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Teaching Of Self Excited Induction Generator For Standalone Wind Energy Conversation System Using "MATLAB GUI"

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Abstract— This paper is an attempt to provide a user friendly software package for teaching of standalone SEIG. Three operating conditions of the generator are mathematically modelled and then simulated using MATLAB commands. Active GUI window with these models are created using Graphical User Interface Capability. The requirements of capacitor bank for SEIG for its self excitation are also incorporated in this paper.

Keywords— Self Excited Induction Generator(SEIG), Graphical User Interface(GUI), Capacitacnce requirement, Teaching Analysis

I. ABBREVIATIONS USED

R_1, R_2, R_M, R_L, R_C : Per-unit stator, rotor, magnetizing, load and exciting resistances, respectively.

X_1, X_2, X_M, X_L, X_C : Per-unit stator, rotor leakage, magnetizing, load and exciting reactance's at base frequency, respectively

Y_1, Y_2, Y_M, Y_L, Y_C : Per-unit stator, rotor, magnetizing, load and exciting admittances, respectively.

F_S : synchronous frequency
F   : per unit frequency
v   : Per-unit rotational speed
E_1, V_T : Per-unit air gap and terminal voltages
Pout   : Output electrical power

II. INTRODUCTION

The squirrel-cage induction motor which can be performed as Self Excited Induction Generator (SEIG) is best suitable for standalone wind energy conversation system due to their several advantages as their low capital and maintenance cost, rugged construction, better transient response and when it act as a Self Excited Induction Generator it does not require any external supply to produce magnetic field for their excitation[1] .

In this study, MATLAB-GUI is design to obtain the steady state performance of the SEIG, using loop admittance method. This paper make us enable to understand different operating condition of the generator easily using MATLAB

GUI. It is a attractive and user friendly software package for teaching a SEIG.

This paper describes not only the requirement to operate in a induction machine as a SEIG, but also it gives idea about the parameters which affect the performance of the generator. Mathematical modeling and GUI of a SEIG under three operating conditions i.e. constant frequency operation, constant speed operation and variable speed variable frequency operation are given in this paper. The capacitance requirements of SEIG for its self excitation are also incorporated in this paper.

III. MATHEMATICAL MODELLING OF SEIG

The steady-state per-phase equivalent circuit of a SEIG, supplying a balanced resistive load, is shown in Fig. 1. In this circuit, only the capacitive reactance is assumed to be affected by magnetic saturation, and all other parameters are assumed to be constants.
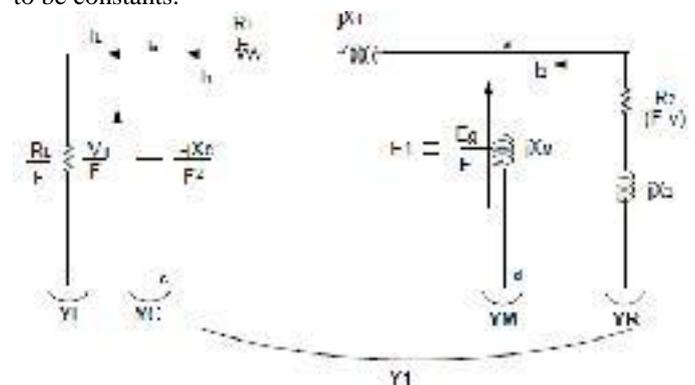

Fig 1:Equivalent circuit diagram of SEIG

$$E_1(Y_1 + Y_M + Y_R) = 0 \qquad (1)$$

During the steady state self excitation, the total nodal admittance must be equal to zero because $E_1 \neq 0$ Therefore,

$$(Y_1 + Y_M + Y_R) = 0 \qquad (2)$$

Where the admittance at different given points is given by:

$$Y_1 = (Y_C + Y_L)(Y_S)/Y_C + Y_L + Y_S \qquad Y_C = 1/(-j X_C/F^2)$$

$$Y_L = 1/(R_L/F) \qquad\qquad Y_S = 1/(R_1/F)+jx_1 \quad (3)$$
$$Y_M = 1/j\,X_M \qquad\qquad Y_R = 1/((R_2/F-\ )+jX_2)$$

The constant speed operation is mathematically modeled by nodal equation deduced in [1]

$$A_6F^6+A_5F^5+A_4F^4+A_3F^3+A_2F^2+A_1F+A_0 = 0 \qquad (4)$$

The X_M is obtained by finding the real roots of equation (2) and substituting it in (5)

$$X_{M=}1/\{X_R/R_R/(F-\ )+(X_R)^2+X_{ac}/((R_{ac})^2+(X_{ac})^2)\} \ (5)$$

After getting the value of F and X_M we can easily predict or estimate the performance characteristics of SEIG using the following relationships:

$$I_1=(E_1/F)/((R_1/F)+jX_1-(jX_CR_L/F^2R_L-FX_C)) \quad V_1=I_LR_L \quad (6)$$
$$I_L= -jX_CI_1/(R_LF-Jx_C) \qquad I_{2=}(-E_1/F)/((R_2/F-\ )+X_2)$$
$$P_{IN}= -3R_2F(I_R)^2/(\ F-\ ) \qquad P_{OUT}=3(I_L)^2R_L$$

During the constant frequency operation and X_M should be considered as unknowns. For this operating condition, eqn. (4) can be simplified to give eqn. (7), which is a quadratic equation in . For a given *F*, *XC* and *RL*, eqn. (7) can be used to obtain and then *XM* may be calculated from eqn. (5).To maintain the frequency of the output voltage constant controlled shaft speed turbine should be implemented to generate the drive generator. If an unregulated turbine drives the generator, the shaft frequency and shaft speed are affected by the energy source.

$$B_2V^2+B_1V+B_0=0 \qquad (7)$$

From the equivalent circuit of SEIG the current I_1 is given by:

$$Z_1I_1=0 \qquad (8)$$
$$Z_S=((-jX_CR_L/F^3)/(R_L/F)-(-jX_c/F^2))+(R_1/F+jX_1)+\{jX_M(R_2/F-\ )+jX_L)\}/(R_2/\ F-\ )+j(X_M+X_L) \qquad (9)$$

During steady-state self-excitation $I_1 \neq 0$ Therefore, from equation (9) Zs = 0, which implies that both the real and imaginary parts of the right-hand side of the equation should be separately zero. Substituting $X_1 = X_2 = X_L$, this simplifies to the following two nonlinear simultaneous equations with X_C and F as unknown variables.

$$f(X_C,F)=C_1F^3+C_2F^2+(C_3\,X_C+C_4)F+C_5\,X_C=0 \quad (10)$$

$$f(X_C,F)=(D_1X_C+D_2)F^2+(D_3X_C+D_4)F+D_5X_C=0$$

On the basis of analytical techniques, a MATLAB's GUI program is developed which determines the load characteristics and facilitates the steady state analysis of SEIG. The above equations have been also used to determining the

capacitance requirements of SEIG for its self excitation .Further the simulation techniques have also been extended for reactive loads and variable speeds operation.

IV. DEVELOPED MATLAB (GUI) WINDOW

This section describe the new interactive as well as attractive GUI which is user friendly software package and can be used by any user, to analysis or check the performance of SEIG under three operating conditions. The three operating conditions are given as:

(a)Constant Speed Operation
(b)Constant frequency operation
(c)Capacitance Determination

Fig. 2 Main page of the GUI tool developed

This is the first window of GUI, if we have choose any of them, then we will be automatically go to the next window, where we will be provoked to choose either of the two types of load i.e. either it is resistive load or it can be an inductive load, where we have to choose any of the two and again we enter in the new window where we enter all the parameters of the machine in per unit which has to be analyzed.
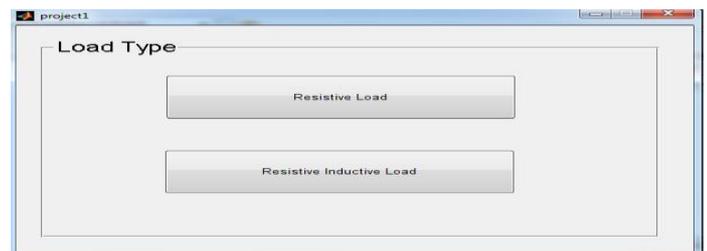

Fig. 3 The load window in GUI

Fig. 4: Interactive window with clear grid and editable Parameters for constant speed operation and purely resistive load:

The user can easily seen these three important plots which are visible in fig:4 by click on the push buttons, the corresponding plot can be plotted in the same window developed. Same as this .other operating modes also have these type of interactive as well as attractive window, where we can plot the important characteristics as we desire and they can be analyzed on the GUI window clearly.

V. RESULTS

With the help of this MATLAB- GUI window, we can obtain the following results as shown in given windows:
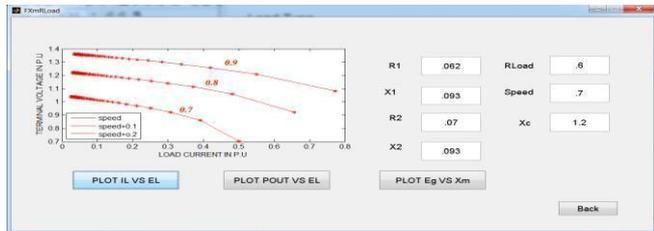
Fig. 5 The load current IL versus terminal voltage VT for purely resistive load in constant speed operation
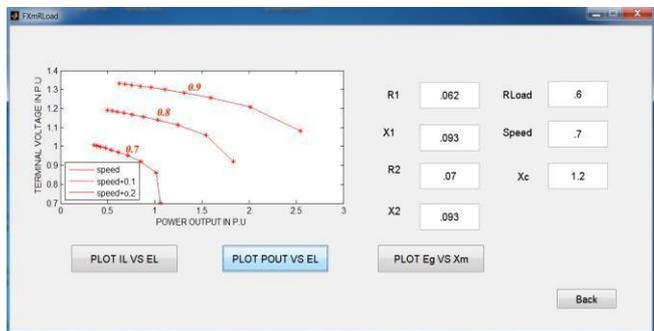
Fig. 6 The power output POUT versus terminal voltage VT for purely resistive load in constant speed operation
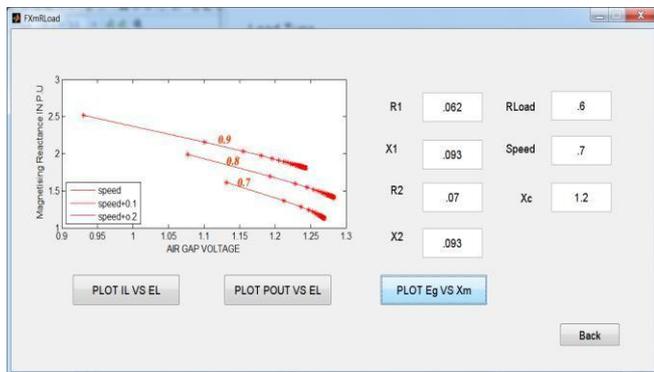

Fig. 7 The air-gap voltage Eg versus magnetizing reactance X_M for purely resistive load in constant speed operation
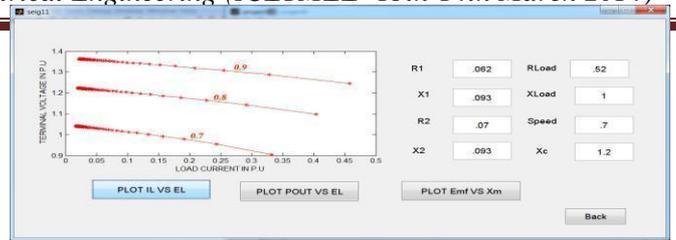

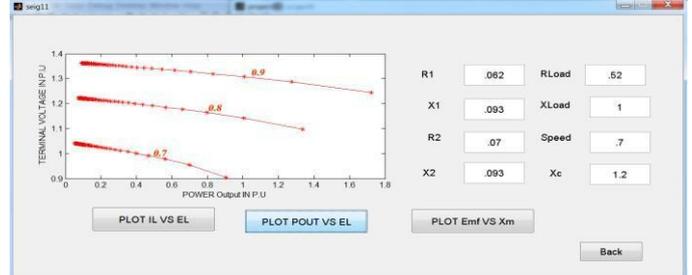Fig. 8 The load current IL versus terminal voltage VT for an Impedance load in constant speed operation

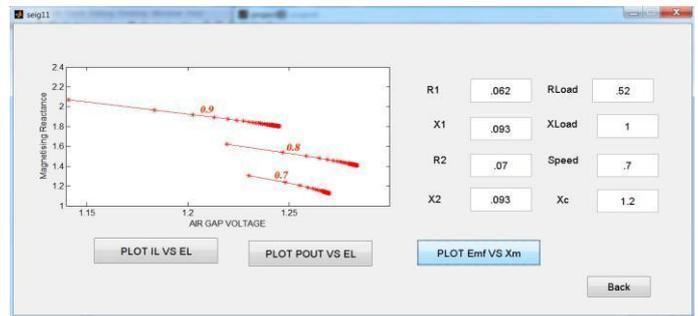Fig. 9 The power output POUT versus terminal voltage VT for an impedance load in constant speed operation

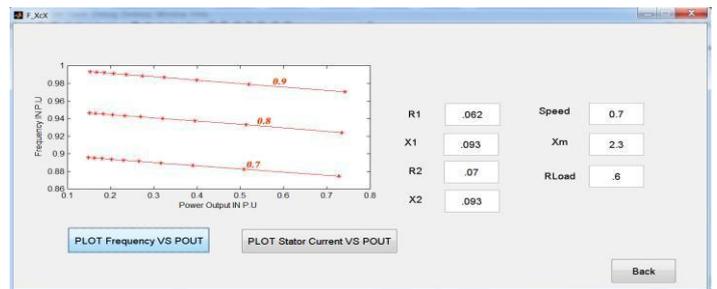Fig.10 This fig shows how the emf voltage is induced with change in magnetizing reactance

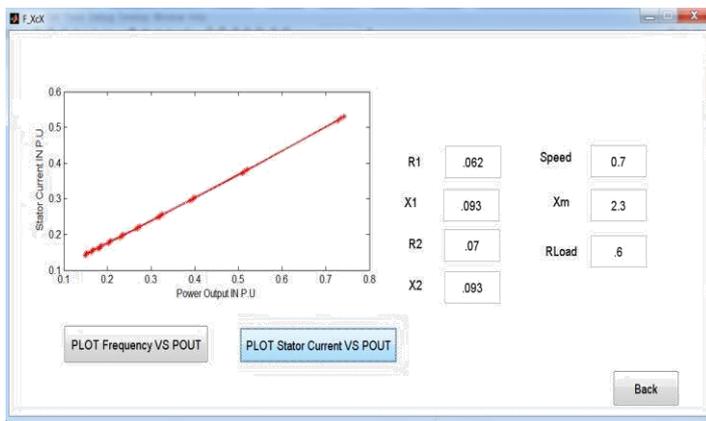Fig. 11 The power output POUT versus Frequency F in p.u for purely resistive load in constant frequency operation

Fig. 12 The power output POUT versus stator current I1 for purely resistive load in constant frequency operation at 1p.u speed

in micro farads for a resistively dominating load

Fig. 14 This fig shows the plot b/w maximum capacitance vs speed

Fig. 15 The load impedance ZL versus minimum capacitance in micro farads for a inductively dominating load

VI . RESULT OF CAPACITANCE DETERMINATION

Before showing the result of capacitance determination, let see the use of capacitor bank in parallel across the load. We put a component, i.e. capacitor bank which supplies the reactive power to the machine to maintain the rotating magnetic field in the machine, so for that we connect capacitors bank and the job of the capacitors to supply reactive power to the induction motor to maintain the rotating magnetic flux. The amount of capacitors depends upon the flux that we build up.
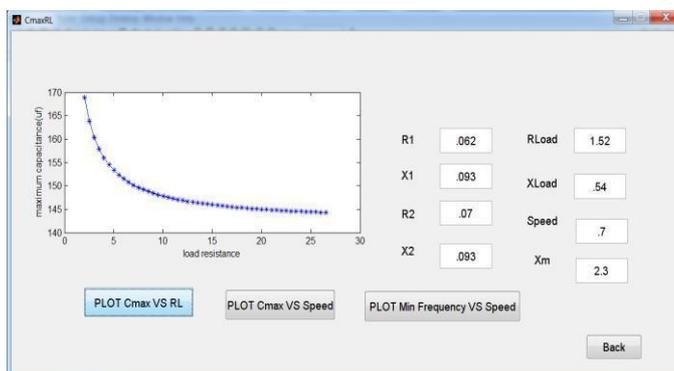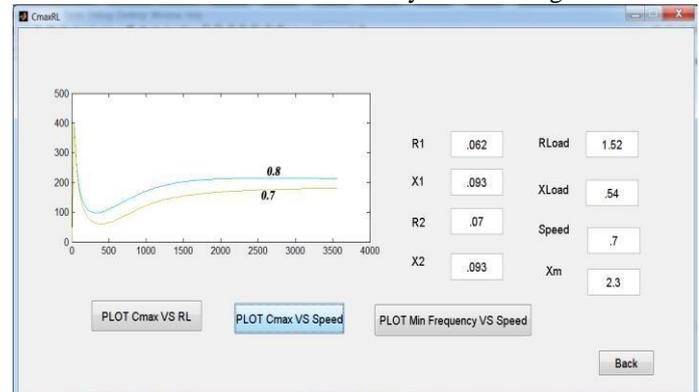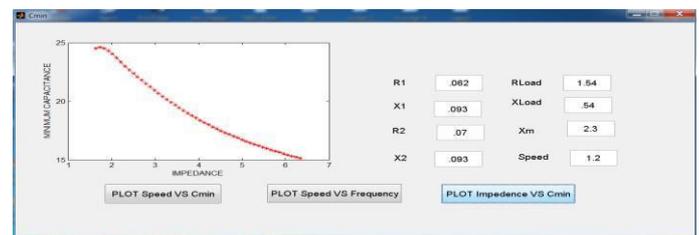
VII. CONCLUSION

Here I represent an interactive as well as attractive approach for teaching a SEIG for standalone wind energy conversion system in this paper. And we have discussed three modes of operation , they are mathematically modeled then simulated in GUI window using basic instruction of MATLAB. The students and researchers can extensively use this software so easily and they can be studying analyzing performance characteristics of the machine easily.

Fig. 13 The load impedance ZL versus maximum capacitance

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