# IMPLEMENTATION OF A PORTABLE MICRO HYDRO POWER PLANT USING AN INDUCTION GENERATOR CONTROLLER

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**ABSTRACT**

*In generating electricity for a short duration use, the normal practice is to use a diesel (or Petrol) generator with the relevant capacity. However, during the construction period of a hydro power plant (mainly mini-hydro) a portable micro hydro power plant can be used instead to supply the site demand. To achieve this, an induction motor can be used as a generator with an Induction Generator Controller (IGC) used to maintain the output voltage at a constant value.*

*This paper presents the basics of such a project, which has been implemented for Nivindu (Pvt.) Ltd at Belihuloya.*

**1. Introduction**

In Sri Lanka, there are many small-scale hydro potentials, which can be used to produce a few kilowatts of electricity. In most cases they are not economically viable to be grid connected. Therefore these can be used to cater the demand of isolated villages.

The project, which was chosen by us, was to supply the power demand during the constructional period of a Mini Hydro Power plant at Belihul Oya for Nivindu (Pvt.) Ltd.

In micro hydro power plants, Induction Motors with capacitors are used instead of synchronous generators. This is mainly because it is much cheaper, simple, widely available, robust and requires little maintenance. With induction motors, Induction Generator Controllers (IGC) which react to the generator voltage rather than to the frequency are normally used.

As the flow through the turbine is not controlled, dump loads are used to control the output power. Thus the output of the generator is not controlled according to the demand. Excess power produced at any moment is diverted through the dump loads.

This is an energy inefficient method. From efficiency point of view, using a governor that steers a flow control valve on the turbine, would be a much better option.

**2. Feasibility Study**

After the discussion with the company Engineers we visited the site on the 15th July 2001 to do a site survey and feasibility study.

The following details were studied.

☞ Load Analysis

From the load flow calculations it was found that the maximum site demand was around 5.25 kW

☞ Available Head

Maximum available head at the site surrounding was 18m, but near the site it was around 14m.

☞ Flow measurement

From a month's data, obtained with the help of Site Engineers, the average value of flow for the month was 1.0776m$^3$/s.

☞ Rain fall data

We did not study this aspect as Engineers from the site advised that they have already done a study on it.

☞ Transmission Lines

Since induction generators are used, we need to minimise the transmission loss. Hence a location near the power house, where the head is 14m, was chosen.

**3. Basic Concept**

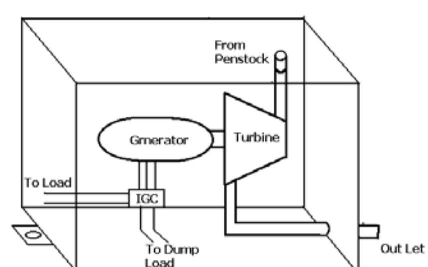



*Fig.1 Basic Connections.*

As shown in figure 1, the generator along with the turbine and controller, is mounted on a frame, which can be easily shifted to another place and assembled.

The Generator is an old 3-phase induction motor in running condition and the turbine is a used pump. (Type: Propeller)

From the cost point of view, it was decided to use PVC pipes instead of flexible hose and also it was decided to use grade 600 PVC near the weir and grade 1000 PVC near the turbine.

Based on the basic design of the controller given by the company, we made the necessary modifications.

## 4. Controller

The controller is based on diverting the excess power to the dump loads in the same way as in some light dimmers.

Since the circuit is a complicated one, the circuit is divided in to several modules and the study is based on these modules.

### 4.1 DC Voltage Supply and Reference Voltage

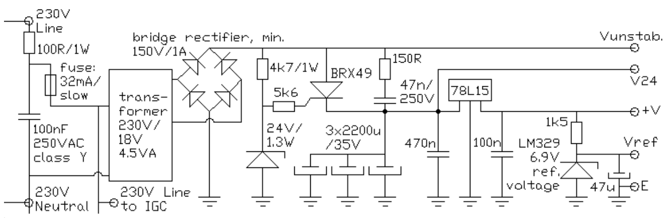
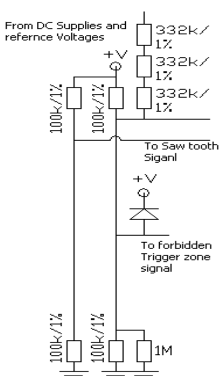



*Fig.2 DC voltage supply circuit*

This module produces a supply voltage that provides power to the other modules or serves as a reference voltage. It works in a series of steps, with input of each step being a rather high and variable voltage with a large current capacity, and output being a lower, more stable voltage with a lower capacity

### 4.2 Voltage dividers




The voltage dividers reduce the 230 V AC generator voltage signal into a voltage signal that can serve as input signal to sawtooth signal and Forbidden Trigger zone signal modules.

*Fig.3 Circuit diagram of the voltage divider*

### 4.3 Saw tooth signal module

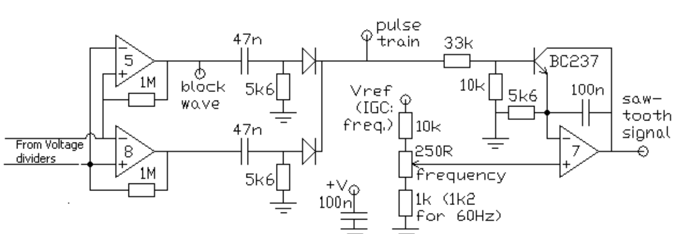



*Fig.4 Saw tooth signal generator*

A saw tooth signal is a signal that increases gradually with a constant slope, then drops sharply when it is `reset', after which the cycle is repeated.

Here, the resets of saw tooth signal follow shortly after the zero crossings of generator voltage.

Saw tooth signal serves two functions:

1. Its <u>momentous value</u> tells how much time has elapsed since the last zero crossing. This information is used by final comparators to set trigger moment for this half period.
2. Its <u>mean value</u> tells about the frequency at which the generator runs. If frequency is rather low, saw tooth signal rises a bit higher before it is reset by the next zero crossing and its mean value will be slightly higher. If on the other hand frequency is relatively high, mean value of saw tooth signal will be below normal. So its mean value is proportional to the inverse of frequency. This mean value is derived in low-pass filter, after which it is fed to PI controller.

### 4.4 Forbidden Trigger zone module

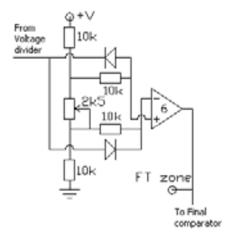



*Fig.5 FTZ module*

On principle, the saw tooth signal contains all the information that is needed to trigger the Triacs at the right moments, achieve the desired trigger angles and with that, the right amount of power diverted to the dump loads. In practice, things can go wrong near the ends of the range of possible trigger angles. Forbidden Trigger zone (or F.T. zone) signal creates a safety margin around the danger zone close to the zero crossings: When it is high, final comparators module will not produce a trigger pulse. This way, the following triggering errors can be avoided:

### 4.5 Low Pass Filter

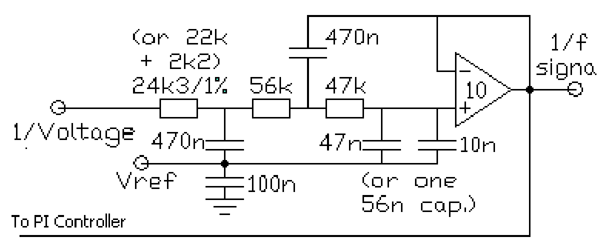



*Fig.6 LPF circuit diagram*

Since the slope of the saw tooth signal is constant, the maximum value it reaches before being reset is proportional to the time lapse between zero crossings. This means that peak voltage of saw tooth signal is proportional to the inverse of frequency of generator voltage. The mean value of the saw tooth signal is the mean value of its maximum (which varies with inverse of frequency) and its minimum (which is constant) so that the mean value can also be used as a measure of inverse of frequency. The Low-pass filter derives this mean value of saw tooth signal and this 1/f signal serves as input to PI controller.

All components of the low-pass filter together form a third-order `Butterworth' low-pass filter with a cut-off frequency of 17.3 Hz. Variations in saw tooth signal with a frequency well below this cut-off frequency, can pass the filter without being dampened noticeably. These low-frequency variations contain the information on changes in generator frequency the PI controller should react to.

### 4.6 P I Controller

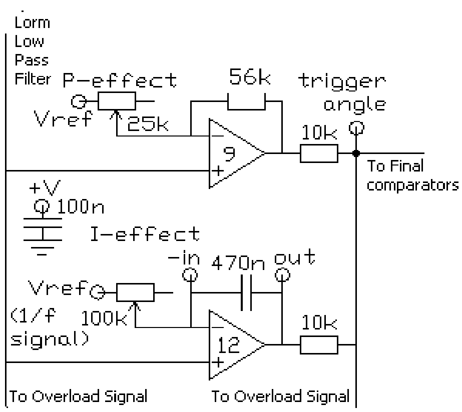



*Fig7. Circuit diagram of PI controller*

In general terms, the PI controller works as follows: It compares actual frequency (an input variable) with desired frequency (a set point, adjusted by means of `frequency' trimmer) and reacts to the difference. If the actual frequency is too high, it decreases the trigger angle so that more power will be diverted to the dump loads. This will make the generator slow down and the frequency will decrease.

The reverse will also occur: If actual frequency is too low, trigger angle is increased, power diverted to dump loads decreases and the generator can speed up some more.

### 4.7 Overload Signal

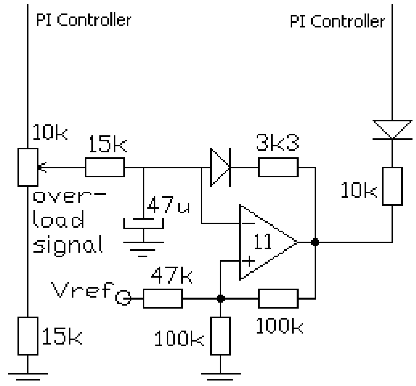



*Fig.8 Overload signal generating circuit*

In a way, the overload signal module is related more to protection features, as it remains inactive as long as the system is operating normally. It is activated only when there is an overload situation, so if user loads draw more power than the system can generate, then the IGC will have switched off dump loads completely, but still generator frequency might drop further. The overload module is meant to warn users that the system is overloaded and that they should switch off some appliances that draw a lot of power, or at least not switch on any more.

### 4.8 Final Comparators

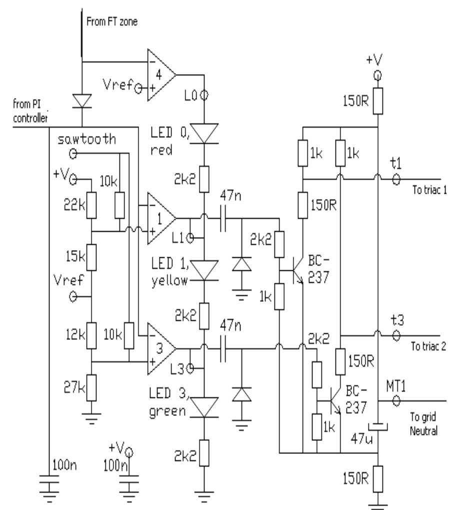



*Fig.9 Circuit of the final comparator*

Apart from creating trigger pulses for the triacs, final comparators also steer the dump load LED's that show how much power the IGC diverting to the dump loads.

### 4.9 Protection Features

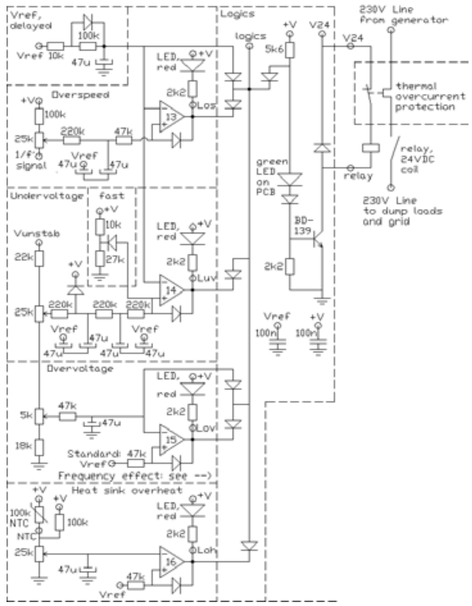


*Fig.10 Protection circuits*

The protection features are meant mainly to protect user appliances against conditions that might destroy certain types of appliances:

1. Over speed: Against too high a frequency. This is dangerous for motor driven appliances, especially if the driven machinery requires much more power when driven too fast, e.g. fans or centrifugal pumps. It can occur if the IGC or dump loads fail and the turbine speeds up to run-away speed.

2. Over voltage: Against too high generator voltage. This is dangerous for many types of appliances. Normally, this can only happen with a compound type generator when the IGC or dump loads fail. So then it is linked with over speed. It might also happen with a generator with AVR if the AVR fails.

3. Under voltage: Against too low voltage. Then electrical motors might be unable to start and might overheat.

A protection against under frequency is added. This is done by adding a `frequency effect' to the `over voltage' feature. This will make that over voltage feature will not only trip when voltage is too high in absolute figures, but also when voltage is too high in relation to frequency,

- IGC overheat: This protects the IGC against overheating of the heat sink to which the triacs are fitted.
- Protection features offer little protection to the generator. There for generator must be protected seperately

### 4.10 Power Circuit Capacity

The capacity of this circuit determines capacity of the IGC as a whole. The maximum current the triacs can handle, determines the kW rating of each dump load. Multiplied by the number of dump loads, this gives the maximum capacity of dump loads that can be connected to the IGC and this is the kW rating of the IGC. This total dump load capacity should be some 5 - 15 % above design power output of the Micro Hydro system.

Current rating of the relay determines the maximum current that user loads may draw. Normally, one can calculate current I by dividing power P (in W) by nominal voltage V. But user loads could draw a much higher current than this if:

- These user loads have a poor power factor
- The system gets overloaded.

In this situation, it is better to express capacity of the IGC in terms of kVA = 1000 * maximum current * nominal voltage

Generally, kVA rating of the IGC should be the same as kVA rating of the generator. Then total capacity of dump loads will be only 50 to 70 % of kVA rating of the generator.

## 5 C – 2C Method.

The motor, which we used as the generator, was a 3 phase one. Since our load was small and we were to supply only within the powerhouse we were advised to use a single-phase output. To do so we used C – 2C method.

## 6 Conclusion

A major problem that we came across during the project was the fact that the calculated values of capacitors for C - 2C method were not sufficient to build up the voltage. So we used the trail and error method and found the relevant values.

Unfortunately we couldn't complete the implementation part. This was due to the fact that by the time of completion of the controller, Project Co-ordinating Engineers of the company had found out, it was not economically viable to implement this Portable Micro Hydro Power Plant instead of the already available diesel generator. Looking on the brighter side, they have given us the assurance that, this controller will be used in future Mini Hydro Projects.

All in all, this project gave us confidence to work on larger projects of this nature.

**References**

Jan Portegijs - "Humming Bird Electronic Controller/ Induction Generator Controller"