Comparison between locally produced low cost electric machine and wind generator

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Abstract

In Pakistan there is a short fall of electricity. Currently, the total amount of energy produced in Pakistan is about 19,500 MW through various resources such as hydel power, natural gas etc. The energy produces via hydel power is much less in comparison to production of energy through Furnace oil or Natural gas. Hydel power produces only 65,00 MW, while rest of 13,000 MW is produced either using Furnace oil or Natural Gas. Furthermore, nuclear and coal resources also contribute in energy production, but the yield is lower than the hydel power production, which is 450 MW and 150 MW respectively. The shortage of electricity reaches its peak i.e 6,000 MW in summer season and it is expected that this figure is expected to rise with time. Since Pakistan posses abundant wind resources for electricity generation, therefore it is essential to build indigenous low cost wind turbine to utilize these available resources efficiently and economically. This study specifically concerns with development of generator of horizontal axis of wind turbine.

In this study, three-phase AC asynchronous induction motor has been converted into a wind turbine generator to produce a robust and economical design. For this purpose, a test rig, consisting of two induction motors, chain sprocket, motor coupling, capacitors, and load bank of 2.3 KWwere used. During experimental trials, high voltage oil based capacitors were used to magnetize the generator coil. As generator motor is rotated slightly above its rated rpm of 2800, capacitors starts magnetizing the coil, which in turns produce potential difference that reverses the motor behavior and it start working as a generator. During the laboratory trials, it has been shown that this approach presents a robust and economical solution for developing wind turbine generators, as these induction motors are easily available at considerably low prices in comparison to DC generators.

Keywords: *Wind turbine, Induction Motor, Generator, Renewable energy.*

1. Introduction

Currently, Pakistan is facing crisis of electricity shortage and as the time passes by, these crisis will only deeper unless available natural resources, such as wind, solar or coal arenot utilized properly. During summer time when electricity demand is at its peak shortfall reaches up to 6,000 MW. Pakistan spends 64% of its foreign exchange on fossil fuels to generate electricity.Hence, it is essential to look into other available resourcesto produce energy at low cost.Since renewable energy through wind, solar or coal presents a economical modefor power production, while reducing the global air pollution and hence providing a clean and safe environment for the world [1]. Among the alternate sources, wind is suitable for the country like Pakistan which posses wind corridor at Gharo.

The Asynchronous generator is widely used all over the world because most of its plants and water pumps consist of induction motors. Asynchronous motoris used as generator in wind turbine. Asynchronous generator is economically cheap and is a reliable generator. It was originally designed as an electric motor but it can also be used as a wind turbine generator in order to lower the price and losses as compared to Permanent Magnet Direct Currentgenerator.In order to convert Asynchronous induction motor into generator it was required to rotate motor at high rotation per minutes (RPM) than its nominal rotation per minutes (RPM). To achieve the required rotation per minutes (RPM), prototype consists of gears with different ration on both sides which is 41:14, where forty one (41) numbers of teeth is of prime mover and fourteen (14) numbers of teeth is of Generator motor.In an asynchronous motor Cage rotor is very important element that differ the asynchronous generator from the synchronous generator. Using slip the generator has a simplemechanical configuration. The machine does not have slip ring as well as brushes. Therefore it requires low maintenance, has a long service life and a robust design. [8]As far as test rig is concerned, Two (2) induction motors were used as AC generator and prime mover respectively. Both star and delta motor connections were used to produce output of 2.3 KW.Forexperimental purpose the speed of prime mover was controlled using Frequency inverter. Motor which was used for wind turbine generator during this study is induction motor. The power rating of the generator was maximum 2.5 KW and had 2800 rotation per minutes (RPM). This technology of induction motorwas based on relatively mature electric motor. Induction motors arethe most common type of motor used in industries and as well all over the world. Motor was converted into generator by using fixed capacitor for excitation of the coil field. This resulted in unstable power output as the excitation could not be adjusted as the load or speed deviated from the nominal values.

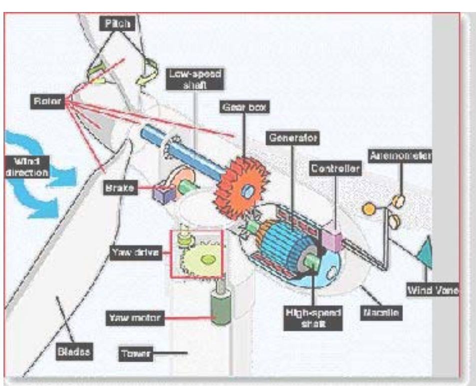


FIGURE 1: WYE AND DELTA CONNECTIONS

As far as speed of the induction motor is concerned, Sysnchronous speed of motor was determined by the speed with which the stator magnetic field rotates, will determine the speed ofthe rotor which is called the Synchronous Speed (SS). The SS is a product of frequencyof the power source and the total number of poles in the motor.[2] The relationshipused to calculate the Speed of an induction motor is given by

$$SS = (120 \times f) / P \qquad [2]$$

Where:
SS = Synchronous Speed (in RPM)
f = frequency (cycles / second)
P = number of poles

The rotor contains number of copper or aluminum bars which were connected electrically by aluminum end rings. The rotor is consist of an "iron" core, having a stack of thin insulated steel laminations, with the holes punched for the conducting bars of aluminum. The placement of rotor was in the middle of the stator, which in this case, was a four-pole stator which was directly connected to the three phases of the electrical grid. The adjustment of the rotor wasautomatedby itself to the number of poles. This same stator may therefore be used with a wide variety of poles. [3]
The three phase AC induction motor comprises of a squirrel cage rotor having aluminum bars or conductors whichwere shorted simultaneously at both ends of the rotor by cast aluminum end rings. A sinusoidal distributed air gap flux was produced when the three current flows through the symmetrically placed windings generating the rotor current. The interaction of the sinusoidal distributed air gap flux and induced rotor currents produces a torque on the rotor.
As shown in figure 2 Three phase motor can be used in two winding types that is star winding and delta winding. Inverter of 5 horse power is used in order to rotate the prime mover at variable rpm and then prime mover will rotate the generator with desired rpm. Capacitors were connected with star winding of coil for excitation of the coil. Prime mover in wye fashion with the inverter and generator was connected in delta fashion with the capacitors to produce single phase output.

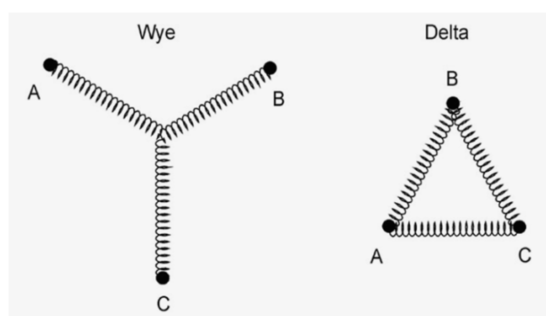


FIGURE 2: WYE AND DELTA CONNECTIONS

A frequency changer or frequency inverter is basically an electronic device that converts one frequency of alternating current (AC) to another frequency of alternating current.[4]Pictorial view of the device is shown in figure 3.Traditionally, these devices are called a motor-generator set, as they consist of electromechanical machines. Also some devices withvacuum tubesof mercury arc rectifiers were used. With the advancement in electronic and advent of solid state electronics, it is then possible to build an electronic frequency inverter economically. These devices normally consist of a rectifier which produces direct current, that direct current was then inverted to produce alternating current of the required frequency.[12] The inverter shown in figure can use thyristorsIntegrated Gate Commutated Thyristorsor insulated gate bipolar transistors. [5] If any voltage conversion is required, a transformer will be included in either at the ac input or at the output circuitry and that transformer can also provide galvanic isolation between the input and output of the ac circuits. Battery can also be added to the dc circuitry of the inverter to improve theinverter's ride-through of brief outages in the input power. [6]

FIGURE 3: FREQUENCY INVERTER

Combination of variable load and wattage was used to test the power generated by the generator. The loads are of inductive nature start turning on one by one with gradually increasing the rotation per minute of the prime mover so that generated voltage remains constant.

2. Experimental Setup

The experimental setup involves mechanical structure of two motors one is prime mover and the other one will act as generator. The motors were mounted on the stand. Both motors coupled through chain and sprocket as shown in figure 4. Sprockets are of different ratios that is 41:14. Prime mover has more number of teeth and the generator has lees no. of teeth. The ratio is approximately 41:14 which means that if prime mover takes one turn then generator will take 2.92 turn. This was done to achieve mechanical advantage desired rpm of generator with fewer rotation of motor. [2]

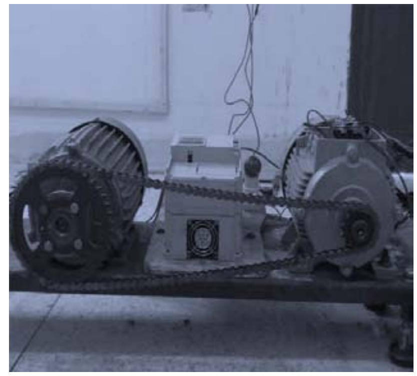


FIGURE 4: MOTOR COUPLING

Forsystem that generates three phase output, the configuration of the capacitors can be in star or delta types, as shown in figure 5. For star connected system, the star point of the capacitor should be disconnected from the generator and system was kept neutral to prevent the waveform distortion and bigger losses. [5]

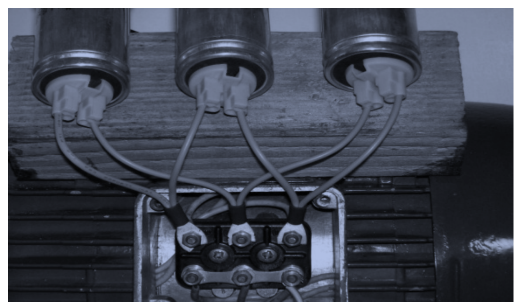
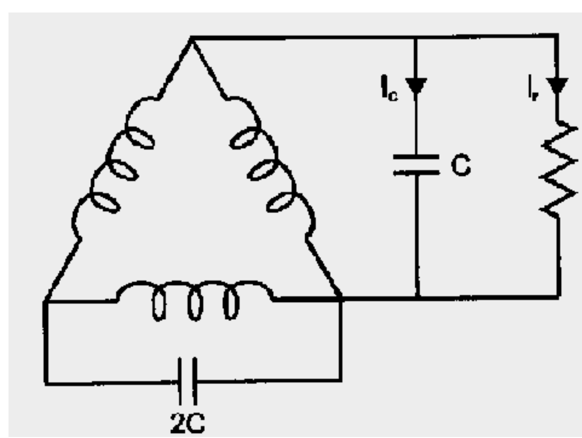


FIGURE 5: PICTORIAL VIEW OF MOTOR AND CAPACITOR

for the system which generates Single phase output capacitor used for this configuration should be in C-2C configuration as shown in figure6.



FGURE 6: CAPACITOR CONNECTING WITH MOTOR

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Load bank was used to observe the generated power from generator.Generators were tested though load bank. Several bulbs of different power ratings like 100 watt 200 watt and 500 watt were connected to test the output power of generator. Load bank picture has shown below. All bulbs were controlled through individual switches. Bulb turns on one by one gradually.[7]

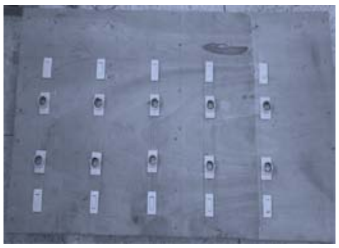

FIGURE 7: LOAD BANK

Firstly, we would have to start the inverter then choose the frequency at which rpm will rotate prime mover. I recommend touse potentiometer instead of using keypad each time as it is time consuming to re enter the frequency each time. Moreover, potentiometer allows us to control the frequency of the prime mover so that it varies speed. By varying the speed of prime mover the speed of the generator varies. As generator (induction motor) reached its desire rpm, through prime mover, motor will be converted into generator which gives the output. At last, when the loads will be turned on, one by one, it results decrease in voltage gradually. In order to maintain the required voltage, the rpm of the prime mover was increased simultaneously by the frequency inverter. In fact, by raising the rpm of prime mover the speed of generator increases which eventually increases the voltage.[8]

3. Analysis

If the speed of the generator is increased above nameplate rpm let say1500 Rotation per minute (rpm) then we have to rotate it around 1525 or 1550 rpm the end effect will be that the rotor will rotate faster and through capacitor it produces excitation in the in the coil. That will then produce the induction of a strong current in the rotor. Power supply transferred as an electromagnetic force to the stator may be increase. By increasing the rpm of generator motor will then result in an increase in the amount of electricity converted. [9]. The mechanical fixture is shown in figure 8.

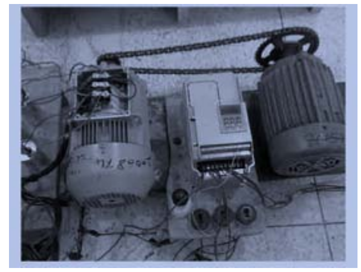

FIGURE 8: COMPLETE SETUP FOR GENERATOR

4. Generator Protection

4.1 Overload

Partial collapsed of excitation is basically the main cause of overload, due to which winding current limits its value until it reach the safer point. That’s why it is recommended to generator whose rating is greater than or equal to the maximum electrical output from the turbine-generator. Another effect on burnt also cause on a three phase system if we given a severe overload on one phase only. [10]

4.2 Underload

The induction generator is at greater from the load loss than from too much load. The reason behind this that with little load or no load connected, generator will speeded up and by that reason the frequency and voltage will increase. Both of these factors (increase in voltage and increase in frequency) increasing the current of the generator flowing in it from the capacitors. And hence it increased winding current, generally a level which exceeds its rated value. In order to protect against the damage to capacitors and the windings miniature circuit breakers must be fitted in series with the capacitors to switch them out if generator over speeds. [11]

4. Load Characteristics

Figure 9 shows the graph of prime mover without connecting generator. The non linear graph shows that voltages applied to the prime mover current I is high because prime mover is in transition time when it achieve in its steady state region current decreases.

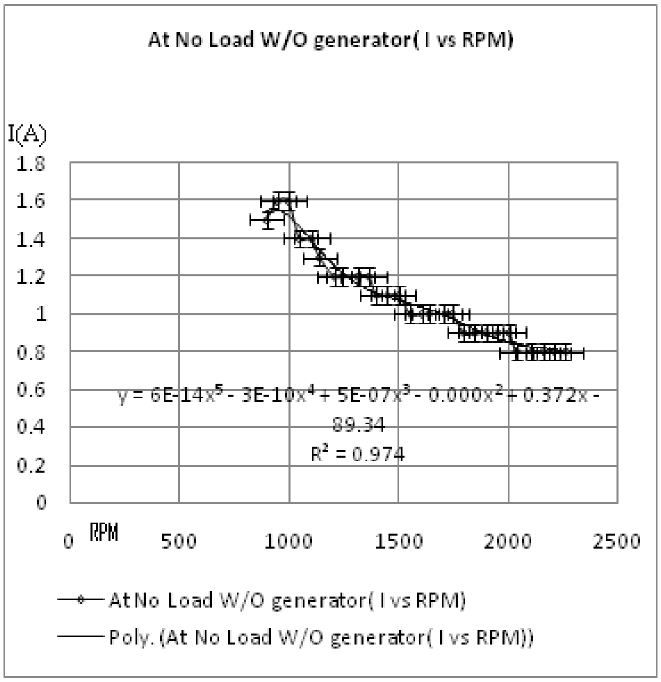

FIGURE 9: CHARACTERISTICS CURVE OF NO LOAD WITHOUT GENERATOR (I VS RPM)

Figure 10 shows the characteristics curve of motor and generator connected with no load (I vs RPM) RPM shows the rotation of prime mover and i(A) show the output in term of current of generator. As generator attains the speed of slightly above its nominal rpm then it behaves as a generator and produced the output in term of current and voltages.

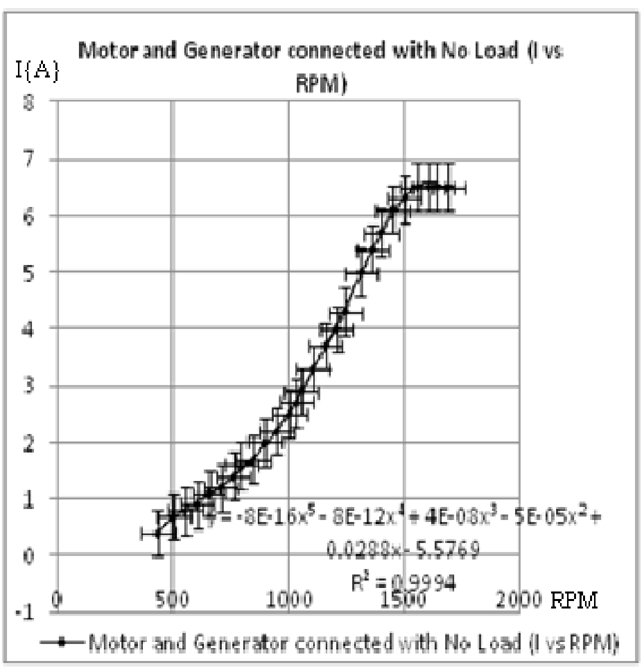

FIGURE 10: CHARACTERISTICS CURVE OF MOTOR AND GENERATOR WITH NO LOAD

In figure 11 graph shows the characteristics curve of motor and generator connected with no load (V vs RPM). Graph depicted that when motor attain its RPM slightly above its nominal RPM motor acts like a generator and producing voltages. As prime mover's RPM increases output voltages also increases that is it reaches to 380V. after that if RPM of generator increases the voltage dips occurred.[12] So the maximum 380V can be achieves through the generator.

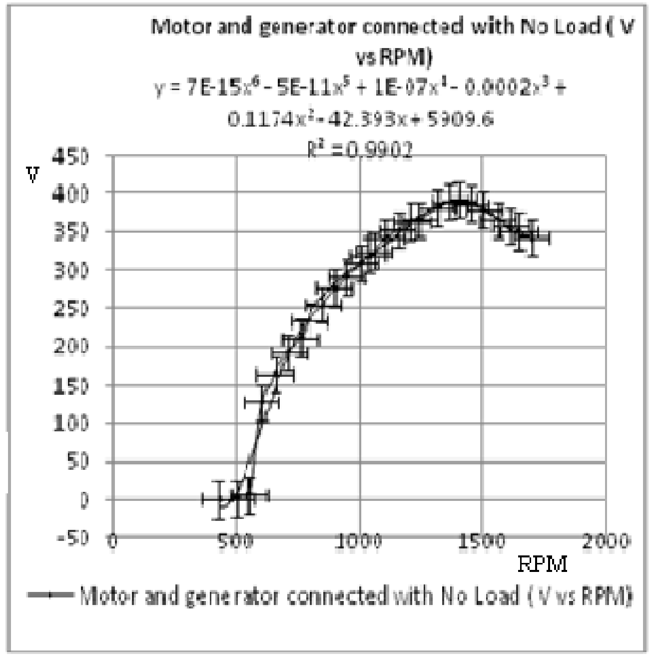

FIGURE 11: CHARACTERISTICS CURVE OF MOTOR AND GENERATOR CONNECTED WITH LOAD

In figure 12 graph shows the current of load and generator. As load current increases generator current also increases. The graph is non linear Graph shows that load current and generator current are directly proportional to each other.

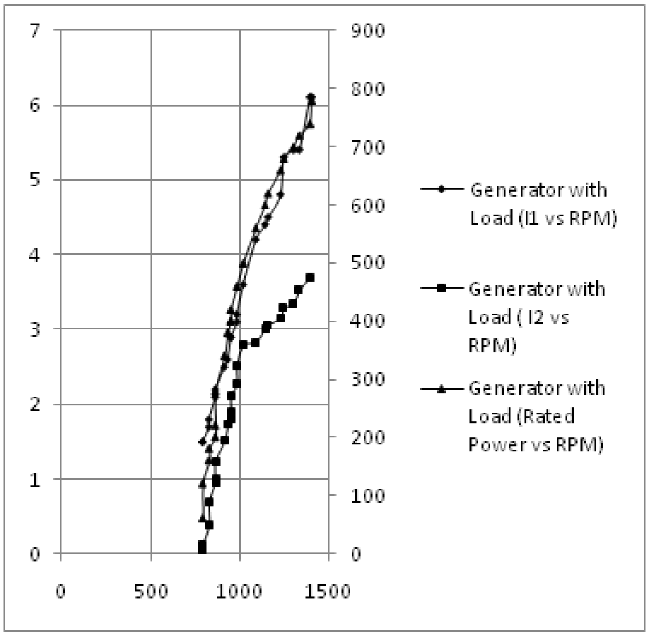

FIGURE 12: CHARACTERISTICS CURVE OF GENERATOR WITH LOAD

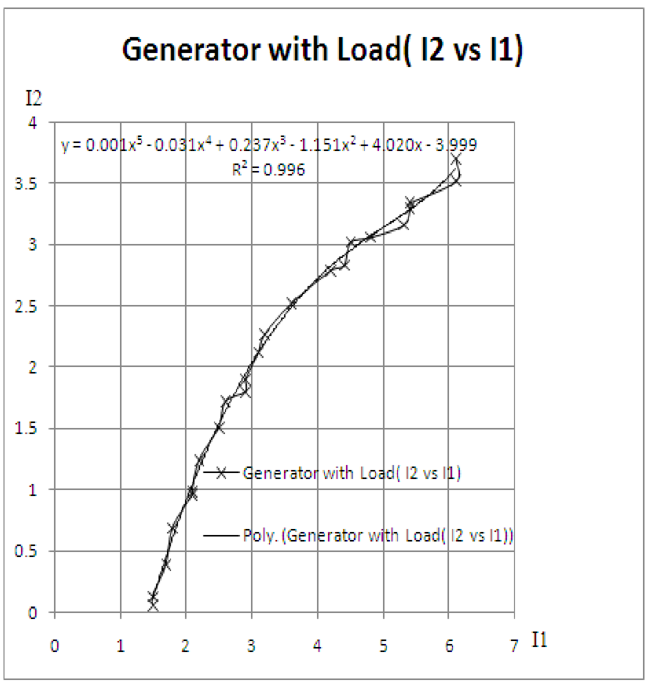

FIGURE 13: COMBINED RESPONSE OF GENERATOR WITH LOAD(I1 VS RPM), GENERATOR WITH LOAD (I2 VS RPM), GENERATOR WITH LOAD (RATED POWER VS RPM)

In figure 13 graph shows the overall characteristics curve of generator. The graph includes the behavior of load, current and power with respect to generator's rotations per minutes.

5. Result and Discussion

An attempt is made to design induction generator to achieve sine wave output however Asynchronous Generator gives pure ac voltages with sine waves but there still having a problem to maintain certain RPM for specific output and for that purpose frequency inverter should be used which should be programmed according to required conditions so that it can generator could match the desired the output. The rating of frequency inverter should be accordingly the rating of generator driven but it is one time cost. Another solution to achieve certain RPM of generator is the gear coupling automatic gears can be used to maintain desired RPM of generator at different speed of wind. The main advantage of this system includes high reliability because of its simple construction requiring neither commutators nor brushes, low price comparable to other machines and its low operating cost.However there are some disadvantages of such a system i.e the necessity of generator's coil excitation and problem connected with energy conversation at low speed even automatic geared system is also connected with the system. This problem can be eliminated by the use of AC/DC/AC converter. The controlled AC/DC/AC converter overcome this problem and makes it possible[13], for the reactive power, to flow from the grid to the generator for its excitations as well as send the active power from the generator to the grid. Asynchronous generator is comparatively efficient from Permanent Magnet DC Generator[14]. As in D.C Generator there is much losses as compare to asynchronous one.

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