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Voltage Regulation of a Stand Alone 3-Ø Self-Excited Induction Generator Using AC/DC/AC Converter Fed RLC Series Circuit

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Abstract: This paper presents the voltage regulation of a stand-alone 3-Ø self-excited induction generator (SEIG) using AC/DC/AC converter fed series RLC circuit. The effects of change in inverter frequency on the terminal voltage of the SEIG and the current, drawn by the rectifier circuit have been analyzed. The frequency variation in series RLC circuit obtained by inverter produces the phenomenon of an inductive, capacitive reactance and resistive effect at the point of common coupling (PCC) of the generator terminal. This is equivalent to injecting leading/lagging reactive power into SEIG. Further the performance study of SEIG has been carried out. The proposed system has been simulated using power system tool box in Matlab/Simulink software.

Keywords: Self-excited induction generator, AC/DC/AC converter, PWM inverter, RLC series circuit, voltage regulation.

I. INTRODUCTION

The continuous increase in power demand scenario emphasis the use of Non-Conventional Energy Sources (NCES) due to fast reduction of conventional energy sources. The recent trend to tap solar, wind and tidal energy are becoming popular amongst the renewable energy sources. Squirrel cage induction generator (SCIG) emerged as a possible alternative to synchronous generator in an isolated power generation because of its low cost, no separate DC excitation requirement, less maintenance and rugged construction etc.[1]-[8]. The different types of voltage control schemes have been presented in detail [9]. R. Bonert et al [10] & [11] controlled the output power of the self-excited induction generators in hydro power generation using the impedance controller. A 3-Ø rectifier circuit is used to convert a.c to d.c power and a d.c chopper circuit is used to control dc power. This technique could control the power that is wasted in the external resistance (Dump load resistance).

S. S. Murthy et al [12] & [13] presented a load controller using 3-Ø rectifier with a d.c chopper circuit in constant power operation of induction generator. The rectifier and d.c chopper circuits are used as power balancers between the loads and dump load in such way that, the induction generator assumed to be fully loaded in all conditions. Bhim Singh et al [14] discussed about the design, analysis and modification of an electronic load controller (ELC) in detail and the technique is successfully implemented in hydro power generation control. Transient analysis of induction generator with ELC has been reported by same authors recently [15]. Yogesh K. et al [16] makes a review of different types of voltage and frequency controllers. Each controller employed for a certain applications [17]. The technique presented by Karim H. Youssef [18] modified and used in the proposed controller. Absence of harmonics generation is a great advantage of this controller.

In this paper the voltage regulation of 3-Ø SEIG is done using AC/DC/AC converter fed series RLC circuit. A simulink model of AC/DC/AC converter fed RLC series circuit and SEIG fed RL load are configured using power system tool box in Matlab/Simulink. A line diagram of the proposed system is shown in Fig.1 (a).

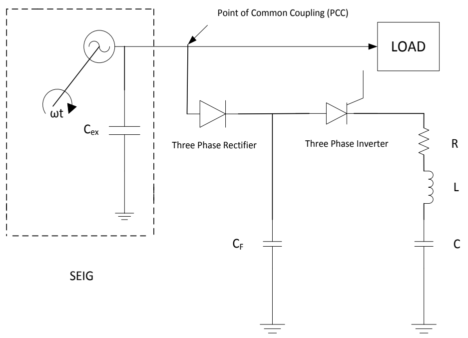

Fig.1 (a). Line diagram of the proposed system

II. SYSTEM CONFIGURATION

A. Proposed System

The power diagram of the proposed system is shown in Fig.1 (b). It consists of an induction motor coupled with a separately excited d.c motor and 3-Ø capacitor bank (C_E). The excitation capacitor bank, connected across the stator windings of the SEIG and supply power to the load. An RLC series circuit is connected with 3-Ø inverter. The inverter is configured with power electronic switches (S_1 - S_6). A 3-Ø uncontrolled bridge rectifier (D1-D_6) circuit with DC filter capacitor is connected to the generator terminals at the PCC shown in Fig.1 (b).

B. Principle of Operation

With main switches open separately excited D.C motor is started and allowed to run till the rotor of an induction motor reaches to a speed above the synchronous speed of the rotating m.m.f. Synchronous speed test is carried out to determine the sufficient 3-Ø capacitor bank to generate e.m.f in the rotor circuit and connected across the stator terminals. As rotor rotates consequently, voltage is induced across the stator terminals. This process is known as self-excitation process and hence called as self-excited induction generator (SEIG). Now the switch (TPST) has been closed and the load is connected to the generator terminals. The current, voltage and power drawn by the load have been measured. When the rectifier switch is closed, the d.c voltage builds up to its rated value. Then, the inverter circuit is triggered using the gate pulses (PWM based gate pulsed). The power switches are gated in such a way that the inverter current may resonate, lead or lag in the series connected passive elements of

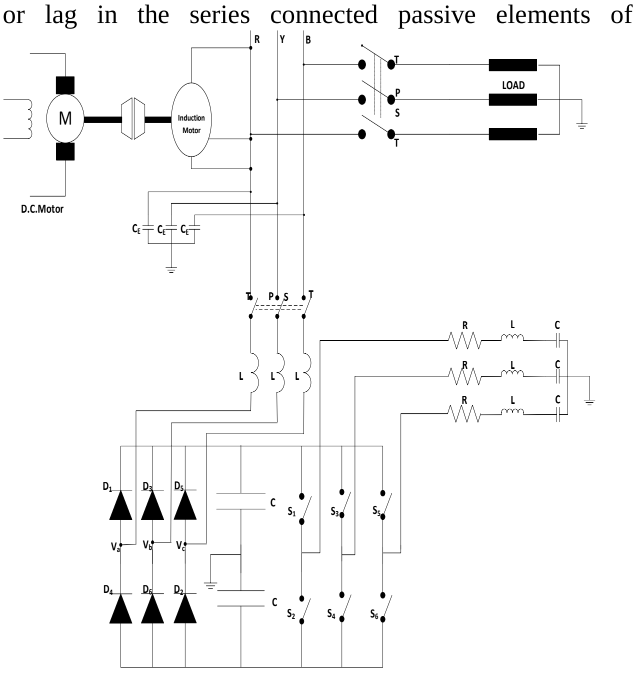

Fig. 1(b). Power diagram of proposed system with controller

resistor, inductor and capacitor (shown in Fig. 2). The performance of SEIG has been changed with AC/DC/AC inverter fed RLC series circuit based on the change in effective impedance. A change of SEIG's performance has been studied at resonance frequency (50Hz); below the resonance frequency (25Hz) and above the resonance frequency (75Hz) of the inverter fed series RLC circuit in constant power operation.

C. Series resonance circuit

The basic concept of the proposed control technique, a well known simple circuit of series connected resistance, inductance and capacitance is presented in Fig. 2. The authors made an experimental attempt to implement this technique in SEIG power control application [19]. The circuit diagram and characteristic equations have been set forth here.

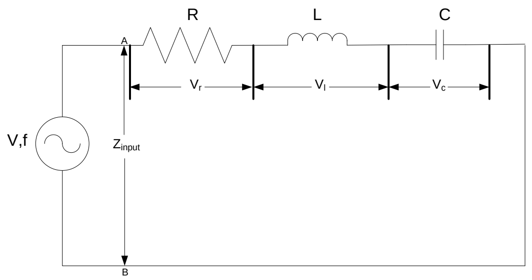

Fig. 2. Typical series RLC circuit

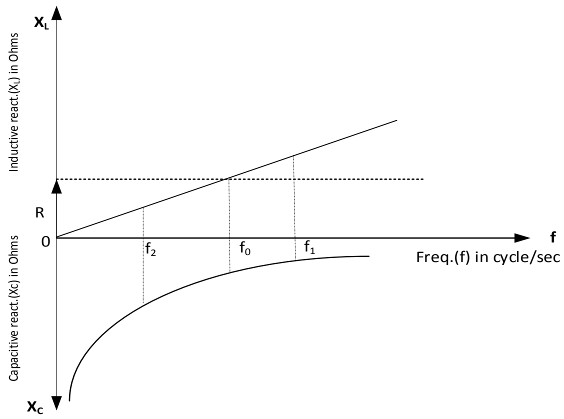

Fig. 3. Characteristics behavior of RLC series circuit with frequency changes

Fig.3 illustrates the RLC series circuit characteristics at different frequencies of operation. These characteristics can also be obtained from equation (1) at different frequencies.

$$f_o = 1/2\pi\sqrt{LC} \qquad (1)$$

III. SIMULATION

The simulation circuit is made using power system tool box of Matlab/Simulink software version R2012a as shown in Fig.4. A star connected induction machine is used as generator. A bank of 3-Ø capacitor (16μF in each

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phase) is connected across the stator terminals of the motor, used to self-excite the machine. A constant mechanical torque of -13.8 NM (negative sign indicates the external torque applied) has been chosen for the simulation study. The external circuit is connected through three measuring units (M_1, M_2 & M_3) and load of resistance (R=100) and inductance (L = 318mH). The inverter are constructed using ideal switches (6 Nos.). Six power diodes (D_1- D_6) are used to make the rectifier circuit and two D.C links capacitors (C= 1000 µF) are used as filters as well as energy storing elements, The triggering PWM based signal for the inverter switches are generate at a carrier frequency of 1080Hz. The simulated results are described in the fifth coming paragraph.

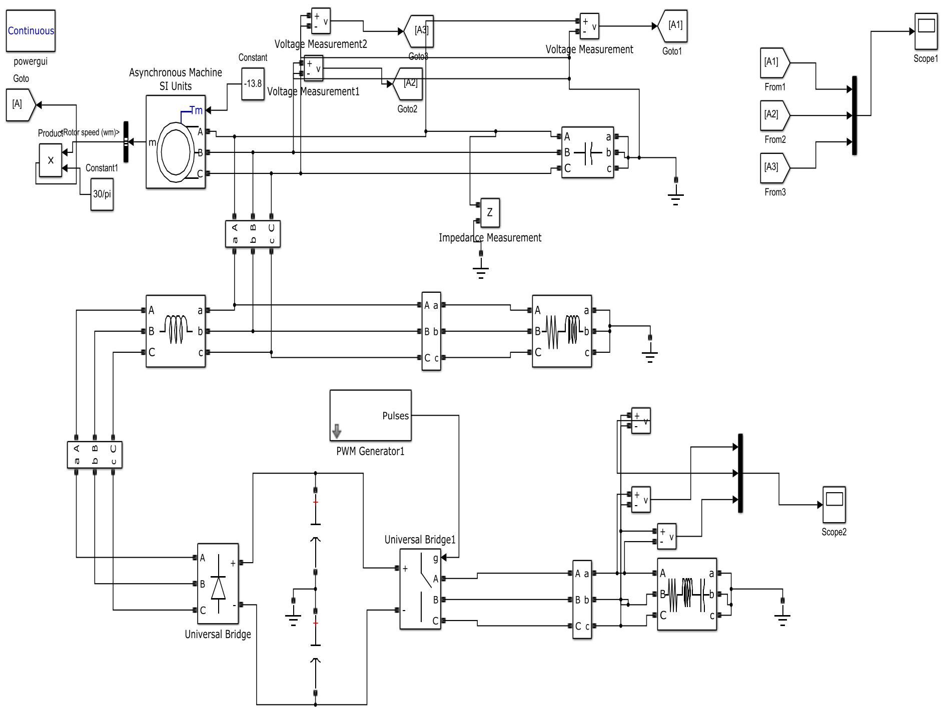

Fig. 4. Simulation diagram of the proposed system

IV. RESULTS AND DISCUSSION

1) The simulation studies of SEIG have been completed with the following conditions

A) Without AC/DC/AC inverter fed RLC series circuit

- No load
- And with RL Load

B) With AC/DC/AC inverter fed RLC series circuit

- With resonance conditions

The above cited conditions have been included in this simulation within 2 seconds. To understand the no load performance of the generator, the external circuit (load/Converter) is disconnected from the generator up to 0.5 seconds). Thereafter, load is connected to the generator terminal.

The simulated result in Fig.5 (a) shows the generated voltage rising more than the rated value and then settled at 2000V approximately peak to peak is shown in Fig.5 (b). From Fig. 5(a) and Fig.5 (b) it is inferred that, the rise in induced voltage is due to the capacitance value (20µF) of the excitation capacitor is more than the required value to meet the full load capacity of the generator. Fig. 5(c) and Fig. 5(d) depicted the load voltage wave form and its extracted wave form respectively. The load current wave form is shown in Fig.5 (e).

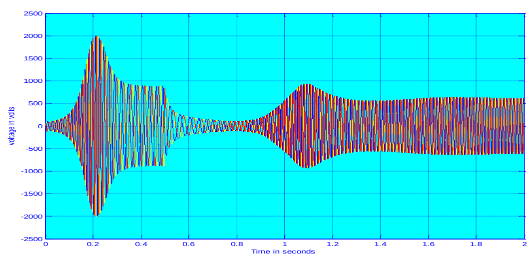

Fig. 5(a). Simulated 3-Ø voltage waveform of SEIG

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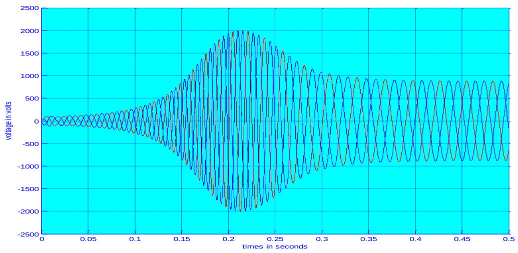

Fig. 5(b). Extracted voltage waveform of SEIG (0.5 seconds)

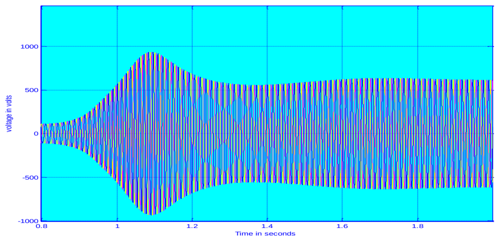

Fig. 5(c). Extracted 3-Ø voltage waveform of SEIG (1.8 seconds)

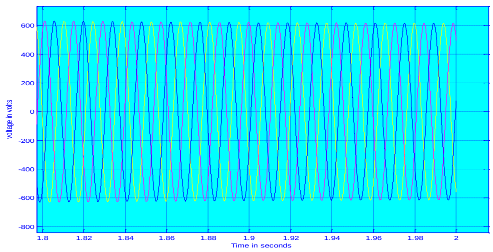

Fig. 5(d). Extracted stable voltage of SEIG (1.8 seconds – 2 seconds)

For the inverter frequency fixed at 50 Hz, the variations of voltage current harmonic generated by the AC/DC/AC converter circuits and its effective impedance of the whole system are shown from Fig.6 (a)-Fig.6 (b) respectively. The output shows the AC/DC/AC converter is an additional load for the SEIG, because the RLC series circuit behaves as a series resonance circuit. Fig.6(c) shows the impedance variation of the system, which reveals the non-linearity.

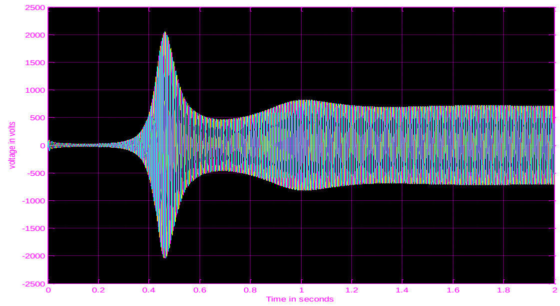

Fig. 6(a). Voltage waveform of the system with AC/DC/AC converter (50 Hz)

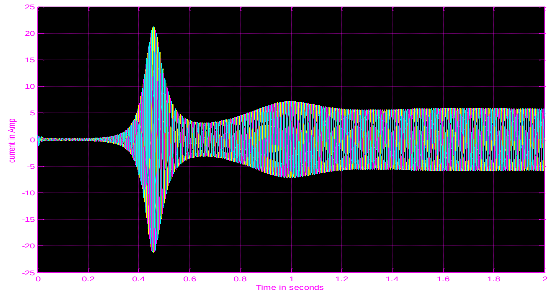

Fig. 6(b). Current waveform of the system with AC/DC/AC converter (50 Hz)

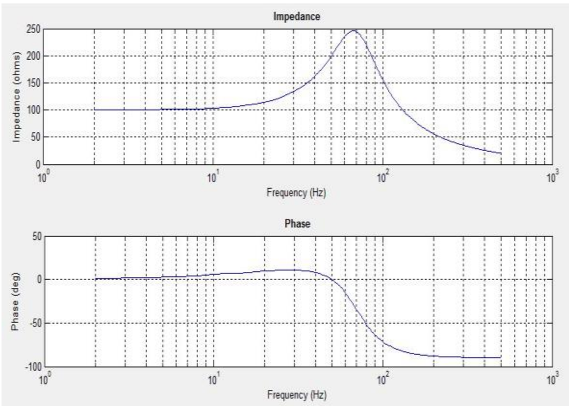

Fig. 6(c). Effective impedance and phase changes at 50 Hz operation of invert

V. CONCLUSION

Simulation of the proposed system with AC/DC/AC inverter fed RLC series circuit in open loop has been studied. The conclusion that the characteristics impedances of series circuit changes due to frequency changes that reflect into the system at PCC. So that a conclusion is made that impedance changes at PCC is a similar to the phenomenon of capacitive VAR injection or consumption. Since, the rectifier circuit has been constructed using diodes; it is not possible to make the current to lead the voltage at PCC. But it is possible to adjust the power factor of the system up to certain limits.

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REFERENCES

[1] Basset E. D. and Potter F. M., "Capacitive Excitation for Induction Generators," *AIEEE committee of Electrical Engineering*, pp 535–545, 1935.

[2] C. F. Wanger, "Self-Excitation of Induction Motors," AIEE Trans., Vol.58, pp. 47–51, 1939.

[3] E. Barkle and R.W. Ferguson, "Induction Generator Theory and Application," AIEE Trans., pt. III A, vol.73, pp 12–19, 1954.

[4] Barkle and Perguson, "Induction Generator Theory and Application," AIEEE committee of Electrical Machinery, pp 12 – 19, 1954.

[5] Novotny D. W.,Gritter and Studtman, "Self-Excitation In Inverter Driven Induction Machines", IEEE Transaction on power apparatus and system, Vol.PAS-96,No. 4, pp 1117–1125,1977,

[6] Arrillaga, J. and Watson, D. B. "Static Power Conversion from Self-Excited Induction Generators," IEE Proc. Vol.125, No.8, pp 743 – 746, 1978.

[7] S. S. Murthy, O. P. Malik, and A. K. Tandon, "Analysis of self-excited induction generator," Proc. Inst. Elect. Eng. C, vol.129, no. 6, pp. 260–265, Nov. 1982.

[8] R. C. Bansal, "Three-Phase Self-Excited Induction Generators: Overview," IEEE Transaction on Energy Conversion, vol.20, No.2, pp. 292 – 299, June 2005.

[9] G. Raina and O. P. Malik, "Wind Energy Conversion Using A Self-Excited Induction Generator," IEEE Trans. Power App. Syst., Vol. PAS -102, no. 12, pp. 3933–3936, 1983.

[10] R. Bonert and G. Hoops, "Stand Alone Induction Generator with Terminal Impedance Controller And No Turbine Controls", The IEEE Energy Development and Power Generation Committee of the IEEE Power Engineering Society for presentation at the IEEE/PES 1989 Summer Meeting, Long Beach, California, pp 28 -32, July 9 - 14,1989.

[11] R. Bonert and S. Rajakaruna, "Self-Excited Induction Generator with Excellent Voltage and Frequency Control", in Proc. IEE Generation, Transmission & Distribution, Vol.145, No. I., pp 31 - 39, January I998.

[12] S. S. Murthy, Rini Jose and Bhim Singh, "A practical load controller for stand-alone small hydro system using Self- Excited Induction Generator", *in Proc, IEEE,* pp 359 – 364, 1998.

[13] Bhim Singh, S. S. Murthy and Sushma Gupta," An Improved Electronic Load Controller for Self-Excited Induction Generator in Micro-Hydel Applications", *in Proc. IEE*, pp 2741 -2746, 2003.

[14] Bhim Singh, S. S. Murthy and Sushma Gupta, "Analysis and Design of Electronic Load Controller for Self-Excited Induction Generators" IEEE Transactions on Energy Conversion, Vol.21, No. 1,pp 285 – 293, March 2006

[15] Bhim Singh, S. S. Murthy and Sushma Gupta, "Transient Analysis of Self-Excited Induction Generators with Electronic Load controller supplying static and Dynamic loads," IEEE Transactions on Industry Applications, Vol.41, No. 5, , pp1194 - 1204, September 2005.

[16] Yogesh K., Chauhan, Sanjay K. Jain, and Bhim Singh,"A prospective on voltage regulation of self-excited induction generators for industry applications", IEEE Transaction's on Industry Applications, Vol.46, No.2, pp 720-730, 2010.

[17] Bhim Singh, S. S. Murthy and Sushma Gupta, "Analysis and Design of Electronic Load Controller for Self-Excited Induction Generators" IEEE Transactions on Energy Conversion, Vol.21, No. 1, pp 285-293, March 2006.

[18] Karim H. Youssef, Manal A, Wahba, Hassan A. Yousef and Omar. A. Sebakhy, "A new method for voltage and frequency control of standalone self-excited induction generator Using PWM converter with Variable DC link voltage", IEEE conference, 2008 American Control Conference Westin seattle Hotel, Seattle, Washington, USA, pp.2486 -2491, June 11-13, 2005.

[19] R. Bonert and S. Rajakaruna, "Self-Excited Induction Generator with Excellent Voltage and Frequency Control", in Proc. IEE Generation, Trans*mission & Distribution*, vol.145, No. I., pp 31 - 39, January, I998.

APPENDIX-A

MACHINE DATA

2.2 kW, 4.5 A, 3 Ø, 415 V, 50 Hz, 4 Pole, 1440 rpm, Delta Connected,

Stator Resistance = Rotor Resistance = 5.6Ω,
Stator Leakage Inductance = Rotor Leakage Inductance = 14mH, Mutual Inductance = 0.2mH,
Inertia = 0.055,
Friction Factor = 0.066Nm.s