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Electronics
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ELECTRICAL POWER ENGINEERING

Design and Construction for Mini-Hydro Control System

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*Abstract_* **Hydro power plants are mostly used over the world for its bulk of resources. Hydro energy is the most reliable and cost effective renewable energy source. It is obviously that among all the renewable energies, hydropower occupies the first place in the world and it will keep that place for many years to come. And the control systems of the hydro power plants are very important. To control the speed of turbine and generator, voltage and frequency, different kinds of methods are used. Among them, using electronic load controller is very easy and also it has less maintenance than other systems. Another reason is its low life-cycle cost.**

Most of the electricity generating plants requires various kinds of control systems. According to the size and use of generating technology, different kinds of controls are widely used. On the other hand, the technologies used in control systems become more and more complicated. As a result, the user became familiar with only black-box technology. So the technology are needed to be a simple and not too sophisticated for the users.

*Keywords_* **Electronic load controller (ELC), control system for mini-hydro power plant, electronic control, automatic control, SCR control, Triggering angle**

I. INTRODUCTION

The control system of hydro-electric plants involves basically the same principles as the control systems of generation from any other form of prime mover but has certain special aspects of deriving from the essential simplicity of water turbines. Thus the rapid starting time and the absence of thermal restrictions on rate of loading permit the fullest and most advantageous exploitation of the stored energy. This fact, together with considerations of economics, encourages the development of water power on a low load factor basic, especially when thermal power resources are available to maintain the base loads. On the other hand, the countries with very limited coal supplies have to operate their hydro electric stations on both base load and peak load service, individual stations often having to assume other of these roles at different times. In both cases, therefore, the greatest flexibility of control facilities is desirable, and is readily attainable with normal plant.

The simplicity of the plant renders unnecessary the provision of a large operation staff and permits not only the combination of electrical and mechanical functions at a single location, but the concentration of those functions for a group of several related stations at a focal control point.

The some important control systems of a hydro-electric station are as follows:

1. Machine starting and stopping
2. Automatic starting methods
3. Machine loading and frequency control
4. Generator and system voltage control
5. Machine running supervision
6. Hydraulic control
7. Control-room layout
8. Using electronic load controller (ELC)

Most of the electricity generating plants requires various kinds of control systems. According to the size and use of generating technology, different kinds of controls are widely used. On the other hand, the technologies used in control systems become more and more complicated. As a result, the user became familiar with only black-box technology. So the technology are needed to be a simple and not too sophisticated for the users.

The Electronic Load Controller control circuit has less sophisticated systems and use only available electronic parts. So the user can manage easily.

In the control technologies, electronic load controller is chosen for the following reasons:

(a) Simplicity makes the difference
(b) Simplicity means also low maintenance cost
(c) Easy to install
(d) Improves productivity
(e) Low life cycle cost
(f) Built tough

II. AIMS AND OBJECTIVES

The main aim of this project is to design and construct the electronic load controller for mini hydro power plant. The aims and objectives of this project are;

Firstly, by using the electronic load controller, the flow rate of the input water is no need to be regulated. And then, turbine and coupling generator can get the constant speed. Secondly, by using this, the components costs can be relatively reduced. As the third and last is to upgrade the technical know-how and skills for the dealers.

This electronic load controller can be used in the simplest way to control the out-put frequency of the hydro electric generators. The electronic load controller controls the load of the generator. By controlling the terminal loads, the speed and following frequency of the generator will be maintained at the controllable level.

II. USE OF ELC

Especially for small capacity systems, a synchronous generator is more expensive than an induction motor and capacitors. But with a synchronous generator with ELC, frequency is more accurately controlled and such systems can produce the large starting current required by electrical motors. This makes that synchronous generators become attractive when,

Capacity is rather high:

(a) when it should power electrical motors (e.g. for productive end-uses)

(b) when it should power expensive, sensitive appliances that need a well-regulated electricity supply.

Using dump loads is an energy-inefficient way of regulating as usually, more than half of electricity produced, will be wasted in dump loads.

From efficiency point of view, using a governor that steers a flow control valve on the turbine would be much better. But then energy is saved by reducing water consumption of the turbine so it only makes sense if water can be stored in a reservoir for future use. Usually Micro Hydro systems do not have such large reservoirs: They are 'run-of-river' systems and any water that is not used right away, gets lost in an overflow. Nowadays only Mini Hydro or full-scale hydro systems have governors as these often have large reservoirs so that water that is saved, can be stored.

Governors are expensive and require careful maintenance, making the M.H. system more expensive and less reliable. Older Micro Hydro systems often had governors, but that was because building affordable ELC only became possible using modern power electronics.

There are M.H. systems that run quite satisfactorily without an ELC, IGC (Induction Generator Controller) or governor. Then a flow control valve on the turbine is adjusted manually. This way of regulating is only feasible if most user loads are connected permanently, so if they cannot be switched off by users. Also, sensitive appliances that might get destroyed by large voltage or frequency variations can not be used. Which type of system is best for a specific Micro Hydro system depends on many factors.

Like an ordinary brake, the ELC dump loads can only consume energy and not produce any. This means that it can control frequency and voltage only as long as total power demand from users is less than capacity of the system. When total power demand would be higher than system capacity, there is an overload situation. Then the ELC can only switch off dump loads completely. It cannot generate any extra power to help coping with a too high demand.

In spite of its size, this project deals with only one part of the technology needed to build and install Micro Hydro systems- the ELC type controller. The ELC regulates power diverted to dump loads in the same way as ordinary light dimmers- by means of phase angle regulation. At some moment during each half period of sine-wave shaped generator voltage, the dump load is switched on and remains switched on for the rest of this half period. The moment at which the dump load is switched on, is expressed as a phase angle. Right at the beginning of a half period, phase angle is 0° and towards the end, it is 180°.The ELC regulates power diverted to dump loads in the same way as ordinary light dimmers- by means of phase angle regulation. At some moment during each half period of sine-wave shaped generator voltage, the dump load is switched on and remains switched on for the rest of this half period. The moment at which the dump load is switched on, is expressed as a phase angle. Right at the beginning of a half period, phase angle is 0° and towards the end, it is 180°. For phase angle regulation as shown in Fig. 1., almost always triacs or thyristors are used as power element. These electronic devices can be switched on by a short trigger pulse on their 'gate' connection and then remain conducting for the remainder of that half period. By then, generator voltage drops to zero, current through the dump load and triac or thyristor drops to 0 and they stop conducting or 'extinguish' by themselves. Triacs can conduct in both directions, so they can operate during both positive and negative half periods of generator voltage. Thyristors can conduct only in one direction so two thyristors would be needed to steer one dump load. A major advantage of phase angle regulation is the fact that those triacs or thyristors can be used. These are the 'work horses' of power electronics. They are old-fashioned, cheap, widely available and can stand rough operating conditions. There are thyristor types that can switch thousands of Amperes at voltages well into kilo-Volt range and at quite high frequencies. Triac ratings are a bit more modest, but still high enough for this ELC design and they have the advantage of simpler triggering requirements.

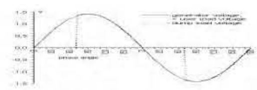

Fig. 1 Principle of Phase Angle Regulation

A major disadvantage of phase angle regulation is the electronic noise that is created when a triac is triggered while generator voltage is at its highest, so at around 90° trigger angle. Also, a load being switched at a phase angle around 90° appears as an inductive load to the grid or generator. For use in dimmers in household situation, these effects pose no real problem since the grid is very powerful compared to the load switched by this dimmer. For use in an ELC or IGC, dump load capacity will be even slightly higher than generator capacity and noise is impressive. This makes that for use with a phase angle regulation ELC, the generator must be overrated.

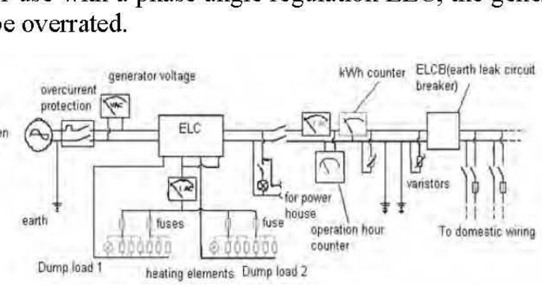

Fig. 2 Functional Block Diagram of an ELC

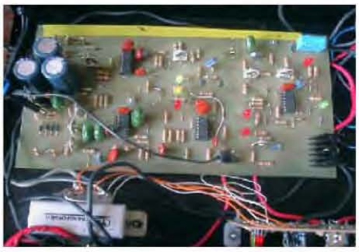

Fig. 3 Constructed ELC circuit

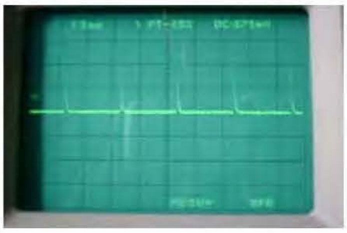

Fig. 4 Generated Pulse Trains

Fig. 5 Generated Saw-tooth wave

Calculation of the Dump Load Capacity

To estimate in advance the necessary resistance, calculate the power dissipated by the kettle elements when run about 10 volts under rated voltage. Suppose the only elements available are rated 2 kW/230 V and each one consists of two 1 kW sub-elements. Since $P = \frac{V^2}{R}$

$$R = \frac{230 \times 230}{2000}$$

$$= 26.45\ \Omega$$

At 220V, the power dissipated is

$$= \frac{V^2}{R}$$

$$= \frac{220 \times 220}{26.45}$$

= 1830 watts

A ballast consisting of three of these elements would dissipates 5.5 kW and four elements would dissipate 7.32 kW, which is 7.3/6=22% over-ballasting. In practice, 10 % over ballasting is the target, and over-ballasting above 15 % should be avoided as the ELC will be loaded above its rated capacity. In this case one of the sub-elements could be removed, so that the ballast effectively consists of 7 sub-elements in parallel, a total resistance of

$$R_t = \frac{26.45 \times 2}{7}$$

$$= 7.56\ \Omega$$

The power which would be dissipated at 220 V is

$$P = \frac{220 \times 220}{7.56}$$

= 6.4 kW which is an over-ballasting of 6.4/6

= 6% (acceptable)

In practice it will be necessary to measure the ballast voltage with the main load off and adjust the ballast resistance until around 10 to 20 volts below the generator voltage. If the ballast voltage lows, increasing the ballast resistance can be made.

Calculating the Required Flow Rate

If a water-cooled ballast loads were chosen, shown in the Fig. 6, using seven 1 kW kettle sub-elements, then it would need to be ensure that the cooling water flowing over the elements is sufficient to dissipate the maximum power ever likely to be produced by the generator.

With a generator output of 6 kW and the maximum temperature of the entering the ballast tank 25° C, then assuming the ballast tank outlet water temperature is not to exceed 50 ° C, then the rate of heat dissipation must be 6000W, that is, 6000 joules/second, and as the specific heat of water is 4200 J/kg.

$$\text{Flow required} = \frac{\max.demand}{4200 \times temp.difference}$$

$$= \frac{6000}{4200(50-25)}$$

= 0.057 kg/sec of water

1 liter of water weighs 1 kg at the temperature concerned. Thus, the required water flow rate must be greater than 0.057 liter/second or 0.1 liter of cooling water per second.

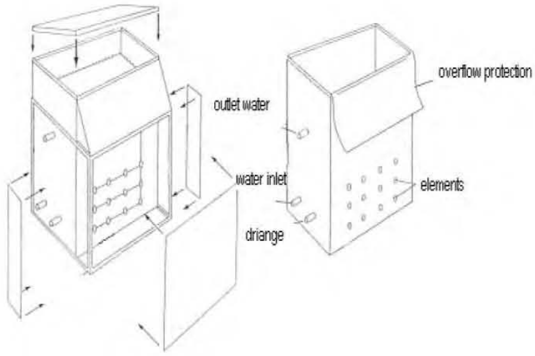

Fig. 6 Water-Cooled Ballast Load Tank
Source: Adam Harvey (Micro Hydro Design Manual)

For 50 kW power generation,

For 230 V, 50 Hz, p.f= 0.8 lagging

Maximum expected demand= 50 kW

For the generator and AVR stability, 60 % of the power is to be added.

So, P= 50 + (0.6×50) =80 kW

For water cooled ballast load, choosing 10 kW/230 V

$$P = \frac{V^2}{R}$$

$$R = \frac{230 \times 230}{10 \times 10^3}$$

$$= 5.29\ \Omega$$

At 220 V, $P = \frac{220 \times 220}{5.29} = 9.149$ kW

For 5 elements, 5×9.149 = 45.745 kW (< 50 kW, not cover condition)

For 6 elements, 6×9.149 = 54.894 kW (~ 50 kW)

Taking 6 elements;

$$\text{Power ratio} = \frac{54.894}{50} = 9.7\ \%\ \text{(acceptable)}$$

Choosing 6 elements in parallel;

$$R = \frac{5.29}{6} = 0.88\ \Omega$$

$$\text{And } P = \frac{V^2}{R} = \frac{220 \times 220}{0.88}$$

$$= 55\ \text{kW}$$

Determination of the required flow rate to compensate the heater coils,

Taking entering water =25 ° C

Outlet water = 50 ° C (< 50 ° C)

Rate of heat dissipation = 50×10^3 W (i.e. 50 kJ/kg° K)

Specific heat of water = 4200 J/kg° K

$$\text{Flow required} = \frac{\max.demand}{4200(T_o - T_i)}$$

$$= \frac{50 \times 10^3}{4200(50 - 25)}$$

= 0.47619 kg/sec of water

1 liter of water weighs 1 kg.

The required water flow rate must be greater than 0.47 liter/ sec. i.e. it should be greater than 0.5 liter/sec.

Calculating the Triac Capacity

For the 6 kW generation,

60% is to be added for safety.

P= 6+ (6×0.6) =9.6 kW

The required triac capacity is;P= VI cos φ

$$I = \frac{9.6 \times 10^3}{220 \times 0.8}$$

= 54.545 A

So for the 2 dump load version, each triac must carry about 30 A.

And for the 3 dump load version, each triac must carry about 20 A.

For the 50 kW generation,

60% is to be added for safety.

So P= 50 + (50x0.6) = 80kW

The required triac capacity is;

P = VI cos φ

= $80 \times 10^3 = 440 \times I \times 0.8$

$$I = \frac{80 \times 10^3}{440 \times 0.8}$$

=227.2727 A

So for the 3 dump load versions, each dump load has at least, 75 A.

V. CONCLUSION

As our country has too much water resources, Hydro Power Generation can be used to fulfill the most of electricity demand. For control system using Electronic Load Controller is very easy and not complicated to apply for the villagers.

The Electronic Load Controller (ELC) designed and constructed in this project is used for a Hydro system fitted with a synchronous generator and powering just some houses or a small, local grid. So it is a stand-alone Hydro System; it is not connected to the national grid.

Together with the dump loads connected to it, an ELC serves as an automatic, electrical brake that controls frequency of electricity produced by the generator. It measures frequency and, depending on whether this frequency is above or below nominal frequency, diverts more or less power to the dump loads that are connected to it.

With a synchronous generator, electrical frequency is related directly to its mechanical speed, so then frequency will drop also. Inversely, turbine and generator will accelerate and frequency will increase when less power is diverted to dump loads. This way, the ELC controls electrical frequency and, with this, speed of generator and turbine. It prevents the generator from over-speeding: when total power demand of user load appliances that are switched on, is less than capacity of the system.

Therefore this ELC is applicable for rural electrification in Myanmar.

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REFERENCES

(1) Ashfeq Ahmed, 1999, Power Electronic for Technology. Bhattacharya S K, S Chatterjee, TTTI Chandigarh, 1995

(2) HARVEY, Adam, 1993, Micro-Hydro Design Manual; A guide to small-scale water power schemes, by Adam Harvey with Andy Brown, Priyantha Hettiarachi and Allen Inversin, Intermediate Technology Publications, London, ISBN 1 85339 103 4

(3) PICO HYDRO (magazine, free for subscribers in developing countries). Micro Hydro Centre, Department of Electrical & Electronic Engineering, The Nottingham Trent University, Burton Street, Nottingham NGI 4BU, United Kingdom

(4) PORTEGIJS, Dec,2000 , The Humming Bird' Electronic Load Controller /Induction Generator Controller)

(5) SIEMENS MATSUSHITA COMPONENTS, 1999, Catalogues on A.O. Varistors and Surge Arrestors. Internet: http:// www.siemens.de/pr/index.htm

(6) SMITH, Nigel, 1994, Motors as Generators for Micro-hydro Power, Intermediate Technology Publications, London, ISBN 1 85339 286 3