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Transient Analysis Of Self Excited Induction Generator With Electronic Load Controller (ELC)

Rahul Gupta, Aseem Chandel, Girijapati Sharma, Raj Kumar Baghel*
B.S.A College of Engineering and Technology, Mathura, India

Abstract

Fast depletion of fossil fuels has drawn attention towards the use of nonconventional energy sources like wind, biomass, tidal/wave, and small hydro potential. In remote locations, harnessing of the electrical energy from such local resources can be cheaper and easier compared to grid connection, which involves long transmission lines and associated losses. A micro-hydro system using natural hydro potential with minimal civil works is a strong candidate in this race. Uncontrolled low head turbines are prescribed for such applications.
In this paper, a transient investigation of a self-excited induction generator (SEIG) with electronic load controller (ELC) utilized as a part of stand-alone smaller scale hydro power generation utilizing uncontrolled turbines. In perspective of the need to sustained single phase loads from such frameworks, the transient behavior because of switching in of such loads is of interest and is completed here. A composite scientific model of the total framework has been created by consolidating the demonstrating of prime mover, SEIG, ELC, and load. Simulated results are contrasted and the exploratory ones, acquired on a created model of a SEIG-ELC framework for the beginning of an IM and switching in a resistive load. For the beginning of an IM, a star/delta starter is utilized to stay away from inrush current.

Keywords: dump load, ELC, induction generator, PI controller

****Corresponding Author***
E-mail: aseemchandel@gmail.com

INTRODUCTION

As the fast degrading of fossil fuels, there is a demand of sources which are non-conventional like solar, wind, tidal, geothermal energy etc. A hydro power generation is the main source which requires a minimum work to establish this and it is very economical. .So this generation is very easy to operate. So, to maintain the input power constant for different types of applications three types of turbine are used low, medium and high head.[1-5] At a far distance the controlling of energy which is obtained from local sites or places is available at very minimum cost. Constant power is required by the SEIG at different varying loads so for this purpose we use the most commonly device Electronic Load controller (ELC).

A system which we have to use for the load which is to be controlled by an uncontrolled rectifier system. His system is to be controlled by varying the on-off period of dc to dc converter to maintain the demand of consumer is to be constant for electronic load controller.[2] The load which we have to obtain for variation of duty cycle of chopper is used for various static and dynamic loads and can be operated for the electrical devices like fan, tube lights, mixer, and grinder and also used for welding, heating and illumination. The loads which we have used will give transient or distorted waveforms. This can be improved by an Induction generator with the interconnection with electronic load controller.[3]

SELF EXCITED INDUCTION GENERATOR

The induction generator (IG) ability to produce a power at different varying speed which will be helpful in various applications in various modes over the traditionally used generators, normally synchronous generators. Most of the industries used small induction generators because of the economic point of view and also the cost point of view. There are so many advantages for induction generators in comparison to other generators.

The most important advantage is that the induction motor is self-starting. The other advantage is that it can be easily to excite, easy to start and control requirements, and easy to detect fault level for the higher voltage .So the selection can be easily considered , and especially take care of potential problems with self-excitation The disadvantage of induction generator is that when the speed of induction generator is variable , generators have vanishing reactive power and a bad voltage variation, but due to advance technique of power electronics components , it can be easily control the voltage of an induction generator.[2-12]

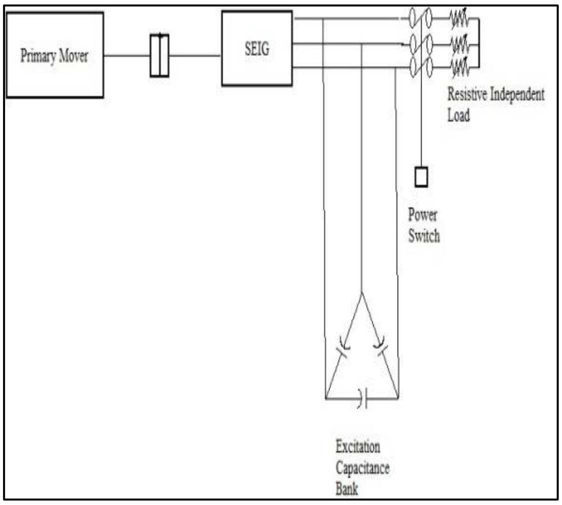

***Fig. 1.** Self Excited Induction Generator**.*

ELECTRONIC LOAD CONTROLLER

An electronic load controller is combination of an uncontrolled rectifier, a filtering capacitor, chopper, and a series dump load (resistor).

An electronic load controller (ELC) is used for Micro Hydro system fitted with synchronous generator and powering just some houses or a small, local grid. So it is a stand-alone M.H. system: It is not connected to the national grid.[8]

Together with the dump loads connected to it, an ELC serves as an automatic, electrical brake that the controls frequency of electricity produced by the generator. It measures frequency and, depending on whether this frequency is above or below the nominal frequency, diverts more or less power to the dump loads that are connected to it. To a large extend, mechanical power required to drive generator, is determined by total electrical load connected to it.

Mechanical power formed by the turbine is approximately constant so when additional power is distracted to dump loads, generator demands more mechanical power than turbine can deliver, causing turbine and generator to slow down.

With a synchronous generator, electrical frequency is related directly to its mechanical speed, so then the frequency will drop also. Inversely, turbine and generator will accelerate and frequency will increase when less power is diverted to dump loads.

This way, the ELC controls electrical frequency and, with this, speed of generator and turbine.

It prevents the generator from over speeding when power demand of user load appliances that are switched on total, is less than capacity of the system.[7]

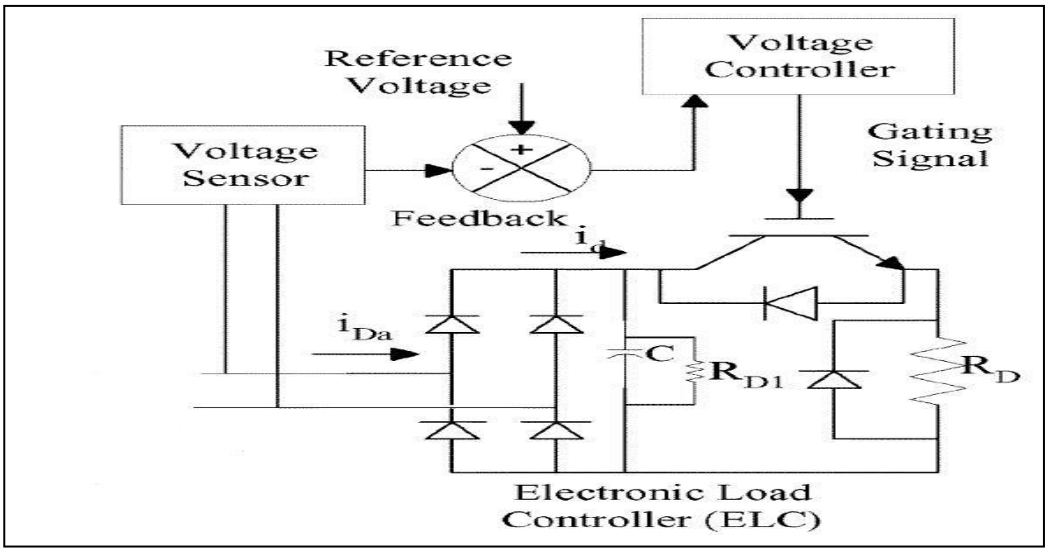

Fig. 2. *Single Phase Electronic Load Controller*.

Mathematical Equations Used for Modeling

i) Current equations:

PI = AI + B Eq. (1)

$$A=\frac{1}{L}\begin{bmatrix} -L_s r_s & -L_m^2 & L_m r_r & -L_m w_r L_r \\ L_m^2 & -L_s r_s & w_r L_r L_m & L_m r_r \\ L_m r_s & L_s w_r L_m & -L_s r_r & L_s w_r L_r \\ -L_s w_r L_m & L_m r_s & -L_s w_r L_r & -L_s r_r \end{bmatrix}$$

$$B=\frac{1}{L}\begin{bmatrix} L_m K_q & -L_r V_{cq} \\ L_m K_d & -L_r V_{cd} \\ L_m V_{cq} & -L_s K_q \\ L_m V_{cd} & -L_s K_d \end{bmatrix}$$

$PI_{qs} = a_1 I_{qs} + a_2 I_{ds} + a_3 I_{qr} + a_4 I_{dr} + a_5 K_q - b_6 V_{cq0}$ Eq. (2)
$PI_{ds} = b_1 I_{qs} + b_2 I_{ds} + b_3 I_{qr} + b_4 I_{dr} + b_5 K_d - b_6 V_{cd0}$ Eq. (3)
$PI_{qr} = c_1 I_{qs} + c_2 I_{ds} + c_3 I_{qr} + c_4 I_{dr} + c_5 K_q - c6Vcq0$ Eq. (4)
$PI_{dr} = d_1 I_{qs} + d_2 I_{ds} + d_3 I_{qr} + d_4 I_{dr} + d_5 K_d - d_6 V_{cd0}$ Eq. (5)

Where a1, a2, a3, a4…. are variables .Here, K_q and V_{cq0} are initial voltage across q-axis rotor winding and stator winding respectively and K_d and V_{cd0} are initial voltage across d-axis rotor winding and stator winding respectively.[13-15]

ii) Voltage across the terminal of the SEIG are given by

$V_{cq} = (1/C)*\int I_{qs} dt + V_{cq0}$ Eq. (6) $V_{cd} = (1/C)*\int I_{ds} dt + V_{cd0}$ Eq. (7)

iii) The equation of motion at the SEIG mechanical shaft or the mechanical torque supplied by the prime mover at the generator shaft is:

$T_{sh} = T_e + J\,(2/P)\, p_{\omega r}$ Eq. (8)

Therefore the derivative of the shaft speed is given as:

$P_{\omega r} = (\frac{P}{2} * J)*(T_{sh} - T_e)$ Eq. (9)

The electromagnetic torque Te is given by the following relation.

$T_e=(3/2)*(P/2)*L_m*(I_{ds}*I_{q\,r}- I_{qs}*I_{dr})$ Eq. (10)

The relationship between the mechanical torque of the prime mover and the shaft speed is, represented by the following formula

$\omega=\omega_0-T_{sh}K\omega$ Eq. (11)

is the ideal no load angular speed of the prime mover (DC separately excited motor) and K is constant and Tsh is shaft torque.

The magnetization current can be find out of the induction generator is as below.

$I_m = \sqrt{(I_{qr} + I_{qs})^2 + (I_{dr} + I_{ds})^2}$ Eq. (12)

$I_{mq}= I_{qr} + I_{qs}$ $I_{md}= I_{dr} + I_{ds}$

The non linear relationship between Magnetizing inductance and magnetizing current is given as

$L_m=a+bI_m + cI^2_m + dI^3_m$ Eq. (13)

Where a, b, c, d are the constants.

Three phase generator currents are obtained from d-q axes components using the relation.

$$\begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} ids \\ iqs \end{bmatrix}$$

For the delta connection of the SEIG, it can be expressed as in terms of phase currents as

$i_{ga}=i_c-i_a$ Eq. (14)

$i_{gb}=i_a-i_b$ Eq. (15)

$i_{gc}=i_b-i_c$ Eq. (16)

Further

$V_a+V_b+V_c=0$ Eq. (18)

Applying Kirchhoff's current law (KCL) to the circuit comprising excitation capacitor and consumer load, node current equations are obtained as

$C_apV_a-C_cpV_c=i_{pca}-i_{pcc}=i_{ca}=i_{ga}-(i_{aL}+i_{Da})$ Eq. (19)

$C_bpV_b–C_apV_a=i_{pcb}-i_{pca}=i_{ca}=i_{gb}-(i_{bL}+i_{Db})$ Eq. (20)

$C_cpV_c–C_bpV_b=i_{pcc}-i_{pcb}=i_{cc}=i_{gc}-(i_{cL}+i_{Dc})$ Eq. (21)

Substitution of results in two equations in derivative of ac voltages (pV_a and pV_b) as

$(C_a+C_c)pV_a+C_cpV_b= i_{ca}$ Eq. (22)

$-C_apV_a+C_cpV_b =i_{cb}$ Eq. (23)

Solving, the voltage derivatives are

$pv_a=\frac{\{ C_b i_{ca}-C_c i_{cb}\}}{K_{eq}}$ Eq. (24)

$pv_b=\frac{\{ C_b i_{ca}+ (C_a+C_c)i_{cb}\}}{K_{eq}}$ Eq. (25)

where

$K_{eq}=C_aC_b+C_bC_c+C_cC_a$

for balanced excitation with equal excitation capacitors $C_a=C_b=C_c=C_x$ for example, $K_{eq}=3C_x^2$

the d and q axes voltages in the stationary reference frame as follows

$V_{ds}= \frac{2}{3} \{(v_a - \left(\frac{v_b}{2}\right) - \left(\frac{v_c}{2}\right)\}$ Eq. (26)

$V_{qs}= \frac{2}{3} \{\left(\frac{\sqrt{3}v_b}{2}\right) - \left(\frac{\sqrt{3}v_c}{2}\right)\}$ Eq. (27)

These voltages V_{ds} and V_{qs} are the forcing functions of the SEIG Modeling of single phase consumer load

$I_{lqs}=V_{qs}/R$ Eq. (28)

$I_{lds}=V_{ds}/R$ Eq. (29)

I_{lqs} is the stator quadrature axis load current and Il_{ds} is the stator direct axis load current which is attained after the load connected to the system.

MATLAB SIMULATION OF SEIG

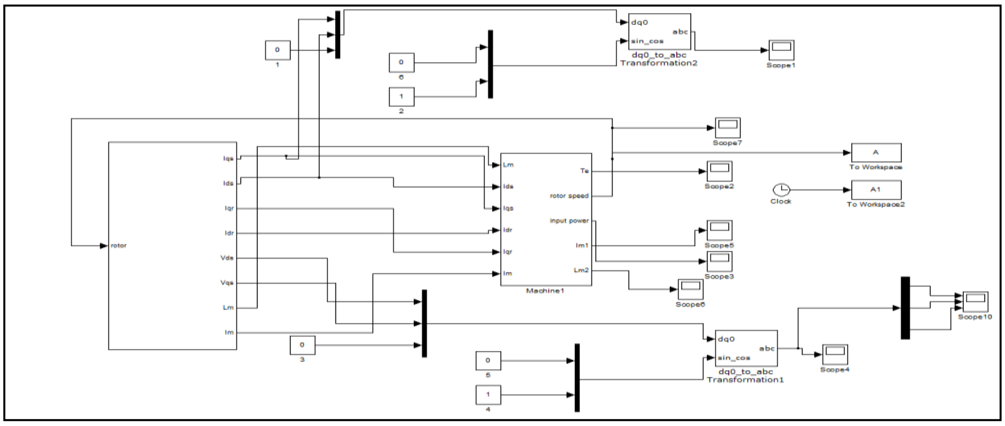

Fig. 3. *Simulink Model of SEIG.*

MATLAB SIMULATION OF ELC

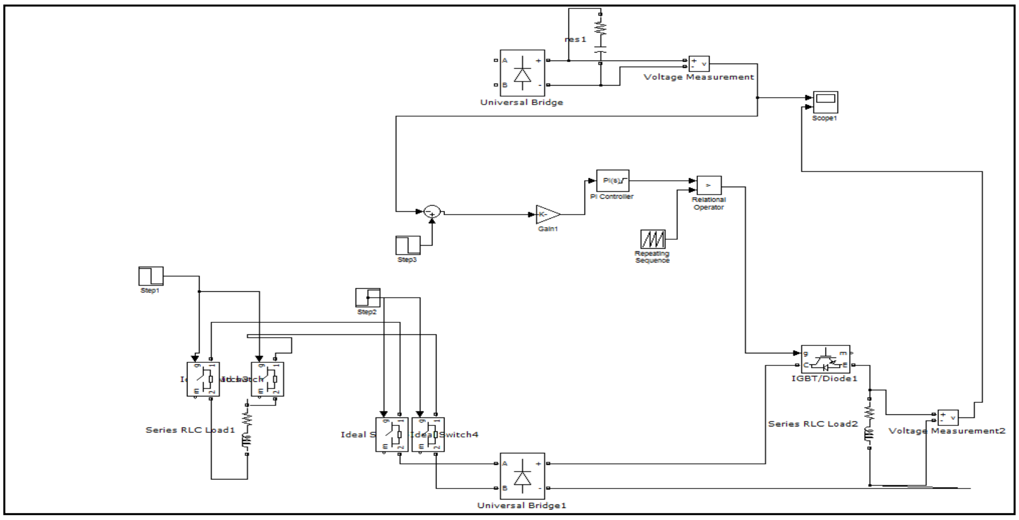

Fig. 4. *Simulink Model of ELC.*

MATLAB SIMULATION OF SEIG WITH ELC

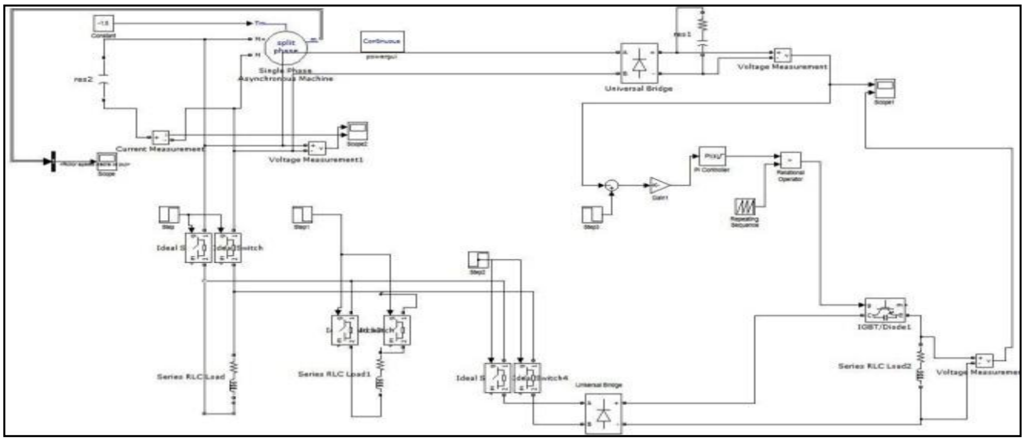

Fig. 5. *Simulink Model of SEIG with ELC.*

SIMULATION RESULT

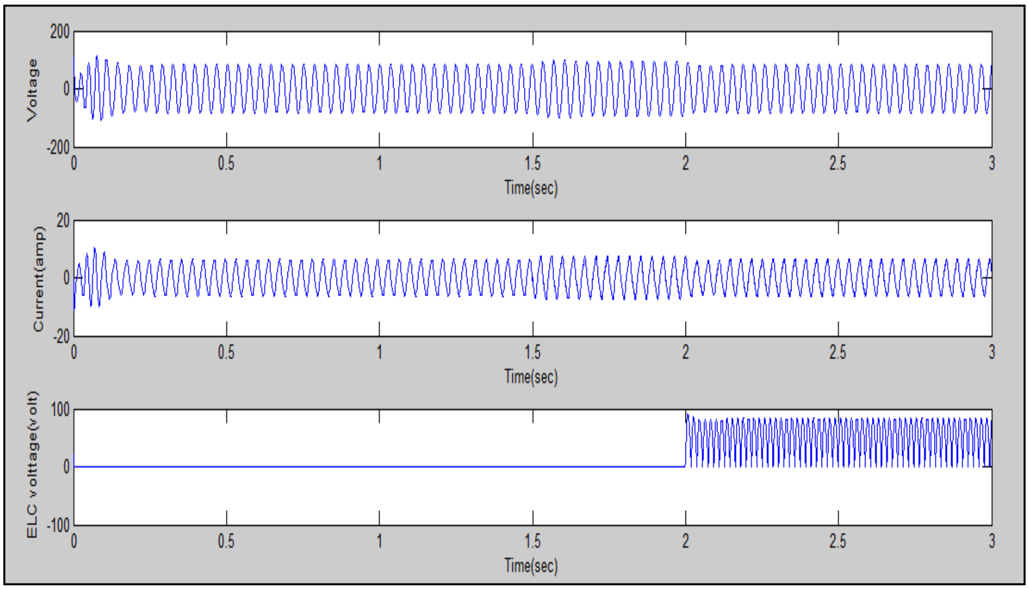

Fig. 6. *Variation of Voltage Current and ELC Voltage across Self Excited Induction Generator Upto t=3sec.*

CONCLUSION

At first simulation of SEIG have been done using MATLAB/SIMULINK block sets. In that output current, output voltage has been determined and we have seen that some voltage dip occurs at the starting and then it can be recovered soon by the generator. Output power, torque and speed has also been determined and shown by the waveforms after that we have developed mathematical model of the SEIG with ELC supplying a resistive load has been found suitable for the transient analysis and to assess the rating of the motor, which can be safely started on the SEIG-ELC system. The simulation has been carried out in MATLAB/SIMULINK environment. With the application of load at certain instant how the voltage is soon recovered has been shown. The dynamic behavior of the SEIG with load controller reveals that this system can be used satisfactorily in constant power applications such as micro-hydro with uncontrolled turbines. Based on this study, the developed SEIG-ELC system can be installed in the field to feed static loads. It has been observed that the ELC is capable of handling the transients caused by load switching. This study has practical significance due to enormous small hydro potential in isolated locations in several countries.

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