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# Performance Analysis of Single Phase Self Excited Induction Generator Using GA and HJ Technique

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**Abstract**: **This paper deals with the steady state analysis of the single phase Self Excited Induction Generators (SEIG). The MATLAB has been used to predict the performance of the SEIG. In this paper the study of two optimization technique viz hookes jeeves(HJ) and genetic algorithm(GA) is done. The results obtained from both the techniques for the single phase SEIG are compared.**

**Keywords: self excited induction generators, steady state analysis, steinmetz model.**

## Nomenclature

a per unit frequency  b per unit speed
Csh excitation capacitance per phase
Cse series capacitance per phase
Xm magnetizing reactance
Zp positive-sequence impedances of the generator
Zn negative sequence impedances of the generator
Zo zero sequence impedances of the generator
ZL load impedance
Zin input impedance
Vr voltage across R phase
Vy voltage across Y phase
Vb voltage across B phase
VL voltage across load impedance
Vse voltage across series capacitor
Ir current in R phase
Iy current in Y phase
Ib current in B phase
P.F. Power Factor
K Compensation Factor

## I. Introduction

Due to the increasing demand and development of the renewable energy resources such as wind energy, the SEIG commonly known as SEIG has been widely used as a source of power generation. The Steinmetz connection which is described in this paper is mainly used to feed the single phase Induction motor as load from a 3 phase Induction generator by providing proper excitation capacitance [1]. For SEIG the excitation is provided by using value of capacitance which is greater than some minimum calculated value which can be obtained by using steady state analysis [9].

A single phase induction motor can also be used to provide balanced power to a three phase induction motor by steinmetz connection for proper phase balancing [2]. A balanced supply can also be obtained if proper selected values of compensators such as SVCs and TCRs are used [2]. The performance for these types of connection is highly unbalanced and proper approach has to be followed for balanced supply [3]. It is studied and evaluated in paper [4] that out of the many connected topologies of the capacitors for the single phase SEIG the delta connected, lagging phase excitation, series compensation and star connected shunt compensation are the best topologies. The single phase SEIG when compared to the self excited synchronous generators has better voltage regulation when operated at fixed speed [10].

In this paper steady state analysis of SEIG is carried out with certain assumptions stated in [5][6]. The performance analysis is carried out and appropriate results are taken and using the genetic algorithm. The results are compared with the results taken with hookes- jeeves described in [7]. In paper [8] genetic algorithm modelling described is very useful in determining the performance of SEIG which is implemented in this paper.

## II. Steady State Analysis of SEIG

The steady state analysis of the SEIG is carried out according to the procedure and equations described in [7].

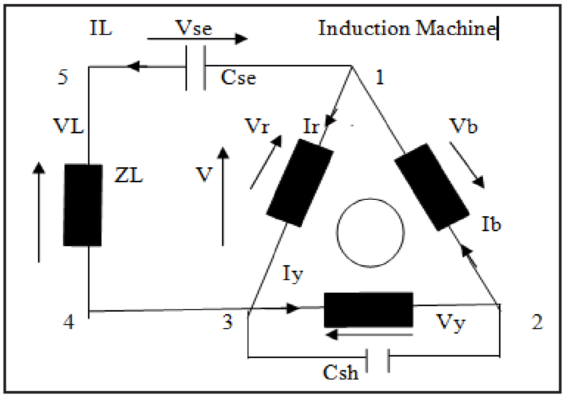


**Fig. 1:** Circuit connection of SEIG, using three phase delta connected setup

The circuit connection of the single-phase SEIG based on the Steinmetz connection for a delta connected induction machine is shown in Fig. 1. The single-phase load is connected across R phase while the shunt excitation capacitance $C_{sh}$ is connected across Y phase which is the lagging phase.

$$V = Vr \tag{1}$$

$$Vr + Vy + Vb = 0 \tag{2}$$

$$I = Ir - Ib \tag{3}$$

$$I2 = \frac{vy}{zsh} Ib - Iy \tag{4}$$

$$IL = -I = \frac{v}{Zl + Zse} \tag{5}$$

where

$$Zsh = \frac{1}{j2\pi fbase * Csh * a2} = -jXsh \tag{6}$$

$$Zse = \frac{1}{j2\pi fbase * Cse * a2} = -jXse \tag{7}$$

and

$$Zl = (Rl/a) + jXl \tag{8}$$

The symmetrical component equations for a delta connected system can also be written

$$\begin{bmatrix} V_r \\ Vy \\ Vb \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} V_o \\ V_p \\ V_n \end{bmatrix} \tag{9}$$

$$\begin{bmatrix} I_r \\ I y \\ Ib \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} Vo/Zo \\ V_p/Zp \\ Vn/Zn \end{bmatrix} \tag{10}$$

where $Z_o$ , $Z_P$ and $Z_n$ are the zero-, positive- and negative sequence impedances of the induction machine and α is the unit complex operator exp (j2n/3). In the subsequent analysis it is assumed that all the equivalent circuit parameters are constant except the magnetising reactance $X_m$ ,(which is a function of the positive-sequence air gap voltage $E_1$). From eqns. 2 and 9 it is apparent that zero sequence voltage and current are absent from the machine system.

$$Vp = \sqrt{3}V \frac{zp(Zsh + \frac{e^{j\pi/6}}{\sqrt{3}} Zn)}{ZpZn + ZpZsh + ZnZsh} \tag{11}$$

$$Vn = \sqrt{3}V \frac{zn(Zsh + \frac{e^{j\pi/6}}{\sqrt{3}} Zp)}{ZpZn + ZpZsh + ZnZsh} \tag{12}$$

The input impedance of induction generator can be expressed as:

$$Zin = \frac{ZpZn + zpZsh + ZnZsh}{3Zsh + Zp + Zn} \tag{13}$$

$$Zin + Zl + Zse = 0 \tag{14}$$

For given values of $C_{sh}$ , $C_{se}$ , $Z_L$ per-unit speed b, eqn.14 may be solved to give the per-unit frequency *a* and magnetising reactance $X_m$ of the single-phase SEIG can then be calculated using eqns. 1 to 12, provided that the magnetisation curve of the induction machine is known.

## III. Optimization Techniques

The input impedance $Z_{in}$ is a complicated function of the variables *a* and $X_m$ due to the multiplication and division involving the complex impedances $Z_P$, $Z_N$ and $Z_{Sh}$ and eqn. 14 is thus very difficult to solve using conventional techniques, such as the Newton-Raphson method. To reduce the amount of algebraic manipulations, an optimisation based approach ie GA is adopted.

The eqn.14 is considered as objective function and evaluated to obtain the optimization results using genetic algorithm method. Matlab program has been developed to implement genetic algorithm and performance analysis of SEIG. Eqn.14 is satisfied when the values of a & Xm result in minimum value of zero for function Z(a,Xm). The method depends upon function values and parameters of a machine.

## IV. Results and Discussions

The written matlab program is simulated through genetic algorithm tool and results thus obtained are compared with results by Hooke Jeeves method [7].

TABLE I: Computed results for single phase SEIG

| $R_L$ (p u) | A(p u) | a(p u) | Xm(p u) | xm(p u) | Z(a,xm) (p u) | z(a,xm) (p u) |
|---|---|---|---|---|---|---|
| 50 | 0.9916 | 0.9942 | 1.6226 | 1.6158 | $9.06 \times 10^{-4}$ | $7.05 \times 10^{-4}$ |
| 10 | 0.9900 | 0.9926 | 1.6329 | 1.6253 | $1.32 \times 10^{-4}$ | $1.28 \times 10^{-4}$ |
| 5 | 0.9880 | 0.9906 | 1.6443 | 1.6358 | $6.24 \times 10^{-5}$ | $4.04 \times 10^{-5}$ |
| 2 | 0.9823 | 0.9850 | 1.6686 | 1.6575 | $1.32 \times 10^{-5}$ | $6.15 \times 10^{-6}$ |
| 1 | 0.9737 | 0.9763 | 1.6771 | 1.6626 | $6.43 \times 10^{-7}$ | $7.37 \times 10^{-8}$ |
| 0.5 | 0.9593 | 0.9619 | 1.5982 | 1.5821 | $8.53 \times 10^{-7}$ | $5.43 \times 10^{-7}$ |
| 0.3 | 0.9455 | 0.9482 | 1.4056 | 1.3943 | $2.92 \times 10^{-7}$ | $2.7 \times 10^{-7}$ |
| 1 | 0.9455 | 0.9482 | 1.4056 | 1.3943 | $4.0 \times 10^{-7}$ | $2.96 \times 10^{-7}$ |

Here, A, Xm and Z have been determinbed by Hooks Jeeves method. These results proved that GA is better than H-J method. Above values are obtained for Csh=125μF, Cse=350 μF, Power Factor=1.0,K=0.357. after proving the superiority of GA over HJ method, results obtained by genetic algorithm and graphs are plotted as shown from Fig. 3 to Fig. 5.

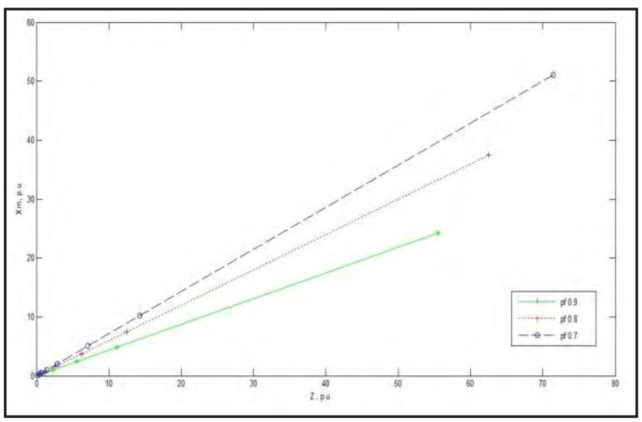


**Fig. 2:** Variation of magnetic reactance with impedances for varying power factor

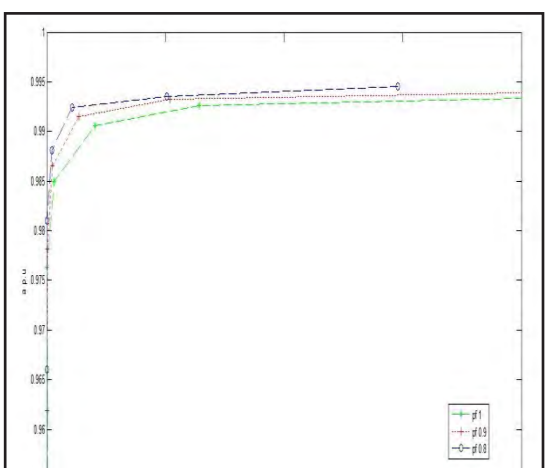


**Fig. 3:** Variation of frequency with impedances for varying power factor,Csh=125μF, Cse =350 μF, P.F=1.0,K=0.357.

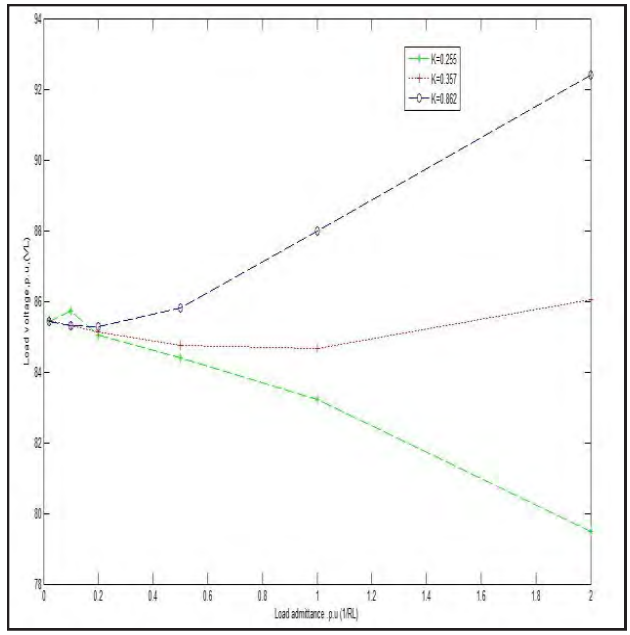


**Fig. 4:** Variation of load voltage with load admittance,Csh=125μF, P.F=1.0, for varying value of K= 0.255,0.357,0.862.

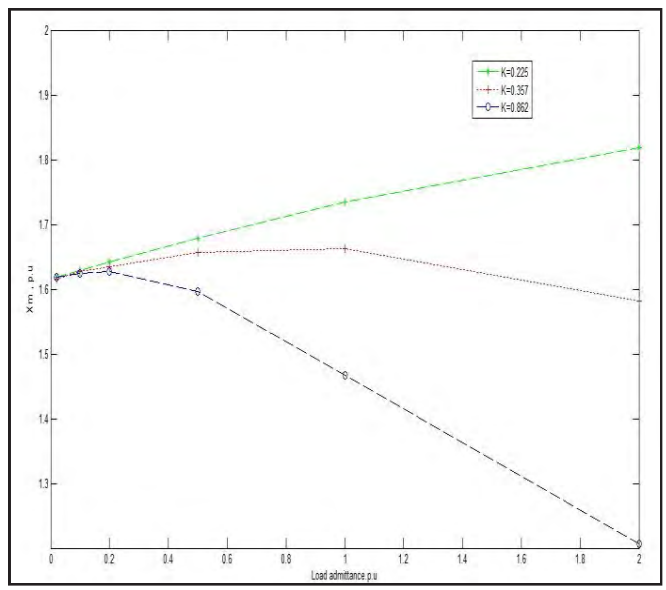


**Fig. 5:** Variation of reactance with load admittance, P.F=1,Csh=125 μF for varying value of K=0.255,0.357,0.862.

## V. CONCLUSIONS

The studies have confirmed that use of an induction machine as a generator becomes popular for the interaction of electrical energy from the renewable energy sources. Steady state analysis of SEIG is carried out for evaluating running performance. Using the steady state analysis, voltage regulation, frequency regulation, can be assessed. The developed computer algorithm facilitates prediction of performance under the given speed, capacitor and load conditions, which helps in estimating system parameter. The developed matlab program predicts the suitable parameters i.e suitable frequency and magnetic reactance value for simulated machine.

The results thus obtained by genetic algorithms prevail better then hookes jeeves method. Solution from Genetic algorithm method gets better with time.

# VI. APPENDIX

The computation is carried for following parameters of machine [7].

2.2kW, 220 V, 9.4 A, 4 pole, 50Hz, three phase, delta connected, squirrel cage induction motor. The machine parameters (in per unit values) are as follows:

R1=0.0844

X1=0.112

R2p=0.0621

R2n=0.0981

X2=0.1

E1 = 1.345- 0.203Xm, Xm<1.728

1.901- 0.525Xm, 1.728<Xm<2.259

3.156- 1.08Xm, 2.259<Xm<2.446

37.49- 15.12Xm, 2.446<Xm<2.48

0, 2.48<Xm

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