ANALYSIS OF THREE PHASES SELF EXCITED INDUCTION GENERATOR WITH RECTIFIER LOAD

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ABSTRACT: ***Self-excited induction generator use is popular for the renewable energy resources like as small hydro and other is wind. The capacitor self-excited induction generators are advance use advantages like synchronous generators for the reason of no require brushes and commutator, low cost, brushless rotor (squirrel cage construction), and absence of separate D.C source and ease of maintenance. In this Thesis, we are presented the steady-state analysis of self excited induction generator and a method to calculate the capacitance value of a 3 phase squirrel cage induction motor working as a generator in the self-excited mode of operation. To the manufacturer data capacitor value is determined. In steady state condition to Performance analysis of self-excited induction generator fed rectifier load. It is well known that, the induction generator, harmonics are generated in input side of due to the presence of rectifier circuit which is that non linear. In this thesis, the various rectifier loads (both controlled and uncontrolled) connected with the Self Excited Induction Generator are simulated and evaluated. Then Fast Fourier transformation algorithm is used to analyze the harmonic currents and voltages under steady-state conditions. Then finally the main objective of the thesis is to perform the steady state analysis of the proposed system. The simulation is done using MATLAB/SIMULINK software power system tools and the harmonics are calculated. The three test like D.C test, No Load test, Block rotor test performed in MATLAB software. Results are discussed and presented.***

I. INTRODUCTION

A device converts the mechanical energy into electrical based on electromagnetic induction. An emf induced in conducting loop or coil, when magnetic flux passing through the loop. When the loop is being closed by connect an external load, the induced voltage will cause an electric current to flow through the loop and load. Then the rotational energy is converted into electrical energy. Similar to an induction motor, when an induction machine driven at speed is greater than synchronous speed by means of an external prime mover , then the direction of the torque is reversed direction and then the theoretically it is start an induction generator. When the induction machine that is the negative slip region, this is show that the machine draws a current, which lagging the voltage is more than 90. That means that real power flows of the machine but the induction machine needs the reactive power. So then after to voltage build up, excitations must be provided; therefore, the two types of excitation provided like, (grid connected and isolated mode). This voltage build up process an induction generator is very much similar to the dc generator. That's must be residual magnetism suitable value present in the rotor. The proper value absence of residual magnetism, the voltage will not build up. That means this is a sensible high value of residual magnetism, as it is ease the excitation of the machine. When the induction generator first starts to run, then the small voltage induced of residual magnetism in the rotor circuit. This small voltage produces a capacitor current flow, which increases the voltage is fully build up. Which increase the voltage built up, so this kind of capacitor may able to supply of induction generator.

II. CLASSIFICATIONS OF INDUCTION GENERATORS

Based on different ways such as rotor construction, excitation process and prime movers induction generators can be classified into Fig. 2.1.

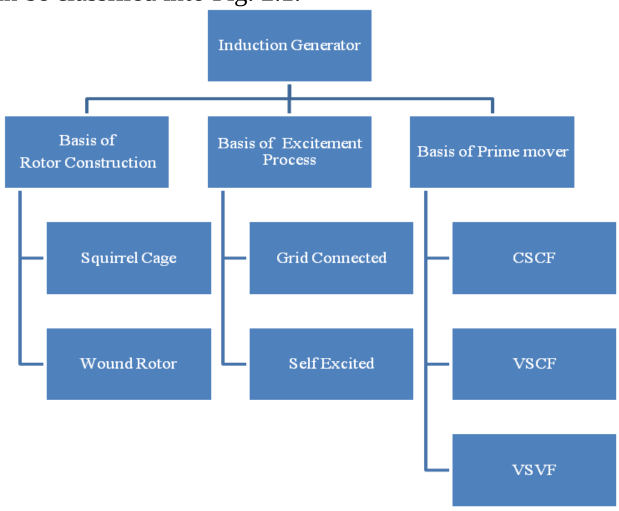

Fig 2.1 Classification of Induction Generator

2.1 Classification on the basis of their Rotor Construction

- Squirrel cage induction generator
- Wound rotor induction generator

A. Squirrel Cage Induction Generator

The squirrel cage type induction generator, the rotor winding consists of un-insulated conductors, in this induction generator copper and aluminum bars embedded in the semi closed slots. These solid bars are short circuited of both ends by end rings of the same material. Without the rotor core, the rotor bars and end rings seen like the cage of a squirrel. The rotor bars are form a uniformly distributed winding in the rotor slots are shown in Fig. 2.2

Fig 2.2 Squirrel Cage Rotor

B. Wound Rotor or Slip Ring Induction Generator
The wound rotor type induction generator, the rotor slots include an insulated distributed winding similar to that used on the stator. The wound rotor of induction generator cost is more and requires increased maintenance. The wound rotor or slip ring rotor is shown in Fig. 2.3

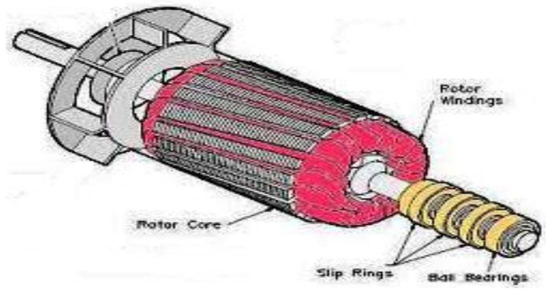

Fig 2.3 Slip Ring Rotor

2.2 Classification on the basis of their Excitement Process

- Grid connected induction generator
- Self-excited induction generator

A. Grid Connected Induction Generator
Grid connected induction generators takes their excitation from the grid, and generate real power via slip control when machine driven above the synchronous speed, so it is called grid connected induction generator. It is also called electric utility and they have no means of producing or generating voltage until such time the generator is connected to the grid. Induction generator is direct drive which is connected to the parallel to the utility system or grid. when the grid becomes goes down or such a blackout then all the sets of generators are goes down or blackout.

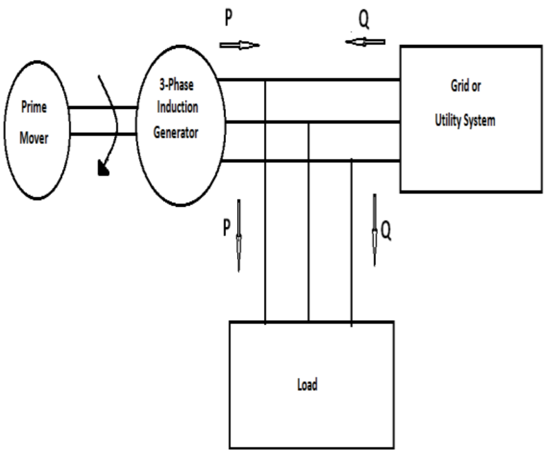

Fig 2.4 Grid Connected Induction Generator

B. Self-Excited Induction Generator (SEIG)
The self excited induction generator (SEIG) receives their power for excitation process from a capacitor bank, which is connected across the stator terminals of the induction generator which provide lagging the reactive power. This capacitor bank also supplies the reactive power to the load. These capacitors are shown in Fig. 2.5.

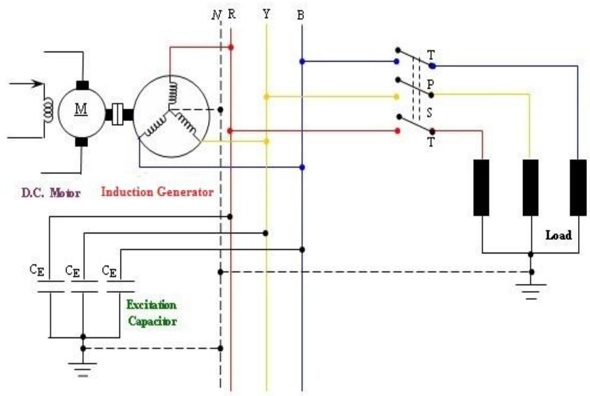

Fig 2.5 Self-Excited Induction Generator (SEIG)

III. STEADY STATE ANALYSIS OF SEIG

In SEIG both terminal voltage and frequency are unknown and by knowing the parameter of machine, it will possible to determine the performance for given capacitance, speed and load condition. If the terminal frequency and voltage are known, when machine should be a connected in infinite bus-bar, the performance is straight forward. For the Steady-state analysis, the following assumptions are made: 1- Only the magnetizing reactance is assumed to be affected by magnetic saturation, and all other parameters of the equivalent circuit are assumed to be constant. 2- Leakage reactance of stator and rotor to be equal. 3- Core loss in the machine should be neglected. 4- mmf space harmonic and time harmonic in induce voltage and current waveform are ignored.
This assumption is valid in well design machine.

IV. STEADY STATE MODEL OF INDUCTION MACHINE

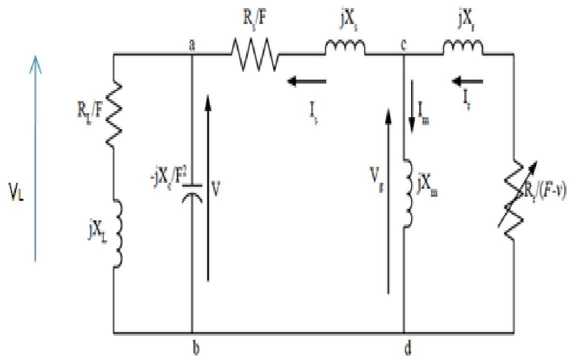

Fig: - 4.1 per phase equivalent circuit

Following two solution techniques based on the steady-state equivalent circuit are:

- Nodal Admittance Method
- Loop Impedance Method

V. DETERMINATION OF EQUIVALENT CIRCUIT PARAMETERS

- No Load Test
- Blocked Rotor Test
- D. C Test

No-Load Test:

This test is conduct for rotational losses of motor and to determine its equivalent circuit of parameter. In this test rated balance ac voltage and rated frequency applied to stator while its running of no load condition. Next in below simulate of no load test. Where three phase y-connected ac source whose per phase voltage 220v/50 hz is applied to stator terminal of induction motor. And also three electrical terminal input (A-B-C), and output terminal (a-b-c) which is short circuited. The mechanical torque (Tm) of machine shaft set to be a zero of no load condition. And also current measurement block are used to instantaneous current in each phase. And output of this current block connected to rms block, which is called signal rms and it's determine rms value of each phase. Similarly voltage measurement block, rms block, and display box are used to measure phase A voltage. And output of current and voltage measurement block of phase A are connected to power measurement block, which called active and reactive measurement, this compact the active and reactive power.

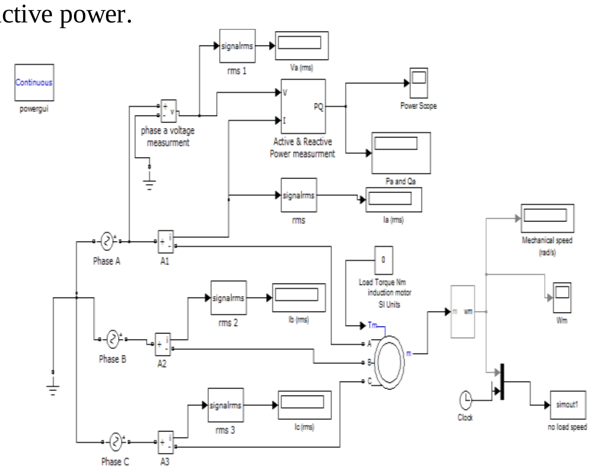

Fig: 5.1- no load test

Blocked Rotor Test

This test is conduct to determine its equivalent circuit of parameter. In this test rotor of induction motor is blocked and reduce voltage is applied to stator terminal. So the rated current flows through stator winding. The input power voltage and current are measured. Next in below simulate of blocked rotor test. This test is almost same as the no load test. There is a slightly difference between the two models. In this model induction motor is set to infinity in order to simulate this test. And again several measurement blocks are used to measure current, voltage, active and reactive power. In this test mechanical torque is not to be zero in case (Tm=5NM), which will not affect the blocked rotor condition since inertia is infinity. This infinite inertia rotor speed remains zero during blocked rotor condition.

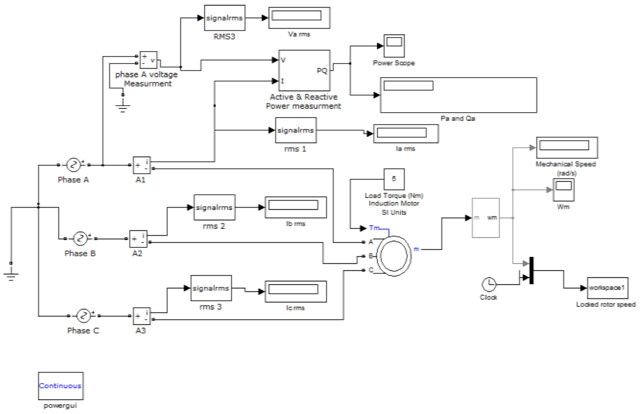

Fig: 5.2- blocked rotor test

Measurement of Stator Resistance (D.C Test)

To measure a stator resistance test a dc voltage is applied to across a winding. The ratio of dc voltage and dc current gives the value of stator resistance. The dc test is performed to compute the stator winding resistance R1. An induction motor block is used to who's electrical and mechanical parameter can specified either (SI). A 220v dc source is applied to two phase A and B of induction motor through series resistance. Phase c is grounded through series resistance. The purpose of series resistance between dc source and induction motor is to limit the current flowing through the two winding of motor.

Stator resistance can easily compute R1=0.5 Vdc/Idc.

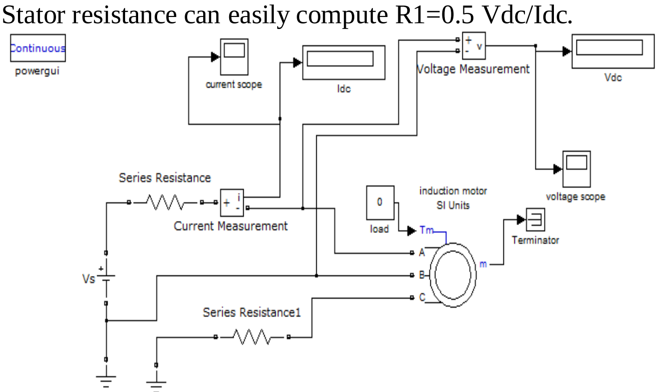

Fig: 5.3- D.C Resistance Test

VI. MATLAB/SIMULINK MODELS WITH DIODE RECTIFIER LOAD:

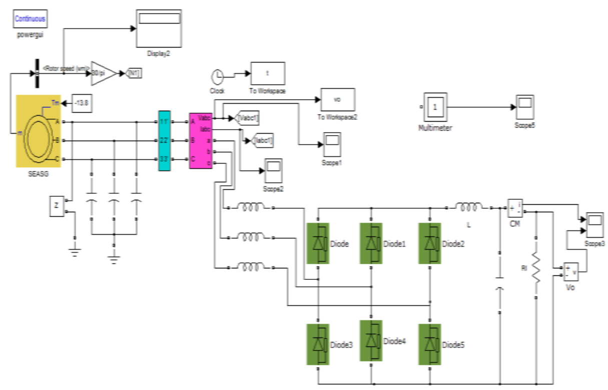

Fig: 6.1-SEIG with Diode Rectifier Load

The performance of the SEIG with non-linear load is shown in Fig.6.1.The uncontrolled rectifier is considered as the non-linear load. The circuit consists of resistive load (91.3Ω), a filter with a shunt capacitor of C_f (250µf) and a series L_f (1mH). It is observed from the waveform that a significant dip occurs at the top of the line current. If a dc load filter is used, it reduces the distortions. The Rectifier gives fixed output voltage. To formulate the uncontrolled rectifier model the MATLAB/SIMULINK software is employed and is shown in Fig .6.1.The input phase voltage of the SEIG is shown in below and due to harmonics the wave form of phase voltage are disturbed means non sinusoidal waves.

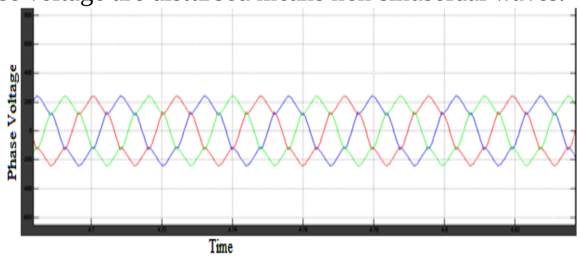

Fig: 6.2-SEIG Phase Voltage Rectifier Load

The output voltage of diode rectifier is shown in Fig. 6.3. It is observed from the waveform that a significant dip occurs at the top of the voltage.

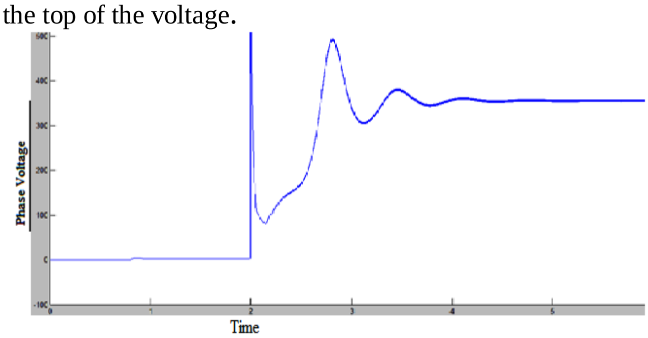

Fig: 6.3- SEIG Diode Rectifier Output Voltage

VII. MATLAB/SIMULINK MODELS WITH MULTI-PHASE DIODE RECTIFIER

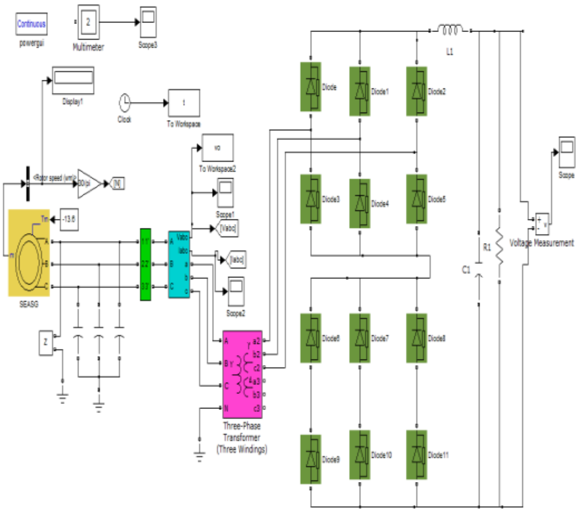

Fig 7.1 SEIG with Multi-Phase Diode Rectifier

Output waveform of multi-phase converter is improved compared to single stage shown in fig.

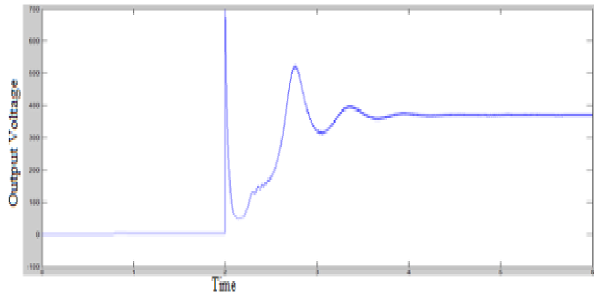

Fig 7.2 Multi-Phase Diode Rectifier Output Voltage

VIII. HARMONIC ANALYSIS

When the rectifier load is connected to the terminals of a SEIG the undesired problems, due to harmonic currents, such as additional power losses, high-frequency pulsating torque, the output capacity etc. will occur .To evaluate the harmonic components that are present in the generated voltages, stator currents, and load currents under the steady state conditions is analyzed. The quality of the generated output voltage is evaluated by the total harmonic distortion. The THD is an index of the closeness in shape between the waveform and its fundamental component of voltage. The harmonic analysis of uncontrolled rectifier is shown in below figures. The harmonics order is taken for a fundamental frequency of 50 Hz.

Harmonics Analysis of Diode Rectifier

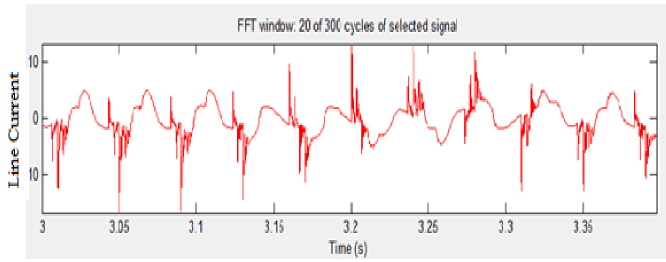

Fig: 8.1- SEIG Line Current Due to Diode Rectifier Harmonics

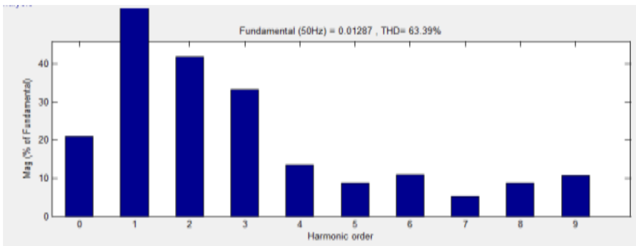

Fig: 8.2- SEIG Line Current Harmonic Order at 50hz

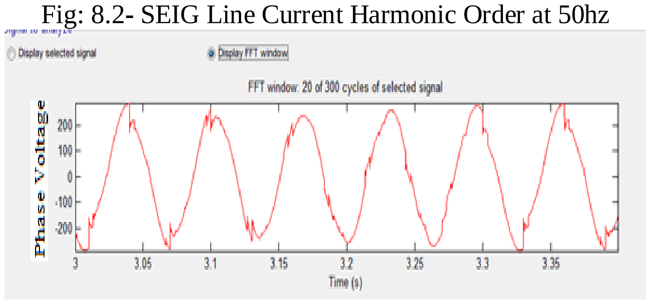

Fig: 8.3- SEIG Phase Voltage Due to Diode Rectifier Harmonics

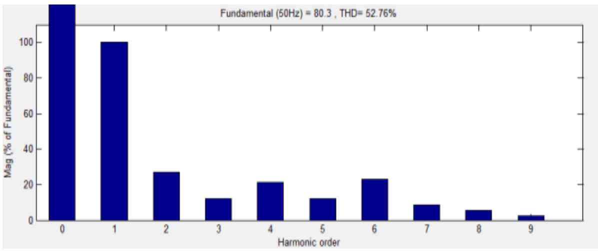

Fig: 8.4- SEIG Phase Voltage Harmonic Order at 50hz

Harmonics Analysis of Multi-Phase Diode Rectifier

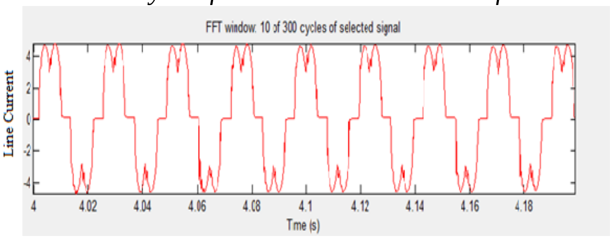

Fig: 8.5- SEIG Line Current Due to Multi-Phase Diode Rectifier

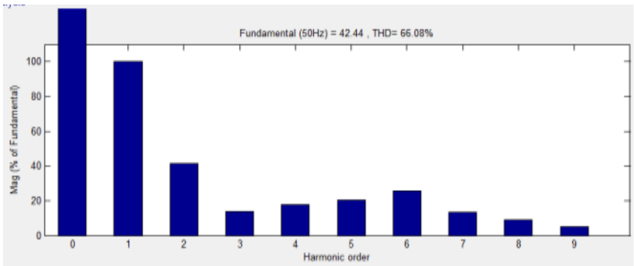

Fig 8.6- SEIG Line Current Harmonic Order at 50hz

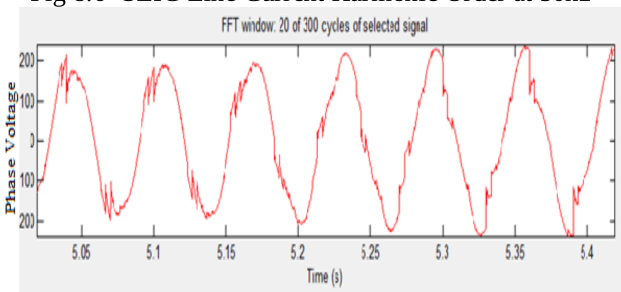

Fig 8.7- SEIG Voltage Due to Multi-Phase Diode Rectifier

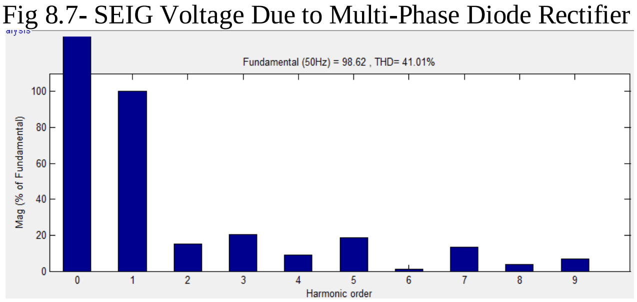

Fig 8.8-.SEIG Phase Voltage Harmonic Order at 50hz

IX. 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. SEIG has several advantages such as reduced unit cost and size, ruggedness, brushless, absence of separate dc source, ease of maintenance, self-protection against severe overloads and short circuits and that there is no need of reactive power from transmission line as it draws reactive power from capacitor bank connected in shunt. SEIGs have been mainly used in a single system like wind or micro hydro, etc. This dissertation has presented the performance of an isolated self-excited induction generator (SEIG) feeding a rectifier load. The steady-state performances are investigated by using the induction machine model. The models of the multi-phase both un-controlled and controlled rectifiers are also formulated by using MATLAB/SIMULINK software. It has been shown that the developed models show the simulated result very well when applied the different non linear loads. Harmonic content caused by the nonlinear rectifier load are estimated with the FFT algorithm. The harmonics of single stage rectifier is analyzed. THD and HF also calculate in this dissertation.

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REFERENCES

[1] R. C. Bansal, "Three Phase Self Excited Induction Generator: An Overview," *IEEE Trans. Energy Convers.* vol. 20, no. 2, Jun. 2005.

[2] Saffet Ayasum, C.O Nwankpa, "Induction motor test using Matlab / Simulink and their integration into under graduate electric machinery course," *IEEE Trans*, vol.48, no.1, pp.37-46, Feb 2005.

[3] R. C. Bansal, T. S. Bhatti, and D. P. Kothari, "A bibliographical survey on induction generators for application of non-conventional energy systems," *IEEE Trans. Energy Convers.* vol. 18, no. 3, pp. 433–439, Sep. 2003.

[4] M. Tazil ,V. Kumar, R.C. Bansal, S. Kong, Z.Y. Dong, W. Freitas, H.D. Mathur, "Three-phase doubly fed induction generators: an overview,'' *IET Electr. Power Appl*. vol. 4, Issue. 2, pp. 75–89, Jan. 2010.

[5] S. Sharma, K.S. Sandhu, "Role of Reactive Power source on power quality of three phase self excited induction generator," WSEAS Trans on power system, issue 4, vol.3, Apr. 2008.

[6] Ion Boldea, "Variable Speed Generators: The Electric Generator Handbook" CRC Press, Boca Raton, FL, 2006.

[7] S.S. Murthy, B.P. Singh, C. Nagamani, and K.V.V. Satyanarayna, "Studies on the use of conventional induction motors as self excited induction generator," *IEEE Trans. Energy Conversion*, vol. 3, pp. 842 – 848, Dec. 1988.

[8] S.Kulandhaivelu, K.K Ray, "Load control of a 3-ø self excited asynchronous generator," *IJEST*, vol.3,

pp.1103-1112, no.7, Feb. 2011.

[9] K. Subramanian, K. K. Ray, K. Hari Prasad, Nand Gopal.E, Nimisha Gupta, Nirupama.V, Pragyajha and Meenakshi Sinha, “State Of The Art of Electronic Load Controller of Self- Excited Asynchronous Generator Used In Mini / Micro Hydro Power Generation,’’ *ACEEE International Journal on Control System and Instrumentation*, vol. 1, no. 1, July 2010.

[10] T. F. Chan, Loi Lei Lai, “Capacitance Requirements of a Three-Phase Induction Generator Self-Excited With a Single Capacitance and Supplying a Single-Phase Load,’’ *IEEE Trans. on Energy Conv*. vol. 17, no. 1, March 2002.

[11] J. M. Elder, J. T. Boys, and J. L. Woodward, “The process of self excitation in induction generators,” *in Proc. Inst. Elect. Eng. B*, vol. 130, no. 2, pp. 103–108, March.1983

[12] D. Bispo, L. Martins, Neto, J.T. de Resende, and D.A. de Andrade, “A new strategy for induction machine modeling taking into account the magnetic saturation,” *IEEE Trans. Industry Applications*, vol. 37, no. 6, pp. 1710-1719, Nov. Dec. 2001.

