Analysis and Novel Performance of Long and Short Shunt Self Excited Generators with Natural Energy Generation

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Abstract: Analysis and Novel Performance of Long and Short Shunt Self Excited Generators with natural Energy generation is presented. An outwardly ambitious induction machine can function as induction generator with unremitting self excitation when a suitable value of a capacitor bank is appropriately associated transversely at the stator terminal of the machine. Such a machine is said to be Self-Excited Induction Generator (SEIG). We proposed the series capacitor bank which really improves the voltage profile and also increases the maximum power delivery capability. The main significant of the projected work is that the effects of both long-shunt and short-shunt connections on the dynamic performance of an SEIG feeding and Induction Motor load is compared. We also examined the analysis of the reactive power prerequisite of self excited induction generator at different load conditions. Finally we originate that the short shunt self-excited induction generator is the attractive option for improved better voltage regulation and also maintain the good power quality. Wind turbine act as the prime mover of the projected work. The simulation work is carried out by the MATLAB and the result of the proposed work promises better voltage profile with grid connected system.

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1. Introduction

Self-excited induction generators are progressively being well thought-out for self-governing applications in wind power systems. If an asynchronous motor is associated to a capacitor and the shaft turns with higher than significant speed, an electric hunting occurs which appears as line voltage on the terminals and provides constructive function. An open source generator is built on this principle. The three-phase SEIG is driven by a variable-speed prime mover (VSPM) such as a wind turbine for the sparkling alternative renewable energy in rural areas. The prime mover speed has been taken both as permanent and uneven and the results have been analyzed. The three phases self excited induction machine can be ready to work as a self-excited induction generator, provided capacitance should have adequate charge to make available required primary magnetizing current. In an externally driven three phase induction motor, if a three phase capacitor bank is associated across its stator terminals, an EMF is induced in the machine windings due to the self excitation provided by the capacitors. The magnetizing prerequisite of the machine is supplied by the capacitors. For self excitation to occur, the subsequent two conditions must be satisfied. The rotor must have adequate exceptional magnetism and the three capacitor bank must be of reasonable value. In a wind turbine an asynchronous machine and the generator driver are used to drive the turbine. It was a high-quality alternative, excellent intrinsic characteristic such as a proficient consistency. It has potential to supply the power to the electrical variable load by the operation self excited of its own [2]. The additional of the capacitor coupled to the self excited induction generator on both long and short shunt, it's desired to control the voltage regulation, while comparing the long and short shunt self excited induction generators, the short shunt is healthier than the long shunt [3].

To control the voltage regulation by choosing the suitable value of the capacitor and the selection of the capacitor is to minimize the voltage divergence at full load circumstance. In the short shunt configuration is to progress the voltage contour, then the short shunt is less than the shunt generator [4]. The short shunt generator is originating to be the most excellent, it can easily distribute power to the rated value and it has a fewer sharp voltage profile. The shunt generator has a very steep voltage profile ant its maximum delivery potential depends on the value of the shunt capacitor used [5]. Under at a variety of operating conditions of the self excited induction generator its voltage and current build up at no-load, switching of a three-phase squirrel cage induction motor to the self-excited induction generator [20] terminals series compensating capacitors. It causes low frequency oscillation in the IM stator voltages, currents and its speed. For reasonable starting of an induction motor from a SEIG, an appropriate value of the capacitor must be connected with the lines between the SEIG & IM. In SEIG without series capacitor as an ineffective starting IM, at the voltage and current are distorted in SEIG. The voltage profile of the self excited induction generator improves i.e. Depends on the series capacitors it's provided that the additional VAR prerequisite during the starting of the induction motor [6, 13]. The steadiness of the generated voltage and the voltage compensation are analyzed in the self excited induction generator. The long shunt and short shunt connection of the voltage regulation presented the relationship between the generated voltage and prime mover speed of the long shunt connection of induction generator. The additional possibilities to progress the voltage compensation in the induction generator [7, 13] is to make progress the performance of a three phase self excited induction generator all the way through series compensation are analyzed by the long and short shunt configuration, suitable value of capacitive-elements and the additional capacitance in series [17] with the load, it is possible to produce the load voltage characteristics of the self excited induction generator. It has progress the voltage regulation and high over competence low values of the capacitance required for the short shunt because the selection of cost-effective reasons. Short shunt is the exceptional performance and the series capacitance recovering the concert of the self-excited induction generator [8, 15].

Hence the main significant of the projected work is the effects of both long-shunt and short-shunt connections on the dynamic performance of an SEIG [14] feeding an IM load will be compared. Here analyzing the long shunt compensations and short shunt compensations at different load conditions and comparing the both compensations with real and reactive power at different loads. The machine has run on 220V at every load condition on both shunts. The machine act as three phase RLC load.

2. General Description About Long & Short Shunt Configuration

2.1. Long Shunt Compensation

A wind turbine and induction generator are mechanically coupled, hear wind turbine act as a prime over to the induction generator. In the long shunt self excited induction generator, after the capacitor series the excitation capacitor was linked. The load has been associated across the capacitor bank, analyze the behaviour of long & short shunt SEIG. It shows in the Fig.1 with the help of MATLAB Simulink [19]. Self-excited induction generator operates in the long - shunt configuration. The recital of self excited induction generator for a range of operating load sharing also compared. In order to get better the voltage regulation, the long shunt connection of the capacitor to the generator is used. The magnetizing inductance of the machines is providing with saturable reactor. The suitable values of the capacitor are obtained from the saturation characteristics of the machine. The excitation is by means of a capacitor as particular attention when the induction generator is in parallel with inadequate reactive sources or when it is operated as an unconnected.

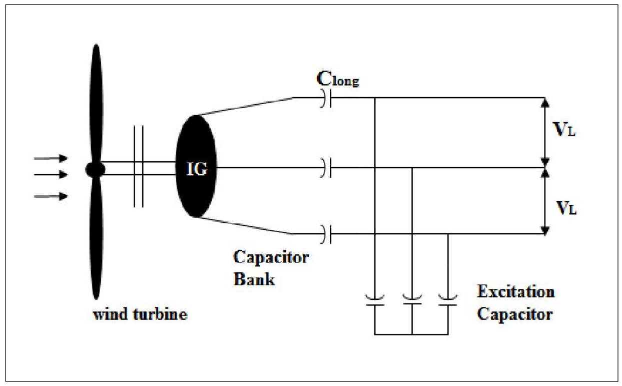


Fig. 1 Schematic diagram of the long shunt SEIG

3.2. Short shunt compensation

A wind turbine and induction generator are mechanically coupled, here wind turbine act as a prime mover to the induction generator. In the short - shunt self excited induction generator, prior to the capacitor bank the excitation capacitor can be associated. The load has been associated across the capacitor bank analyze the behaviour of long & short shunt SEIG with the help of MATLAB Simulink [19] it shows in Fig.2. In the short- shunt the series capacitance getting better the recital of the self excited induction generator, it has the enhanced voltage profile, its distribute the greatest power and the capacitance values are fewer for the getting better voltage profile it depends on the series capacitor and it provide the additional VAR requirement[13]. The shunt capacitor is unswervingly connected across the machine terminals. The load is the associated to the machine terminals all the way through the series capacitors even for the short shunt configuration, the voltage profile in the complete operating range from no load to full load. The voltage profile as well as maximum power can appreciably be improved by using higher values of series capacitor.

3. Mathematical Analysis of SEIG

A d-q axis IM flux model in reference frame is used for the simulation of the SEIG system in MATLAB/ Simulink [19]. The electrical system of the SEIG is represented all the way through fourth-order flux state-space model equation and mechanical system by a first-order torque balance equation. The mathematical model is simulated in the form of matrices to solve the d-q-axis fluxes finally, their respective d-q-axis currents and corresponding three-phase stator currents. The saturation in the SEIG is integrated through a relationship between magnetizing inductance (Lm) and magnetizing current. The self-excited is a test of synchronous speed, is used to simulate three-phase P-pole. In the squirrel cage rotor stator winding are connected to the delta in the induction motor.

$$\rho\psi_{ds} = V_{ds} - R_S i_{ds} \tag{1}$$

$$\rho\psi_{qs} = V_{qs} - R_s i_{qs} \tag{2}$$

$$\rho\psi_{dr} = V_{dr} - R_r i_{dr} - \omega_r \phi_{qr} \tag{3}$$

$$\rho\psi_{qr} = V_{qr} - R_r i_{qr} + \omega_r \varphi_{dr} \tag{4}$$

Where $\rho = d/dt$

The developed torque of SEIG is given by:

$$T_e = \frac{3}{4} P(\psi_{ds} i_{qs} - \psi_{qs} i_{ds}) \tag{5}$$

The voltages of a squirrel-cage rotor are:

$$V_{dr} = V_{qr} = 0 \tag{6}$$

These *d–q*-axis flux linkages may be expressed in terms of their respective currents as

$$\psi_{ds} = L_s i_{dr} + L_m i_{dr}, \psi_{qs} = L_s i_{qs} + L_m i_{qr} \tag{7}$$

$$\psi_{dr} = L_r i_{dr} + L_m i_{ds}, \psi_{qr} = L_r i_{qr} + L_m i_{qs} \tag{8}$$

$$L_s = L_{ls} + L_m, L_r = L_{lr} + L_m \tag{9}$$

Where subscripts *s*, *r*, *l*, and *m* denote stator, rotor, leakage, and magnetizing quantities, respectively, in *d*- and *q*-axis.

The magnetizing inductance *Lm* is calculated from the synchronous speed test on IM and is represented in the form of a polynomial as follows:

$$L_m = a + bI_m + cI_m^2 + dI_m^3 \tag{10}$$

Where *a*, *b*, *c*, and *d are* constants given in the Appendix.

The magnetizing current of a SEIG is computed as:

$$I_m = \sqrt{(i_{ds} + i_{dr})^2 + (i_{ds} + i_{qr})^2} / \sqrt{2} \tag{11}$$

The electromechanical equation of the SEIG can be:

Written as

$$T_{sh} - T_e = \left(\frac{2J}{P}\right)\rho\omega_r \tag{12}$$

The derivative of the rotor speed from (12) is given as:

$$\rho\omega_r = \left(\frac{p}{2J}\right)(T_{sh} - T_e) \tag{13}$$

Where *Te* is the electromagnetic torque, T_{sh} is the shaft torque, *J* is the mutual rotor and load inertia, ω_r is the electrical rotor speed (rad/s), and *P* is the number of poles in machine.

The prime mover torque speed characteristic is given as:

$$T_{sh} = K_1 - K_2\omega_r \tag{14}$$

Where *K*1 and *K*2 are constants.

4. Modeling and Simulation of SEIG

The simulation work is carried out by the MATLAB [19] In Fig.3 Long shunt compensation the wind turbine act as a prime mover of the induction generator which is mechanically attached and it delivers the mechanical energy to the induction generator.

4.1. Long Shunt Compensation

The electrical parameters are the line voltage 220V, the power is 1.1kw and frequency is 60HZ, the C_{long} capacitors values are 248.7μF. The parallel capacitors are wide-ranging. In long shunt compensation we have analysed at different load conditions, from this simulation we can be intended, the load voltage, the p_{load} value and the reactive load value, the load condition has been from 25% to 125% here the p_{load} is considered as creator and the qload is the absorber.

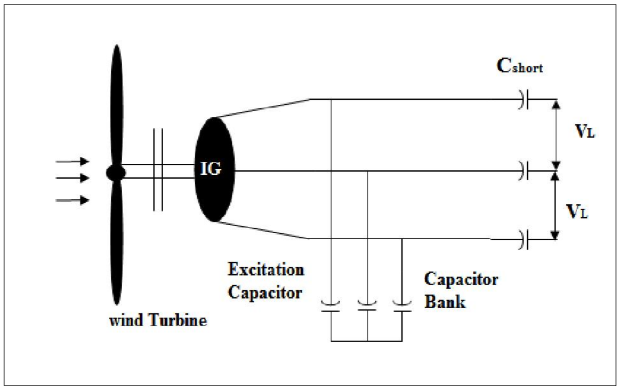


Fig. 2. Schematic diagram of the short shunt SEIG

In the long shunt, the connection of the capacitor to the generator is used to progress the voltage regulation [14]. The various operating condition and capacitors values are shown in the Table.1 the induction motor has been act as a load i.e. it act as a RLC load. The capacitor C_{Long} is seriesly associated with the load [. In all conditions the voltage must be constant at 220V. The capacitor C_{long} value is 248.7μF. The Excitation capacitor is varied at different load conditions. The series capacitance value is 248.7 μF. The parallel capacitance values are varied at 200μF, 160μF,178μF and 135μF. The voltage waves, p_{load} waves and q_{load} waves Shows in Fig 4(a-e),5(a-e) and 6(a-e).

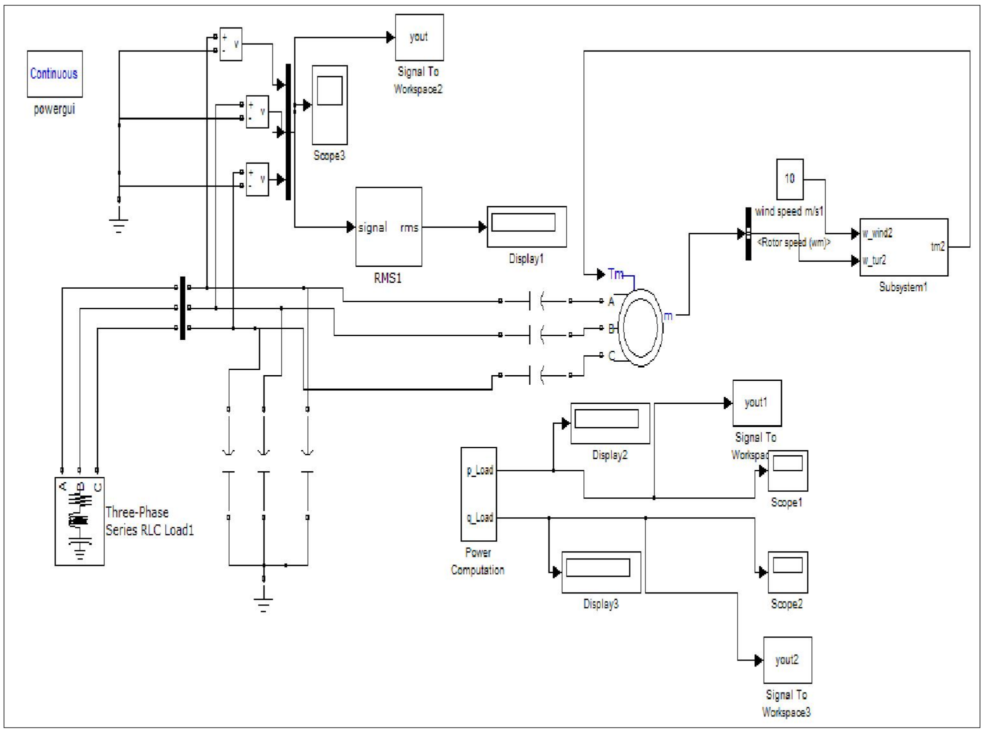
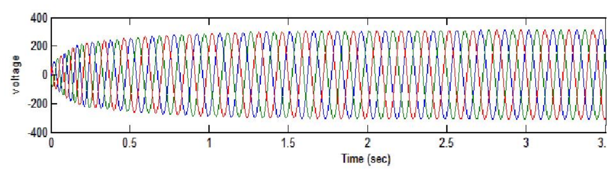
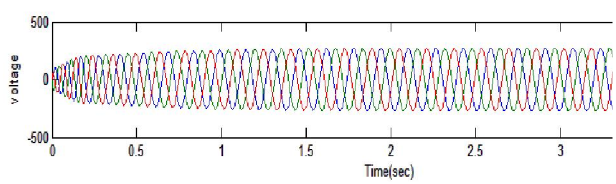


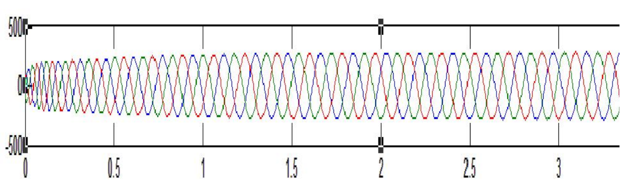
Fig.3. The simulation diagram of the long shunt compensation

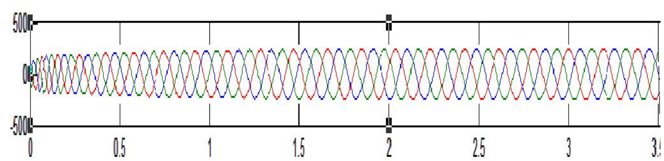


(a) 25%



(b) 50%


(c) 75%


(d) 100%

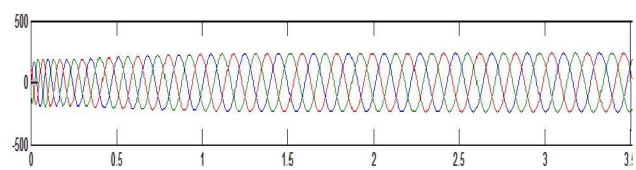

(e) 125%

Fig. 4. Characterstics of voltage versus time at different load conditions

The Table 1 illustrates the Long shunt Compensation comparisons of various loads with Series and parallel capacitance values and the measurement of Real load power load PL and the Reactive load QL.

a) 25% of full load, b) 50% of full load, c) 75% of full load, d) 100% of full load, e) 125% of full load.

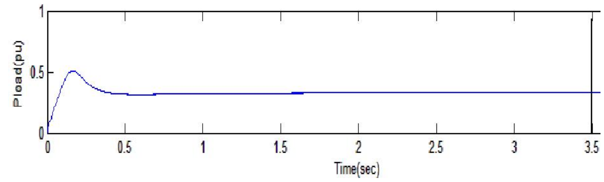
TABLE 1. Long Shunt Compensation

Load	Long shunt			
	Series Capacitance	Parallel capacitance	P_{load} (pu)	Q_{load} (pu)
25%	248.7µF	275µF	0.2345	0.3748
50%	248.7µF	200µF	0.3301	0.5542
75%	248.7µF	160µF	0.395	0.8006
100%	248.7µF	178µF	0.3825	0.7918
125%	248.7µF	135µF	0.3849	0.8806

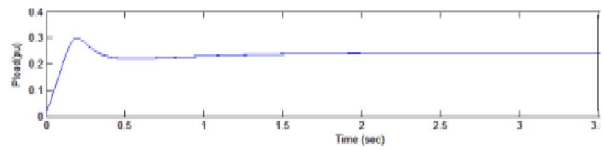
In Fig. 4. it shows the characteristics of voltage waves for different load range from 25% to 125% in long shunt around 200V to 220V. The output wave form shows the Time vs. voltage. The initial output waveform (a) shows that at 25% of the full load the active power is 275 Watts, the Inductive reactive power QL is 206.21 in Var and the capacitive reactive power QC is 204.99 in Var. The output waveform (b) shows 75% of the full load the active power is increased to 550 Watts, the Inductive reactive power QL is also improved to 412.40 in Var and the capacitive reactive power QC are bettered to 407.42 in Var. The output waveform (c) shows 50% of the full load the active power is increased to 825 Watts, the Inductive reactive power QL is also improved to 618.60 in Var and the capacitive reactive power QC are bettered to 607.52 in Var. The output waveform (d) shows 100% of the full load the active power is doubled to 1100 Watts, the Inductive reactive power QL is improved to 824.84 in Var and the capacitive reactive power QC are bettered to 805.07 in Var. The output waveform (e) shows when the full load is 125% its active power is increased to maximum of 1375 Watts, the Inductive reactive power QL is improved to 1031 in Var and the capacitive reactive power QC is increased to 1000 in Var.

In Fig. 5 Shows characteristics of p_{load} versus time at different load conditions with the real load power for various operate condition, by adjusting the excitation capacitor with respect to the time constant. The capacitor C_{Long} is serially associated with the load. In all operating conditions the voltage must be constant at 220V. The capacitor C_{long} value is also constant at 248.7µF. The Excitation capacitor is varied at different load conditions. The series capacitance value is 248.7 µF. The parallel capacitance values are varied at 240µF, 200µF, 160µF, 178µF and 135µF.

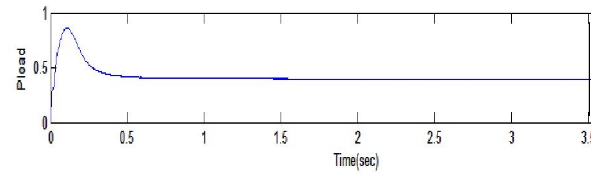
The P_{load} waves with time constant of (a) illustrates in Fig. 5 with 25% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 240µF the wave form of P_{load} value (0.2345pu) with time is shown.



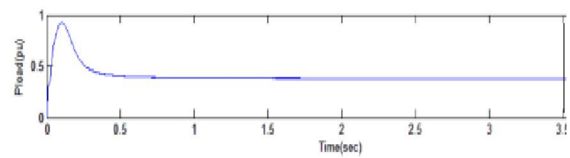
25% (a)



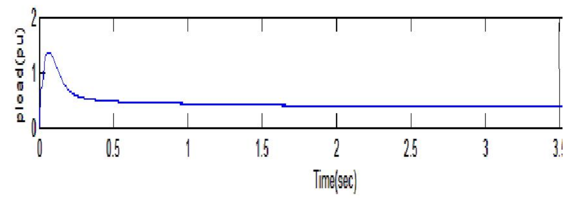
50% (b)



75% (c)



100% (d)

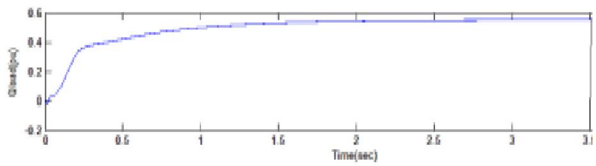


125%(e)

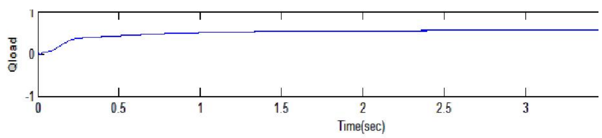
Fig. 5 characteristics of p_{load} versus time at different load conditions a) 25% of full load, b) 50% of full load, c) 75% of full load, d)100% of full load, e)125% of full load.

The P_{load} waves with time constant of (b) illustrates with 50% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 200µF the wave form of P_{load} value is (0.331pu) with time is shown. The P_{load} waves with time constant of (c) illustrates with 75% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 160µF the wave form of Pload value (0.395pu) with time is shown. The P_{load} waves with time constant of (d) illustrates with 100%

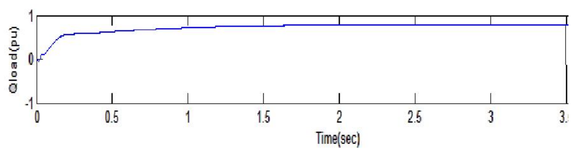
of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 178µF the wave form of P_{load} value(0.3825pu) with time is shown. The p_{load} waves with time constant of (e) illustrates with 125% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 135µF the wave form of P_{load} value(0.389pu) with time is shown.



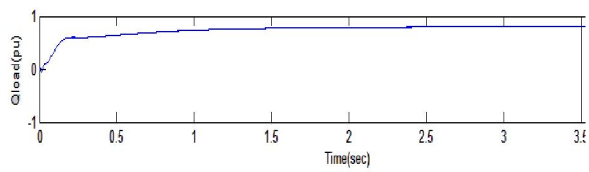
25% (a)



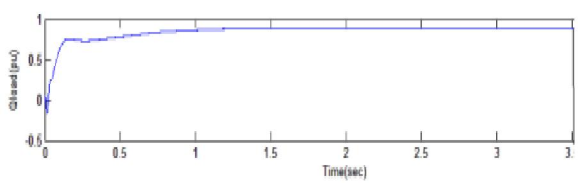
50% (b)



75% (c)



100% (d)



125% (e)

Fig. 6. characteristics of q_{load} versus time at different load conditions a) 25% of full load, b) 50% of full load, c) 75% of full load, d) 100% of full load, e) 125% of full load

In Fig. 6 Shows the real load power for various operating condition, by adjusting the excitation capacitor with respect to the load, the Q_{load} can be intended. Time versus Q_{load} waves with time constant of (a) illustrates with 25% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 240µF the wave form of Q_{load} value(0.3748pu) with time is shown. The q_{load} waves with time constant of (b) illustrates with 50% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 200µF the wave form of Q_{load} value is (0.5542pu) with time is shown. The Q_{load} waves with time constant of (c) illustrates with 75% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 160µF the wave form of Q_{load} value (0.8006pu) with time is shown. The Q_{load} waves with time constant of (d) illustrates with 100% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 178µF the wave form of Q_{load} value(0.7918pu) with time is shown. The Q_{load} waves with time constant of (e) illustrates with 125% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 178µF the wave form of Q_{load} value(0.8806pu) with time is shown.

4.2. Short Shunt Compensation

In the Fig.7. short shunt compensation, the operation of the short shunt is comparable to that of long shunt but the connection is dissimilar from the long shunt, after the excitation capacitor. The C_{short} can be associated; here also series capacitor value is 248.7µF. The parallel capacitor are varied, the electrical parameters are similar. The short shunt compensation can be analyzed at different load conditions, voltage, p_{load} and Q_{load} can be computed. It results are shown in the table.2, the induction motor has been act as a load i.e. it act as a RLC load. The capacitor C_{Long} series is linked to the load. In all conditions the voltage must be in 220V. C_{long} values are 248.7µF. The Excitation capacitor is changed at different load conditions. The series capacitance values are 248.7µF. The parallel capacitance values are varied 240µF, 200µF, 170µF, 75µF and 50 µF. The voltage, pload and qload waves are shows in Fig.8(a-e), 9(a-e) and 10(a-e).

The voltage waves are described and it is shown in Fig.8 at different load conditions from 25% to 125% for the short shunt, the voltage range in each condition around (200V to 220V).

In Fig. 9 the real load power for various operating condition is shown, by adjusting the excitation capacitor with according to the load, the p_{load} is computed. Time versus $p_{load.}$ In Fig. 10 Shows the real load power for various operating conditions, by adjusting the excitation capacitor with accordance to the load, the p_{load} can be intended. The short shunt self excited induction generator is one of the attractive option to improve voltage regulation and maintain the good power quality. The series capacitor not only improves the voltage profile but also increases the maximum power delivery capability.

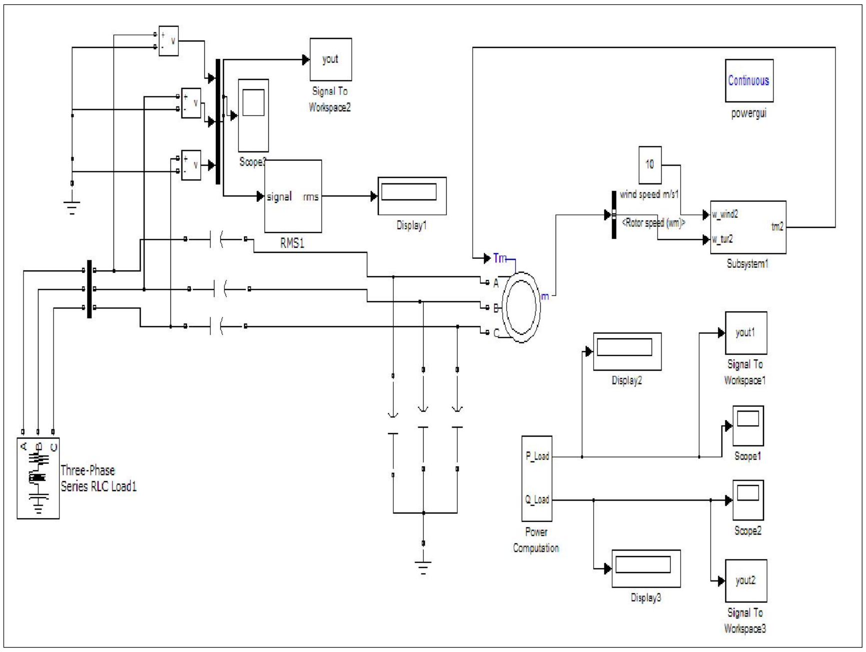


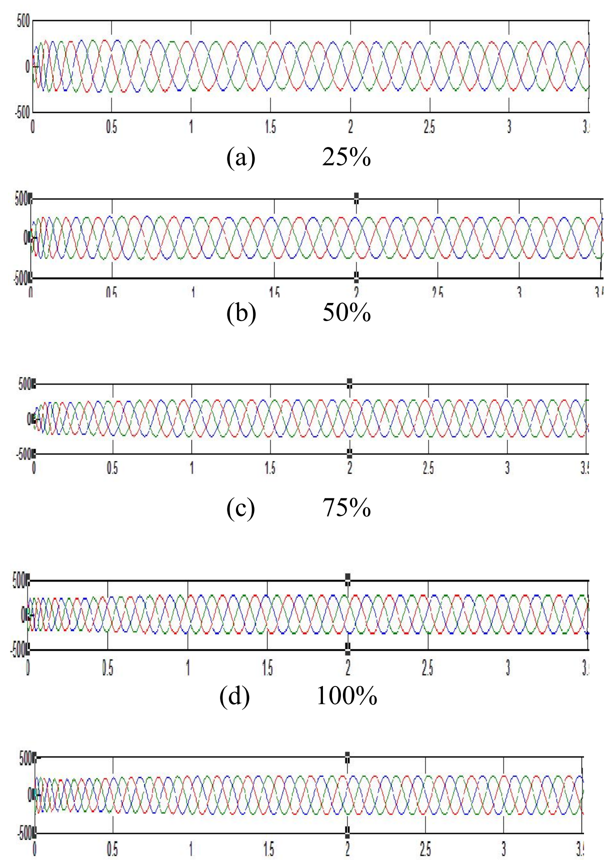
Fig. 7. The simulation diagram of the short shunt compensation

In the Short- shunt, the connection of the capacitor to the generator is used to progress the voltage regulation. The various operating condition and capacitors values are shown in the Table 2. The Table 2 also illustrates the Short shunt Compensation comparisons of various loads with Series and parallel capacitance values and the measurement of Real load power load PL and the Reactive load QL.

Table 2. Short Shunt Compensation

Load	**Short shunt**			
	Series capacitance	**Parallel capacitance**	**Pload (pu)**	**Qload (pu)**
25%	248.7μF	240μF	0.0535	0.1674
50%	248.7μF	200μF	0.1204	0.3492
75%	248.7μF	170μF	0.2541	0.6148
100%	248.7μF	75μF	0.4143	0.599
125%	248.7μF	50μF	0.4602	1.045

In Fig. 8 shows the similar measurement as the Short-shunt as it shows the voltage waves for different load range from 25% to 125% in long shunt around 200V to 220V. The output wave form shows the Time vs. voltage. The initial output waveform (a) shows that at 25% of the full load the active power is 240 Watts, the Inductive reactive power QL is 206.21 in Var and the capacitive reactive power QC is 204.99 in Var. The output waveform (b) shows 75% of the full load the active power is increased to 550 Watts, the Inductive reactive power QL is also improved to 412.40 in Var and the capacitive reactive power QC are bettered to 407.42 in Var.



(a) 25%

(b) 50%

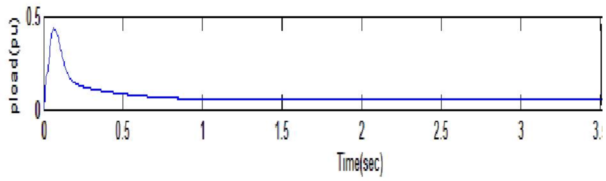
(c) 75%

(d) 100%

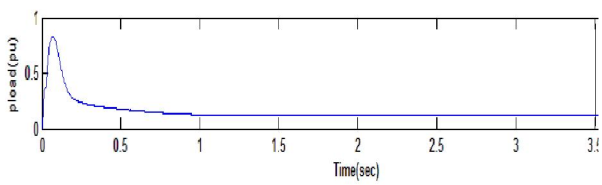
(e) 125%

Fig. 8. characteristics of voltage versus time at different load condition a) 25% of full load, b) 50% of full load, c) 75% of full load, d) 100% of full load.

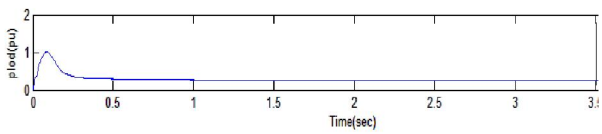
The output waveform (c) shows 50% of the full load the active power is increased to 825 Watts, the Inductive reactive power QL is also improved to 618.60 in Var and the capacitive reactive power QC are bettered to 607.52 in Var. The output waveform (d) shows 100% of the full load the active power is doubled to 1100 Watts, the Inductive reactive power QL is improved to 824.84 in Var and the capacitive reactive power QC are bettered to 805.07 in Var. The output waveform (e) shows when the full load is 125% its active power is increased to maximum of 1375 Watts, the Inductive reactive power QL is improved to 1031 in Var and the capacitive reactive power QC is increased to 1000 in Var.



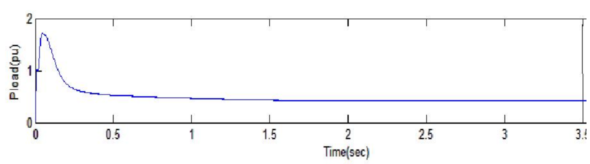
25% (a)



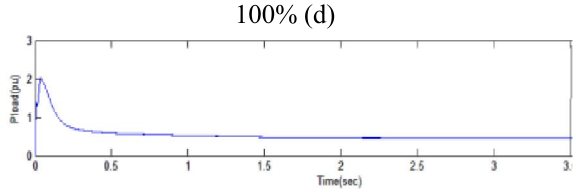
50% (b)



75% (c)



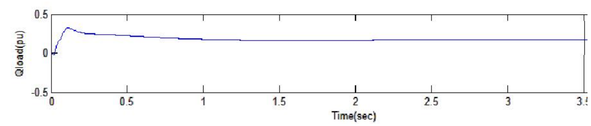
100% (d)



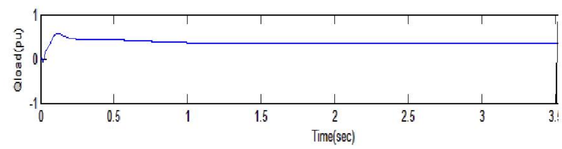
125% (e)

Fig. 9. characteristics of pload versus time at different load condition a) 25% of full load b) 50% of full load c) 75% of full load d) 100% of full load e) 125% of full load.

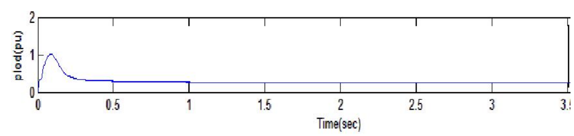
The P_{load} waves with time constant of (a) illustrates in Fig.9 with 25% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 240µF the wave form of P_{load} value(0.0535pu) with time is shown. The P_{load} waves with time constant of (b) illustrates with 50% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 200µF the wave form of P_{load} value is (0.1204pu) with time is shown. The P_{load} waves with time constant of (c) illustrates with 75% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 170µF the wave form of Pload value (0.2541pu) with time is shown. The P_{load} waves with time constant of (d) illustrates with 100% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 75µF the wave form of P_{load} value(0.4143pu) with time is shown. The p_{load} waves with time constant of (e) illustrates with 125% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 50µF the wave form of P_{load} value(0.4602pu) with time is shown.



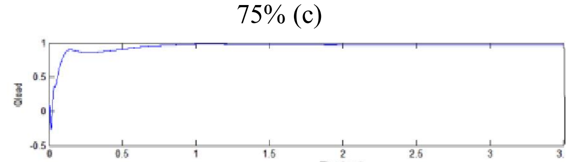
25% (a)



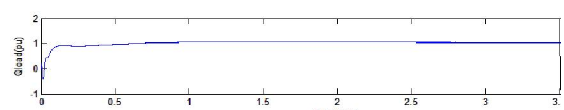
50% (b)



75% (c)



100% (d)



125% (e)

Fig. 10. characteristics of qload versus time at different load conditions a) 25% of full load b) 50% of full load c) 75% of full load d)100% of full load e)125% of full load.

In Fig. 10 Shows the real load power for various operating condition, by adjusting the excitation capacitor with respect to the load, the Q_{load} can be intended. Time versus Q_{load} waves with time constant of (a) illustrates with 25% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 240µF the wave form of Q_{load} value(0.1674pu) with time is shown. The q_{load} waves with time constant of (b) illustrates with 50% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 200µF the wave form of Q_{load} value is (0.3492pu) with time is shown. The Q_{load} waves with time constant of (c) illustrates with 75% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 170µF the wave form of Q_{load} value (0.6148pu) with time is shown. The Q_{load} waves with time constant of (d) illustrates with 100% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 75µF the wave form of Q_{load} value(0.599pu) with time is shown. The Q_{load} waves with time constant of (e) illustrates with 125% of load with series capacitance value of 248.7 µF and varied parallel capacitance value of 50µF the wave form of Q_{load} value (1.045pu) with time is shown. Hence the short shunt self-excited induction generator is one of the attractive options to improve voltage regulation and maintain the good power quality. The series capacitor not only improves the voltage profile but also increases the maximum power delivery capability.

5. Conclusion

Self excited induction generators are progressively being well thought-out for self-governing applications in wind power systems. In the short -shunt self excited induction generator, prior to the capacitor bank the excitation capacitor can be associated. In the long shunt self excited induction generator, after the capacitor series the excitation capacitor was linked. Long & Short shunt SEIG behaviours are analyzed with the different load conditions by using Mat lab Simulink. Based on the simulation results, load contribution of short shunt SEIG is better than the long shunt SEIG with the real and reactive power requirement. The comparison of long shunt & short shunt has been done, the effects of both long-shunt and short-shunt connections with the same capacitances on feeding the IM have been clearly analyzed. Induction machines for both SEIG and IM have the same voltage and same KVA ratings. SEIG with short-shunt connection can maintain better voltage profile. And also it has an ability to supply more sufficient load voltage to the RLC load. SEIG with short-shunt connection voltage profile is better compensation by using various capacitors.

About Author

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