattern around the lights. Furthermore, they are created by artificial light and fly in a similar manner. The moth is trapped in a fatal spiral if a light is too close to it. The moths reached toward the light in the end. The moths' behavior has been mathematically modeled to explain this process of optimization. In the algorithm, the variables are the positions of moths in space, and the solutions are those positions. Consequently, it is possible to travel in one, two, or three dimensions, as well as in overexcited dimensions, and to change the location vectors. Matrix representation of the moth set is as (6).

$$X = \begin{bmatrix} x_{1.1} & x_{1.2} & x_{1.3} & \cdots & x_{1.n} \\ x_{2.1} & x_{22} & \cdots & \cdots & x_{2.n} \\ \vdots & \ddots & \vdots & \vdots & \cdots \\ x_{n.1} & \cdots & \cdots & \cdots & x_{n.d} \end{bmatrix} \quad (6)$$

n: Number of mothes
d: Dimension (Variables)

For sorting the corresponding moths' objective values, the following array is assumed in (7).

$$OX = \begin{bmatrix} ox_1 \\ ox_2 \\ ox_3 \\ \vdots \\ ox_n \end{bmatrix} \quad (7)$$

Fitness value is the return value of each objective function. A position vector is passed to each objective function. A fitness value is assigned to the consistent moth. Flames also play an important role in the introduced technique. A matrix similar to this is presented in (8).

$$F = \begin{bmatrix} f_{1.1} & f_{1.2} & f_{1.3} & \cdots & f_{1.n} \\ f_{2.1} & f_{22} & \cdots & \cdots & f_{2.n} \\ \vdots & \ddots & \vdots & \vdots & \cdots \\ f_{n.1} & \cdots & \cdots & \cdots & f_{n.d} \end{bmatrix} \quad (8)$$

X and F arrays dimensions are equal. To sort the objective values of the flames, an array is assumed as shown in (9).

$$OF = \begin{bmatrix} of_1 \\ of_2 \\ of_3 \\ \vdots \\ of_n \end{bmatrix} \quad (9)$$

Flames and moths differ in the way they move between one another. As the moths move around the search space, flames have proved to be the most advantageous positions so far. It will be updated until a better solution is found, provided that the most suitable solution will not be dropped. MFO provides a three-tuple that is similar to the global optimum of the optimization problems, and is defined as (10).

$$MFO = (J, K, T) \quad (10)$$

Random population function is J. Its model is (11).

$$J: \emptyset \rightarrow \{X, OX\} \quad (11)$$

The function K represents the moth's movement within the search space. It is modeled by an X matrix, and the revenues are updated.

$$K: X \rightarrow X \quad (12)$$

T function continues true only when satisfying termination standard: $T: X\,\{true, false\}$
The ub_i and lb_i matrices express the ith variable upper and lower limits (13).

$$ub_i = [\, ub_1, ub_2, ub_3, \cdots . \cdots . ub_n] \quad (13)$$

$$lb_i = [\,lb_1, lb_2, lb_3, \cdots . \cdots . lb_n] \quad (14)$$

Initialization is followed by iterative running for the J function until the T function proceeds. According to the mathematical model, each position is efficient with respect to a flame by (15).

$$X_i = S\,(X_i\,, F_n) \quad (15)$$

X_i : indicating the i^{th} moth
F_n: The n^{th} flame is indicated
S: A logarithmic spiral function with the following definition

$$S\,(X_i\,, F_n) = D_i\,.\,e^{bt}\,.\cos(2\pi t) + F_n \quad (16)$$

where,
D_i: indicates the distance between the i-th moth and the n-th flame
b: A constant that defines the shape of the logarithmic spiral
t: a random number between [1, 1].
D: can be calculated as (17).

$$D_i = |F_n - X_i| \quad (17)$$

Thus, an ellipse is predicted in all directions around the flame, and the moth's next position would fall within this ellipse. Therefore, the search space can be exploited and explored with certainty. Figure 4 shows the algorithm flow diagram.

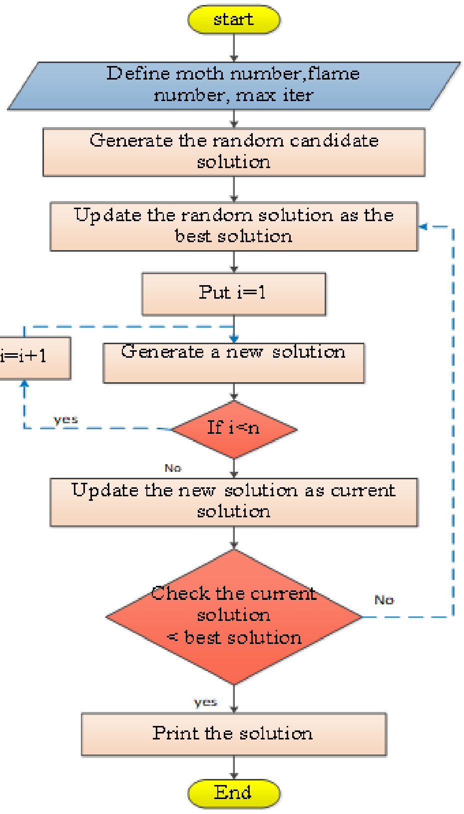

Figure 4. MFO Flow chart

5. SIMULATION RESULTS FOR THE PROPOSED TECHNIQUES

Simulink and PSIM simulations using a Rung Kutta fixed-step solver yield the best results when the sampling time is simulated at 5s and the total simulation time is 0.2s. PSIM was used to simulate the power circuit, while MATLAB/Simulink was used to simulate the optimization technique and the control system. A summary of the characteristics of the wind turbine is presented in Table 1 and a summary of the PMSG parameters is shown in Table 2. Three optimization algorithms were implemented and compared in order to determine the optimal controller parameters. As a result, grid-delivered power would be optimized. In order to determine the most appropriate method.

Table 1. Wind turbine characteristics

Parameter	Values
Input for blade pitch angle	0
Inertial moment power	1 kg.m2
Power nominal output wind	19 kW
Wind speed at base	12 m/s
Rotational speed at base	190 rpm

Table 2. PMSG parameters

Parameter	Values
L_q (q-axis inductance)	1 mH
L_d (d-axis inductance)	1 mH
Moment of inertia	100 kg m2
R_s (stator resistance)	1 Ω
P (Poles Number)	30

As shown in Figures 5, the simulation results for the system with a speed of 12 m/s are presented. The purpose of this study is to determine which technique is most effective. The following subfigures illustrate the system response: Figures 5(a) grid delivered power and its average; Figures 5(b) turbine torque and speed; Figures 5(c) 3-Φ generator current; Figures 5(d) 3-Φ grid current; and Figures 5(e) DC link voltage.

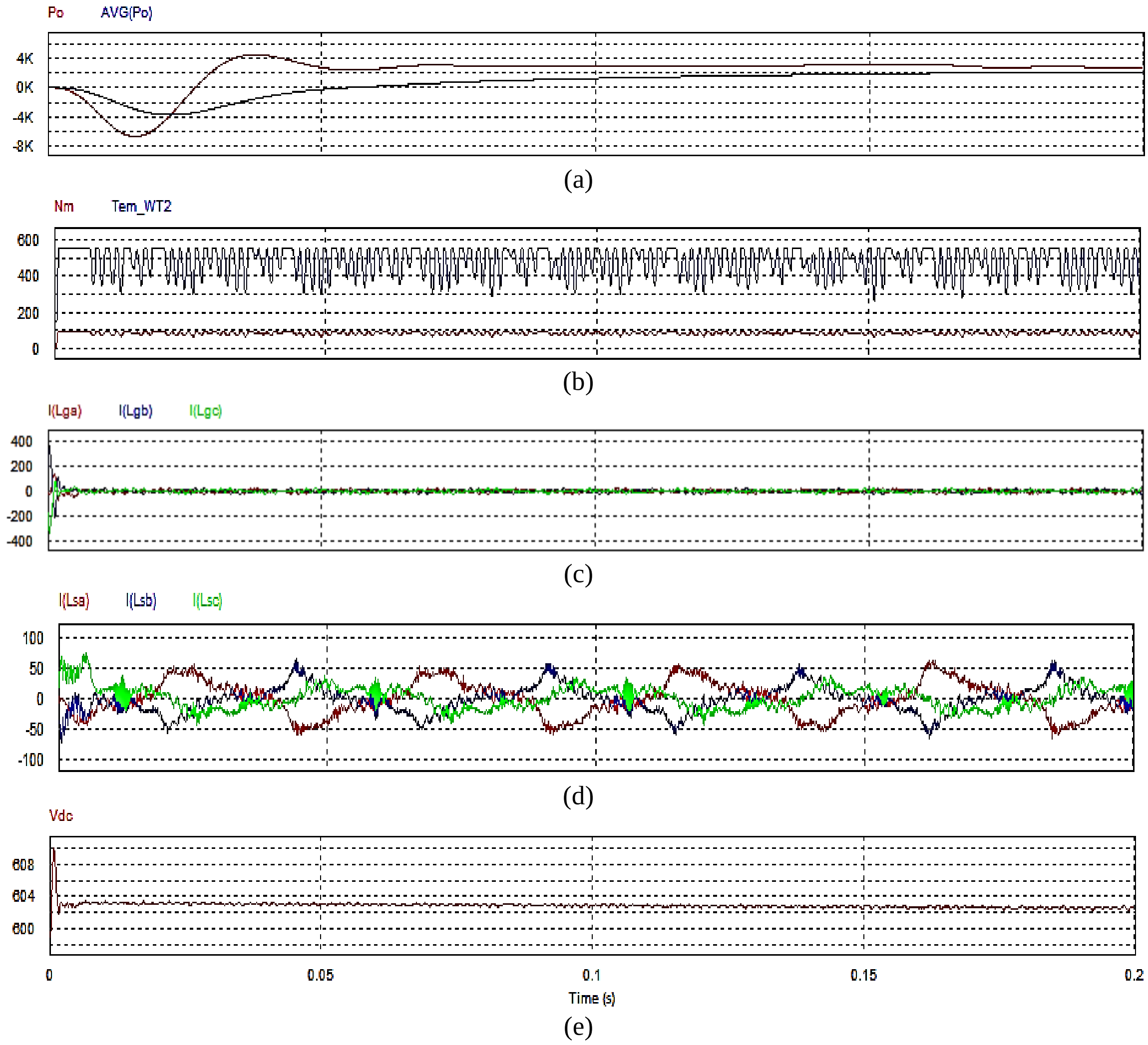

Figure 5. Results of the simulation for MFO (a) the grid delivered power and its average; (b) Torque and speed of the turbine; (c) 3-Φ generator current; (d) 3-Φ grid current; (e) A voltage of the DC link

As shown in Figures 6, the simulation results for the system with a speed of 12 m/s are presented. The purpose of this study is to determine which technique is most effective. The following subfigures illustrate the system response: Figure 6(a) grid delivered power and its average; Figure 6(b) turbine torque and speed; Figure 6(c) 3-Φ generator current; Figure 6(d) 3-Φ grid current; and Figure 6(e) DC link voltage.

As shown in Figures 7, the simulation results for the system with a speed of 12 m/s are presented. The following subfigures illustrate the system response: Figure 7(a) grid delivered power and its average; Figure 7(b) turbine torque and speed; Figure 7(c) 3-Φ generator current; Figure 7(d) 3-Φ grid current; and Figure 7(e) DC link voltage.

In Figure 8, three power curves are illustrated, namely the grid-delivered power curve and the DC-link voltage curve. The MFO response with the lowest maximum positive overshoot reached steady state the quickest. Figure 9 illustrates a comparison of the DC-link voltage between the three techniques.

It is noticeable that the system response with MFO remains stable at 605 V without change, resulting in an accurate output response. The results of the speed and torque of the turbine for the three techniques are similar with few changes as shown in Figures 10 and 11.

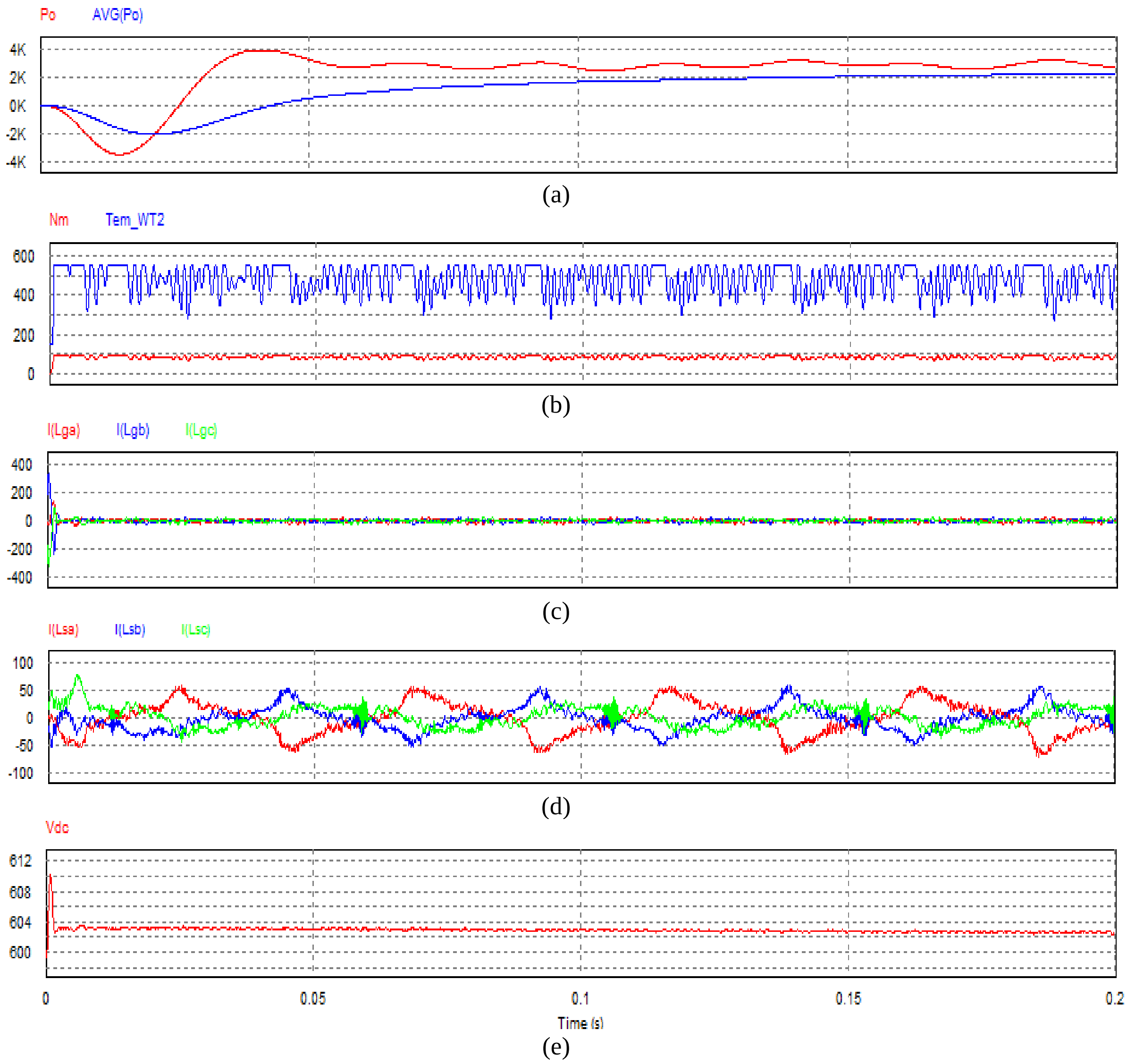

Figure 6. Results of the simulation for HSO (a) the grid delivered power and its average; (b) Torque and speed of the turbine; (c) 3-Φ generator current; (d) 3-Φ grid current; (e) A voltage of the DC link

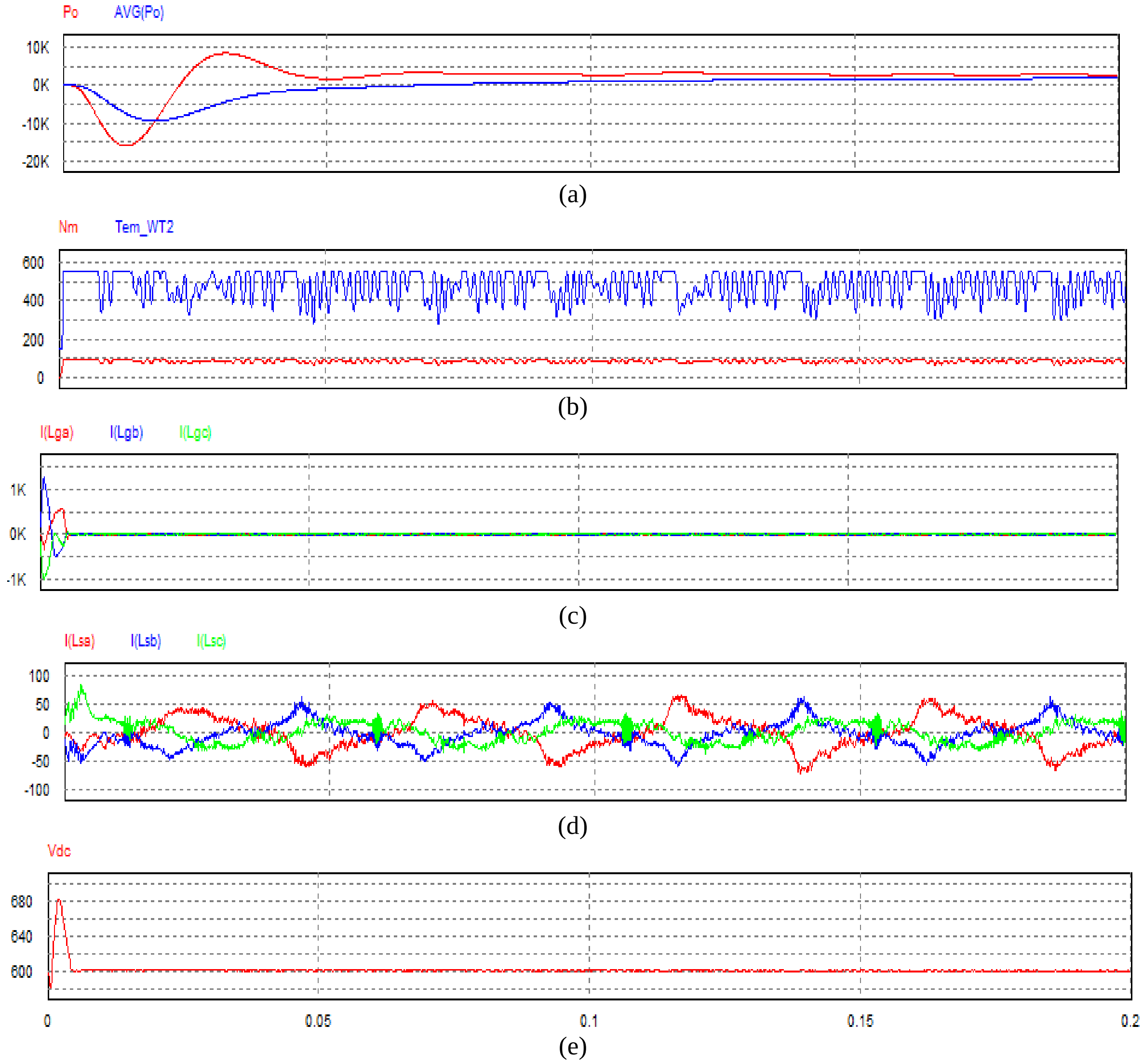

Figure 7. Results of the simulation for PSO (a) the grid delivered power and its average; (b) Torque and speed of the turbine; (c) 3-Φ generator current; (d) 3-Φ grid current; (e) A voltage of the DC link

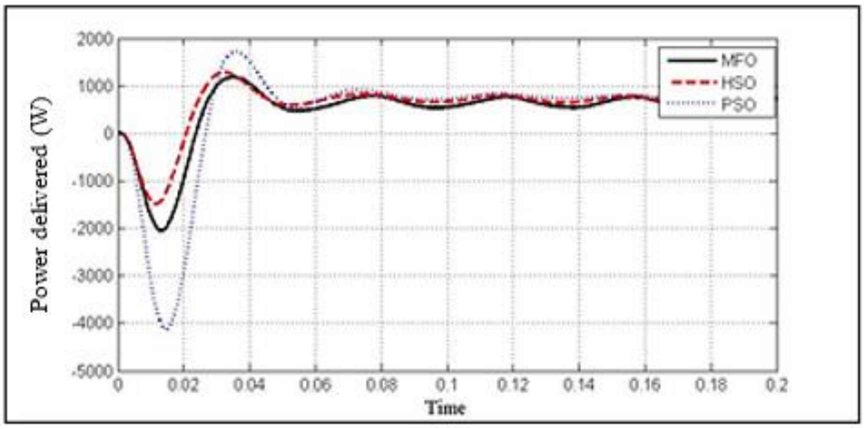

Figure 8. Grid power delivered for all three techniques

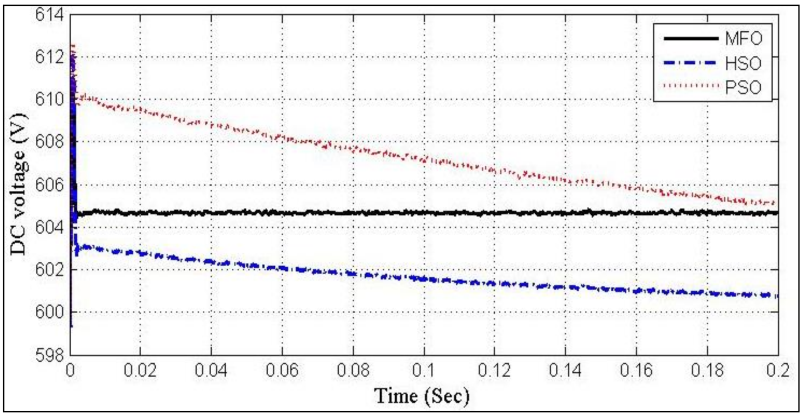

Figure 9. DC voltage of the DC link in the three techniques

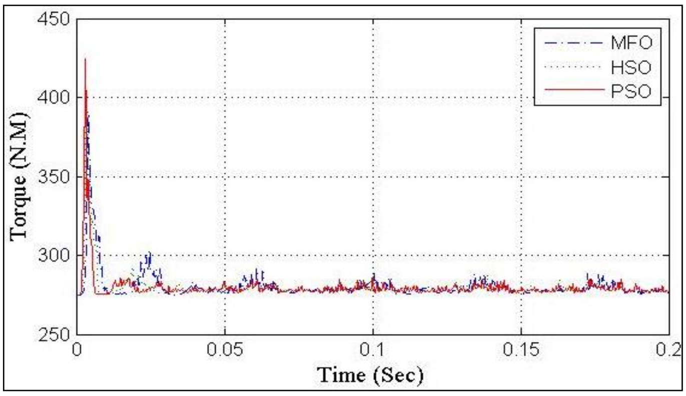

Figure 10. Wind turbine for the three techniques

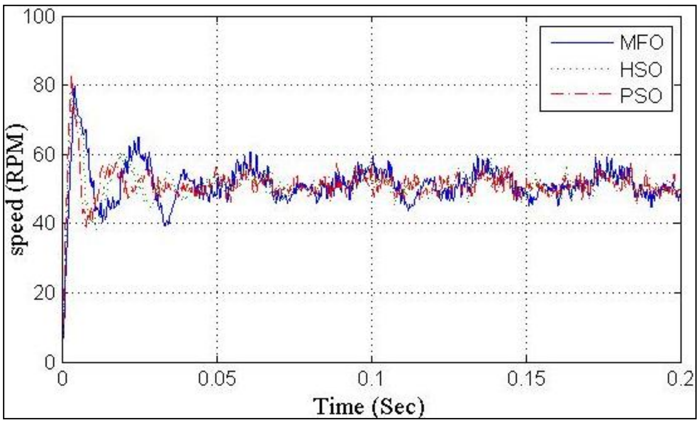

Figure 11. The wind turbine torque for the three techniques

6. CONCLUSIONS

A double controller that is used with the PMSG on WECS is optimized using the MFO technique in this paper. MATLAB/Simulink was used to simulate the controllers and three optimization techniques, and PSIM was used to simulate the converters and power circuits. A fully controlled generator side converter, a direct drive turbine without a gearbox, and a fully controlled inverter are included. The grid-side converter was controlled to enhance power quality, whereas the generator-side converter was controlled to maximize the amount of power extracted. Our research has compared the results of three optimization techniques in order to arrive at optimum controller parameters, namely MFO, HSO, and PSO. A MFO technique achieved optimal parameters that were more accurate than others, with an output power signal with minimal overshoot and a DC link voltage that was more stable. A double controller WECS combined with PMSG could be used with the MFO technique in order to maximize grid power delivery.

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REFERENCES

[1] S. Li, T. A. Haskew, R. P. Swatloski, and W. Gathings, "Optimal and direct-current vector control of direct-driven PMSG wind turbines," *IEEE Transactions on Power Electronics*, vol. 27, no. 5, pp. 2325–2337, May 2012, doi: 10.1109/TPEL.2011.2174254.

[2] J. Lagorse, M. G. Simoes, and A. Miraoui, "A multiagent fuzzy-logic-based energy management of hybrid systems," *IEEE Transactions on Industry Applications*, vol. 45, no. 6, pp. 2123–2129, 2009, doi: 10.1109/TIA.2009.2031786.

[3] X. Tan, Q. Li, and H. Wang, "Advances and trends of energy storage technology in Microgrid," *International Journal of Electrical Power and Energy Systems*, vol. 44, no. 1, pp. 179–191, Jan. 2013, doi: 10.1016/j.ijepes.2012.07.015.

[4] P. F. Ribeiro, B. K. Johnson, M. L. Crow, A. Arsoy, and Y. Liu, "Energy storage systems for advances power applications," *Proceedings of the IEEE*, vol. 89, no. 12, pp. 1744–1756, 2001, doi: 10.1109/5.975900.

[5] A. Chauhan and R. P. Saini, "A review on integrated renewable energy system based power generation for stand-alone applications: configurations, storage options, sizing methodologies and control," *Renewable and Sustainable Energy Reviews*, vol. 38, pp. 99–120, Oct. 2014, doi: 10.1016/j.rser.2014.05.079.

[6] C. N. Bhende, S. Mishra, and S. G. Malla, "Permanent magnet synchronous generator-based standalone wind energy supply system," *IEEE Transactions on Sustainable Energy*, vol. 2, no. 4, pp. 361–373, Oct. 2011, doi: 10.1109/TSTE.2011.2159253.

[7] K. Tan and S. Islam, "Optimum control strategies in energy conversion of PMSG wind turbine system without mechanical sensors," *IEEE Transactions on Energy Conversion*, vol. 19, no. 2, pp. 392–399, Jun. 2004, doi: 10.1109/TEC.2004.827038.

[8] M. E. Haque, M. Negnevitsky, and K. M. Muttaqi, "A novel control strategy for a variable-speed wind turbine with a permanent-magnet synchronous generator," *IEEE Transactions on Industry Applications*, vol. 46, no. 1, pp. 331–339, 2010, doi: 10.1109/TIA.2009.2036550.

[9] D. Vinnikov, L. Bisenieks, and I. Galkin, "New isolated interface converter for PMSG based variable speed wind turbines," *Przeglad Elektrotechniczny*, vol. 88, no. 1 A, 2012.

[10] T. Thiringer and J. Linders, "Control by variable rotor speed of a fixed-pitch wind turbine operating in a wide speed range," *IEEE Transactions on Energy Conversion*, vol. 8, no. 3, pp. 520–526, 1993, doi: 10.1109/60.257068.

[11] M. Ermiş, H. B. Ertan, E. Akpmar, and F. Ülgüt, "Autonomous wind energy conversion system with a simple controller for maximum-power transfer," *IEE Proceedings B: Electric Power Applications*, vol. 139, no. 5, pp. 421–428, 1992, doi: 10.1049/ip-b.1992.0052.

[12] R. Chedid, F. Mrad, and M. Basma, "Intelligent control of a class of wind energy conversion systems," *IEEE Transactions on Energy Conversion*, vol. 14, no. 4, pp. 1597–1604, 1999, doi: 10.1109/60.815111.

[13] J. H. R. Enslin and J. D. Van Wyk, "A study of a wind power converter with micro-computer based maximal power control utilising an over-synchronous electronic scherbius cascade," *Renewable Energ*y, vol. 2, no. 6, pp. 551–562, Dec. 1992, doi: 10.1016/0960-1481(92)90018-X.

[14] Q. Wang and L. Chang, "An intelligent maximum power extraction algorithm for inverter-based variable speed wind turbine systems," *IEEE Transactions on Power Electronics*, vol. 19, no. 5, pp. 1242–1249, Sep. 2004, doi: 10.1109/TPEL.2004.833459.

[15] M. A. Abdullah, A. H. M. Yatim, and C. W. Tan, "A study of maximum power point tracking algorithms for wind energy system," in *2011 IEEE 1st Conference on Clean Energy and Technology, CET 2011*, Jun. 2011, pp. 321–326, doi: 10.1109/CET.2011.6041484.

[16] A. B. Raju, B. G. Fernandes, and K. Chatterjee, "A UPF power conditioner with maximum power point tracker for grid connected variable speed wind energy conversion system," in *2004 1st International Conference on Power Electronics Systems and Applications Proceedings*, 2004, pp. 107–112.

[17] M. Beghdadi, K. Kouzi, and A. Ameur, "New Design of an optimized synergetic control by hybrid BFO-PSO for PMSG integrated in wind energy conversion system using variable step HCS fuzzy MPPT," in *Lecture Notes in Networks and Systems*, vol. 102, 2020, pp. 30–40, doi: 10.1007/978-3-030-37207-1_4.

[18] M. H. Qais, H. M. Hasanien, and S. Alghuwainem, "Enhanced whale optimization algorithm for maximum power point tracking of variable-speed wind generators," Applied Soft Computing, vol. 86, p. 105937, Jan. 2020, doi: 10.1016/j.asoc.2019.105937.

[19] M. Z. Mohd Tumari, M. H. Suid, and M. A. Ahmad, "A modified grey wolf optimizer for improving wind plant energy production," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 18, no. 3, pp. 1123–1129, Jun. 2020, doi: 10.11591/ijeecs.v18.i3.pp1123-1129.

[20] A. H. Shimaa, M. A. Deab, and N. S. Hosny, "Improving the delivered power quality from WECS to the grid based on PMSG control model," *International Journal of Electrical and Computer Engineering*, vol. 10, no. 6, pp. 6349–6360, Dec. 2020, doi: 10.11591/ijece.v10i6.pp6349-6360.

[21] S. Mirjalili, "Moth-flame optimization algorithm: A novel nature-inspired heuristic paradigm," Knowledge-Based Systems, vol. 89, pp. 228–249, Nov. 2015, doi: 10.1016/j.knosys.2015.07.006.

[22] I. M. Diaa, N. M. Badra, and M. A. Attia, "Harmony search and nonlinear programming based hybrid approach to enhance power system performance with wind penetration," *International Electrical Engineering Journal (IEEJ)*, pp. 2323–2330, 2016.
[23] M. A. Deab, F. M. A. Bendary, E. M. Said, and M. A. M. Hassan, "Optimizing control of wind energy conversion system using particale swarm optimization," in *2013 International Conference on Control, Decision and Information Technologies, CoDIT 2013*, May 2013, pp. 208–211, doi: 10.1109/CoDIT.2013.6689545.
[24] N. Singh and V. Agrawal, "A survey on power quality improvement converter of PMSG," in *IET Seminar Digest*, 2013, vol. 2013, no. 8, pp. 93–100, doi: 10.1049/ic.2013.0299.
[25] A. M. Eltamaly and H. M. Farh, "Maximum power extraction from wind energy system based on fuzzy logic control," *Electric Power Systems Research*, vol. 97, pp. 144–150, Apr. 2013, doi: 10.1016/j.epsr.2013.01.001.

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