Renewable Energy Laboratory for Engineering Students

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ABSTRACT

Renewal Energy is now included in the curricula of Engineering Education. There is a need to develop a laboratory for the subject. This paper presents experiments on Renewable Energy based on Wind turbine, Induction Generator and PV solar cell characteristics. The experiments developed are based on readily available equipment in engineering colleges. For further quick development more sophisticated equipment is required. It concludes that dSPACE can come to the rescue with its potential of rapid prototyping. This will result in reduced time to market

1. INTRODUCTION

Energy is a critical input required for development. Fossil fuel reserves in the country are limited and there is a need to develop viable cost effective alternatives. Renewable energy is a possible long term solution for the energy problems. The development of new energy technologies provides a technological challenge. There is a requirement for high quality trained manpower in the energy sector. This also provides scope for engineering innovators/entrepreneurs. Renewal Energy is now included in the curricula of Engineering Education to make the required manpower available. There is a need to develop a laboratory for the subject. This paper presents experiments on Renewable Energy based on Wind turbine, Induction Generator and Photo Voltaic solar cell characteristics.

2. LABORATORY EXPERIMENTS

The experiments are designed to use the equipment which is normally available in the Electrical Engineering Department of an Engineering College. There are mainly two types of experiments, Wind Energy based and Solar Energy based.

2.1 WIND TURBINE GENERATOR

<u>2.1.1 Resources</u> -To conduct the experiment single phase ac supply, single phase fan, anemometer, DC turbine generator, load resistance and ac and dc ammeters and voltmeters are required.

<u>2.1.2 Procedure -</u> Referring to Figure1, the single phase fan is the source of wind for the wind generator. The speed of the fan is varied by variable ac supply to change the wind speed. The wind generated drives the wind turbine dc generator. The dc generator is loaded by resistive load. The single phase supply is turned on. Following experiments are conducted.

1. With fixed load resistance and variable wind speed.
2. The speed of the wind generated by the fan is measured by the anemometer. DC output voltage and current of the generator are also measured. Graph is plotted for dc generator voltage Vs wind speed.
3. With fan speed at maximum and variation of load resistance. With fan speed reduced and variation of load resistance
4. Graph is plotted for dc generator voltage Vs current for fixed wind speed in case 2. and 3 above on the same graph.

<u>2.1.3 Learning Outcome-</u> Students learn how the generated power changes with wind speed when the load resistance is constant and how the generated power changes with load when the load is varied by varying load resistance keeping the wind speed constant.

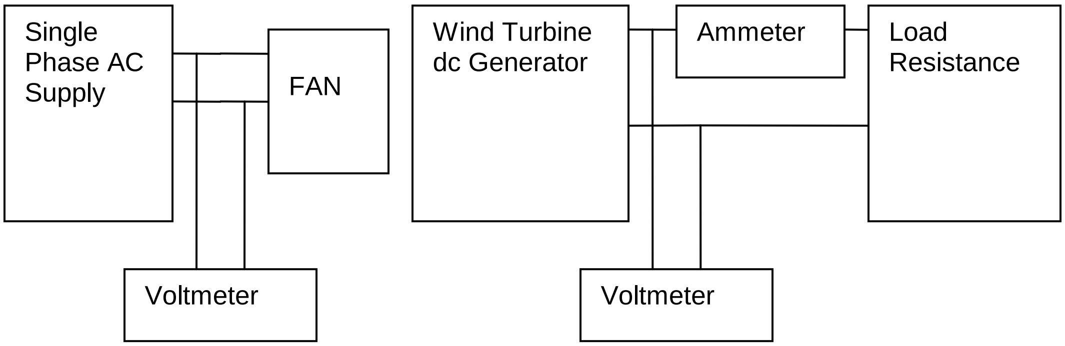

Figure1

2.2 WIND ENERGY GENERATOR EMULATION USING SQUIRREL CAGE INDUCTION GENERATOR FEEDING POWER TO THE MAINS

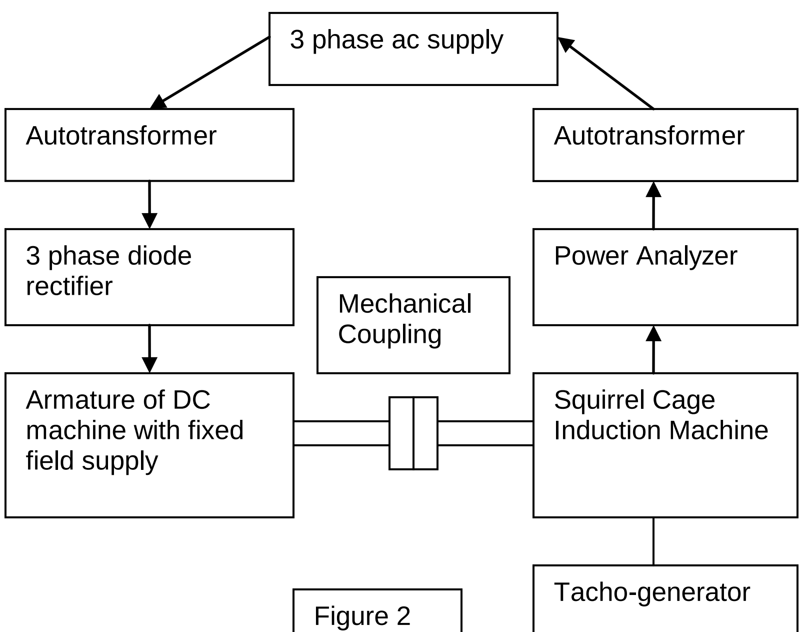

Figure 2

<u>2.2.1 Resources</u>- To conduct the experiment separately excited dc machine, squirrel cage induction machine, power analyzer, resistive load on dc machine side, 3 phase autotransformer, three phase diode rectifier, dc voltmeter, dc ammeter and tachometer are required.

<u>2.2.2 Procedure-</u>Initially the circuit is connected as shown in Figure2, with connection between dc machine and diode rectifier removed. The autotransformer on dc machine side is set to minimum output voltage. The induction motor is started and taken to full speed using the autotransformer on ac machine side. The no load speed is measured with

tachometer. The field winding of the dc machine is energized to check the voltage at the output of the dc machine operating as a generator. The dc machine voltage polarity is noted and the motor voltage is set to a predetermined value. The dc machine is loaded by lamp load to a predetermined load. The power flows from 3 phase ac supply to the lamp load. Both real power and reactive power are noted down from the power analyzer. The lamp load is disconnected. The diode rectifier output is now connected to the dc machine terminals so that the cathode of rectifier is connected to the positive voltage of the dc generator and anode to the negative. The autotransformer on the dc machine side is adjusted to increase the voltage. Initially the diode rectifier remains reverse biased till the voltage exceeds that of the dc generator back emf. The diode rectifier voltage is increased so that current flows in the armature on the dc machine in the reverse direction. The armature voltage is increased to set the current to a predetermined value. The readings on the power analyzer are noted down. The tacho- generator indicates that the induction machine rotates at super-synchronous speed. It is noted that the sign of real power is reversed. The power now flows into the 3 phase ac supply on ac side. However the reactive power sign does not change. The mains still supplies the reactive power. Readings are noted down at different speeds and hence loads within the rated values.

2.2.3 Learning Outcome-Students observe and learn that induction machine generates power at super-synchronous speed and how this can be used in wind energy generation. Students learn that although real power is absorbed by the mains, reactive power has to be supplied by the mains.

2.3 STAND-ALONE WIND ENERGY GENERATOR EMULATION USING SQUIRREL CAGE INDUCTION GENERATOR FEEDING POWER TO THE MAINS

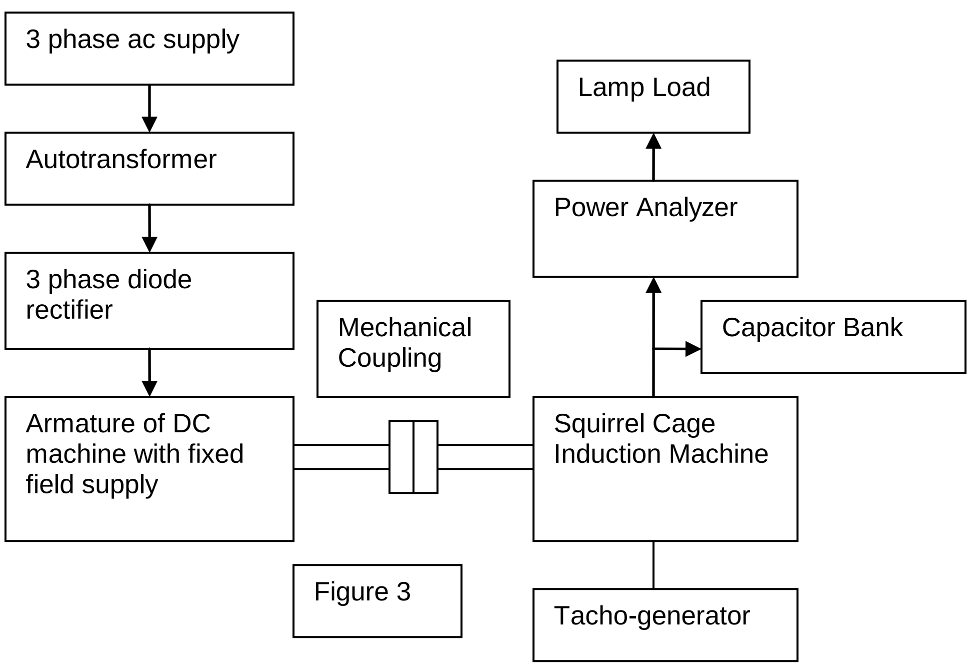

Figure 3

2.3.1 Resources-In addition to the resources required in 2.2 above, this experiment requires three phase power factor correction capacitor, and lamp load on induction machine side.

2.3.2 Procedure-From the experiment in 2.2 above, the reactive power measured by the power analyzer is noted. A capacitor bank is now connected between the induction machine and the power analyzer to compensate for the reactive power requirement. The procedure of 2.2.2 above is now repeated. It is observed from the power analyzer that now the reactive power required to be supplied by the mains is reduced and the capacitor bank now supplies it. A lamp load is now connected between the power analyzer and autotransformer as shown in Figure3 and the connection of auto-transformer is removed. The lamps continue to glow as the induction machine continues to work as a generator even after it is disconnected from the ac supply.

2.3.3 Learning Outcome-Students learn that the reactive power required for the induction generator can be supplied from capacitor bank and that with proper supply of reactive power from capacitor bank, the induction generator can work as Standalone Generator in self excited mode.

2.4 WIND ENERGY GENERATOR EMULATION USING SLIP RING INDUCTION GENERATOR WITH ROTOR RESISTANCE CONTROL.

Induction Generator using squirrel cage machine has a limitation that it can operate only in a small band above synchronous speed. Energy in a small band of speed range only can be tapped. It is possible to increase the slip by using rotor resistance control and operating the machine at super-synchronous speed.

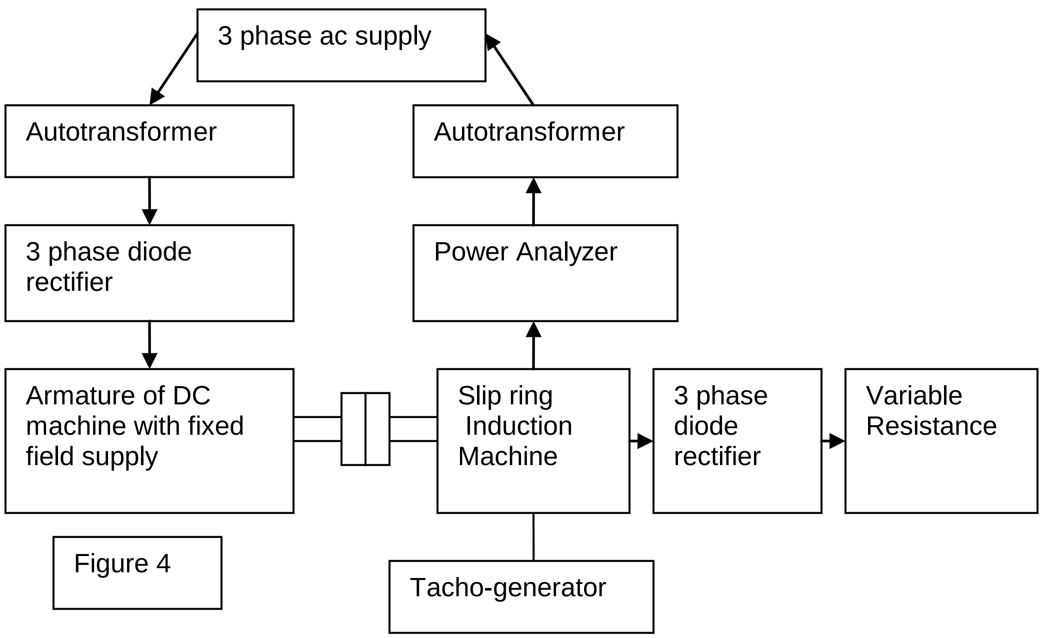

Figure 4

2.4.1Resourses-To conduct the experiment, separately excited dc machine, slip ring induction machine, power analyzer, resistive load on dc machine side, 3 phase autotransformer, three phase diode rectifier, dc voltmeter, dc ammeter, tachometer and rheostat are required.

2.4.2 Procedure-The circuit diagram is shown in Figure4. The procedure is the same as in 2.2.2 Advantage with this system is that the speed range can be increased by increasing the rotor resistance. The speed range over which wind energy can be generated is much wider than that with squirrel cage induction generator.

2.4.3 Learning Outcome-Students learn that the speed range over which wind energy can be recovered is much wider with slip ring motor using rotor resistance compared to squirrel cage induction motor.

2.5 WIND ENERGY GENERATOR EMULATION USING SLIP RING INDUCTION GENERATOR WITH SLIP POWER RECOVERY SCHEME.

2.5.1 Resources-To conduct the experiment, separately excited dc machine, slip ring induction machine, power analyzer, resistive load on dc machine side, 3 phase autotransformer, three phase diode rectifier, dc voltmeter, dc ammeter, tachometer and rheostat are required.

2.5.2 Procedure-The circuit diagram is shown in Figure5. The procedure is the same as in 2.4.2 except that the rotor resistance in Figure4 is replaced by line commutated inverter which feeds the rotor power back to the mains.

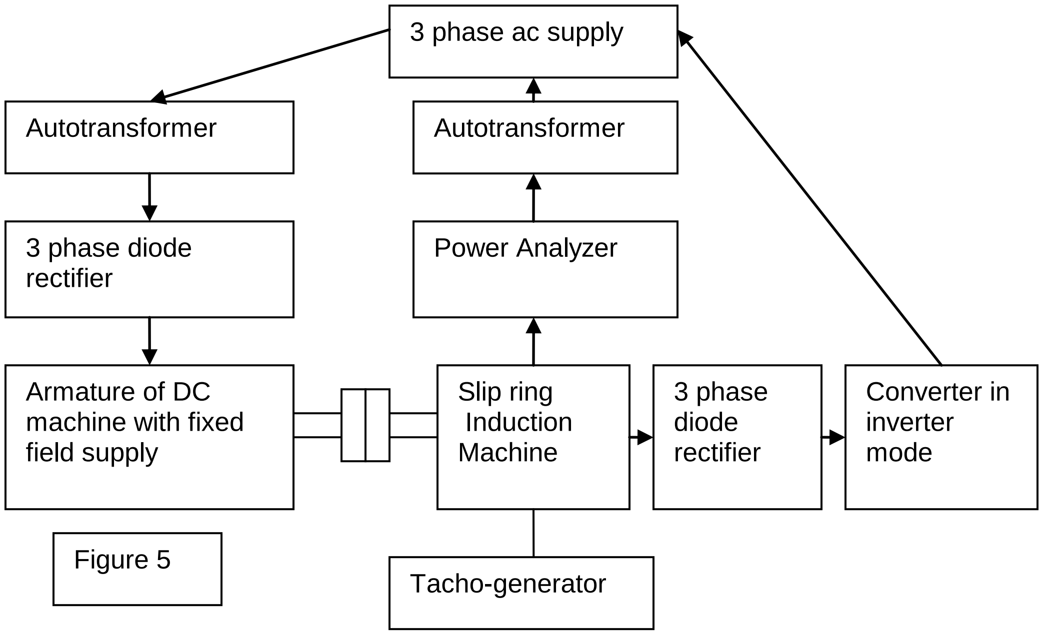

Figure 5

2.5.3 Learning Outcome- Students learn how the doubly fed induction generator works and how wind energy can be converted to electrical energy and fed to the mains both from the stator and the rotor. They learn that the doubly fed induction generator allows larger speed range than squirrel cage induction generator and gives higher yield as power is fed back to the mains both from the stator and the rotor side of the induction machine.

2.6 NONLINEAR CURRENT-VOLTAGE CHARACTERISTICS FOR PV SOLAR CELLS.

2.6.1 Resources-To conduct this experiment, variable single phase ac supply, light bulb, luxmeter, PV solar cell, ac and dc ammeters and voltmeters and load resistance are required.

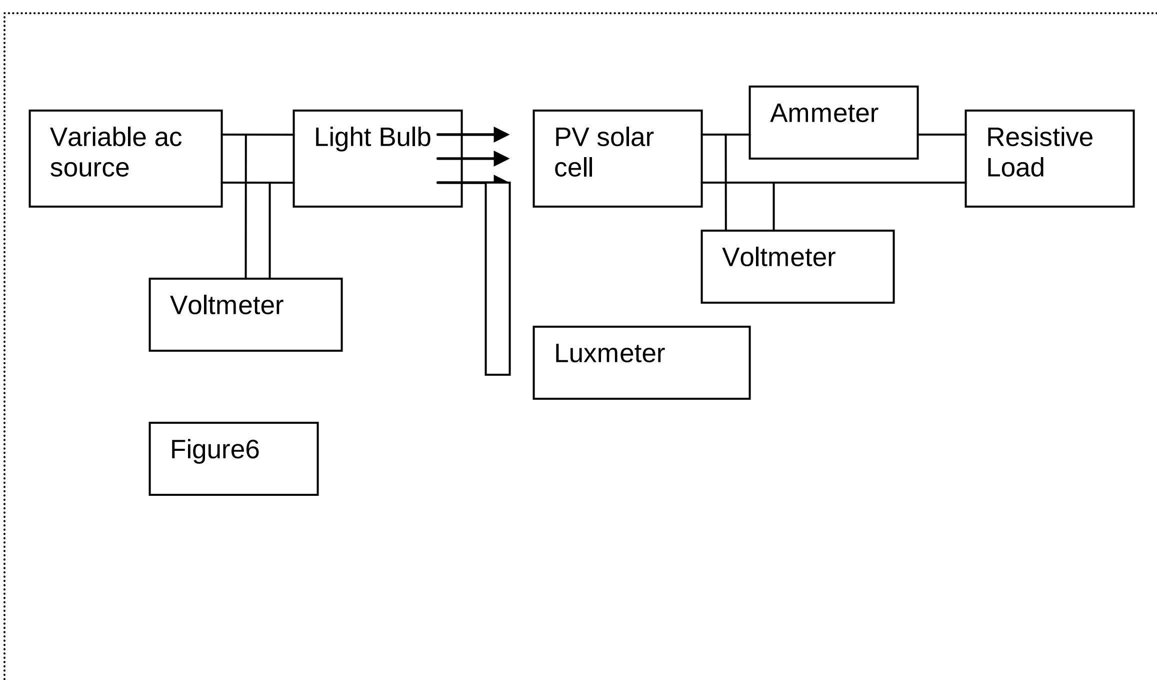

Figure6

2.6.2 Procedure-When single phase ac supply to the light bulb is varied light intensity varies. When the light is incident on the PV cell, it converts it to electrical energy. The light intensity is measured using a luxmeter. The experiment is conducted in two parts.

1. The light intensity is fixed at maximum and the load resistance is increased incrementally from zero to one mega ohm and associated dc voltage and current are measured. Two separate graphs are plotted for current Vs voltage and power Vs voltage with voltage on X axis. Maximum power points are identified.
2. The light intensity is reduced to half and the load resistance is increased incrementally from zero to one mega ohm and associated dc voltage and current are measured. Two separate graphs are plotted for current Vs voltage and power Vs voltage with voltage on X axis. Maximum power points are identified.

The results of 1 & 2 are superimposed on the same graph with same axis.

2.6.3 Learning Outcome**-**Students learn the current- voltage and power- voltage characteristics and that there is a maximum power point for the solar cell. They learn the effect of change of light intensity on the characteristics.

3 CONCLUSION

Experiments on wind turbine, induction generator and solar cell are presented. There is a scope of further development in the standalone induction generator to use dSPACE software and control the voltage using variable capacitor and in the doubly fed induction generator where dSPACE can be used for extending wind power recovery range by replacing diode bridge by a thyristor bridge. Fast development is possible using dSPACE.

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