GA BASED PERFORMANCE ANALYSIS OF SELF-EXCITED INDUCTION GENERATOR

Harish Kumar, Shivcharan
1,2 ECE Deptt. G.I.T.M. Bilaspur Gurgaon Haryana
Email: 1harishkhola@gmail.com, 2yadavshivcharan@yahoo.co.in

Abstract: The paper deals with the steady state analysis of self-excited induction generator using Genetic Algorithm optimization technique. The performance of a self-excited induction generator for a given value of capacitance and speed is analysed under resistive loads. Further the paper deals with effects of various system parameters on the steady state performance of induction generator. Simulated results obtained from optimization technique are shown graphically. The results, had lead to their comparative importance.

Key Words: Induction Generator, Optimization Technique, steady state analysis

I. INTRODUCTION

Presently, most of the electricity generated comes from fossil fuels (coal, oil and natural gas). These fossil fuels have finite reserves and will run out in the future. The negative effect of these fossil fuels is that they produce pollutant gases when they are burned in the process to generate electricity. Fossil fuels are a non-renewable energy source. However, renewable energy resources (wind, hydro, solar, biomass, geothermal and ocean) are believed not to run out, and are environmental friendly.

In renewable energy resources wind energy is the dominating source. It is a clean and abundant resource that can produce electricity with no pollutant gas emission. Induction generators are widely used for wind powered electric generation, especially in remote areas, because they do not need an external power supply to produce the excitation magnetic field. An induction generator offers various advantages over the conventional synchronous generators such as reduced unit cost, easy maintenance, rugged and simple construction, brushless rotor (squirrel cage) and so on [1].

It is well known that a three-phase induction machine can be made to work as a self-excited induction generator (SEIG) [2]. In an isolated application an induction generator operates in the self-excited mode by connecting the capacitors to the stator terminals. In a grid connected induction generator the magnetic field is produced by excitation current drawn from the grid. In this paper the steady state performance of an isolated induction generator excited by the capacitors is analyzed with optimization technique. The effects of various system parameters on the steady state performance have been studied.

II. ANALYSIS

NOMENCLATURE

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_s, R_r</td>
<td>Per phase stator and rotor resistance respectively</td>
</tr>
<tr>
<td>X_s, X_r</td>
<td>Per phase stator and rotor leakage reactance respectively</td>
</tr>
<tr>
<td>X_m</td>
<td>Magnetizing reactance</td>
</tr>
<tr>
<td>X_c</td>
<td>Per phase capacitive reactance of the terminal capacitance C</td>
</tr>
<tr>
<td>R_L</td>
<td>Per phase load resistance</td>
</tr>
<tr>
<td>F_v</td>
<td>Per unit frequency and speed respectively</td>
</tr>
<tr>
<td>I_s, I_r, I_l</td>
<td>Per phase stator, rotor and load current respectively</td>
</tr>
<tr>
<td>V_T, V_G</td>
<td>Terminal and air gap voltage respectively</td>
</tr>
<tr>
<td>VAR</td>
<td>Per phase volts ampere reactive</td>
</tr>
<tr>
<td>Pin &amp; Pout</td>
<td>Per phase input and output power respectively</td>
</tr>
</tbody>
</table>

(All these quantities are referred to the stator and at base frequency)

In the present paper, the standard steady state equivalent circuit of a SEIG with the usual assumptions [3], considering the variation of magnetizing reactance with saturation as the basis for calculation. The equivalent circuit is normalized to the base frequency by dividing all the parameters by the p.u. frequency as shown in Fig. 1.

![Fig. 1 Per-phase equivalent circuit of SEIG](image)

For the purpose of obtaining performance of self-excited induction generator for the given value of capacitance and speed, the unknown parameters are X_m and F.

From the Fig. 1 the loop equation for stator current is given by:

\[
\begin{align*}
V_T' &= R_L + jX_C I_s + jX_S I_l + jX_m I_r \\
M &= V_T' - jX_C I_s - jX_S I_l - jX_m I_r
\end{align*}
\]
\[ Z_s I_s = 0 \]  
(1)

Where

\[ Z_s = Z_1 + Z_2 + Z_3 \]  
(2)

\[ Z_1 = \frac{-j X_C R_L}{R_L F^2 - j X_C F} \]  
(3)

\[ Z_2 = \frac{R_S}{F} + j X_s \]  
(4)

\[ Z_3 = \frac{j X_M [R_K + j (F - v) X_K]}{R_K + j (F - v) (X_M - X_K)} \]  
(5)

Since under steady state operation of SEIG, \( I_s \) cannot be equal to zero, therefore:

\[ Z_S = 0 \]  
(6)

This equation after separation into real and imaginary parts, can be rearranged into two nonlinear equations which are solved using GA optimization technique to obtain value of \( X_M \) and \( F \) after substituting \( X_S = X_K = X_L \) [4].

An objective function is given by equation

\[ Z = (f^2 + g^2)^2 \]  
(7)

(Where \( f \) & \( g \) are given in Appendix-I)

The relation between \( X_M \) and \( V_g/F \) is given by equation

\[ X_M = \frac{(K_1 - \frac{V_g}{F})}{K_2} \]  
(8)

Where \( K_1 \) and \( K_2 \) are depends on the design of the machine.

\[ V_g = V_f \left( \frac{Z_1 + Z_2}{Z_1} \right) \]  
(9)

Thus for a given value of \( R_L \) and \( V_f \), the value of \( V_g \) can be determined from equation (9). With the known values of \( V_g, F, X_C, v, R_L \) and the generator’s equivalent circuit parameters, the following relations can be used for the computation of the machine performance [5].

\[ I_s = \left( \frac{V_g}{F} \right) \left( \frac{I_3 + Z_2}{Z_1} \right) \]  
(10)

\[ I_R = \left( \frac{(-V_g)}{R_K (F - v) + j X_R} \right) \]  
(11)

\[ I_L = \frac{-j X_C I_s}{R_L F - j X_C} \]  
(12)

\[ V_f = I_R R_L \]  
(13)

\[ VAR = V_f^2 (F / X_C) \]  
(14)

\[ P_{in} = -\frac{|I_R|^2 R_L F}{(F - v)} \]  
(15)

\[ P_{out} = |I_L|^2 R_L \]  
(16)

### III. OPTIMIZATION TECHNIQUES

This paper deals with the implementation of Genetic Algorithm (GA) optimization technique which are based on the software of MATLAB. The above optimization technique used to solve the above objective function equation irrespective of the unknown parameter which is not possible in other conventional methods of analysis. The equations can be solved for magnetizing reactance and frequency of the generator.

(a) Genetic Algorithm

The GA is a method for solving optimization problems that are based on natural selection, as process is derived from biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. At each step, the GA selects individuals at random from the current population to be parents and uses them to produce the children for the next generation. Over successive generations, the population evolves toward an optimal solution. The GA has several advantages over other optimization methods. It is robust, able to find global minimum and does not require accurate initial estimates [7] [8].

The flowchart describing the GA optimization technique implemented in this paper is shown in Fig. 2. The two unknowns \( X_M \) and \( F \) are determined by optimizing the fitness function.

---

Special Issue on International Journal of Recent Advances in Engineering & Technology (IJRAET) V-4 I-2  
For National Conference on Recent Innovations in Science, Technology & Management (NCRISTM)  
ISSN (Online): 2347-2812, Gurgaon Institute of Technology and Management, Gurgaon 26th to 27th February 2016
IV. RESULTS AND OBSERVATIONS

The performance characteristics of capacitor excited, 3.7 KW, cage generator (specification of machine in Appendix-II) has been obtained by using optimization technique. Fig. 3 to Fig. 10 represents the performance characteristics of SEIG obtained by GA.

From Fig. 3 it can be noted that the terminal voltage and frequency decreases with output power and generator efficiency improves with load.

From Fig. 4 it can be seen that the terminal voltage are almost parallel, indicating the proportional increase of \( V_T \) with capacitance. The frequency drop with output power was not very much affected by the capacitance.

From Fig. 5 and 6 it can be shown that at increased value of stator and rotor resistance causes more drooping the characteristics and decrease the maximum output power.
From Fig. 8 it can be seen that at increase value of K1 causes increased terminal voltage and maximum output power. These changes are quite significant.

V. CONCLUSIONS

This paper presents the steady state performance of SEIG with GA optimization techniques. At given load, speed and capacitance two unknowns i.e., p.u. magnetizing reactance and frequency are determined. The steady state equivalent circuit is used to compute the performance of SEIG after determining the unknowns. The effects of various system parameters are presented. It has been observed that the value of terminal voltage varies over a wide range for a fixed value of capacitance. The small change in stator resistance and leakage reactance do not affect the performance. Where as the magnetizing reactance is found to be very sensitive parameters.

REFERENCES


GA BASED PERFORMANCE ANALYSIS OF SELF-EXCITED INDUCTION GENERATOR

APPENDIX-I

\[
\begin{align*}
  f (X_M, F) &= (C_1 X_M + C_2) F^3 + (C_3 X_M + C_4) F^2 + (C_5 X_M + C_6) F
  \quad + (C_7 X_M + C_8) = 0
\end{align*}
\]

\[
\begin{align*}
  g (X_M, F) &= (D_1 X_M + D_2) F^3 + (D_3 X_M + D_4) F^2 + D_5 = 0
\end{align*}
\]

Where the constants are defined as,

\[
\begin{align*}
  C_1 &= -2 X_L R_L \\
  C_2 &= -X_L R_L \\
  C_3 &= -C_1 \times \nu \\
  C_4 &= -C_2 \times \nu \\
  C_5 &= X_C (R_L + R_S + R_R) \\
  C_6 &= X_C X_L \left( R_S + R_L + R_R \right) + R_S R_L R_R \\
  C_7 &= -X_C \left( R_S + R_L \right) \times \nu
\end{align*}
\]

\[
\begin{align*}
  C_8 &= -X_C X_C \left( R_S + R_L \right) \times \nu \\
  D_1 &= 2 X_L X_C (R_S + R_R) \\
  D_2 &= R_L X_L (R_S + R_R) + X_L^2 X_C \\
  D_3 &= -\left( R_S R_L + 2 X_C X_L \right) \times \nu \\
  D_4 &= -\left( X_L R_S R_L + X_C X_L^2 \right) \times \nu \\
  D_5 &= -X_C R_S (R_L + R_S)
\end{align*}
\]

APPENDIX-II

Rating of Machine

3.7KW/5HP 3-phase, 415 Volts, 7.6 Amp, 4 poles, 50 Hz, delta connected cage induction motor

Base Quantities


Equivalent Circuit Parameters

\[
\begin{align*}
  R_S &= 0.053 \text{ p.u., } R_R = 0.061 \text{ p.u., } X_S = X_R = X_L = 0.087 \text{ p.u., } X_M (\text{unsaturated}) = 2.35 \text{ p.u., } K_1 = 1.6275, K_2 = 0.3418, \text{Air gap voltage } V_{g/F} = K_1 - K_2 X_M
\end{align*}
\]