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Analyzing the Performance of Self Excitation Induction Generator by Considering the Effect of Terminal Capacitance

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***Abstract*— The conventional energy sources are facing severe energy demand pressure due to exponentially increasing world population. This has led to go for a proper mix of power from conventional and renewable energy resources. India has a large potential of wind, biomass and small hydro power plants in remote areas from the existing power grids. To harness this renewable energy autonomous operation of induction generators has proved to be fruitful. Due to increasing role of self excited Induction Generator (SEIG) it has become essential to improve its performance. In this dissertation work, effect of terminal capacitance needed for self excitation, on generator performance has been obtained with a suitably developed mathematical model and with the help of digital computer. In the capacitance range where self-excitation is possible, the induction generator characteristics are greatly affected. It is shown that the value of capacitance can be obtained so that the terminal voltage is constant irrespective of the power output. This value of capacitance is decided by load and power factor. The sole method adopted for analysis has been discussed at length. A self explanatory flow chart for computer program is presented and results have been discussed at length depicting influence of terminal capacitor on SEIG performance.**

***Index Terms*—Conventional energy, energy source, renewable energy.**

I. INTRODUCTION

Population will decide future energy demand in India's case. Developing countries still have a high population growth rate. It has been expected that this group will have 60 per cent of World's population by the year 2015. India, one among developing countries will have 1.2 billion people in the same year, according to projections made by U.N. Population Studies. Second factor to be considered is that of food supply. For correcting imbalance between future food demand and food production modern energy intensive techniques will have to be introduced. Energy will be needed for land preparation, irrigation and in the form of fertilizers, which will largely depend upon agro climatic conditions, intensity of cropping etc. Energy is also needed for harvesting, threshing, processing of products to be determined by yield level. This mechanism will stimulate growth for packaging, transportation and storage, etc. Increased farm income will put demand on other industries which in turn will need additional energy for increasing their production. This will be expected to raise energy demand per capita almost similar to the history of U.S. Agriculture.

Third factor of major importance is termed as urbanization of population in India in particular and in developing countries largely. It is estimated that by the year 2015 over 34% of India's population and over 40 percent of population of developing countries will be living in cities from a level of 21.47 percent and 23 percent respectively in 1975. This implicity implies a higher demand for energy to provide services for urban living compared to rural living. Also increasing urbanization will be offsetting energy savings likely to be obtained due to measures taken under energy conservation programmes.

The historical growth rate of primary energy consumption from 1970-71 was 3.94 percent per capita per year. Current trend in primary energy consumption has been estimated as 5.22 percent per capita per year. For medium term projections of this kind, it is assumed that current per capita primary energy consumption trend will continue till 2015 due to increasingly greater role being assigned to coal/gas based generation for meeting electricity demand.

II. MODELLING AND ANALYSIS OF SEIG

A three phase induction generator as SEIG, is operated in variable frequency-variable speed mode. The block schematic diagram of a SEIG system is shown in Fig. The steady-state per-phase equivalent circuit of SEIG supplying a balanced resistive load of R_L is shown in Fig.

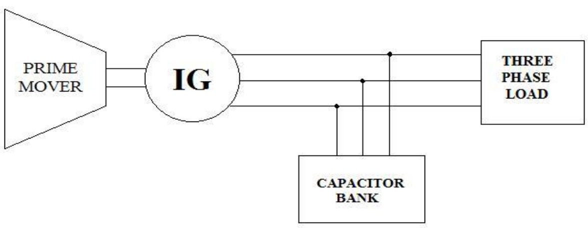

FIG.1: SEIG MODEL

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The following assumptions are made during the steady state analysis of SEIG:

1. In this circuit all the parameters except the magnetizing reactance are assumed to be constant.

2. Core loss is neglected, although the analysis can be extended to account for the same.

3. Leakage reactance of stator and rotor, in per unit, are taken to be equal. This assumption is normally valid in induction machine analysis.

4. The effect of harmonics, both space and time harmonics, in the voltage and current waveforms are ignored. This assumption is valid in well designed machines

III. NEED OF CAPACITANCE FOR SEIG

As already pointed out the renewable resource power potential is largely in the remote areas from the conventional power grids. To obtain a proper mix of power from conventional and non-conventional power resources the ministry for Non-conventional Energy Sources has planned to harness mini-micro hydel resources in the remote hilly areas of north east and for flanged wind resources. This needs self excitation of induction generators. As in the case of self excited dc shunt generators, the residual magnetism in the rotor develops some voltage across the stator terminals of the induction machine. The role of shunt field windings is played by the capacitor bank connected across the stator winding terminals and the current flowing through capacitance augment the process of voltage build up. In the absence of capacitance the voltage build up is not possible. Hence we need a capacitor bank of proper values in SEIGs. The value of capacitance for optimum performance is obtained with the mathematical analysis as discussed in the following sections.

Reduces the capacitor current

Obviously bus over-voltage protection will be present, to this aim the same protection used in case of motor drive was used. Thanks to active excitation the induction generator will work in an optimal operating point because no saturation is required to help voltage regulation. In this way its efficiency increases. A CCVSI requires the measurements of inverter currents, to this aim two Hall effect sensors measure phase currents. These currents are transformed in d-q currents by Park's transformation, being the angle of this transformation the output of the air gap flux observer. The flux observer mimics the field-oriented control structure. In order to obtain induction generator air gap flux its voltages and currents must be measured. Generator voltages are the line voltages and can be measured directly, otherwise generator currents can be obtained directly or subtracting inverter currents from line currents. Voltage of components can be obtained from the measurement of two line voltages, then the voltage module v = v2 + v is computed starting from line voltages and the result is used for the line voltage control loop.

In case of grid connected operations the induction generator is excited by the grid itself. The system versatility allows to control the power factor using the CCVSI as a continuous

VAR compensator. To this aim a simple algorithm based on V_L, P measurements and on the knowledge of the capacitor bank value can be developed to control CCVSI reactive current.

IV. ALGORITHM OF THE PROPOSED METHOD

The steps involved in the computation of the performance indices of self excited induction generator (SEIG) with varying terminal capacitance at various load resistance level are as follows:

(i) Values of stator and rotor resistance's and leakage reactance's all in p.u., are made available. Values of speed (in rpm), base impedance and frequency, load reactance and final values of load resistant (R_f) and magnetizing reactance (X_{mf}) are also arranged. The required load voltage is fed to the computer.

(ii) Initial value of load resistance and magnetizing reactance are chosen suitably (say 0.25 and 0.5 p.u. respectively)

(iii) Values of constants a_i, where i = 1,2,……5,& b_i, where i = 1,2,-- 7 and L_i where, i = 1,2, .4 are computed.

(iv) Expression $K = L_4 F^4 - L_3 F^3 + L_2 F^2 - L_1 F + Lo$ is calculated for some initial value of F (=.01 say). K is compared with a small positive value and hence F is obtained.

(v) From above value of F, X_c and C are computed.

(vi) Corresponding to the value of excitation capacitance as computed in step (v) above the performance indices of the machine such as generated voltage E, Load current I_L , output power, power factor (R_L/Z), and efficiency etc. are calculated. This is one line of values at assumed value of load resistance.

(vii) Excitation capacitance C is changed by changing X_m in steps and steps (iii) to (vi) are repeated to obtain a set of values corresponding to initial load resistance.

(viii) Now load resistance R is increased in steps. Again steps from (ii) to (vii) are repeated for each value of load resistance. Hence we obtain the effect of terminal capacitance on the performance characteristics of given SEIG.

A flow chart used to prepare computer program for the above solution algorithm is given in Fig. 2 As discussed in wind power conversion schemes, induction generators are most suited to harness wind-energy. In remote areas autonomous operation of induction generators need a terminal capacitance for making them self-exciting. This terminal capacitance effects a lot to the generator performance characteristics.

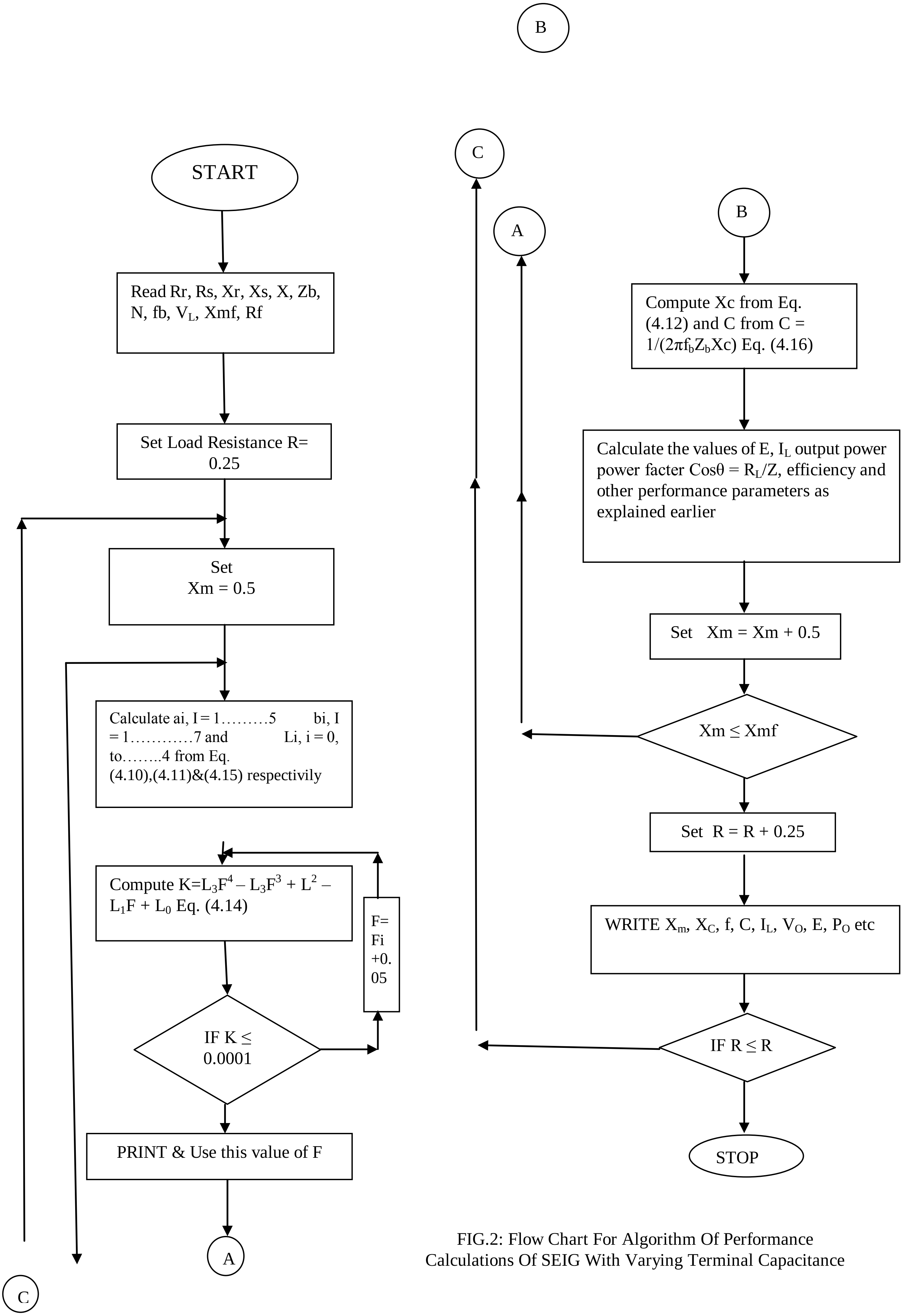

FIG.2: Flow Chart For Algorithm Of Performance Calculations Of SEIG With Varying Terminal Capacitance

V. RESULTS AND DISCUSSION

A computer program based on flow chart (fig. 2) gave various values of performance indices corresponding to different values of terminal capacitance for different values of load resistance for the SEIG parameters given in Appendix A. The results obtained are provided there in Appendix A in tabular form. The values of generated voltage V_g for constant frequency, and 'E' for given load voltage V_l have been obtained. Values of load current, magnetizing reactance, output power etc. gives a way to obtain machine performance with changing C. Some of the results have been plotted and discussed as follows.

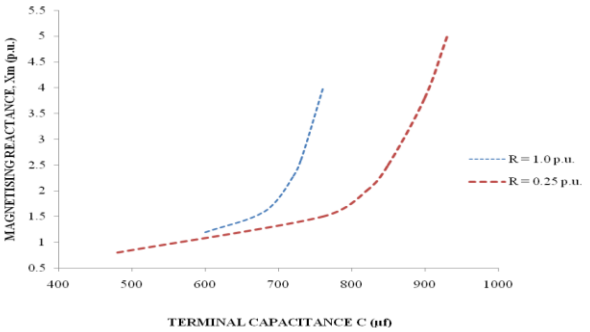

Fig.3: Variation Of Magnetising Reactance With C

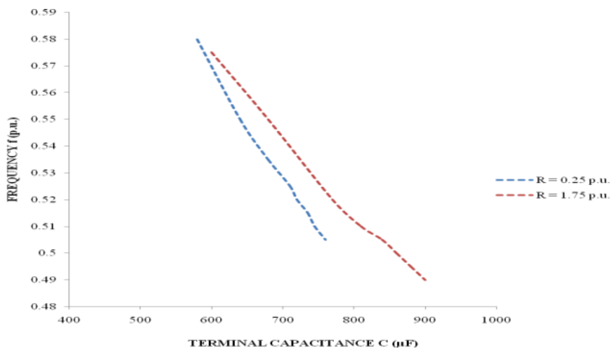

Fig.4: Variation Of Frequency With Terminal Capacitance

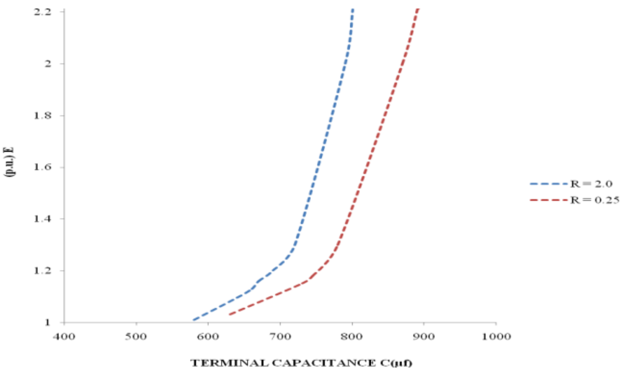

Fig.5: Variation Of Generated Voltage 'E' With Terminal Capacitance 'C'

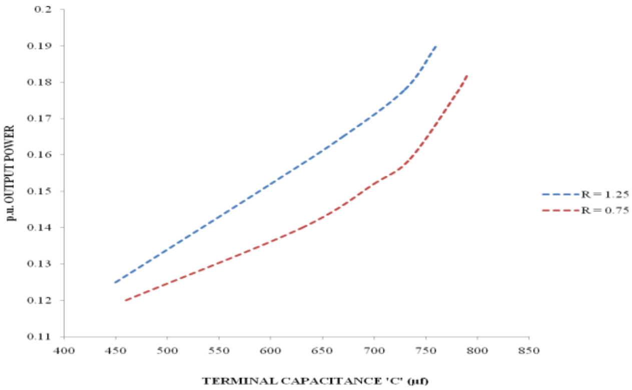

Fig.6: Variation Of Output Power With Terminal Capacitance

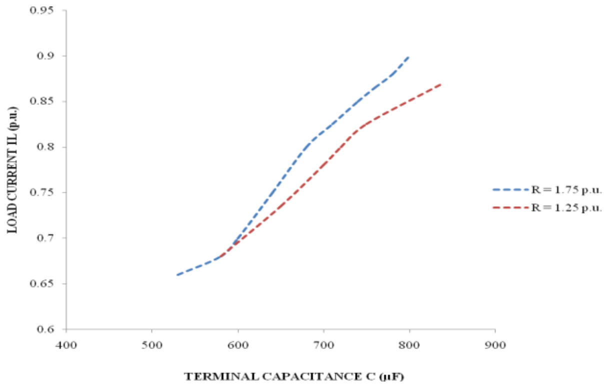

Fig.7: Variation Of Load Current With Terminal Capacitance

VI. CONCLUSION

As discussed in wind power conversion schemes, induction generators are most suited to harness wind-energy. In remote areas autonomous operation of induction generators need a terminal capacitance for making them self-exciting. This terminal capacitance effects a lot to the generator performance characteristics.

To evaluate the effect of terminal capacitance of SEIG performance a suitable mathematical model has been developed for computer solution of the problem. The results obtained shows that the role of terminal capacitance is highly important. It is not possible to sustain self-excitation if excitation capacitance is outside a specific range as is made clear in plots from performance computations. It is found that a minimum load impedance need be connected for self excitation. In the range of capacitance values where self excitation is possible performance of the SEIG feeding a balanced three-phase load is greatly affected. Voltage at base frequency drops with terminal capacitance. For fixed load voltage, the generated voltage rises linearly with terminal capacitance. Load current, output power etc. rises not only with excitation capacitance but also with load impedance. Thus the key role is played by excitation capacitance in the performance of SEIG. The method developed has made it easier to determine influence of terminal capacitance on the generator performance and is very important in near future for Rajasthan also as a wind power plant has been installed in Jaisalmer district with a capacity of 2 MW. This will further increase the use of improved SEIGs..

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