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Power Generation using Single Phase Self-Excited Induction Generator

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Abstract:-- **The self-excited induction generators have been found suitable for energy conversion for remote locations. This paper present a new method to supply single phase loads using single phase self-excited induction generator. This machine can be used to meet the local demand of remote area in the absence of grid. Induction generators are widely used to extract energy from renewable energy as it gives synchronized electrical power at variable speed its prime mover turbine. As electrical energy sources can be cheaper compare to grid connection in remote locations. Wind and mini/micro, portable diesel/kerosene engines can be used as a prime mover for induction generator.**

Keywords:**—Induction Genetaor, Self-Excitation Capacitor Bank, Prime Mover.**

I. INTRODUCTION

Today energy consumption has been increasing due to population growth, economic and industrial development. The energy supply is less than our increasing demand, so continues to face serious energy shortage problem such as load shedding which mainly affect rural area. To overcome this energy problem, we have to look towards non-conventional energy source like wind, micro hydro plant etc. With increased emphasis on non-conventional energy system and autonomous power generation, development of improved and appropriate generating system is needed. The three phase self-excited induction generator has the ability because of its specific advantages such as ability to generate power at varying speed. But these units may be applicable for power range upto100 KW, whereas for small portable unit we need single phase self-excited induction generator upto a power of 10 to 20 KW. Such generators may be commonly used in the remote areas where it is not possible to draw from transmission line. This machine can be used to meet the local-demand of remote areas in the absence of a grid.

When single phase self-excited induction motor forced to run at slightly faster than the synchronous speed it generate active power and work as a single phase self-excited induction generator. Prime mover provide mechanical torque on the motor shaft and self-excitation capacitor provide a reasonable amount of reactive power to establish the magnetic field necessary to convert the mechanical power from its shaft into electrical power. By selecting proper value of prime mover torque and excitation capacitor we can generate rated terminal voltage.[1]

II BASIC CONCEPT

A single phase induction motor can operate as a single phase induction generator provided that there is residual magnetism present in the rotor and proper reactive power is supplied to it. The required reactive power is supplied by connecting capacitor of proper value to the motor terminal. For any given load, there is maximum and a minimum value of capacitor which can excite the generator. Any capacitor beyond these two extremes cannot excite the generator. When an induction motor is connected to supply, it draws lagging current and the rotating magnetic field in the air gap induces emf in the rotor bars causing rotor current. The rotor current lags the air gap voltage. When the speed of the rotor is increased up to synchronous speed by external prime mover, the rotor current become zero. If the rotor speed is increased beyond synchronous speed, the direction of induced emf and current in the rotor changes. Stator current also changes its direction and motor act as generator. Stator current has active and reactive components and the reactive component is either supplied by connecting capacitors to generator terminal or from the supply system.[2-4]

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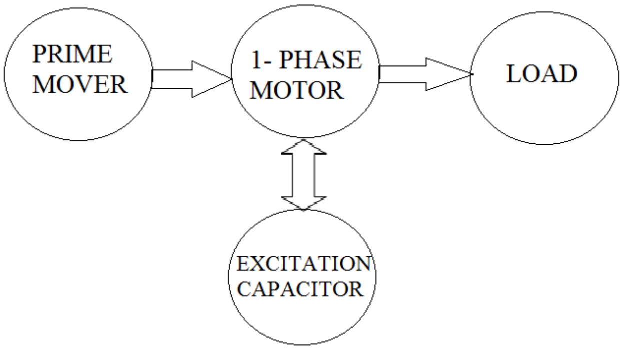

Fig.1. Block Diagram

The phasor diagram is shown in below figure. For simplification only stator side is shown. Vt is terminal voltage, I_L is the load current. Ic is the capacitor current. V_g is the generated voltage. In absence of external terminal capacitor, the generator draws reactive power from grid.[5]

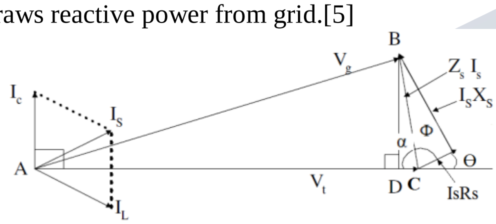

Fig.2 Phasor diagram of Induction generator.

The standard equivalent circuit of a three phase induction generator which is used for steady state analysis as shown in figure below.

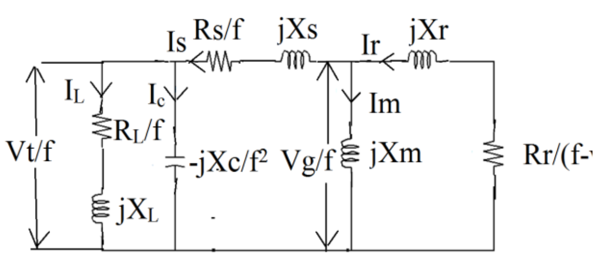

Fig.3 Per phase per unit equivalent circuit diagram of SEIG at base frequency.

III. SINGLE PHASE INDUCTION GENERATOR SYSTEM

There are different configurations of single phase self- excited induction generator according to stator winding.

3.1 Single winding stator

When a suitable capacitor is connected across the stator winding terminals, a voltage induce due to self-excitation, whose magnitude is being dependent on the values of capacitor and speed and magnetization characteristics. The magnetic saturation limit continuous rise of voltage and fixes the steady state value. When winding is electrically loaded, the voltage drop by value dependent on the magnitude and power factor of the load. Fig.4 shows the speed supplies the machine current I_m which is the sum of capacitor or excitation current Ic and the load current I_L.

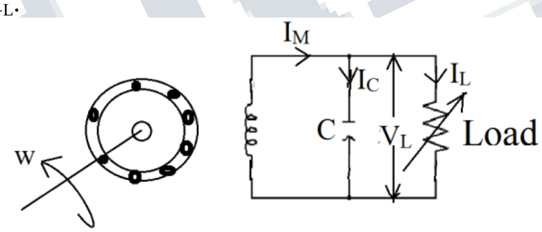

Fig.4 Single winding stator of SEIG

3.2 Two winding stator

By employing both the main and auxiliary winding of the induction machine as shown in Fig.5.capacitor was connected across one winding and load across the second winding. Tests were repeated by swapping the capacitor and load. The reading were also taken by connecting capacitor across both the winding.

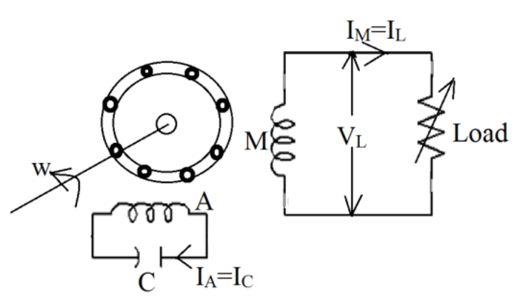

Fig.5 Two winding SEIG

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3.3 Tap changing stator

Tapping were incorporated to study the feasibility of automatic tap changing with load to effect the voltage regulation. Experiments on this model, also did not give encouraging results through tap changing, helped in obtaining the most suitable turns for the windings- Main and Auxiliary.

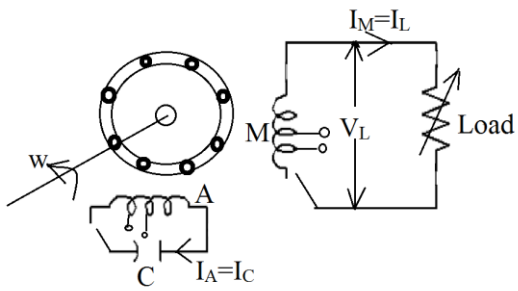

Fig.6 Two winding SEIG with tapped windings

IV. FINAL WORKABLE MODEL

4.1 Laboratory setup and tests

Final workable model consists of two windings, main windings i.e. load winding and auxiliary winding i.e. excitation winding. Suitable value of excitation capacitor connected across auxiliary winding and lamp load (purely resistive load) is connected across main winding. Induction generator driven by D.C. Shunt motor. The configuration as shown in Fig.7 [6-8]

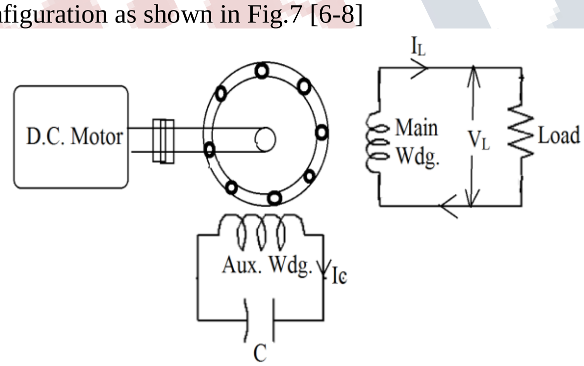

Fig.7 D.C. Motor coupled to SEIG

Load value increases from 0 to 800 Watts. Results of above experimental setup tabulated as below.

Table No.1 Tabulated results

Sr. No.	Voltage V_L (V)	Current I_L (A)	Load (W)	Speed (RPM)
1	220	0	0	1282
2	220	0.38	100	1272
3	218	0.68	200	1268
4	214	1.07	300	1260
5	210	1.39	400	1256
6	204	1.77	500	1252
7	202	2.12	600	1240
8	198	2.52	700	1236
9	194	2.88	800	1230

4.2 Result Analysis

For fixed value of capacitor excitation, the voltage levels were monitored at different speeds. As below graphs shows that the voltage level goes on decreasing with increment of load (Resistive only). The value of capacitor used for aboveanalysis is 150μF across the auxiliary winding. The different plots as shown in below figures.[9]

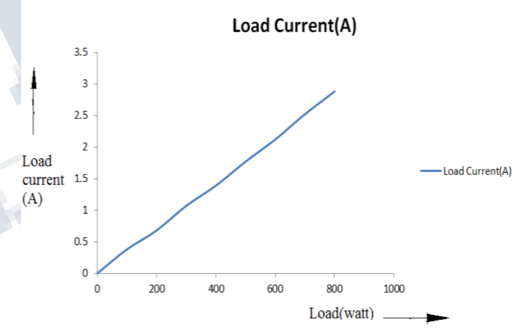

Fig.8 Load current Vrs Load

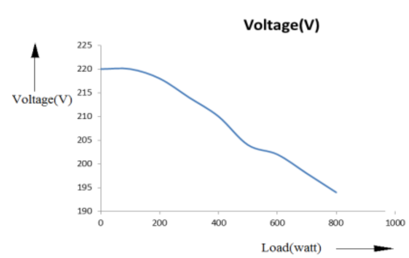

Fig.9 Voltage Vrs Load

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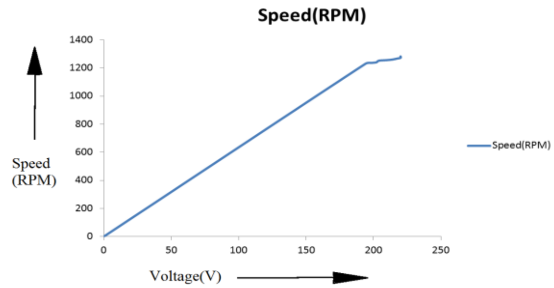

Fig.10 Speed Vrs Voltage

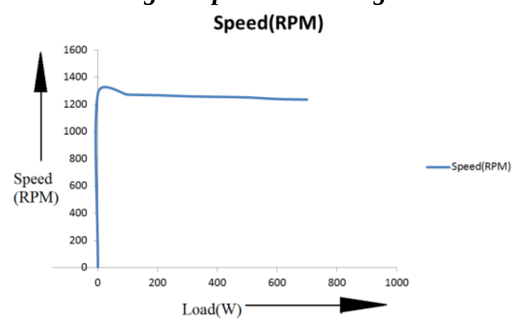

Fig.11 Speed Vrs Load

V MATLAB SIMULATION AND RESULTS

5.1 MATLAB simulation model

The simulation of Single phase SEIG is done withMATLAB. This model consists of two winding asynchronous single phase motor with auxiliary and main winding. The excitation capacitor of 150MFD is connected across auxiliary winding and load(purely resistive) of 100 Watts connected across the main winding. Result were analyzed with practical setup, which are nearly equal.

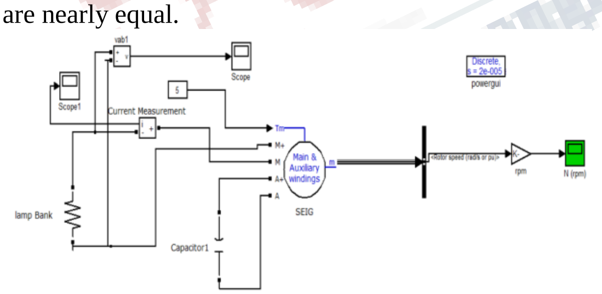

Fig.12 Simulation model

The MATLAB simulation of single phase SEIG which consists following parameters as shown below in table.[10]

Table No. 2 Parameters

Sr. No.	Parameter	Value
1	Nominal power	1.119 kw
2	Phase voltage	220 volt
3	Fundamental frequency	50 Hz
4	Main winding resistance	2.20 Ω
5	Main winding leakage inductance	0.0074 H
6	Auxiliary winding resistance	7.14 Ω
7	Auxiliary winding leakage inductance	0.0085 H
8	Rotor resistance	4.12 Ω
9	Rotor leakage inductance	0.0056 H
10	Mutual inductance	0.187 H
11	Inertia	0.0146 kg/m^2

5.2 SIMULATION results

MATLAB R2010b used for simulation. This simulation run for 5 sec. and results are shown below. Fig.13 shows generated output voltage across loaded winding i.e. across main winding. Fig.14 shows output current i.e. current through purely resistive load and Fig.15 shows speed variation between 1086 rpm to 1124 rpm.[11]

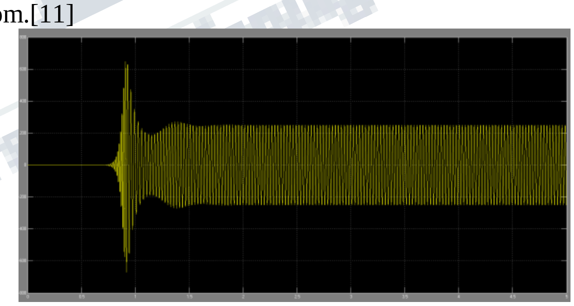

Fig.13 Voltage waveform

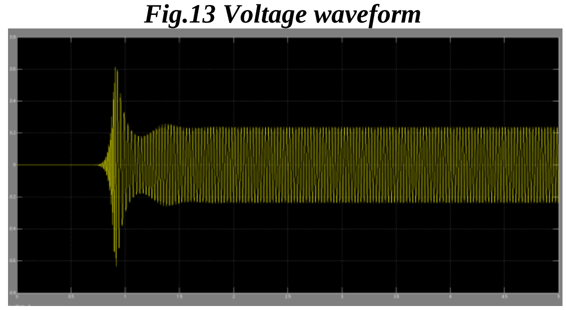

Fig.14Current waveform

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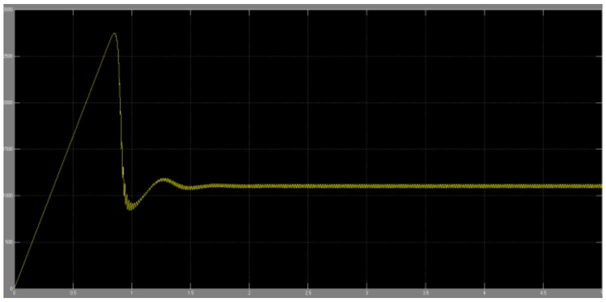

Fig.15 Speed waveform

VI CONCLUSION

Single phase SEIG have poor voltage regulation but it is quite as good as three phase SEIG. When the current unit loaded for an hours it suffers from heating problem.Which can be overcome by changing certain design parameters of SEIG. Current acute shortage of electrical power can be mate to some extend by deploying small generating units on small waterfalls or small water flows, low power winds to feed power to remotely located population throughout the year. Also for emergency demand we can implement this unit with portable kerosene/diesel engine.

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Photograph of the developed SEIG in LAB

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