Review of Research on Pico Hydro Generation

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***Abstract*-This paper presents a review of research work on pico hydro generation. Use of induction motors as self excited induction generators (SEIG) is well known . Slip ring induction motors are being used in wind mills for generation of electrical power, but Squirrel cage induction motors offer more advantage over slip ring induction motors as they are simple in construction, cheap, available in various ratings and almost maintenance free. They offer a good alternative for costly conventional alternators.**

Generating units with capacity less than 5 KW are called as pico generating units. Research is in progress to develop such small power generating units to supply electrical power to remotely located consumers with low loads.

The authors are working on development of a pico hydro unit with low water head and using self excited induction generator. The main aim of this paper is to focus on the current status of research work going on in this field.

***Index Terms*- Self-excited induction generator (SEIG), Pico hydro generation**

I. INTRODUCTION

Since last couple of decades, whole world has realized the importance of renewable energy sources due to the rapid depletion of fossil fuels and increasing demand of electric power due to massive growth in industrial sector. Research is in progress to tap alternative energy sources like solar, wind, hydro and tidal energy and to improve the efficiency of conversion. Hydro power units are well developed and they exist in very large capacity all over the world. But still thermal power plants dominate the power generation field. The potential of hydro power is not yet exploited to its fullest capacity. Waterfalls at many places can be utilized for generating small amount of electricity. Population situated in remote areas, with low consumption potential is deprived of electrical power because of high transmission costs and low revenue. Small generating plants can provide sufficient electrical power to them at low cost.

Squirrel cage induction motors can operate as induction generators if capacitors of proper rating are connected to their terminals. They provide cheaper alternative for generating small amount of electrical power. The major hurdle in using a squirrel cage induction motor instead of a conventional alternator is that the terminal voltage of self-excited induction generator (SEIG) drops with increase in load and the frequency also varies with variations in the load. Several types of controllers are designed to overcome this drawback. A review of current research in this field is presented in this paper.

II. SELF EXCITED INDUCTION GENERATOR

Mathematical analysis to estimate the proper value of terminal capacitors for operating an induction motor as a self - excited induction generator is given in [1]-[4]. For a given load, there is a maximum and a minimum value of excitation capacitor which can excite the generator. Any value of capacitor between these two extreme values can be used for excitation, but for higher value of terminal capacitor, the cost of capacitor, the charging current increases and the frequency of terminal voltage decreases hence lower value of capacitor is preferred because it helps in maintaining supply frequency close to the base value. The maximum load for which self - excitation can occur depends on the magnetizing reactance of the generator. Sudden load variations cause fluctuations in the terminal voltage and frequency. The main advantage of induction generator is that it is self protected against overloads. The generation automatically stops when it is overloaded and the generation can be resumed by removing the load.

Steady state analysis of a self excited induction generator is carried out with the help of equivalent circuit. M.H. Haque presented steady state analysis by using mesh equations for the equivalent circuit. The load used in the analysis consists of active and reactive part and equations are developed by separately equating active and reactive parts of the circuit to zero [5].

T.F. Chan presented an iterative method for steady state analysis by using nodal analysis to estimate the magnetizing reactance of the generator. It involves fewer calculations and is accurate [6].

S.S. Murthy et al presented a technique of steady state analysis using graphical user interface feature from MATLAB software. A simple resistive load was considered for analysis. Effect of speed, terminal capacitance and magnetizing reactance on the terminal voltage are discussed. This method is fast and gives fairly accurate results [7], [8].

When the load on the SEIG is not constant or the variations are fast, dynamic analysis is essential. D. Seyoum et al presented a method of dynamic analysis of SEIG. A d-q axis model is used for the purpose of analysis. It is used to estimate the maximum and minimum speed for a given value of terminal capacitor and load. This analysis is helpful when the prime mover speed is not constant [9].

M. L. Elhafyani et al presented a method of dynamic analysis of variations in the terminal voltage with variation in the load resistance, speed and terminal capacitance by using MATLAB. In this method a d-q axis model of induction generator is used [10].

Burac Ozpineci and Leon M. Tolbert presented analysis of an induction machine by using modules of MATLAB. The model is general and can be used for analysis when the machine is operating as a motor or as a generator. Each module is explained in detail so that clarity in understanding is more and anyone can use the modules for further research and study [11].

III. CONTROLLERS FOR SEIG

It is evident from the analysis that terminal voltage and frequency control is essential for stable and reliable operation of SEIG. Eduardo Sukez and Gustavo Bortolotto suggested a method in which the induction generator is operated in the linear region of the magnetization curve. External capacitors with fixed value are connected permanently and inductances are switched by electronic circuit. The circuit simulation results by considering initial conditions are presented but it is not verified practically [12].

Bhim Singh et al presented a design and analysis of an electronic load controller. The method involves a dump load which is permanently connected to the generator terminals and it can be controlled by electronic switches. The generator operates at rated load and the terminal capacitor is fixed for rated load. When consumer demands electric power by connecting load, the dump load is reduced proportionately and the total load on the generator is maintained constant. This method is simple, cheap and easy to maintain. It requires a constant input to the prime mover and a constant power will be consumed irrespective of consumer demand [13].

Bhim Singh and Gaurav Kumar Kasal presented simulation results of a voltage and frequency controller using current controlled voltage source converter. In this method, the generator voltage and load current are sensed to develop a signal which controls a high speed chopper. The chopper is used to control dump load. The advantage of this method is that it can work even for unbalanced loads [14].

Bhim Singh et al presented simulation results of a decoupled electronic load controller which controls dump load to maintain terminal voltage constant [15].

S.S. Murthy and Rajesh Kr. Ahuja presented a method in which the generator output is rectified by a three phase rectifier and fed to a voltage source inverter. A d.c.-d.c. boost converter is used to maintain a constant d.c. link voltage and consumer load is connected across the voltage source inverter. Only simulation results are presented [16].

Mustafa A. A1-Saffar et al presented a scheme of controlling the excitation capacitor current which is equivalent to controlling terminal capacitor itself. In this method, terminal voltage and load current are sensed and signal is developed by comparing with reference value. This signal is used to control the capacitor current by using high speed electronic switching devices. This method requires less components and is economical simulation and experimental results are presented [17].

IV. PICO GENERATION

Electrical power generation up to 5KW is called as pico generation. Normally such small generating plants use low head hydro power or wind power. Many times it is not possible to transmit small amount of electrical power over longer distances where population density is very low. For such consumers, it is economical to generate electrical power near their place of residence by employing wind, hydro or solar power. Such units are cheap and easy to maintain. One more advantage is that they can be afforded by public.

Sombat Chuenchooklin presented his study on a prototype pico hydro power plant where the water head was 10 meters and the water flow was 15 liters per second. A three phase induction motor and turbine was used as the main components. The electrical power generated was 640 watts at a terminal voltage of 280 volts and frequency 50 hertz. There was a drop of 50 volts and 5 hertz in the voltage and frequency respectively when the generator was loaded [18].

H. Zainuddin et al presented their study on pico hydro generation by using water distributed to houses. In this paper they proposed to use a home made turbine of poly vinyl chloride pipe, a permanent magnet d.c. generator. The estimated power output of the unit is 10W and they proposed to use it for battery charging [19]. D.A. Howey presented a different type of generator construction using axial flux instead of the conventional radial flux type. He stated that iron is not required in stator and the machine produces flux axially by means of permanent magnets. The expected power output from the machine is 500 watts. The technology is still under testing for small power output of less than 1 KW [20]. Kharisma S. Gautama et al presented a paper on their work for distributed power generation in Indonesia by using solar and hydro power. The paper lacks in technical details about pico hydro generation and the control technology adopted. It is mentioned that a 5.5 KW motor is used and the water head available is 10 meters. The power generation from the hydro and solar units was around 1 KW [21]. Ahmed M.A. Haidar et al presented their work on pico hydro generation and simulated a scheme by using MATLAB software. A high speed turbine using pelton wheel was employed. The speed was 1000 rpm at 1000lit/min discharge. They used the generated supply to charge batteries of 12 V, 60 AH and again converted the d.c. supply to 220V, 50 Hz a.c. supply by using 1 KW inverter. The alternator used was of 14 V, 75 A. The load connected was around 35 watts [22]. Wim Jonker-Klunne presented his study on the present status of hydro power in southern Africa. He has given a comparison of developments in other countries in the field of hydro power and the potential available in southern Africa. He has given more emphasis on villages in Africa where still electricity is not available but it can be provided by installing micro hydro power plants [23]. Arthur Williams and Stephen Porter presented a study of environmental, social and economical effects of large, small and pico hydro power plants in developing countries. They have mentioned that very large power plants adversely affect the wild life in the region, the community located nearby and ecology of that area. It is seen that population which is directly affected due to such huge projects always criticize and object for construction of such power plants. Instead of constructing large power plants, they suggest small power plants or run off river plants, and isolated mini power plants require small expenditure and they can cater the need of local population[24]. Williams A.A, and Simpson R. emphasized the construction of pico hydro power plants using indigenous equipment available at low cost. They stressed the need of further research on pico hydro generation. They also presented a study on locally manufacture turbine which is used for pico hydro generation in Kenya [25].

V. CONCLUSION AND DISCUSSION

Large hydro power plants are in operation in many countries and the technology is well developed. Very small power plants below 5 KW. known as pico hydro power plants are in operation in very few countries and they have huge potential all over the world. Conventional pico hydro power plants employ small alternators and turbines where sufficient water head and flow is available. These generating plants are environment friendly, easy to operate and they provide electrical power to remotely situated population. Recently self excited induction generators have offered a good alternative to the conventional alternators. Main problem of SEIGs is fluctuations in the terminal voltage and frequency under varying loads. Several schemes are proposed by researchers and some of them are tried practically with encouraging results.

India has great potential for pico hydro generation. In Maharashtra state of India, several waterfalls and low head water flows are available and this potential can be exploited further. Authors have developed such a unit where a water wheel is used as a prime mover and developed 500 watts electrical power. Such small units will definitely reduce the stress on the existing power system and help in preserving the fossil fule for the next generation.

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