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Induction Generator for Pico Hydro Generation

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Abstract- **Around 16% of the electrical energy supply generated in world is through hydro power. In rural high terrain areas with low population density the energy per capita is low compared to city needs. Grid supply to these areas is not economical. Micro - hydro and Pico - hydro are most appropriate for rural high terrain areas with water streams. The initial cost mainly involves construction and equipment cost. Pico hydro plant does not require construction of dam It is a run off river plant. Pumps as turbine provide huge relief in the equipment cost. Centrifugal pump which are readily available have advantage over custom made turbine s for micro and Pico hydro power generation. Induction generators are useful in applications such as mini, micro and Pico hydro power plants because e they can recover energy with relatively simple controls. The Selection of capacitors for induction generator used for standalone Pico hydro is also explained in this paper. Pico turbines can provide power for small clusters or even single households, Individual hydropower supply cuts out the efforts of organizing a community.**

1. INTRODUCTION

India's 1.25 billion population of which about 300 million live without electricity. More than 75 million households (45% of the total rural households) are yet to be electrified (Census of India, 2011). As per latest data, about 19,909 villages are yet to be electrified (Progress report of village electrification as on 31-01-2015 as per 2011). The Government has up-scaled the target of renewable energy capacity to 175 GW by the year 2022 which includes 100 GW from solar, 60 GW from wind, 10 GW from bio-power and 5 GW from small hydro-power. Pico, Mini, micro and small hydro power schemes can be installed in remote areas to fulfill their own electricity needs such that it reduces burden on the electricity boards.

Classification of hydro power plants:

TYPE	CAPACITY
Large-Hydro	More than 100 MW and usually feeding into a large electricity grid
Medium - Hydro	15 - 100 MW - usually feeding a grid
Small - Hydro	1 - 15 MW - usually feeding into a grid
Mini - Hydro	Above 100 kW, but below 1 MW; either standalone schemes or more often feeding into the grid.
Micro - Hydro	From 5kW up to 100kW;usually providing power for a small community or rural industry in remote areas away from grid
Pico - Hydro	From a few hundred watts up to 5kW

1. Pico-Hydro

Pico-hydropower plant generates powerless than 5kW.In remote areas Pico hydro systems can be used as standalone systems where grid connection is not economical. Pico-hydropower is easy to operate and maintain. Wind power plants have associated noise pollution and biomass based energy systems cause environmental pollution while, hydro-power plants does not cause any environmental pollution. Pico hydro power plants are useful for small industries, agriculture and to power home appliances in remote high terrain rural areas. These plants are run of river type and have low initial cost as construction of dam is not required.

2. Pump as Turbine (PAT)

Hydropower systems generate electrical energy by converting the energy of falling water to mechanical energy with a turbine and from mechanical to electrical energy by generators coupled to turbines. In case of remote rural and high terrain areas it is more appropriate to use a pump coupled with induction motor as custom made turbines are expensive.

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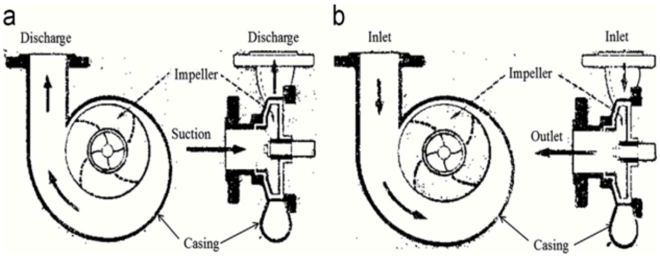

Fig (a): as a pump **fig (b): as a turbine**

The pump is used only to pump the water from low level to high level. Whereas, pump as turbine (PAT) pumps flowing water to its discharge end and supplies it to penstock and induction motor. Here induction motor is converted into generator in order to increase efficiency of power plant.

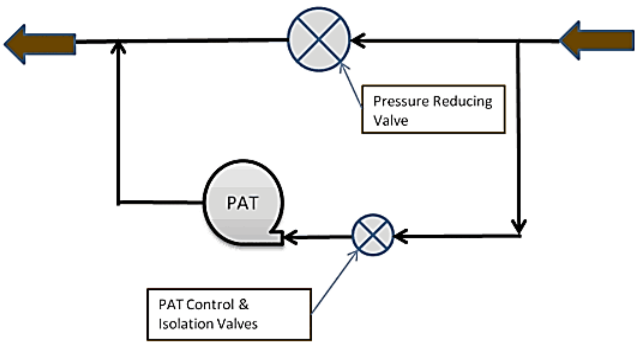

Fig (c): block diagram of pump as turbine

2.1. The main advantages of PAT are as follows

O Centrifugal pumps are readily available for a wide range of heads and flows in a large

o number of standard sizes, their spare parts are easily available.

o They are easy to install being a mono block unit requiring less space and use standard pipe fittings.

o Direct drive arrangement between pumps and motor have low friction which provides 5% savings in output power.

o They are simpler constructions with fewer bearings with longer bearing life requiring less maintenance and are available at lower cost.

2.2. Limitations of Pico - hydro and PAT

Pico-hydro requires suitable run of water site with suitable topography (Jafar, 2000). Pico - hydro requires transportation of equipment to remote rural high terrain areas. It requires technical expertise and funding for setup. Manufactures provide the characteristic curves of their pumps for pump mode operation but they do not provide the same for reverse mode operation of the pump. This is the major limitation in using a pump as a turbine as it is difficult to predict pump behavior and performance .Pump operates in turbine mode with higher

head and discharge at the same rotational speed.

3. Induction Motor as Generator in Pico- hydro

Induction motors with prime movers are used in hydro power plant for generation of electricity. In normal motor operation, the stator flux rotation is faster than the rotor rotation. This causes the stator flux to induce rotor currents, which create a rotor flux with magnetic polarity opposite to stator. In this way, the rotor is dragged along behind stator flux, with the currents in the rotor induced at the slip frequency. In generator operation, a prime mover (turbine or engine) drives the rotor above the synchronous speed (negative slip). The stator flux still induces currents in the rotor, but since the opposing rotor flux is now cutting the stator coils, an active current is produced in stator coils and the motor now operates as a generator, sending power back to the electrical grid. An induction machine requires externally supplied armature current; it cannot start on its own as a generator. A source of excitation current for magnetizing flux (reactive power) for the stator is still required, to induce rotor current. This can be supplied from the electrical grid or, once it starts producing power, from the generator itself. Active power delivered to the line is proportional to slip above the synchronous speed.

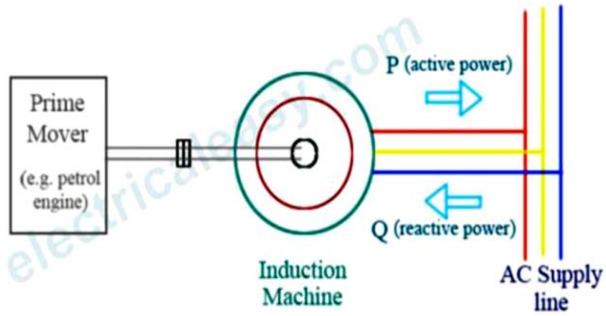

Fig 3. Induction Motor or Generator taking Reactive Power from Grid (Source: electricaleasy.com)

3.1. Principle of operation of IG

An induction generator or asynchronous generator is a type of alternating current (AC) electrical generator that uses the principles of induction motors to produce power. Induction generators operate by mechanically turning their rotors faster than synchronous speed. An induction generator produces electrical power when its rotor is turned faster than the synchronous speed. An induction generator usually draws its excitation power from an electrical grid or self-excited by using phase-correcting capacitors. A capacitor bank must be used to supply reactive power to the motor when used in stand-alone mode. The reactive power supplied should be equal or greater than the reactive power that the machine normally draws when operating as a motor. Terminal voltage will increase with capacitance, but is limited by iron saturation

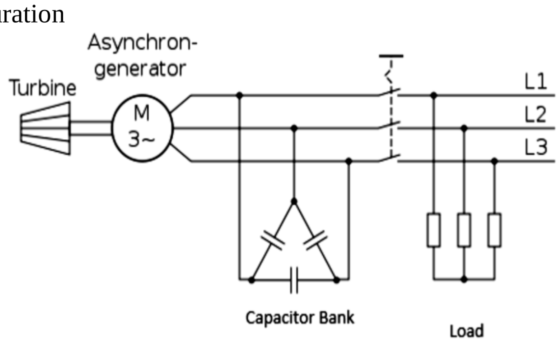

Fig 4. Capacitor bank connected to IG

5.2. Difference between synchronous generator and induction generator

1. In a synchronous generator, the waveform of generated voltage is synchronized with (directly corresponds to) the rotor speed. The frequency of output can be given as f = N * P / 120 Hz. where N is speed of the rotor in rpm and P is number of poles. In case of inductions generators, the output voltage frequency is regulated by the power system to which the induction generator is connected. If induction generator is supplying a standalone load, the output frequency will be slightly lower (by 2 or 3%) that is calculated from the formula f = N * P / 120.
2. Separate DC excitation system is required in an alternator (synchronous generator). Induction generator takes reactive power from the power system for field excitation. If an induction generator is meant to supply a standalone load, a capacitor bank needs to be connected to supply reactive power.
3. Construction of induction generator is less complicated as it does not require brushes and slip ring arrangement. Brushes are required in synchronous generator to supply DC voltage to the rotor for excitation.

5.3. Calculation of Capacitance for IG

The torque produced by three phase induction motor depends upon, magnitude of rotor current, flux which interact with the rotor of three phase induction motor and is responsible for producing emf in the rotor part of induction motor, and the power factor of rotor of the three phase induction motor. Combining all these factors together we get the equation of torque as-

$$T \propto \phi I_2 \cos\theta_2$$

Where, T is the torque produced by induction motor,
Φ is flux responsible of producing induced emf, I2 is rotor current,
Cosθ2 is the power factor of rotor circuit.
The flux Φ produced by the stator is proportional to stator emf E1.
i.e. Φ∝ E1

II. CONCLUSION

1) In rural high terrain areas especially among the developing countries which suffer from energy problems supply of electricity through grid is not economically feasible. Growth of these areas cannot be ignored for holistic growth of a country. Pico hydro seems to be most appropriate alternative. Among renewable energy technologies. Pico hydro is the cheapest to install as standalone power generation system for these areas where water streams are available.

2) Power generated can be used for lighting, communication and small scale agricultural activities.RE technology can only be meaningful for such areas if they are low cost, simple and easy to maintain and operate. PAT offers a solution to these concerns.

3) The key advantage of using PAT in Pico - hydro systems is major savings in equipment cost as compared to using custom made turbines for a particular site.

4) There has been considerable work done by many researchers in PAT development. The review of these works suggests that CFD is an important tool in understanding of pumps behavior in turbine mode.

5) Approach for improving the efficiency of PAT should be focused on areas in pump which result in low cost implementation and that such modified components are readily available and their replacement is easier.

6) The end suction radial discharge centrifugal pump is more readily available, cheaper easy to install and maintain. These pumps are available with different impeller material such as brass, bronze, cast iron, stainless steel, aluminum, plastic etc. The future work will be on selection of impeller material and impeller modification focusing on reducing internal losses and providing a cheaper and easy to replace concept.

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