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Controller Design of a Stand Alone Micro Hydro Power Plant with Energy Storage Abilities for Sustainable Energy Development of Bangladesh

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Abstract*- Hydropower is an eco-friendly, pollution free, clean power generation system. Bangladesh is mainly a plain land, so the scope of hydro power generation is limited. It covers only 4 % of the national electricity needs of this country. Besides there is a big potential for micro-hydro power generation especially in the northeast and southeast parts of the country. Nowadays micro hydropower plants are emerging as a major renewable energy resource as they do not encounter the problems of population displacement and environmental problems associated with the large hydro power plants. To maintain constant power supply to the consumer, micro-hydro power generation system has to be controlled, since there are variations in input flows. This paper implements an electric load controller with Battery energy storage system to control a micro-hydro power plant especially those plants which are operated in isolated mode. In addition this controller is interfaced with PC and MATLAB data acquisition tool box is used to collect data for whole day/week/month/year and store this data to the computer. Also this scheme can take necessary attempts in case of load failure or system instability.*

Keywords: Micro-hydro, Induction motor, Electronic load controller, Ballast load, Energy storage device

1. INTRODUCTION

There is a growing awareness of the severe environmental and ecosystem impacts associated with the use of fossil fuels, nuclear power, and large hydro systems. These impacts include land, water, and air pollution, widespread habitat destruction, as well as increasing evidence of links between fossil fuel use and climate change due to global warming. Climate change is recognized as one of the greatest challenges that Bangladesh is facing. Electric energy plays an important role in accelerating economic growth of a country. Bangladesh is a developing country. To enhance its development sustainable and reliable electric energy production is necessary. Presently this country faces severe electric power capacity crisis with power demand shooting up to 6000 MW since early August, 2010 against a generation capacity of 4600 MW [1]. Almost 89.22 % of this generated power primarily depends on natural gas, whose reserve is limited (5 TCF) [2] and assumed to be exhausted within limited times. Further, over 57% of its population still lives with no electricity, and the rate of grid expansion to connect rural villages is threatened by the looming capacity shortage.

The present electric energy crisis has given a chance to the exploitation of renewable energy sources. In Bangladesh there is a big potential for micro hydro power generation especially in the northeast and southeast parts of the country [3-4]. There are lots of canals, tributaries of main river as well as tiny waterfalls having potentials for setting up mini/micro hydropower unit in those region. Micro hydro plants are emerging as major renewable energy resources today as they do not encounter the problems of population displacement and environmental problems associated with the large hydro power plants [5-12]. Micro hydro has an output of less than 100kW. They are usually installed to supply electricity to small communities in remote areas where the grid fails to reach. Self excited induction generator is used rather than synchronous generator because of its simple construction and inherent robustness [7-14]. But this advantage is offset due to the complexity of the voltage and frequency control technique [14]. This paper presents an efficient and reliable software based electronic load controller for proper operation of micro-hydro schemes.

The organization of this paper is as follows: Section 2; gives description and formulation of induction generator operation for the micro hydro plant. Section 3; describe the operation of the designed controller. In section 4; conclusions are drawn.

2. PRINCIPLES OF POWER GENERATION

In this project self excited induction motor is used as generator, because of its simple construction and inherent robustness and wide availability in markets and generally cheaper than synchronous generators including their excitation capacitors. When an induction machine is connected to an ac supply, magnetizing current flows from the supply and creates a rotating magnetic field in the machine. The rotating field cuts the short circuited rotor bars, inducing currents in them which, because they are flowing in the magnetic field, react with it producing a torque. This torque drags the rotor round with the field, but at a slightly lower speed. The small difference in speed arises because without it no currents would be induced in the rotor and therefore, no torque would be produced to turn it. When a load is applied to the motor the speed difference will increase as a greater torque must be produced. The magnetizing current of an induction machine can be supplied in total or in part, by capacitors to reduce the reactive current drawn from the supply. Therefore in order to obtain the required operating voltage at the desired frequency the amount of capacitance must be carefully chosen. A 3-phase generator can be converted into a single- phase generator which produces approximately 80% of machine rating by connecting 2 capacitors as shown in Fig. 1.

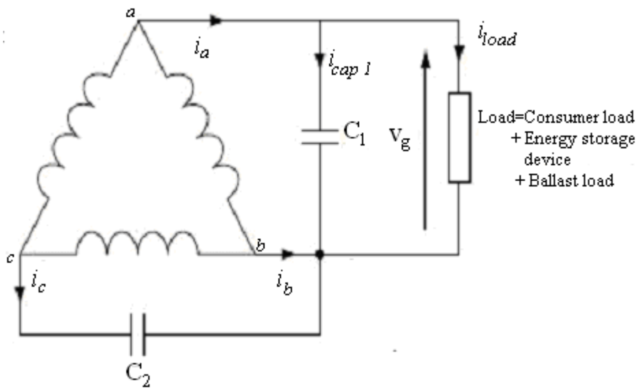

Fig. 1: Single-phase output from a 3-phase Induction Generator

In order to analyze the circuit of Fig. 1, assume that the load connected which is the consumer load plus the energy storage device (Battery bank) and ballast load, is a constant and is resistive [8].

$$i_a = i_{load} + i_{cap1} \tag{1}$$

$$i_b = -(i_a + i_c) \tag{2}$$

Using equations (1) and (2) and assuming that the machine is operating as a balanced three-phase machine, the phasor diagram can be constructed as shown in Fig. 2. As capacitor C_2 is connected across phase's *b* and *c*, i_c is perpendicular to the voltage vector V_{bc}. In order to obtain balanced operation the following two conditions should be satisfied:

$$\theta = 60^0 \quad and\, |i_c| = |i_a| \tag{3}$$

The conditions for balanced operation can be expressed in terms of the currents as in equations 4 and 5.

$$|i_c| = 2 * |i_{cap1}| \tag{4}$$

$$|i_{load}| = \sqrt{3}|i_{cap1}| \tag{5}$$

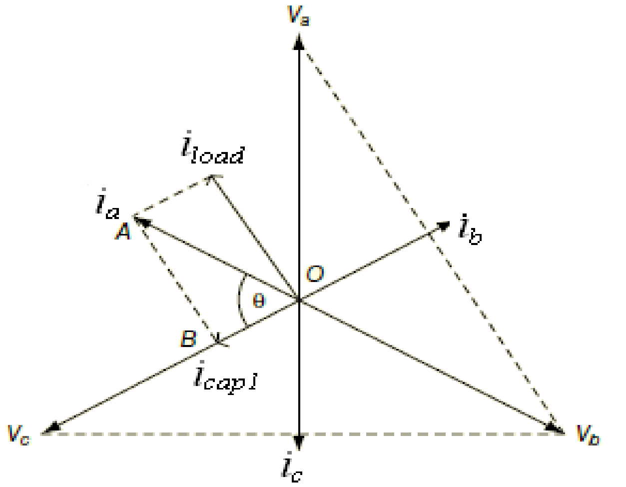

Fig. 2: Phasor diagram for the 1-phase connection

That is, in order to obtain balanced operation of the 3-phase motor, capacitor C_1 should be selected such that equation 5 is true, and also from equation 4 capacitor C_2 should be equal to $2C_1$. When an induction generator is used in this way, particular care must be taken over the connection of the capacitor C_2. If capacitor C_2 is connected between phases *a and c* instead of *c* and *b* then the generator will run as an unbalanced system. It can be seen that the current through one of the windings of the induction generator becomes twice that of the other winding currents. Under this condition, the generator winding will overheat. Therefore, correct connection of the capacitor C2 is important.

3. DESIGN OF ELECTRIC LOAD CONTROLLER

In typical induction generator based small hydro schemes, the turbines used are run off river type, where the water input and thus the mechanical power into the generator cannot be controlled. In these schemes if the consumer loads changes, then the generated voltage and the frequency also vary. When the load on the generator is increased, the voltage will drop immediately by an amount determined by the characteristics of the generator. The increased load on the turbine will cause the turbine speed to drop, resulting in a corresponding reduction in operating frequency. The drop in frequency causes a further drop in voltage, due to reduced excitation. Conversely, if the load on the generator is reduced the generated voltage will rise and the turbine speed will increase. When the entire load on the generator is disconnected the voltage and turbine speed will increase until the losses in the generator equal the power output from the turbine. The electric load controller is used to maintain the generated voltage and frequency at rated value and also maintains the total load connected to the machine almost constant by Charging Battery bank and ballast load (resistive load). Since the terminal voltage under this condition is constant, voltage sensing is used to control the total load on generator at near constant. So it is very important to sense correct generated voltage of the generator at every instant and according to this data, proper decision for load management could be make. In the case of voltage rise i.e. low load demand, at this instant to keep constant load demand on generator, extra energy will be diverted to energy storage device (charging battery bank) and this battery could be used to drive UPS and electric vehicle. When all the batteries of the battery bank are full charged and then drain the extra energy through ballast load. This will ensure consumer loads security against over voltage. In the case of low voltage i.e. heavy load demand, at this moment to maintain normal terminal voltage some consumer load disconnected for keeping the micro-hydro generation system stable. Load shade is maintained by defining priority of consumer.

3.1 Design of Analog Data Conditioning Circuit.

The generated ac voltage from induction generator is converted to dc voltage suitable for ADC chip. This task is performed by using circuit shown in fig.3. Here generated voltage from induction generator is step down 220volt to 12 volt by a single phase transformer. Further this step downed voltage is rectified to DC with bridge rectifier, and then DC voltage is filtered with capacitor.

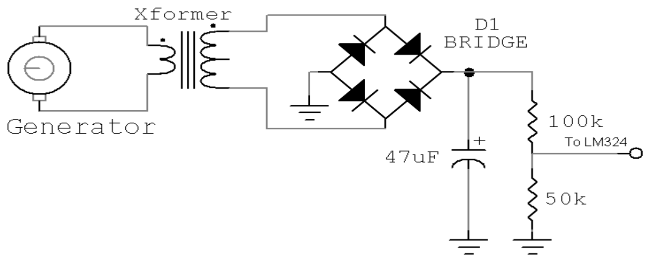

Fig. 3: Schematic diagram of signal conditioning setup.

Table 1: Collected data for characterization of Transformer

No. Obs.	Input to ADC (dc)	Generated Voltage (ac)	No. Obs.	Input to ADC (dc	Generated Voltage (ac)
1	0.03	1.732	15	1.775	131
2	0.07	1.78	16	1.941	140
3	0.059	10.56	17	2.111	150
4	0.103	20.5	18	2.262	160
5	0.228	30	19	2.433	170.6
6	0.357	40.7	20	2.597	180.8
7	0.523	50.4	21	2.75	190.8
8	0.685	61	22	2.903	200.7
9	0.845	70.5	23	3.065	210
10	1.019	81.7	24	3.228	221.5
11	1.175	91.5	25	3.368	230.8
12	1.345	102.1	26	3.511	240
13	1.497	11.5	27	3.667	250.9
14	1.65	121			

Smoothing capacitor value plays an important in the design process if this value is large, then the analog input to the ADC is delayed for a while, so the processor gets wrong digital data from ADC and makes wrong decision.

Voltage divider is used to get suitable input voltage range for ADC. With this above combination data are collected with 47µF capacitor to characterize the signal transformer and a curve fitting equation was made. Here parallel port is used as an interface media, which interfaces between PC and ADC-0832 chip. For enabling and other operation of ADC chip signals are sending to the chip from PC through Parallel Port using MATLAB program and this program is developed by using data from table-1. Again, this program is used to read converted data from ADC chip.

3.2 Decision Making

Here the generated voltage of micro-hydro plant is used as a control parameter. So at every instant it measured the generated voltage and make decision accordingly. This program is written MATLAB and practically tested in Chittagong University of Engineering and Technology (CUET) Machine LAB. The flow chart of the program is shown in figure 4. The Schematic diagram of the controller circuit and the experimental setup of this project is shown respectively in figures 5 and 6. Here 220V is referred as nominal reference voltage, when the generated voltage is over 250 volt then it switched on ballast one after another and measured the generated voltage respectively. Ballast load is made with gradual combination of resistor. The values of these fixed resistors are binary weighted so as to achieve the maximum numbers of load steps with the minimum number of resistors and switches. The main advantages of this approach are that waveform distortion is not produced since the Ballast load is resistive. When the voltage is greater than 220 volt then it stored the extra energy to battery bank. When generated voltage is less than 180 volt then it switched off the battery bank and ballast load accordingly.

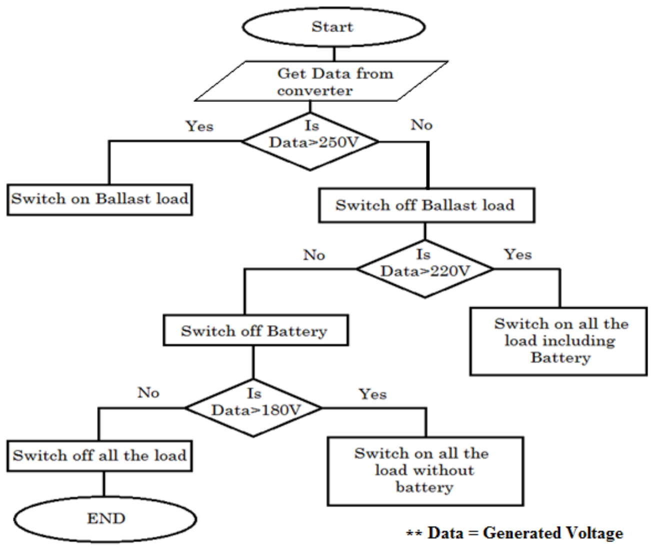

Fig. 4: Flow chart for MATLAB program.

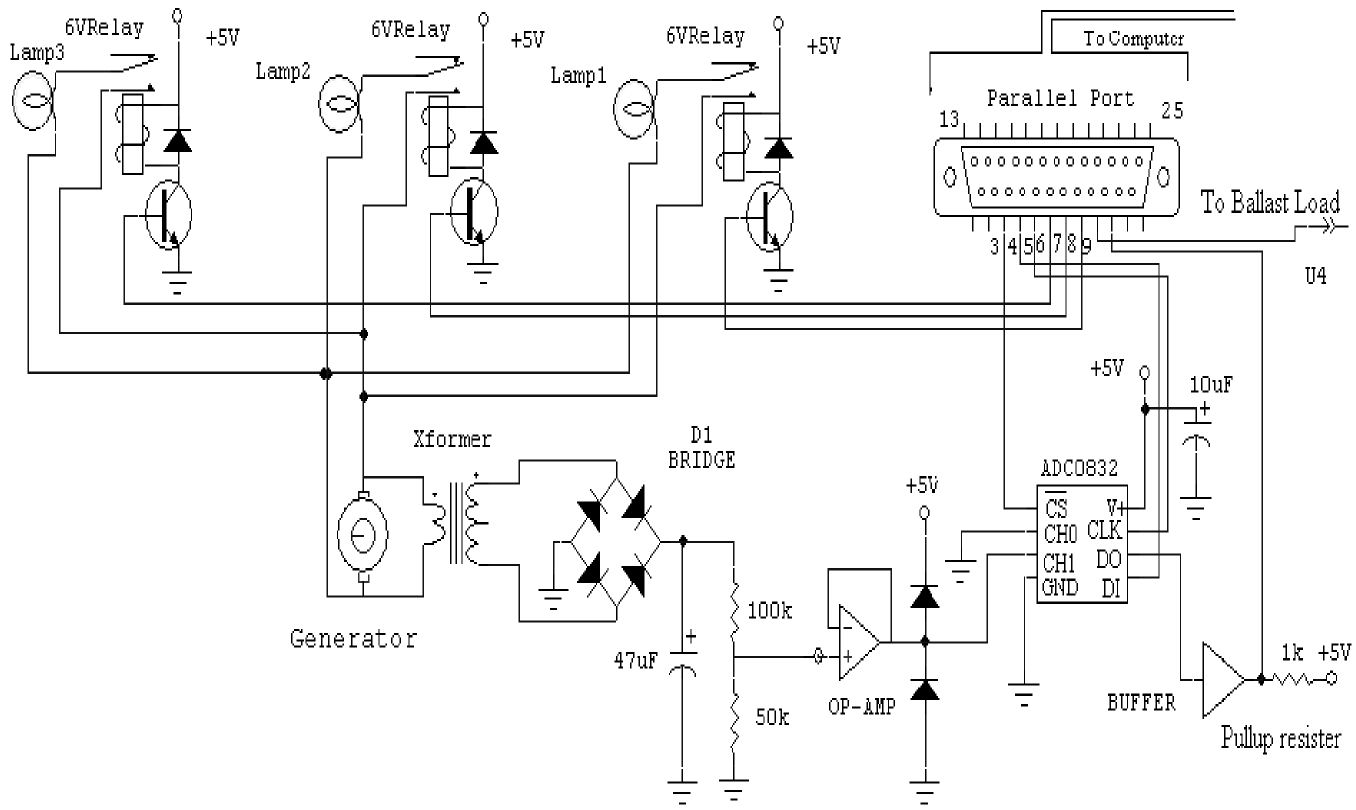

Fig. 5: Schematic diagram of the controller circuit

Fig. 6: Full setup while testing in LAB.

4. Conclusion

This paper describes software based simple electronic load controller for micro-hydro schemes which are suitable for those plant whose are operated in standalone mode. Since the load on the generator are maintained according to its generated voltage so this scheme can take necessary attempts in case of load failure or system instability. MATLAB data acquisition tool box is used to collect data for whole day/week/month/year and store this data to the computer.

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