Electronic Load Controller in Pico Hydro Power System

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Abstract—**This paper describes the design and development of a prototype of an uncontrolled turbine in pico hydro power generation with constant input power. This system produces small output power not exceeding thirty watt. A water wheel turbine was used to spin rotor of alternator. The alternator converted kinetic energy into electrical energy.**

The paper also describes the design of a simple and cheap controller namely Electronic Load Controller (ELC) for alternator on a standalone applications. ELC contains Dummy Load and DC to DC Buck Converter. A Dummy Load is connected in shunt with the Real Load. It is necessary to maintain total output current at alternator's terminal. Power MOSFET switch in DC to DC Buck Converter is functioned to control the disconnection or connection of the Dummy Load. When the total output current maintained, the speed rotator of alternator was stable.

Keywords-component; Alternator, Elecronic Load Controller (ELC), Dummy Load, DC to DC Buck Converter, metal oxide semiconductor field effect transistor (MOSFET)

I. Introduction

Hydropower is a one of the most important, most efficient and non-polluting renewable energy sources (RES) [2, 3]. Figure 1 shows that RES are the second largest contributor to the global energy consumption after fossil fuel. In the year 2010, fossil fuel contributed 80.6% in the global energy consumption, while 2.7% for nuclear, 3.3% for hydropower, and the rest 13.4% for other renewables (non-hydro). The other renewable include biomass, solar, geothermal, wind, and biofuels[1].

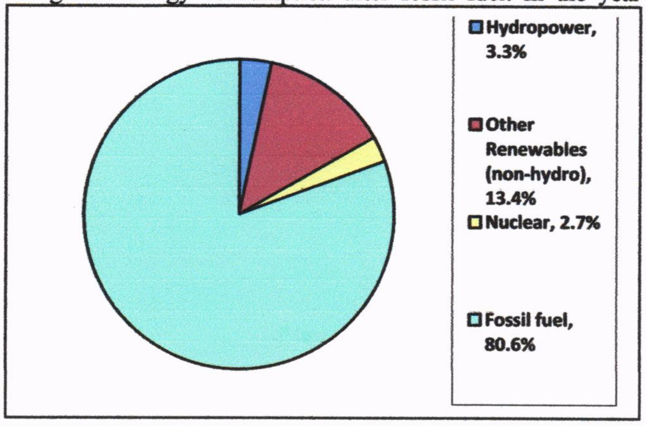

Figure 1. Renewable energy share of global energy consumption 2010[1]

Small hydropower is reliable, mature, and proven technology which is non-polluting and does not require an expensive construction of a dam. It only needs to divert some of water from river[3, 4]. Based on the output power capacity, hydropower can be classified as pico hydro power which has an output power of less than 5 kW [2] .

The problem studied in this paper is to ensure a stable speed rotation of alternator. Speed rotation change because of back electromotive force (back-EMF). Back-EMF also known as counter-electromotive force (CEMF) and occurs when increasing or decreasing of real or consumer load current[5]. When consumer current load increase, the alternator will try to provide for the current which caused decreased speed of alternator. Otherwise, alternator will rotate in over spin condition if no consumer loads current[5].

This is achieved by introducing an ELC to control unstable consumer current load. Dummy load is installed in shunt with consumer loads while ELC will control feeding of lack current load from consumer loads. ELC contains main part of power electronic circuit, DC to DC Buck Converter. Power MOSFETs is important as a switch in DC to DC Buck Converter. It is used to control current flow from alternator to dummy load in time required.

One of the objectives can be achieved by designing a water wheel turbine. A water wheel turbine is an uncontrolled small hydro power turbine which is used to rotate the rotor of alternator. It needs energy from free-flowing or falling water to convert mechanical power to electrical power. Normally, the wheel is mounted vertically on a horizontal axle[6]. A prototype water wheel turbine has been designed to supply 12V to the overall load controller circuit.

Figure 2. A prototype water wheel turbine

In order to supply 12V to the overall load controller circuit, the speed rotations of the alternator need a minimum of 2000 rpm[7]. The prototype has been tested as shown in Figure 2. The results show that the maximum speed of rotation than can be achieved is only 1171 rpm. This result is due to the gear ratio is not suitable enough to obtain the expected speed of rotation. As a result, the prototype will not be used for this project. In order to supply 12V to the overall load controller circuit, 12V voltage supply will be used. The prototype needs to be redesign in order to achieve the expected speed of rotation for future recommendation.

II. METHODOLOGY

Figure 3 shows the work flow in designing the ELC from beginning until the project complete. There are several steps to be taken in order to complete the project which include project research and development of hardware and software.

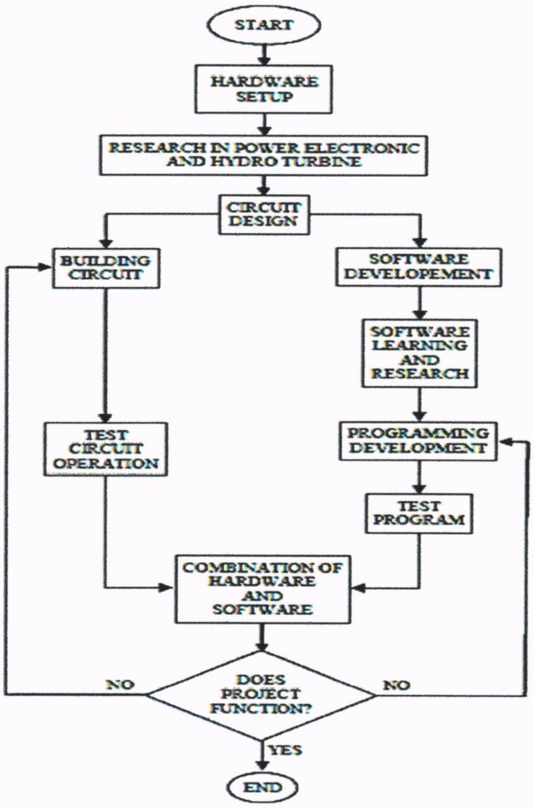

Figure 3. Overall project design flowchart

A. *Project research*

This project started by researching about the main circuit need to use in ELC. In power electronic, DC chopper was introduced to convert a fixed voltage DC source into a variable voltage DC source[8]. There are four types of DC chopper. After finishing all the research, it is found that a suitable DC chopper is DC to DC buck chopper since it is a step-down DC to DC converter[9].

Besides that, research about hydro turbine has been done. It has been found that, a water wheel turbine does not need high pressure water to rotate an alternator[6].

B. *ELC Circuit design*

Figure 4 shows the overall system of the electronic load controller (ELC). The ELC is designed to solve the problem of the current drop at the alternator's terminal. The unstable current can cause changes in the speed rotation of alternator. When no load current is used at the consumer loads side, the electronic load controller digitally controlled by microcontroller thus will open a path for current flowing through the dummy load. Therefore, the total current used at alternator's terminal in balance condition.

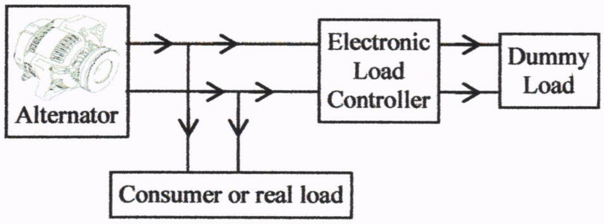

Figure 4. Overall system of electronic load controller

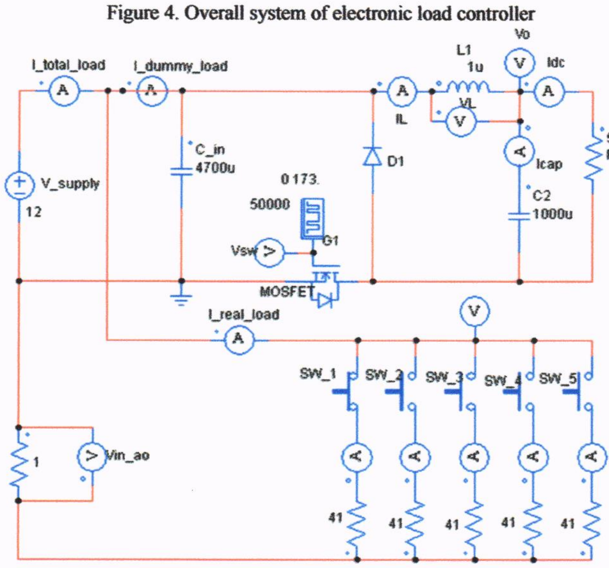

Figure 5. Full circuit design

Figure 5 shows the full circuit design. This circuit contains DC to DC buck chopper, consumer or real load, and dummy load.

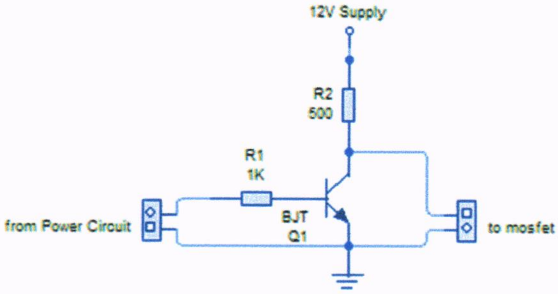

Figure 6. Drive circuit

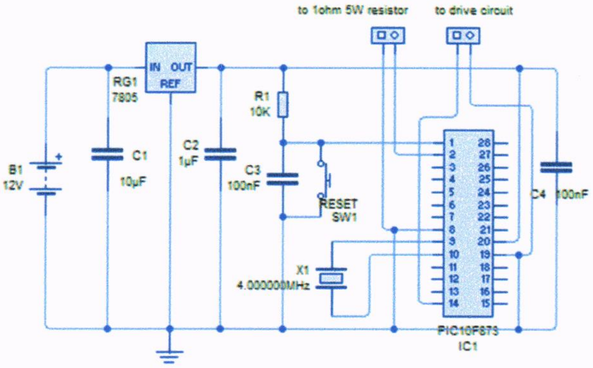

Figure 7. Power circuit

Figure 7 shows power circuit which is used to switch ON and OFF MOSFET at a certain time. MOSFET is used and it needs a minimum of 10V across to switch ON. The problem is, the microcontroller in power circuit can only supply 5V hence, a drive circuit is needed as shown in Figure 6.

C. Software development

MicroBasic Pro with assembly language is used to develop programs and burn it to the Peripheral Interface Controller (PIC) Microcontroller[10]. Programming is needed to control PIC16F873A in order to convert analog to digital input and to control switch ON and OFF MOSFET.

III. RESULTS AND DISCUSSION

In this paper, ELC performances were analyzed through the simulation using PSIM Simulation Software and measurement process on breadboard.

A. Simulation results

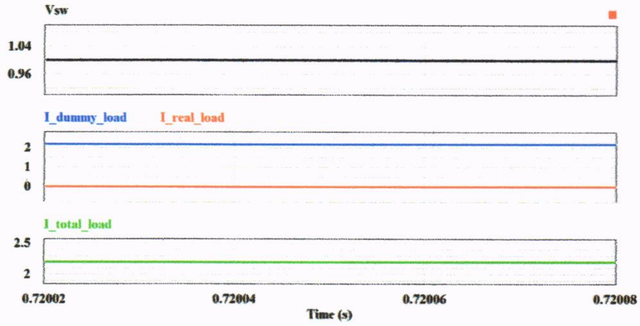

Figure 8. The condition of the MOSFET at 100% ON

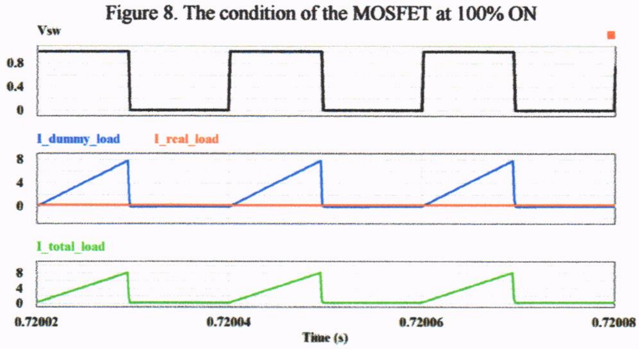

Figure 9. The condition of the MOSFET at 48.06% ON

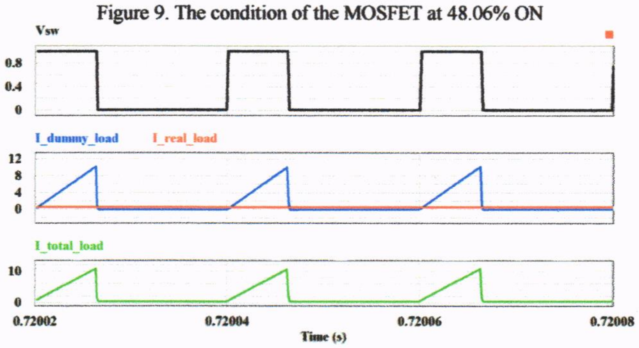

Figure 10. The condition of the MOSFET at 31.94% ON

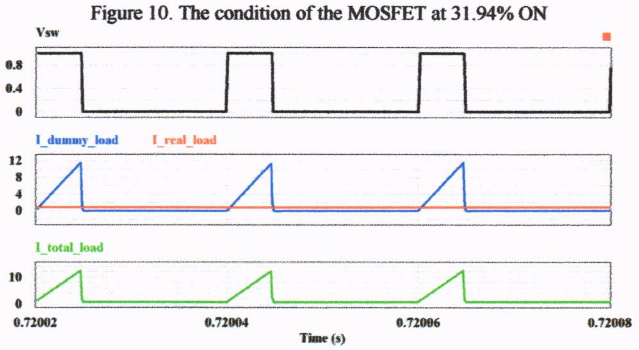

Figure 11. The condition of the MOSFET at 23.89% ON

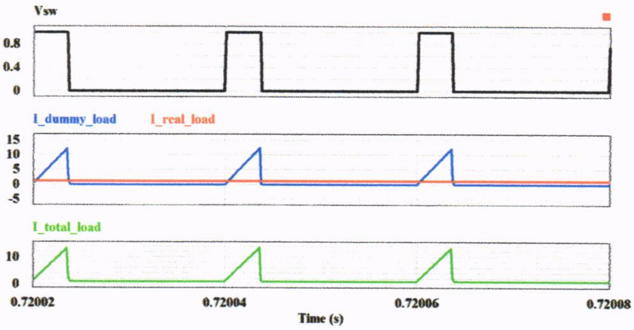

Figure 12. The condition of the MOSFET at 18.33% ON

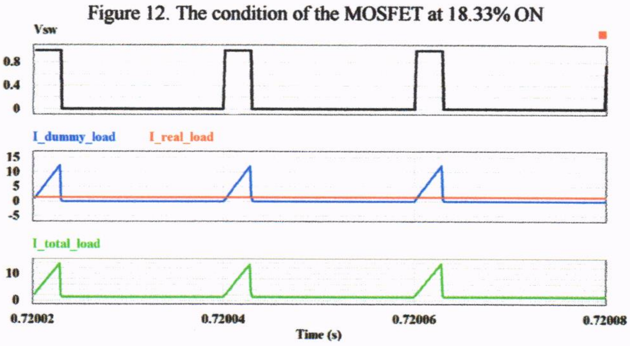

Figure 13. The condition of the MOSFET at 14.44% ON

The simulation results indicate that by increasing the number of turns on the switch(es), the load current will increased. In order to maintain the total load current at 2.2A, the duty cycle must be adjusted accordingly so that the sum of the dummy load current and the real load current will always results in 2.2A. Hence, the duty cycles varied with the number of turns on the switch.

Table 1. The corresponding real load current and dummy load current towards the number of switch ON with the respect to total load current

Switch(SW)	I_{real_load}(A)	I_{dummy_load}(A)	I_{total_load}(A)
0 switch ON	0.0000	2.2018	2.2018
1 switch ON	0.2857	1.9161	2.2018
2 switch ON	0.5581	1.6531	2.2112
3 switch ON	0.8182	1.4086	2.2268
4 switch ON	1.0667	1.1498	2.2165
5 switch ON	1.3043	0.9178	2.2222

B. *Measurement Result*

For the measurement results, the duty cycles are preprogrammed into the microcontroller with the reference from the simulation results. Multimeters are set to record three parameters; real load current, dummy load current and total actual current. The actual current is calculated by tallying the real load current and the dummy load current. From table 2, the actual current differs with the total actual current. It occurs because of the voltage drop that exhibits along the cable.

Table 2. The corresponding real load current and dummy load current towards the number of switch ON with respect to total load current

Switch(SW)	I_{Real_load}	I_{Dummy_Load}	I_{Total}	I_{Total_Actual}
0 switch ON	0.00	2.13	2.13	2.18
1 switch ON	0.28	1.87	2.15	2.20
2 switch ON	0.55	1.60	2.15	2.20
3 switch ON	0.81	1.34	2.15	2.20
4 switch ON	1.05	1.11	2.16	2.20
5 switch ON	1.29	0.87	2.16	2.20

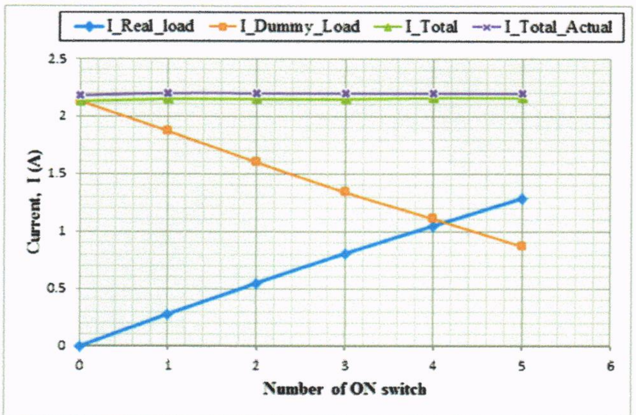

Figure 14. Graph of Current versus Number of ON switch

IV. CONCLUSIONS

The electronic load controller provides a cost efficient and a simple technique to control current. It is easy to implement into pico hydropower system. The control of the output current from no load to full load operation condition is quick and effective. The ELC performance and response varies with the type of MOSFET used. The MOSFET is easy to trigger using the PIC16F873 and is easy to program in microBasic Pro that using assembly language.

V. RECOMMENDATIONS

Another aspect of the project is the designing of the water wheel turbine is to rotate rotor of alternator at rated condition. In this project, alternator needs minimum speed rotation around 2000rpm. Practically, it is hard to drive the rotor up to its rated speed. To solve this further tweaking of the gear ratio is needed to obtain optimal speed of alternator.

Besides that, monitoring system can be implemented for easy monitoring the input, output current and the rotating speed. LCD, Rotational Speed Sensor can be used as these can easily be integrated and coded into the existing microcontroller.

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