International Journal of Advanced Science and Technology
Vol. 29, No. 6, (2020), pp. 6601 – 6615

An Elephant Herding Optimization Approach to Enhance the Performance of SEIG in Transient and Steady State

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Abstract

An Elephant Herding Optimization (EHO) is presented to enhance the performance of single phase Self Excited Induction Generator (SEIG) in steady and transient state. The parameters of single phase SEIG such as speed, frequency, impedance, total harmonic distortion and terminal voltage are optimized using proposed approach. The results are compared with Particle Swarm Optimization (PSO) and Firefly method (FM) using MATLAB. The results are more effective than existing approach.

Keywords: *EHO, SEIG, Transient and steady state.*

1. Introduction:

Usually in rural and remote areas, where the grid supply is not available, so SEIG play an important role in such inaccessible locations. In context of economy of country present energy scenario plays one of the vital roles. The SEIG is developed as the greatest electro-mechanical energy converter to exchange the traditional synchronous generator in recent years [1]. Less price, roughness, the lack of an individual DC source for excitation brushless rotor construction and easy maintenance are main benefits of the SEIG [2]. The induction machine can utilized as the generator is distributed requirement of reactive power is satisfied through capacitor links is called SEIG [3]. The SEIG is fitting for creating electricity from renewable sources mainly in inaccessible regions because the SEIG doesn't need a secondary power for generating the magnetic field [4, 5]. Single phase and three phases are required to generate a single phase and three phase electricity are mostly used in remote, hilly and rural areas [6, 7]. Three phase induction machines are ready to operate as SEIG if capacitance should have an adequate charge to provide initial magnetizing current [8, 9]. When induction motor is running with the prime mover, motor is producing an Electro-Motive-Force (EMF) via magnetism in stator windings frequency is corresponding to speed of the rotor [10, 11]. The current flow through the stator windings because the capacitor is connected to the terminals and EMF is induced in the terminal. In this way, the machine magnetizing flux is perceived [12]. Without consumption of the grid supply, in remote areas the induction motor is act as a generator. The working of the SEIG is depends on prime-mover speed, DC-link capacitor and loads an analysis are complicated. It suits for power system engineers and

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generation analysis involves precise and brief representation of SEIG [15, 16]. In recent years, the SEIG is presented about classification process, the value of unstable short-circuit experiment in valuing synchronous generator constraints [17, 18]. The response of steady-state analysis is eminent designed for protecting excellent power and measuring the arrangement for a specific appliance [19, 20]. In this work is planned an EHO algorithm for the steady and transient state analysis of two winding single-phase SEIG.

2. Problem formulation:

In this sector is considered the single-phase SEIG with the controlling structure for regulation of voltage and analysis of transient and steady state conditions. Single-phase two winding SEIG and shunt connected capacitor is illustrated in the figure1. Generally, the SEIG consists of the two windings which are main windings and auxiliary windings. The auxiliary capacitor C_{aux} is connected through auxiliary winding and main capacitor C_{main} is connected thru the main winding as well the load is joined parallel to the winding which is the main winding. The series capacitor and shunt capacitor is used in the circuit for controlling the demagnetizing effect because of loading and it provide the excitation current to produce the voltage are no load condition.

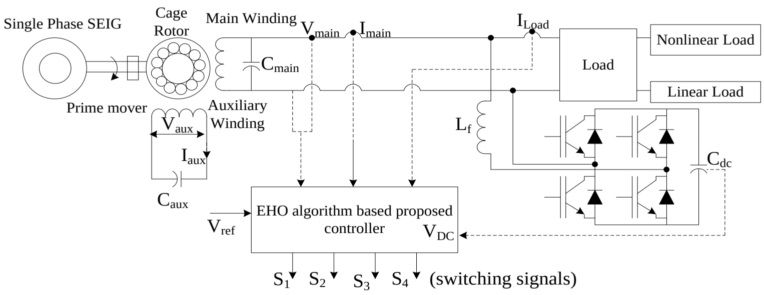

Figure.1: The configuration of the two winding Single-phase SEIG

The single-phase SEIG steady state is analyzed based on speed, capacitor and load variation which is illustrated in the figure 2 and explained the balanced constraints and enhancement above prior one model [28].

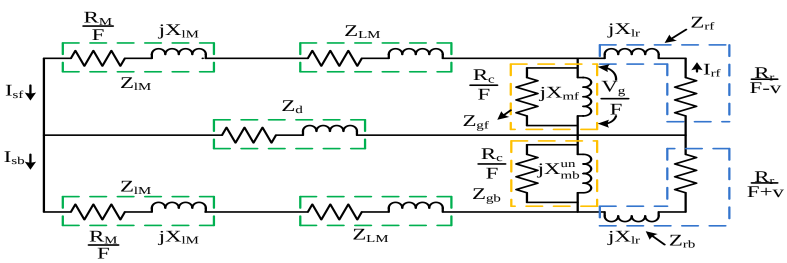

Figure.2: The equivalent circuit for single-phase SEIG in steady-state performance

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Generally, the impedance of the two winding single phase SEIG are computed between the main and auxiliary windings are Z_{LM} and Z_{LA}. The impedance of the auxiliary windings is represented in the equation (1)

$$Z_{LA} = -\left(\frac{jX_{cex}}{F^2}\right) \quad (1)$$

The main windings impedance is calculated based in the capacitor and load impedance which is described in the equation (2)

$$Z_{LM} = R_{LM}(F) + jX_{LM}(F) \quad (2)$$

Where, R_{LM} and X_{LM} are real and imaginary part of the main windings, F is the function of the main winding. The main winding impedance is described in the below equation (3)

$$Z_{LM} = \frac{R_L}{F} + jX_L - \left(\frac{jX_{Cse}}{F^2}\right) \quad (3)$$

Load impedance Z_L of the main winding is described in the below equation (4)

$$Z_L = \frac{R_L}{F} + jX_L \quad (4)$$

Now, R_L is labeled as leakage resistance. The unified equivalent circuit is based on the symmetrical component concepts is integrates the entire parameters, core loss and capacitors through no expectations. This circuit is standardized to initial frequency and each parameter is preferred to main winding turns. Then the parameters are given in followed equations (5) to (11),

$$Z_{1M} = \frac{R_M}{F} + jX_{1M} \quad (5)$$

$$Z_{sM} = Z_{1M} + Z_{LM} \quad (6)$$

$$Z_{sA} = \frac{R_A}{F} + jX_{1A} - \frac{jX_{Cex}}{F^2} \quad (7)$$

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$$Z_d = \left(\frac{Z_{sA} - Z_{sM}}{2}\right) \quad (8)$$

$$Z_f = \left(\frac{Z_{rf} Z_{gf}}{Z_{rf} + Z_{gf}}\right) \quad (9)$$

$$Z_b = \left(\frac{Z_{rb} Z_{gb}}{Z_{rb} + Z_{gb}}\right) \quad (10)$$

$$Z_{sb} = Z_{sM} + Z_b \quad (11)$$

The thevenin equivalent impedance Z_{eq} is given as equation (12),

$$Z_{eq} = Z_{sM} + \left(\frac{Z_{sb} Z_d}{Z_{sb} + Z_d}\right) \quad (12)$$

$$Z_t = Z_{eq} + Z_f \quad (13)$$

From the equivalent circuit,

$$I_{sf}(Z_t) = 0 \quad (14)$$

In self-excitation in steady state condition, I_{sf} cannot be zero and consequently $Z_t = 0$. In steady state operation, the unknown parameters are saturated magnetizing reactance X_m and per unit generated frequency F which is provide the speed, capacitance and load impedance. The unknown parameters are resolved by Newton-Raphson method. When compute the unknown parameters, voltage of air gap V_g based on magnetizing response between V_g and X_m is attained from the synchronous speed test for single phase SEIG system [29]. So, the measured output responses of the system are calculated using the corresponding circuit. The forward field current of the stator is calculated as equation (15),

$$I_{sf} = \frac{V_g}{(F\, Z_{eq})} \quad (15)$$

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And the backward field current of the stator is calculated as equation (16),

$$I_{sb} = \frac{I_{sf}\, Z_d}{(Z_{sM} + Z_b + Z_d)}$$
(16)

Main winding current is evaluated as equation (17),

$$I_M = I_{sf} + I_{sb}$$
(17)

Auxiliary winding current is defined as equation (18),

$$I_A = \frac{j(I_{sf} - I_{sb})}{a}$$
(18)

Now, α is represented as the turn's ratio $\left(\frac{N_A}{N_M}\right)$. Henceforth the voltage across the main winding is assessed as equation (19),

$$V_M = I_M Z_{LM}$$
(19)

The voltage across the auxiliary winding is defined as equation (20),

$$V_A = \frac{-(I_A\, jX_{Cex})}{F^2}$$
(20)

The load current I_L is equal to the I_M for series connection. And the terminal load voltage is calculated as equation (21),

$$V_L = I_L\left[\frac{R_L}{F} + jX_L\right]$$
(21)

Output power is calculated as equation (22),

$$P_L = |I_L|^2 R_L$$
(22)

The steady state and dynamic characteristics of single-phase SEIG is analyzed with the help of the EHO algorithm. The design of the SEIG is depends upon the equivalent circuit of the circuit loop impedance in SEIG. The objective

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of proposed EHO algorithm is reducing the circuit impedance of the single-phase SEIG generator to attain the frequency and unknown parameters.

2.1 **C**ontroller:

The system frequency of the SEIG with connected in a small hydro turbine is maintains stable by satisfied the below equation (23),

$$P_{mech} * \eta_{con} = P_{cons} + P_{dump}$$
(23)

Where, P_{mech} is the prime mover mechanical power, η_{con} is the conversion efficiency of the SEIG, P_{cons} is described as linear load power and P_{dump} is described as dump load power. For frequency regulation, the output power of SEIG or system frequency is taken as the feedback signal [30]. In this proposed controller, the power doesn't take as a feedback signal because the frequency is an input of the SEIG for generate the power; If power taken as a feedback signal, which is reducing efficiency of the frequency control loop. In same, the power is taken as feedback signal, the system frequency is maintains at constant based on the mechanical power supplied to the prime mover constant but it is not a possible in practice because changes of seasonal and geographical changes. In the circuit configuration, the dump load is designed with an IGBT switch which is connected with series connection of resistor. The switching pulse of the IGBT is calculated by the utilization of the EHO algorithm for frequency controller. The load is varied; the excess power is supplied to dumb load and also maintains the system frequency constant. Here, the tuning purpose, the PI controller is utilized. The frequency error is minimized with the help of the EHO algorithm. Initially, the load varying condition, the frequency error calculated based on the frequency (f) and reference (f^{ref}). Based on this, the error frequency $(f^{e})$is calculated. The error minimized with the help of the EHO algorithm by find the optimal switching pulses to the IGBT switch. The frequency error of n^{th} sampling moment is described in the below equation (24)

$$f^{e}(n) = f^{ref}(n) - f(n)$$
(24)

The output frequency of the controller for n^{th} sampling instant is described in the below equation (25)

$$V_f^{ref}(n) = V_f^{ref}(n-1) + K_p\{f^{e}(n) - f^{e}(n-1)\} + K_I f^{e}(n)$$
(25)

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Where, K_P and K_I are the proportional and integral gain parameters of the controller of PI. The PI controller is used to attain the stable system operation by the frequency controller. The PI controller output is generate the optimal pulses for maintain the frequency of the system. The optimal pulses are feed to the IGBT switch, for reduce the frequency error and maintain the system frequency. The switching pulses are providing to the IGBT switch by the way of PWM. The optimal tuning of PI controller is achieved with the help of the EHO algorithm. The switching pulse generation is based on the EHO algorithm is given in followed section.

2.2 Algorithm:

The EHO calculation is a swarm based heuristic calculation, which is used for finding the ideal control signal in the inquiry space. It is picked to abbreviate progressive perfect rules.

1. The elephant populace has joined as explicit inner circles and every family has a safe number of elephants. In the meekest strategy, every group has precisely equivalent and settled number of elephant substances.

2. A static amount of male elephants will holiday their family gathering and live singularly inaccessible far from the most noteworthy elephant amass at the lead of all generation.

3. The elephants in all tribe live respectively under the direction of a lady.

All in all, an matriarch in every tribe is the most established one and can be envisioned as the fittest elephant is particular in this family for the enhancement inconvenience. There are two administrators are utilizing decided grouping conduct of elephants, for example, clan updating operator and separating operator, the expressed strides of EHO are shown as pursues.

2.2.1 Clan updating operator:

As expressed previously, all elephant lives respectively in the initiative of a lady in every clan. Along these lines, each elephant in the group , its next position is moved by a female authority (matriarch). While part the nastiest qualities from the populace, the suitable qualities are updated utilizing the clan updating operator and worst values are disposed of. For the elephant j in the clan, it very well may be refreshed as condition (26),

$$x_{ci,j}^{new} = x_{ci,j} + \alpha \times \left(x_{ci}^{best} - x_{ci,j} \right) \times r \qquad (26)$$

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The recently updated and earlier area for the elephant in the family are marked as $x_{ci,j}^{new}$ and $x_{ci,j}$. . The scale factor $\alpha \in [0,1]$ administers the impact of matriarch on $x_{ci,j}$. The fittest elephant is discrete from the clan is x_{ci}^{best} by matriarch. It is a class of stochastic appropriation can intentionally advance the assortment of the populace in the propelled search space. As a current structure, even appropriation is utilized [31]. It ought to be pronounced the fittest elephant in every clan can't be successful. This condition for the fittest elephant can be updated as condition (27),

$$x_{ci,j}^{new} = \beta \times x_{ci}^{center} \tag{27}$$

The controlling component is the impact of the x_{ci}^{center} on $x_{ci,j}^{new}$. We can get another individual $x_{ci,j}^{new}$ is delivered by the information is gotten by every elephant people in the clan. The focal point of the clan c_i is d_i dimension can be assessed as condition (28),

$$x_{ci,d}^{center} = \frac{1}{n_{ci}} \times \sum_{j=1}^{n_{ci}} x_{ci,j,d} \tag{28}$$

The number of elephants in the clan c_i is represented as n_{ci} and the d^{th} elephant individual is $x_{ci,j,d}$.

2.2.2 Separating Operator:

The separating operator is utilized to part the most noticeably worst and fittest value. The most noticeably worst elephant is isolated from family by utilizing separating operator of EHO. In elephant cluster, male elephants will leave their family gathering and live single once achieve youthfulness. This separating procedure can be tried by separating operator once taking care of enhancement issues [32]. To advance the accessibility of the EHO procedure, let us accept the elephant people with the worst fitness will execute the separating operator at every age as showed in condition (29),

$$x_{ci}^{worst} = x_{min} + (x_{max} - x_{min} + 1) * rand \tag{29}$$

Here $x^{\max}$ and $x^{\min}$ are upper and lower bound of the position of elephant individual. The most exceedingly worst elephant individual in the clan is x_{ci}^{worst}.

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The stochastic appropriation and even dispersion in the range [0, 1] is utilized in the ongoing capacity.

2.3 Proposed EHO flow chart:

The flow chart of the proposed EHO calculation is appeared in figure 3.

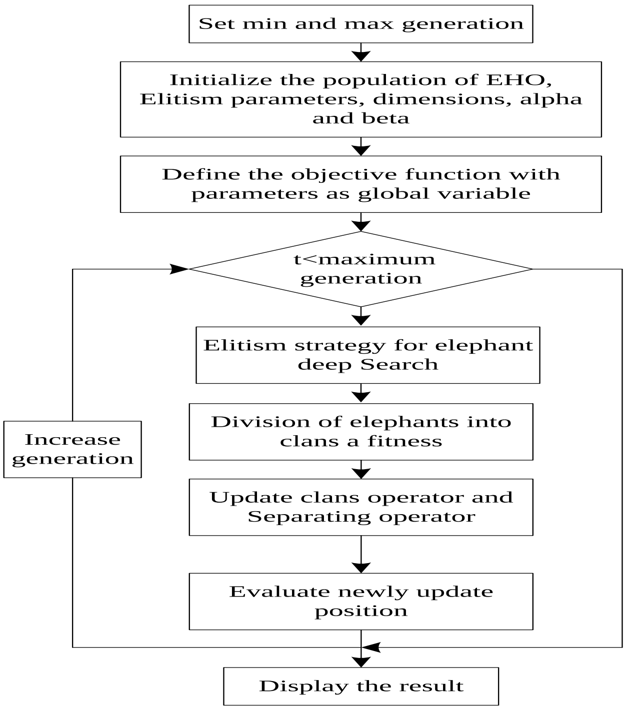

Figure.3: The flow diagram for the proposed EHO optimization

2.4 Elitism Strategy:

Alternative metaheuristic algorithm, a kind of elitism strategy is used as shielding the top elephant individuals from ruined by clan updating and separating operator. Initially, the best elephant individuals are locked and the worst ones are omitted and saved best elephant individuals at the end of the search process. This elitism strategy approves that the advanced elephant population is not constantly worse than the preceding one. The EHO algorithm is performed for tuning PID controller profits to minimize the system fitness function. Then, the application is executed with the support of MATLAB/Simulink and the result and arguments are reached in a monitored part.

3. Results and Discussion

The proposed system simulation model is exposed in figure 4. In table 1 is shown the implementation parameters of the proposed single phase two winding SEIG.

ISSN: 2005-4238 IJAST

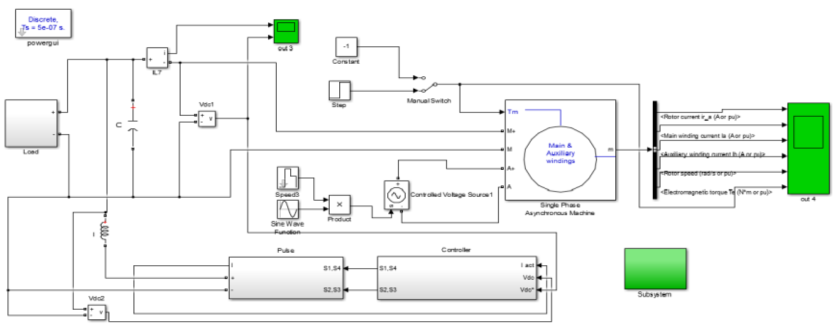

Figure.4: The simulation diagram of the proposed system

Table.1: Implementation parameters of the proposed two winding SEIG

Machine Parameters		
S.No	***Parameters***	***Values***
1.	Nominal power	3.7 kW
2.	Voltage	230V
3.	Pole pairs	4
4.	frequency	50Hz
5.	Main winding stator Rs	2.02ohm
6.	Main winding stator Lls	7.4mH
7.	Main winding rotor Rr	4.12ohm
8.	Main winding stator Llr	5.6 mH
9.	Auxiliary winding rotor Rs	7.14ohm
10	Auxiliary winding stator Lls	8.5 mH

Based on the SEIG performances are examined the steady state and dynamic response under variation of load and unbalanced input of the system. Thus, the estimated cases are

Case1: The steady-state response under varying load

Case2: The dynamic response under unbalanced input

Case1: The steady-state response under varying load

In steady-state response, the voltage regulation of SEIG stator is found utilizing the controller despite the presence of step changing of resistive load. Figure 5 displays the generator state voltage and current variation from the different resistive load (100 Ω) is simulated at t = 1sec and set the DC-link voltage 100 V.

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The output responses of the induction generator in the winding current variation are indicated in figure 6. The voltage magnitude of the stator and DC-link are completely traced from the input references. Next, the output response of the DC-link voltage and current is shown in figure 7.

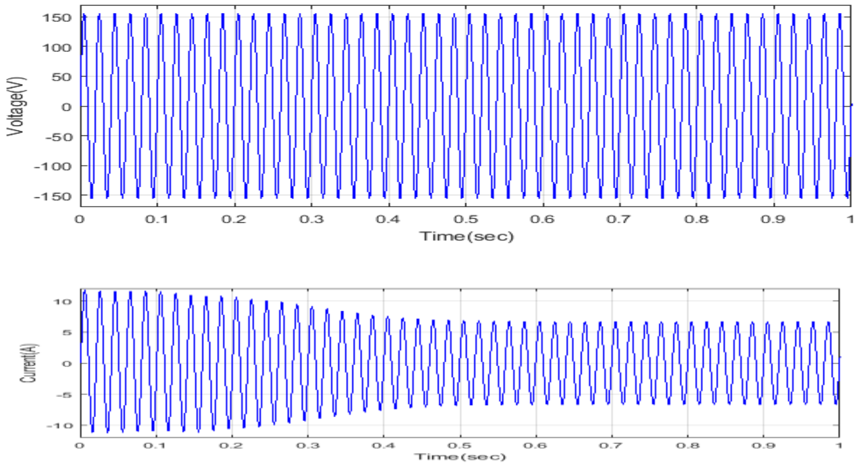


Figure.5: The dynamic response for the SEIG during startup voltage and current

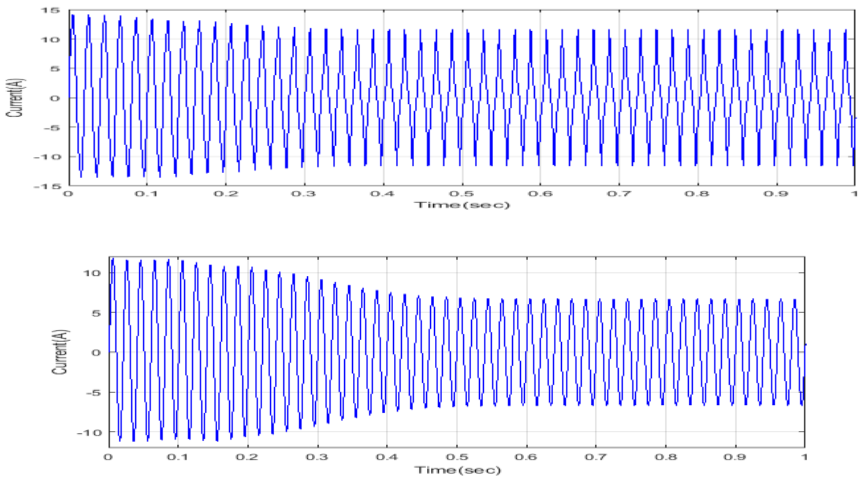
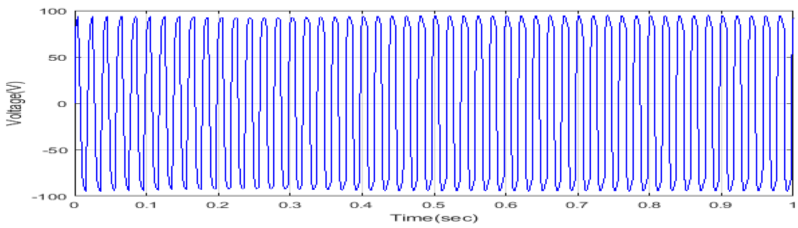


Figure.6: The steady-state response of main winding and auxiliary winding current of SEIG



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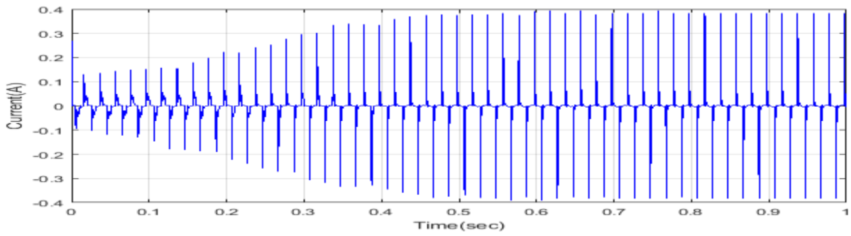

Figure.7: The response of the DC-link voltage and current

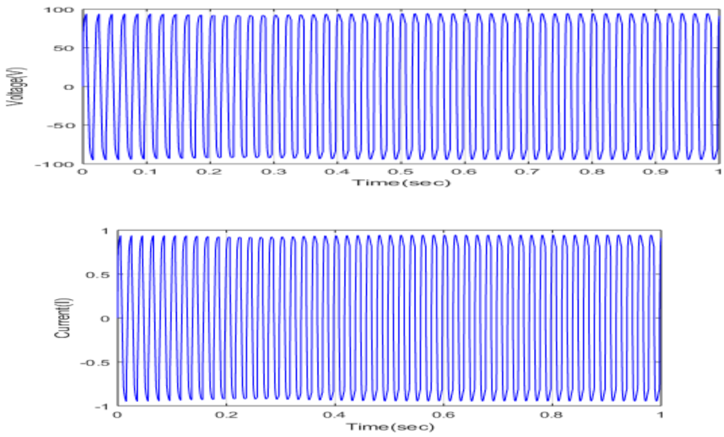

Figure.8: The steady-state response of the load voltage and current

In this case analysis, at the dynamic condition, the output voltage is maintained based on the reference voltage with the utilization of the proposed controller. The steady state analysis, the voltage and current waveforms are illustrated in the figure 8, which is simulated based on the load variation. The controller is analysis the change of the load voltages, when the load voltage is decreased that time it connected the capacitor across the SEIG. In this way the load voltage is restored at the reference value from the maximum capacity reactive power in the capacitor. The shunt-controlled capacitor value is defined from the SEIG terminal rated voltage at the rated load.

Case2: The dynamic response under unbalanced startup

The dynamic analysis of the proposed two winding SEIG under unbalanced startup is assessed in this case. Figure 9 demonstrates the simulated waveforms of the source voltage and current in unbalanced startup condition. The applications of loads are measured for the valuation of the dynamic response of the proposed controller. Figure 10 shows the dynamic performance of auxiliary and main winding current of the SEIG system. The DC-link voltage and current waveforms are expressed in figure 11.

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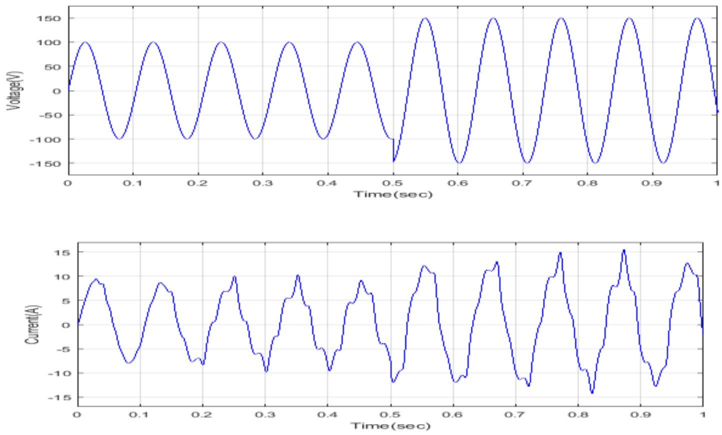


Figure.9: The dynamic response for unbalanced startup voltage and current

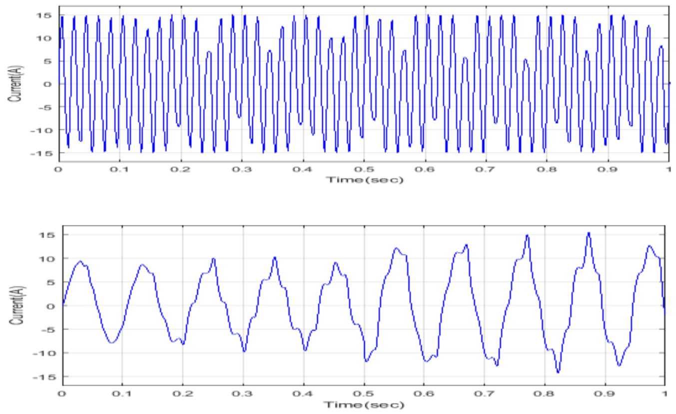


Figure.10: The dynamic response of main winding and auxiliary winding current of SEIG

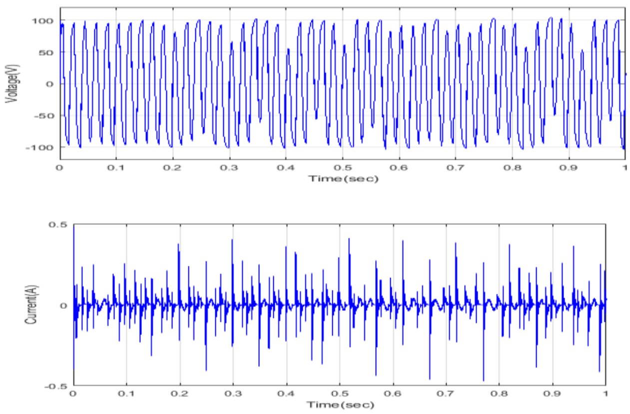
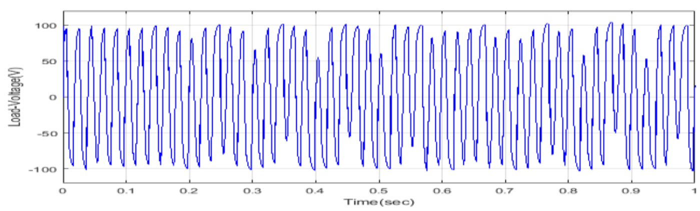


Figure.11: The analysis of the DC-link voltage and current



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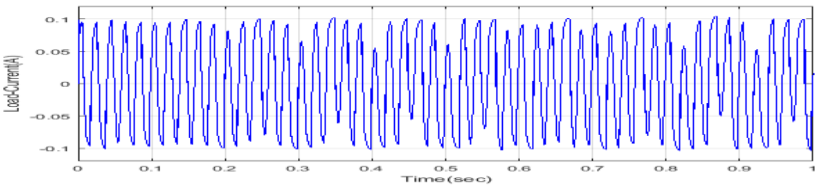

Figure.12: The output response of the load voltage and current

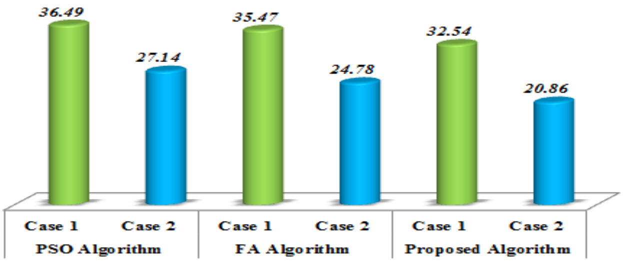

Figure.13: THD analysis of the presented techniques in both cases

The waveforms of single-phase two winding SEIG load current and voltage are displayed in figure 12 likewise the performance of the THD response is given in figure 13. Based on the replicated results, the load current THD is 20.86% in case 2 and case 1 is 32.54%. The FA algorithm has 24.78% in case 2 and 35.47% in case 1 also the PSO algorithm uses THD of the load current is 39.49% in case 1 and 27.14% in case 2.

4. Conclusion

An Elephant Herding Optimization is applied to get the performance of single phase Self Excited Induction Generator in steady and transient state. The controlling parameters of single phase SEIG depends upon speed, frequency, impedance and capacitor. The performance of single phase SEIG gives total harmonic distortion, current and terminal voltage is optimized using proposed approach. The results are compared with Particle Swarm Optimization (PSO) and Firefly method (FM) using MATLAB. So, the replicated results are similar with existing algorithm response hereafter confirm the proposed algorithm. Based on the comparative analysis, the proposed method is giving a reliable and effective performance in linear and non-linear cases.

References

[1] O.Kiselychnyk, M.Bodson and J.Wang, "Linearized State-Space Model of a Self-Excited Induction Generator Suitable for the Design of Voltage Controllers", IEEE Transactions on Energy Conversion, Vol.30, No.4, pp.1310-1320, 2015

[2] W.S.Abu-Elhaija and A.Muetze, "Self-Excitation and Stability at Speed Transients of Self-Excited Single-Phase Reluctance Generators", IEEE Transactions on Sustainable Energy, Vol.4, No.1, pp.136-144, 2013

[3] L.Wang and D.J.Lee, "Coordination Control of an AC-to-DC Converter and a Switched Excitation Capacitor Bank for an Autonomous Self-Excited Induction Generator in Renewable-Energy Systems", IEEE Transactions on Industry Applications, Vol.50, No.4, pp.2828-2836, 2014

ISSN: 2005-4238 IJAST

[4] U.K.Kalla, B.Singh and S.S.Murthy, "Modified Electronic Load Controller for Constant Frequency Operation With Voltage Regulation of Small Hydro-Driven Single-Phase SEIG", IEEE Transactions on Industry Applications, Vol.52, No.4, pp.2789-2800, 2016

[5] S.N.Mahato, S. P. Singh and M. P. Sharma, "Capacitors Required for Maximum Power of a Self-Excited Single-Phase Induction Generator Using a Three-Phase Machine," IEEE Transactions on Energy Conversion, Vol.23, No.2, pp.372-381, 2008

[6] B.Singh, S.S.Murthy, R.S.Reddy and P.Arora, "Implementation of modified current synchronous detection method for voltage control of self-excited induction generator," IET Power Electronics, Vol.8, No.7, pp.1146-1155, 2015

[7] S.S.Murthy, B.Singh and V.Sandeep, "A Novel and Comprehensive Performance Analysis of a Single-Phase Two-Winding Self-Excited Induction Generator," IEEE Transactions on Energy Conversion, Vol.27, No.1, pp.117-127, 2012

[8] U.K.Kalla, B.Singh and S.S.Murthy, "Enhanced Power Generation From Two-Winding Single-Phase SEIG Using LMDT-Based Decoupled Voltage and Frequency Control", IEEE Transactions on Industrial Electronics, Vol.62, No.11, pp.6934-6943, 2015

[9] P.J.Chauhan, J.K.Chatterjee, H.Bhere, B.V.Perumal and D.Sarkar, "Synchronized Operation of DSP-Based Generalized Impedance Controller with Variable-Speed Isolated SEIG for Novel Voltage and Frequency Control", IEEE Transactions on Industry Applications, Vol.51, No.2, pp.1845-1854, 2015

[10] J.N.Bae, Y.E.Kim and C.H.Yoo, "Torque Control Topologies of a Self-Excited Induction Generator as an Electric Retarder," IEEE Transactions on Energy Conversion, Vol.31, No.2, pp.557-565, 2016

[11] Yi Liu, Wei Xu, Gang Zhi and Junlin Zhang, "Performance Analysis of a Stand-alone Brushless Doubly-fed Induction Generator Using a New T-type Steady-state Model", An International Journal of Power Electronics, Vol.17, No.4, pp.1027-1036, 2017

[12] Taoufik, Mhamdi, Barhoumi Abdelhamid and Sbita Lassad, "Stand-alone self-excited induction generator driven by a wind turbine" An International Journal of Alexandria Engineering, 2017

[13] Scherer, Lucas Giuliani, Celso Becker Tischer and Robinson Figueiredo de Camargo, "Power rating reduction of distribution static synchronous compensator for voltage and frequency regulation of stand-alone self-excited induction generator", An International Journal of Electric Power Systems Research, Vol.149, pp.198-209, 2017

[14] S.N. Mahato, S.P. Singh and M.P. Sharma, "Dynamic behavior of a single-phase self-excited induction generator using a three-phase machine feeding single-phase dynamic load", Electrical Power and Energy Systems, Vol.47, pp.1–12, 2013

[15] Rachid El Akhrif, Ahmed Abbou, Mohamed Barara, Mohamed Akherraz and Youssef Majdoub, "dSPACE Implementation for a Fuzzy Logic Voltage Control using a Self-Excited Induction Generator and a Voltage Source Inverter", An International Journal of Electrical and Computer Engineering (IJECE), Vol.7, No.4, pp.1749-1759, 2017

[16] Mahajan S, Subramaniam S, Natarajan K, Gounder A.G.N and Borru D.V, "Analysis and control of induction generator supplying stand-alone AC loads employing a Matrix Converter", An International Journal of Engineering Science and Technology, Vol.20, No.2, pp.649-661, 2017

[17] Ion C.P and Marinescu C, "Three-phase induction generators for single-phase power generation: An overview", An International Journal of Renewable and Sustainable Energy Reviews, Vol.22, pp.73-80, 2013

[18] Basic, Mateo, Dinko Vukadinovic and Goran Petrovic, "Dynamic and pole-zero analysis of self-excited induction generator using a novel model with iron losses", An International Journal of Electrical Power and Energy Systems, Vol.42, No.1, pp. 105-118, 2012

[19] Tiwari A.K, Murthy S.S, Singh B and Shridhar L, "Design-based performance evaluation of two-winding capacitor self-excited single-phase induction generator", An International Journal of Electric Power Systems Research, Vol.67, No.2, pp. 89-97, 2003

[20] Chauhan, Yogesh K, Sanjay K.Jain and Bhim Singh, "Operating performance of static series compensated three-phase self-excited induction generator", An International Journal of Electrical Power and Energy Systems, Vol.49, pp.137-148,2013.

ISSN: 2005-4238 IJAST