CHAPTER 3

ANALYSIS OF THREE PHASE AND SINGLE PHASE SELF-EXCITED INDUCTION GENERATORS

3.1. INTRODUCTION

Recently increase in energy demand and limited energy sources in the world caused the researchers to make effort to provide new and renewable energy sources particularly for rural electrification [147]. As per the scenario, in India more than million populations do not have access to electricity. Therefore the available renewable energy sources such as wind, natural gas, bio-gas and rivers with low flow can be utilized for decentralized units. Since the type of loads in remote, hilly and rural areas are mostly single phase and three phase, it is required to generate single phase and three phase electricity [148]. It is well known that the three phase induction machine can be made to work as a self-excited induction generator, provided capacitance should have sufficient charge to provide necessary initial magnetizing current. In an externally driven three phase induction machine, if a three phase capacitor is connected across its stator terminals, an EMF is induced in the machine windings due to the self excitation provided by the capacitor. The EMF is sufficient to circulate leading current in the capacitors. The flux produced due to these currents would assist the residual magnetism. This would increase the machine flux and larger EMF will be induced. This in turn increases the current and the flux. The induced voltage and current will continue to rise until the var supplied by the
capacitor is balanced by the var demanded by the machine, a condition which is essentially decided by the saturation of the magnetic circuit. This process is thus cumulative and the induced voltage keeps on rising until saturation is reached [146]. Magnetizing inductance is the main factor for voltage buildup and stabilization of generated voltage for unloaded and loaded conditions.

3.2. MODELING OF THREE PHASE AND SINGLE PHASE SEIG

The steady state and dynamic modeling of three phase and single phase self-excited induction generator are discussed in this section. The steady state model is developed using nodal admittance by the method of inspection from the equivalent circuits. This model can be utilized to find steady state characteristics of SEIG, which is discussed in section 3.4.

3.2.1 Steady State Modeling of Three Phase Induction Generators

A mathematical model using nodal admittance by the method of inspection from the equivalent circuit is developed. The developed model results in a matrix form which is convenient for computer solution irrespective of any combinations of unknowns. Fig. 3.1 shows the steady state equivalent circuit of a three phase SEIG.

![Fig. 3.1 Steady state equivalent circuit of the three phase system](image-url)
The various elements of equivalent circuit are given below

\[
Z_s = \frac{R_1}{a} + jX_1 \quad Z_L = \frac{R_L}{a} \quad Z_R = \frac{R_2}{a-b} + jX_2 \\
Z_c = -j\frac{X_c}{a^2} \quad Z_M = jX_m
\]  
(3.1)

The various branch currents of the equivalent circuit (Fig. 3.1) are given below

\[
I_C = \frac{(V_2)}{Z_c} \quad I_G = \frac{(V_2 - V_1)}{Z_s} \\
I_M = \frac{(V_1)}{Z_M} \quad I_R = \frac{(V_1)}{Z_R} \quad I_L = \frac{(V_2)}{Z_L}
\]  
(3.2)

From Fig. 3.1 the node equations can be written as follows

At node 1 \((V_1)\), the Kirchhoff's current law equation can be written as

\[
I_G = I_R + I_M
\]  
(3.3)

By substituting the values of \(I_G\), \(I_R\) and \(I_M\) in equation (3.3) and rearranging we get

\[
V_1 \left( \frac{1}{Z_R} + \frac{1}{Z_M} + \frac{1}{Z_s} \right) - V_2 \left( \frac{1}{Z_s} \right) = 0
\]  
(3.4)

At node 2 \((V_2)\), the Kirchhoff's Current Law equation can be written as

\[
I_L + I_C + I_G = 0
\]  
(3.5)

By substituting the values of \(I_L\), \(I_C\) and \(I_G\) in equation (3.5) and rearranging we get

\[
\frac{V_2}{Z_L} + \frac{V_2}{Z_c} + \frac{V_2-V_1}{Z_s} = 0
\]  
(3.6)

The equations (3.4) and (3.6) can be written in matrix form as follows

\[
\begin{bmatrix} \frac{1}{Z_R} + \frac{1}{Z_M} + \frac{1}{Z_s} & -\frac{1}{Z_s} \\ -\frac{1}{Z_s} & \frac{1}{Z_L} + \frac{1}{Z_C} + \frac{1}{Z_s} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}
\]  
(3.7)

above matrix can be written as

\[
\begin{bmatrix} Y_R + Y_M + Y_S & -Y_S \\ -Y_S & Y_L + Y_C + Y_S \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}
\]  
(3.8)

where,

\[
Y_R = \left( \frac{1}{Z_R} \right), \quad Y_M = \left( \frac{1}{Z_M} \right), \quad Y_S = \left( \frac{1}{Z_S} \right), \quad Y_L = \left( \frac{1}{Z_L} \right) \quad \text{and} \quad Y_C = \left( \frac{1}{Z_C} \right)
\]

The equation (3.8) is in matrix form which can be utilized for the steady state analysis of the three phase SEIG.
3.2.2 Dynamic Modeling of Three Phase Induction Generators

Fig. 3.2 shows the d-axis and q-axis equivalent circuit of the three phase induction generator.

The differential equations governing the stator and rotor currents in stator flux reference frame of the induction machine can be written as follows [149].

\[ L_s \frac{d}{dt}(i_{sq}) = v_{sq} - R_s i_{sq} - (\omega_{ms}) (L_s i_{sd} + L_o i_{rd} ) - L_o \frac{d}{dt}(i_{rq}) \] (3.9)

\[ L_s \frac{d}{dt}(i_{sd}) = v_{sd} - R_s i_{sd} + (\omega_{ms}) (L_s i_{sq} + L_o i_{rq} ) - L_o \frac{d}{dt}(i_{rd}) \] (3.10)

\[ L_r \frac{d}{dt}(i_{rq}) = v_{rq} - R_r i_{rq} + (\omega_{ms} - \omega_e) (L_r i_{rd} + L_o i_{sd} ) - L_o \frac{d}{dt}(i_{sq}) \] (3.11)

\[ L_r \frac{d}{dt}(i_{rd}) = v_{rd} - R_r i_{rd} + (\omega_{ms} - \omega_e) (L_r i_{rq} + L_o i_{sq} ) - L_o \frac{d}{dt}(i_{sd}) \] (3.12)
The modeling of the excitation system are given below

\[
\frac{d}{dt}(v_{sd}) = \frac{1}{C}(i_{sd} - i_{Ld} + i_d) + \omega_m v_{sq} \tag{3.13}
\]

\[
\frac{d}{dt}(v_{sq}) = \frac{1}{C}(i_{sq} - i_{Lq} + i_q) - \omega_m v_{sd} \tag{3.14}
\]

The modeling of resistive load

\[
\frac{v_{sd}}{R_L} = i_{Ld} \quad \text{and} \quad \frac{v_{sq}}{R_L} = i_{Lq} \tag{3.15}
\]

where,

\[
\psi_{sq} = -L_{ls} i_{sq} - L_m (i_{rq} + i_{sq}), \quad \psi_{sd} = -L_{ls} i_{sd} - L_m (i_{rd} + i_{sd})
\]

\[
\psi_{rd} = -L_{1r} i_{rd} - L_{m} (i_{rd} + i_{sd}) \quad \text{and} \quad \psi_{rq} = -L_{1r} i_{rq} - L_{m} (i_{rq} + i_{sq})
\]

### 3.2.3 Steady State Modeling of Single Phase Induction Generators

The steady state equivalent circuit of the single phase SEIG is shown in Fig.3.3. A new mathematical model for the steady state analysis in matrix form (equation (3.23)) is presented in this section.

Fig.3.3 Steady state equivalent circuit of SESPIG
The parameters of equivalent circuit are:

\[ Z_1 = j a X_M; \]
\[ Z_2 = Z_1; \]
\[ Z_3 = R_2 \frac{a}{(a - b)} + j a X_{Ir}; \]
\[ Z_4 = R_2 \frac{a}{(a + b)} + j a X_{Ir}; \]
\[ Z_5 = R_L + j a X_L - \frac{j X_{C_2}}{a} + R_{1M} + j a X_{1M}; \]
\[ Z_6 = Z_5; \]
\[ Z_7 = -R_L/2 - j a X_L/2 - \frac{j X_{C_2}}{2a} + R_{1A}/2a^2 + j a X_{1A}/2k^2 \]
\[ -j X_c/2ak^2 - R_{1M}/2 - j a X_{1M}/2; \]

The branch admittances are:

\[ Y_1 = 1/Z_1; \quad Y_2 = 1/Z_2; \quad Y_3 = 1/Z_3; \quad Y_4 = 1/Z_4; \]
\[ Y_5 = 1/Z_5; \quad Y_6 = 1/Z_6 \quad \text{and} \quad Y_7 = 1/Z_7; \]

Let \( V_1, V_2 \) and \( V_3 \) be the node voltages at nodes 1, 2 and 3 respectively. By applying Kirchhoff’s current law at node 1

\[ I_3 = I_4 + I_5; \quad (3.16) \]

Similarly, by applying Kirchhoff’s current law at node 2 and node 3, Eq. (3.17) and Eq. (3.18) are developed.

\[ I_1 + I_7 = I_2 + I_8 \quad (3.17) \]
\[ I_2 + I_4 + I_6 = 0 \quad (3.18) \]
where,

\[ I_1 = (V_1 - V_2)Y_1; \quad I_2 = (V_2 - V_3)Y_2; \quad I_3 = (V_2 - V_1)Y_3; \]
\[ I_4 = (V_2 - V_3)Y_4; \quad I_5 = V_4Y_5; \quad I_6 = -V_3Y_6; \]
\[ I_7 = -V_2Y_7; \quad I_8 = I_3 + I_4; \]  

(3.19)

On substituting equation (3.19) in equations (3.16), (3.17) and (3.18) and rearranging the resulting equations, the following three node voltage equations are obtained.

\[ V_1 (Y_1 + Y_3 + Y_5) - V_2 (Y_1 + Y_3) = 0 \]  

(3.20)

\[-V_1 (Y_1 + Y_3) + V_2 (Y_1 + Y_2 + Y_3 + Y_4 + Y_7) - V_3(Y_2 + Y_4) = 0 \]  

(3.21)

\[-V_2 (Y_2 + Y_4) + V_3 (Y_2 + Y_4 + Y_6) = 0 \]  

(3.22)

Equations (3.20), (3.21) and (3.22) are summarized in matrix form as

\[
\begin{pmatrix}
Y_1+Y_3+Y_5 & -(Y_1+Y_3) & 0 \\
-(Y_1+Y_3) & (Y_1+Y_2+Y_3+Y_4+Y_7) & -(Y_2+Y_4) \\
0 & -(Y_2+Y_4) & (Y_2+Y_4+Y_6)
\end{pmatrix}
\begin{pmatrix}
V_1 \\
V_2 \\
V_3
\end{pmatrix}
=
\begin{pmatrix}
0 \\
0 \\
0
\end{pmatrix}
\]  

(3.23)

Eq. (3.23) can also be written in short form as

\[ [Y][V] = [0] \]  

(3.24)

where, \([V]\) is the node voltage matrix and \([Y]\) is the nodal admittance matrix.

For successful voltage build up, \([V] \neq 0\) and therefore from Eq. (3.24), \([Y]\) should be a singular matrix i.e., \(\text{det}[Y] = 0\). It implies that both the real and the imaginary components of \(\text{det}[Y]\) should be independently zero. Therefore to obtain required unknown parameter of the equivalent circuit which results \(\text{det}[Y] = 0\), fuzzy logic approach [116] or genetic algorithm [117] can be utilized.
3.2.4 Dynamic Modeling of Single Phase Induction Generators

The d-q representation of single phase two-winding induction generator is shown in Fig. 3.4.

\[
\begin{align*}
(L_{ids}) \frac{d}{dt}(i_{ds}) &= v_{ds} - r_{ds}i_{ds} - \frac{d}{dt}(\Psi_{md}) \\
(L_{iqs} + L_r) \frac{d}{dt}(i_{qs}) &= v_{qs} - r_{qs}i_{qs} - R_{r}i_{qs} - \frac{d}{dt}(\Psi_{mq}) \\
(L_{idr}) \frac{d}{dt}(i_{dr}) &= v_{dr} - r_{dr}i_{dr} - \frac{d}{dt}(\Psi_{md}) - a\omega_r (L_{iqr}i_{qr} + \Psi_{mq}) \\
(L_{iqr}) \frac{d}{dt}(i_{qr}) &= v_{qr} - r_{qr}i_{qr} - \frac{d}{dt}(\Psi_{mq}) + \frac{a\omega_r}{a} (L_{idr}i_{dr} + \Psi_{md})
\end{align*}
\] (3.25) (3.26) (3.27) (3.28)

The state equations of capacitor bank are derived using the d-q components of stator voltages as state variables from the Fig. 3.4.

\[
\begin{align*}
\frac{d}{dt}(v_{ds}) &= -\frac{i_{ds}}{C_{sh}} \\
\frac{d}{dt}(v_{qs}) &= -\frac{i_{qs}}{C_{se}}
\end{align*}
\] (3.29) (3.30)

where

\[
\begin{align*}
\Psi_{mq} &= L_{mq}i_{mq}, & \Psi_{md} &= L_{md}i_{md}, \\
i_{mq} &= i_{qs} + i_{qr}, & i_{md} &= i_{ds} + i_{dr}
\end{align*}
\]
3.3 EXPERIMENTAL SETUP AND MACHINE PARAMETERS

A three-phase and single phase cage induction generators are used for the test. The experimental setup is shown in Fig. 3.5(a) and 3.5(b).

![Three phase SEIG and Single phase SEIG](image)

**Fig. 3.5:** Experimental setup of 3φ and 1φ self-excited induction generators

**Specifications of three-phase SEIG**
Three-phase, 50 Hz, 4-pole, 400V, 2A, 0.75 KW, Star Connected

**Base values**

- $V_{\text{base}}$ = rated voltage = 400/√3 = 230.9V, $I_{\text{base}}$ = rated current = 2A
- $Z_{\text{base}} = V_{\text{base}} / I_{\text{base}}$ = 115.45 ohms, Base power $P_{\text{base}} = V_{\text{base}} \times I_{\text{base}} = 461.8$W
- Base speed $N_{\text{base}}$ = 1500 rpm, Base frequency $f_{\text{base}}$ = 50 Hz

**The p.u parameters of the machine are**

- Stator resistance $R_S = 0.2374$, Rotor resistance $R_r = 0.3079$
- Stator and rotor leakage reactance $X_{ls} = X_{lr} = 0.3105$
- The magnetizing reactance $X_M$ versus air gap voltage $V_g/F$ expressed (in p.u) by a set of piecewise linear approximations are given below.

  $V_g/a = 1.1333 - 0.2615X_M, \quad X_M \leq 3.652 \quad \text{and} \quad V_g/a = 1.786 - 1.5415X_M, \quad X_M > 3.652$

**Specifications of single-phase SEIG**
Single-phase, 50 Hz, four-pole, 230V, 2A, 0.75 KW

**Base values**

- $V_{\text{base}}$ = rated voltage = 230 V, $I_{\text{base}}$ = rated current = 2A
- $Z_{\text{base}} = V_{\text{base}} / I_{\text{base}}$ = 115 ohms, Base power $P_{\text{base}} = V_{\text{base}} \times I_{\text{base}} = 460$W
- Base speed $N_{\text{base}}$ = 1500 rpm, Base frequency $f_{\text{base}}$ = 50 Hz

**The p.u parameters of the machine are**

- $R_{1M} = 0.0734$, $R_2 = 0.1036$, $X_{1M} = X_{lr} = 0.1675$, $R_{1A} = 0.1357$, $X_{1A} = 0.3074$, and $k = 1.25$
- The magnetizing reactance $X_M$ versus air gap voltage $V_g/F$ expressed (in p.u) by a set of piecewise linear approximations are given below.

  $V_g/a = 1.689 - 0.2X_M$ for $X_M \leq 3.2$ and $V_g/a = 2.844 - 0.555X_M$ for $X_M > 3.2$
3.4 ANALYSIS OF THREE PHASE AND SINGLE PHASE SEIG

The steady state and dynamic characteristics of three phase and single phase SEIG are discussed in this section for various operating conditions.

3.4.1 Steady State analysis of three phase SEIG

Fig. 3.6(a) shows variation of the var and capacitance with output power for constant terminal voltage at rated speed. For constant terminal voltage, the value of capacitance and var increases with output power. It may also be seen that for an increase in output power of the machine at rated speed, the var has to vary continuously for regulating the terminal voltage. Fig. 3.6(b) shows the variation of capacitance with speed to maintain constant rated terminal voltage under no load and loaded condition of the generator. It may be noted that, as the speed increases, the
capacitance requirements are reduced at full load and no load. It is also observed that, the generator requires higher value of capacitance at full load when compared to no load conditions.

Fig. 3.7 shows the load characteristics of the three phase SEIG, indicating the variation of terminal voltage and frequency with output power for fixed capacitance at constant per unit speed \( b = 1.0 \text{ p.u.} \). The terminal voltage variation is shown for different values of fixed shunt capacitance. For lower value of capacitance, the terminal voltage drops at lower output power, on the other hand for the higher value of capacitance the terminal voltage drops at higher output power. The frequency variation is also shown in Fig. 3.7 which is almost constant.

### 3.4.2 Dynamic Analysis of three phase SEIG

The no load per phase voltage waveform across the load terminals is shown in Fig. 3.8(a). The load is applied after the voltage build up to the steady-state level (230V) with a fixed excitation capacitance. It is observed from the current waveform (Fig. 3.8(b)) that when the load is increased, the load current also increases from 1.2A...
to 1.6A and hence the load voltage decreases from 230V to 200V (Fig.3.8(c)). If the load is further increased, again the load current increases from 1.6A to 1.8A, now the load voltage almost gets collapsed around 75V (Fig. 3.8(c)). This is due to the fixed capacitance, which is not sufficient to meet the change in load.

On the other hand, if a suitable capacitance connected across the load terminals the collapse of load voltage can be eliminated with increase in load. The stage by stage simulated waveform has been shown in Appendix. From the simulated waveform, it is evident that in order to sustain the load voltage under varying load, the capacitance value and hence the var has to be increased.

3.4.3 Steady state Analysis of single phase SEIG

The steady state analysis of the single phase two winding induction generator is carried out for the following cases.
i. No load voltage characteristics under varying speed at different capacitance values

ii. Performance characteristics of SESPIG without series compensation

iii. Performance characteristics of SESPIG with series compensation

### 3.4.3.1 Performance voltage characteristics under varying speed at different capacitance values

The no load voltage across main winding under varying speed is predicted by using the matrix equation (3.23) and fuzzy logic optimization approach [116] or genetic algorithm [117]. Fig. 3.9 shows the variation of no-load terminal voltage with rotor speed for three different values of excitation capacitance.

![Variation of no-load voltage with speed](image)

**Fig. 3.9 Variation of no-load voltage with speed**

Fig. 3.9 suggests that for successful voltage build-up, the capacitance must exceed some ‘threshold’ value for a given rotor speed, and the speed must exceed some ‘threshold’ value for a given value of terminal capacitance. In general, the no-
load terminal voltage increases with excitation capacitance and speed, but magnetic saturation as well as the thermal capability of the machine winding will impose an upper limit on the voltage at which the machine can be operated.

### 3.4.3.2 Performance characteristics of SESPIG without series compensation

Fig. 3.10-3.12 shows respectively the variations of voltage and current across main winding and auxiliary winding with output power when the generator is excited by three different capacitances and supplying a resistive load, the rotor being driven at rated synchronous speed. It is evident that an increase in the voltage of shunt capacitance leads to an increase in the power output. However, the voltage regulation remains approximately the same. With the value of C selected, the voltage in auxiliary windings builds up to 400V (C=38.5μF). Since the current in both windings are still less than the rated current (Fig. 3.11 & Fig. 3.12) it does not affect the safe operation of the machine so far as loading is concerned.
3.4.3.3 Performance characteristics of SESPIG with series compensation

Although the variable capacitor excitation scheme as discussed gives good performance, the requirement of a variable capacitor to regulate the terminal voltage makes the single phase SEIG system complex. It restricts the advantage of recommending the system for small portable power units.

Fig. 3.11 Main winding current under varying load

To make the single phase SEIG system simple and cost-effective, an investigation is carried out to study the series-capacitor excitation on regulating the

Fig. 3.12 Auxiliary winding current under varying load
load terminal voltage of the system. In this analysis capacitance ($C_{se}$) in series with load (main winding) and a fixed shunt capacitance ($C$) across auxiliary winding are considered. To predetermine the performance characteristics of single phase SEIG with series compensation, the same matrix equation (3.23) can be used.

Figs. 3.13-3.14 have demonstrated the effectiveness of series capacitance in improving the voltage regulation and power output of the two winding single phase SEIG system at unity power factor load. It is evident that the addition of series

![Graph 3.13: Main and auxiliary winding voltage under varying load](image1)

**Fig. 3.13 Main and auxiliary winding voltage under varying load**

![Graph 3.14: Main and auxiliary winding current under varying load](image2)

**Fig. 3.14 Main and auxiliary winding current under varying load**
capacitor of 100\(\mu\)F in main winding and an excitation capacitance of 38.5\(\mu\)F across auxiliary winding improves both the voltage regulation and power output of the SEIG system. The main winding and auxiliary winding current are also shown in Fig. 3.14 for unity power factor loads.

Comparison of the results shows that the connection of a series capacitor permits maximum utilization of the generator. The load voltage is self-regulated from no-load to maximum power output in unity power factor loads. The self-regulating feature of the scheme significantly reduces the cost and complexity of the single phase SEIG system as it avoids the use of a voltage regulator.

### 3.4.4 Dynamic analysis of single phase SEIG

To obtain the dynamic characteristics of single phase two winding induction generator, the capacitance is connected across the auxiliary winding and the load along with the series capacitance is connected across the main winding. The dynamic response of generator voltage and current are obtained for the following cases.

i) No-load voltage build up

ii) Step changes in load without series capacitance

iii) Step changes in load with series capacitance

iv) Short circuit at load terminals

v) Short circuit across auxiliary winding terminals

#### 3.4.4.1 No-load voltage builds up

The no load voltage build-up in the main winding is shown in Fig. 3.15. The steady-state terminal voltage at the main winding is 230 V.
3.4.4.2 Step changes in load without series capacitance

It is observed that (Fig. 3.16) when load increases, the current across the main winding also increases from 0.8A to 1A and hence the load voltage decreases from 230V to 200V. Further increase in load, the load current increases from 1A to 1.3A and hence the load voltage decreases from 200V to 50V. Since, a fixed capacitance is used across the auxiliary winding, the reactive power supplied by this is fixed. The voltage across the main winding can be improved by appropriate series capacitance.
3.4.4.3 Step changes in load with series capacitance

In this scheme, a fixed capacitance is connected across the auxiliary winding and a series capacitance \( C_{se} = 100\,\mu F \) is connected across the main winding. It is observed from the Fig. 3.17 that the voltage across the main winding can be improved around 200V, when compared to Fig. 3.16.

Fig. 3.17 Load voltage and current across main winding (with series capacitance)

Fig. 3.18. Short circuit at load terminals (Main winding)
3.4.4.4 Short circuit at load terminals

A common type fault that usually occurs is the short circuit across the load terminals. Therefore the response of the main winding voltage and current to sudden short circuit across the load is investigated and is shown in Fig. 3.18.

It is observed that generator does not de-excite, but continues to feed the fault. Since the regulating capacitor $C_{se}$ will come in parallel to the main winding terminals during the fault, the generators overexcites [143] and increase the generator voltage to 1.83pu (420.9V). This increased voltage will in turn charge the capacitor to a higher voltage and hence the generator current increased to 1.76pu (3.52A). Since the rise in magnitude of short circuit is only around 1.76pu (3.52A), it can be simply avoided by over current protection. Because of the presence of series capacitance it helps to limit the short circuit current, otherwise the short circuit magnitude will be so high.

![Graph showing current and voltage over time](image)

**Fig. 3.19.** Short circuit across auxiliary winding terminals and re-excitation on clearance of short circuit
3.4.4.5 Short circuit across auxiliary winding terminals

Fig. 3.19 shows the case when the SESPIG supplying load through main winding and short circuit across the auxiliary winding capacitor $C_{sh}$. The voltage and current in the main winding before short circuit, at the time of short circuit and after removal of short circuit (re-excitation – voltage build up will take place) are shown in Fig. 3.19. It is observed that after removal of short circuit across the auxiliary winding terminals the generator inherently re-excite due to the availability of residual flux in the magnetic circuit. The stage by stage simulated waveform of SESPIG has been shown in Appendix.

3.5 CONCLUSION

Dynamic and steady-state analysis of three-phase and single phase SEIG has been discussed under no-load and loading conditions. From the three-phase and single phase SEIG characteristics it is observed that, the shunt capacitance and series capacitance has to be selected such that it has to meet the change in load. It is also observed that the system exhibits inherent protection for short circuit fault and re-excitation takes place after the removal of fault. The satisfactory performance of three-phase and single phase SEIG under dynamic and steady state shows the suitability of its applications in wind energy conversion system under isolated operation. Even though satisfactory performance has been observed in wind energy conversion, the wind potential is seasonal and continuous generation is difficult. Therefore a hybrid energy conversion system employing wind and solar can be utilized in isolated generation for an uninterrupted power generation. The advantage of the hybrid scheme is, similar voltage regulation can be achieved without series capacitance. Such hybrid system is discussed in the following chapter utilizing the fuzzy based MPPT controller proposed for photovoltaic systems.