DESIGN OF THE ELECTRONIC LOAD CONTROLLER USING MICRO CONTROLLER BASED ZERO CROSSING DETECTOR FOR PICO-HYDRO POWER PLANT

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ABSTRACT

Small hydro power plant project (SHPP) a significant role in renewable energy sector in several countries, Especially Indonesia, among different categories, community based and estate based hydro projects use electric load control technology since it can be locally manufactured, easily to installation and the low cost. For example; constant voltage and frequency in Self-Excited Induction Generator (SEIG). In this method, the principle of phase angle control of back to back thyristor is used. A thyristor is fired at a specific delay angle relative to the zero voltage crossing of the sine wave. A thyristor commutates at zero crossing, will be occurs a twice the frequency and generates total harmonic distortion about of 40% in current with added reactive power burden. This scheme can continuously vary the dump power over nearly the entire range from zero to full load as the delay angle varies from 0 to 180 degree.

KEYWORDS

Pico hydro power, Induction of generator controller (IGC), Electronic load controller (ELC), Zero Crossing Detector.

1. INTRODUCTION

Small Hydro Power Plant (SHPP) a significant role in renewable energy sector in several country especially for remote area. Among different categories, community based and estate based hydro projects use electric load control technology since it can be locally manufactured, easily adopted in to existing hydro plants and the low cost. Micro Hydro Power Plant (MHP) is a small scale power generator water as a driving force such as irrigation channels, rivers or natural waterfalls by way of utilizing high waterfall (head) and the amount of water discharge. Technically, micro hydro has three main components namely water at a certain height (as an energy source potential), turbines and generators. Microhydro gets energy from the flow of water that has a height difference certain.

Micro hydro uses potential energy water fall (head). The higher the water fall, the greater the potential energy and great electrical energy can also be obtained. In addition to geographical factors (river layout), water fall height can also be obtained with stem the flow of water, so the surface water is high. The water that is flowed through the pipes is sent to power house (power house) in general built near the river bank to drive turbine which later the turbine will move generators and produce electricity [1] Potential energy from water that falls in a pipe will turning the water turbine and the energy turns into mechanical energy. The turbine that rotates is coupled

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with generator, so the turbine's mechanical energy will raises mechanical energy in the generator rotor and transformed into electrical energy [2]

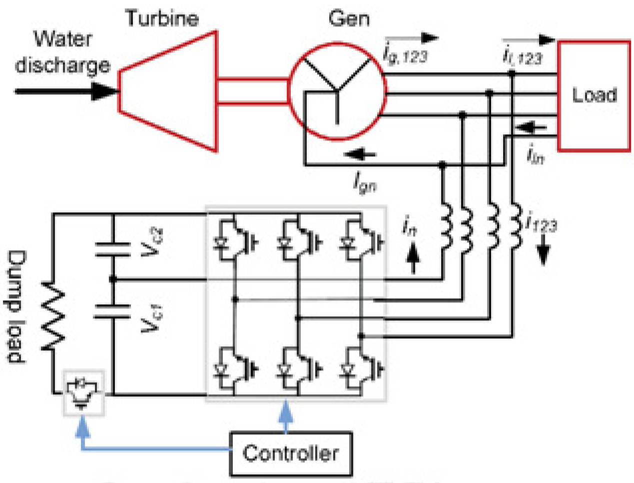

Figure 1. Lay out of SMHP with ELC system

2. LITERATURE STUDY

Voltage control system on micro hydro used in MHP is a Electronic Load Controller (ELC). The main part of this control system consists of control panel and ballast load where is the principle the arrangement is balancing between the power generated by a generator with a load (power) consumer. Due to the variation of load, there are some issues related to pico hydro power plants. Due to these variations, the speed of the generator can be adjust using the frequency variable of the electricity is changing. In case for system that isolated, for example in power system generation units with a power rating less than 20kW using of elf-excited induction generator (SEIG) driven by a constant speed uncontrolled turbine are most favorite [1-3]. While, by compare with the wound-rotor synchronous generators (WRSG), the SEIG offers several advantages such as: reduced unit cost per generated kilowatt, ruggedness, absence of a DC-source for excitation, absence of brushes and simplicity of maintenance [4].

Recently, many paper propose of voltage control and frequency control have been more attention given to the SEIG [5-8]. Therefore, significant research has conducted regarding these variations and several different methods have been proposed for voltage control and frequency control [10-12]. The Voltage and frequency control for a SEIG in remote area can be achieved by constancy of load power [13]. For this reason the generator output power should be maintained constant (or near constant) even if there are instantaneous variations experienced in consumer loads. In this case, a shunt resistive dump load can be utilized at the generator site to keep the SEIG output power constant. Electronic Load Controllers (ELCs) employ power electronics to adjust power in the dump load. Several different methods of voltage regulation based on the ELC approach have been proposed, phase angle control, binary weighted switch resistors, and a variable mark-space ratio chopping method [14]. The phase angle control approach can be challenging for the SEIG due to a variable lagging power factor. Despite producing unity power factor, the complexity associated with wiring of the switching devices, discrete control of the output power, and cost of the required resistive loads are the main bottlenecks of the binary weighted switch method. On the other hand, the variable mark-space ratio method, proposed in [14], has been used in one form or another by several researchers. For instance, in the impedance controller approach [15,16], voltage regulation can be achieved using an uncontrolled rectifier and a chopper switch connected to the dump load.

An improved ELC method has been proposed [17], replacing the uncontrolled rectifier with a 2-level IGBT based converter to achieve voltage regulation for both balanced and unbalanced loads. In [18], conduct of model simulation with grid connection of DC linked hybrid system. The objective of this study is to develop a new Zero Crossing Detector (ZCD) topology. This topology can be split into two parts. The first part is a regular ZCD of low rated power, which should be installed at the generator site and it is responsible for precise voltage regulation. It is worth noting that, the voltage variation sources in this study arise from fluctuation in consumer loads and variation in hydro system mechanical output power. The second part of this proposed approach is a simplified and inexpensive ELC which should be installed at each household to direct the excess power to a low wattage household apparatus, beside its main task, participation in voltage and frequency regulation. In [19] a topology of micro-hydro power plant using electronic load controller (ELC) have presented. Finally, for this paper is organized as follows. A brief explanation of literature study in Section 2. The proposed of ELC and the ZCD topology, their related mathematical calculations are provided in Section 3. Data and results are presented in Section 4. Section 5 provides conclusions for the paper.

3. ZERO CROSSING DETECTOR PROPOSE

As noted above, electricity meters are rarely used in remote areas and so consumers are charged a monthly fee based on the power limit for a given household. In a conventional ELC system power may be wasted in a dump load at the generator site. This problem can be solved by installation of a separate ELC for each household, i.e. the Zero Crossing Detector (ZCD) concept. With the help of the ZCD in each household, the excess power at each household can be utilized for domestic hot water possibly leading to health related benefits. This excess power can be directed to a low wattage apparatus such as space heating device or water heating system.

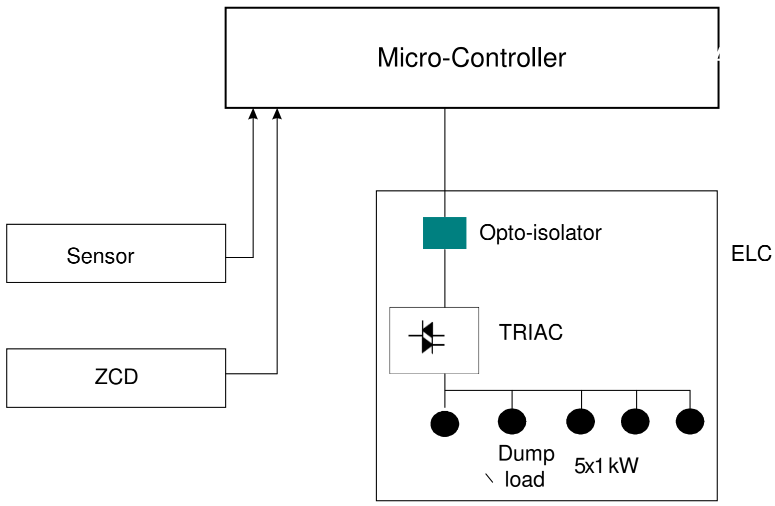

Fig. 2. Topology of Zero Crossing Detector

the proposed ZCD is more reliable than the conventional ELC since a failure in one ELC unit will not significantly impact in the entire power network. This new proposed ZCD for households per phase is depicted in Fig. 2. This figure consists of a prime mover, an induction generator, the excitation capacitor bank, three-phase unbalanced household loads, the ZCD and their related control block diagrams, and low- power rated ELC which has been installed at the generator site for the purpose of back-up control in fault conditions and to provide control in response to the small variations in the water flow rate. The low rated ELC is responsible for precise voltage regulation. In the case of safe operation and with fixed speed turbine, an approximate voltage regulation with acceptable accuracy can be achieved by the ZCDs. In this condition the low-power rated ELC is used for increasing the voltage regulation. However in the case of fluctuations in the water flow, resulting variation in generator speed and its related produced power or any failure in each household power system, the low-power rated ELC would be responsible for providing of the required dump load to regulate the output voltage. This dump load can be calculated based on the allocated power to each household.

4. RESULTS

The results show, the proposed topology has a very robust performance in the case of failure for one or two IGBT switches in each phase. The consequence of a failure for one IGBT switch in the C-ELC can be a major problem especially when the total consumer power consumption is close to its minimum value.

Table 1. Impact of trigger angle to voltage

α (trigger angle)	V(Volt)	Load (W)
0	220	5000
1	220	5000
15	219.59	4981.2
30	216.81	4855.8
90	155.56	2500
120	97.274	977.51
150	37.358	144.17
180	0.0000	0.0056407

To show the proposed system capability to deal with fluctuations in the water flow rate, a sinusoidal distortion has been considered in the water flow rate and performance of the system with and without the low-power rated ELC is depicted in table 1. In this case, the generated output power by the hydro system will fluctuate between 0 until 5000 W (permitted for only periods) .

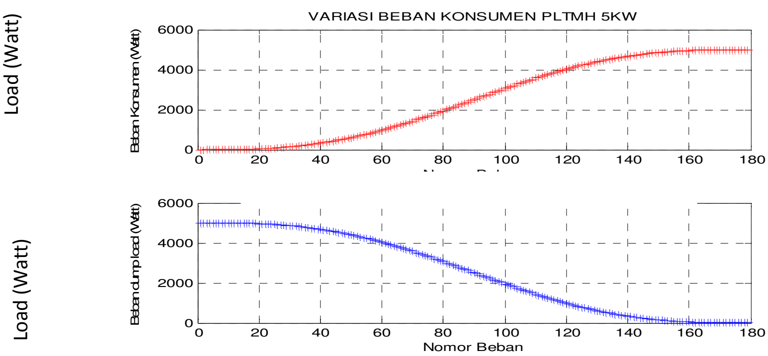

Fig.3. The relationship trigger angle with load

The output power with the low-power rated ELC and without ELC are shown in fig.[3]. In the system with the low-power rated ELC, excess power is dissipated in the dump load, resulting in constant output voltage and constant frequency. This output voltage is depicted in Fig.1. The system without an ELC is not successful in dissipating power, resulting in fluctuation in output voltage and accelerating of the machine. The output voltage in this case output voltage fluctuations in these two cases are 2.5% and 5 %, respectively.

5. CONCLUSIONS

A new Electronic Load Controller configuration, referred to here as a Zero Crossing Detector (ZCD), is presented in this paper. The main objective for this proposed ZCD approach is the transfer of excess power for domestic consumption such as water heating or space heating, in addition to providing voltage regulation. This objective has been achieved using bi-directional IGBT switches in a ZCD that is located in each consumer household. Since the ZCD makes use of available power that otherwise would go to a dump load, the proposed system can be considered more efficient compared with conventional ELC, in the sense that the ZCD system capacity factor will be much higher than for the conventional system. In this scheme, the principle of phase angle control of back to back thyristor is used. A thyristor is fired at a specific delay angle relative to the zero voltage crossing of the sine wave. The thyristor commutates at next zero crossing. Switching occurs a twice the frequency and generates total harmonic distortion as high as 35-40% in current with added reactive power burden. This scheme can continuously vary the dump power over nearly the entire range from zero to full load as the delay angle varies from 180 to 0 degree.

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