Implementation of Electronic Governor & Control System of a Mini-hydro Power Plant

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Abstract

Mini-Hydro power plants are now increasing their popularity due to current shortage of power potential in the country and their close proximity to the remote areas, which are isolated from the national grid. The governor of such a mini-hydro power plant controls the power output of the generator utilizing the water available. Almost all the electronic governors use a stepper motor to control the mechanical actuator part that opens or closes the water inlet valve of the turbine.

The main intention of this project was to design a PC based electronic governor, synchronizer and the protection system of a mini-hydro power plant. We have designed a PC based PID controller which has a precise control over a stepper motor which addresses the actuator to control the valves of the turbine.

Some of the features of this governor are very low cost, easy tuning of the turbine and very high reliability. In future automatic data logging facility, remote monitoring and forecasting facilities of the water level and power output are also can be implement. This governor can be used in any type of a hydro power plant. According to initial on-site testing this governor displayed an excellent performance and it can be a good replacement for the conventional governors in the industry.

1.0 INTRODUCTION

The governor of a mini-hydro power plant controls the output power utilizing the available water supply to the turbine. When the power plant is a grid connected one, it should be able to build the generator frequency up to the grid frequency. These two operations are achieved by controlling the gate valves of the turbine. Almost all the turbine units use this method of control and it comprises of a mechanical actuator and electrical control device to give the desired command signals to the actuator to open or close valves appropriately.

Electronic governors are considered as a very expensive piece of equipment. And it is not easy to tune them to reach the best operating condition.

In the initial stage, we studied the entire control system of a mini-hydro power plant that is situated at **Niriella**. Some of the electronic devices of that system, such as frequency counters and various other sensors could be used in our governor, but we decided to design each and every important part of the entire system.

2.0 BASIC OPERATION

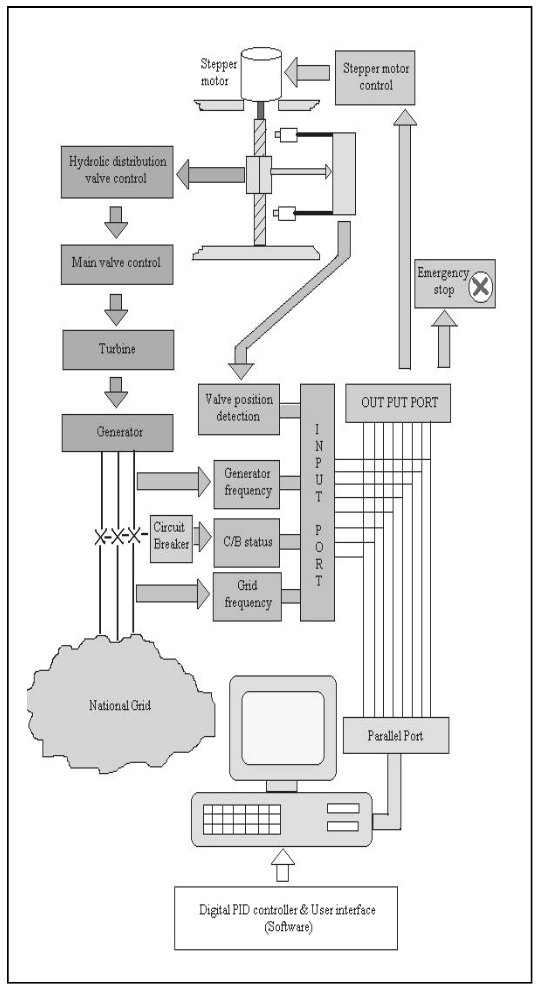

Figure 1: Basic Block Diagram of the System

This design uses a PC based PID (Proportional, Integral and Derivative) controller, which has a precise control over a stepper motor. That stepper motor controls the pressurized fluid flow and hence the actuator controls the water flow to the turbine. Two frequency counters, which are used to get the frequencies of the generator and the grid, are two of the main input devices of the system. The water level is the next input to make the decision on opening or closing the water inlet valve.

The PID controller and the system control software were programmed using C++ and Visual Basic. The system control software decides the number of steps of the stepper motor to be rotated in order to open the valve to keep the power level while following the grid frequency. It uses the PID controller to make that decision, results in a fast but smooth operation. The number of steps as decided, is fed to the driver circuit of the stepper motor. The protection rules are defined and embedded to the system, ensuring a better protection in addition to what the conventional systems generally have in the control panel of the power house. The system can be tuned by changing the mode settings and PID constants. After tuning properly, this system can be used in any type of a hydro power plant.

3.0 FUNCTIONAL UNITS

The entire system is an integration of several functional units. The system software controls those units.

1. Generator Frequency Counter
2. Grid Frequency Counter
3. Water Level Sensor
4. Valve Position Sensor
5. Stepper Motor Driver
6. Emergency Circuit Breaker unit
7. Main Board

3.1 Frequency Counters

The Generator and Grid frequencies are two of the main inputs of the system. The frequency counters and the device driver software calculate the frequency in Hertz with the accuracy of 0.05Hz.

The voltage signals of the grid and the generator are used in the calculation of their respective frequencies. The larger signal of 230V maximum is stepped down to approximately 5V signal by using a step down transformer. This small but sinusoidal signal is then converted to a square wave by using a Schmidt trigger.

The converted square wave is again converted to single sided square wave by a J-K flip-flop. Four counters of 4-bit each are used in a single unit; therefore the frequency counter is 16 bit. Those counters count the number of zero-crossings of the sampled signal. The zero-crossings results the output pulses (maximum of 64k) of the AND gate. Flip-flops are used to latch the output of the counters until the read signal is given. The buffers keep the number of counts until they receive the read signal. When the frequency counter is selected to read the frequency input, the number in the buffer is put in the data bus.
The number of counts in the data bus is used in the calculation of the frequency, and it is done using the software. The counter is calibrated to have premium accuracy near 50Hz, where small frequency fluctuations should also be considered at the point of synchronizing.

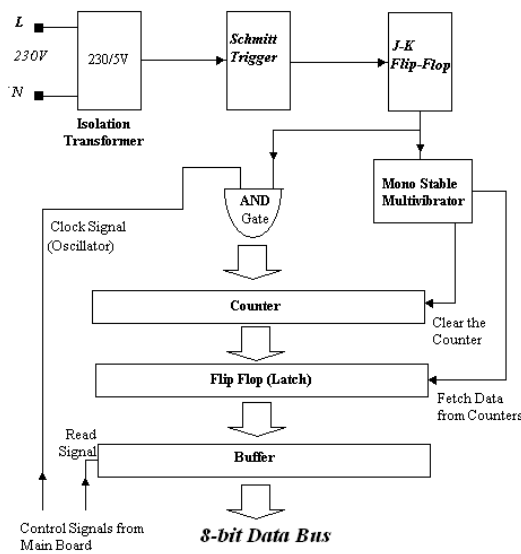

Figure 2: Block Diagram of the Frequency Counter

3.2. Water Level Sensor

Output power utilization with available water supply is a main function of a governor system. For that purpose water level must be sensed. Depending on the water level the valve of the turbine is opened or closed to optimize the power output while consuming all the water available at the fore-bay tank.

The Software has introduced a dead band, which does not allow change of the valve position for small fluctuations of water level. This arrangement provides the necessary automatic adjustment of power level while getting the feed back from the water level sensor and the PID controller loop arranges the necessary stability requirement for adjusting power levels.

When water level is reduced beyond some set value a signal is gone to low water level alarm system for protection. This ON duration of the alarm or the Beep will increase with the rate of reduction of the water level below the set minimum safety level. Also this sensor system includes a power failure indicator, which is really helpful to track whether the system has undergone a power failure.

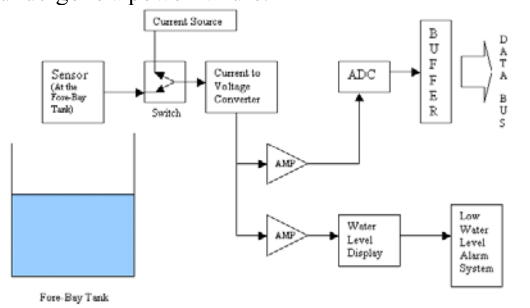

Figure 3: Block Diagram of the Water Level Sensor

3.3. Valve Position Sensor

Valve position is sensed at the screw position and fed to data bus when buffer is enabled. This gives information such as the valve fully closed position, fully opening position and it is also used to derive power output of the generator. This positioning data is used and referred the calibration tables to decide power output.

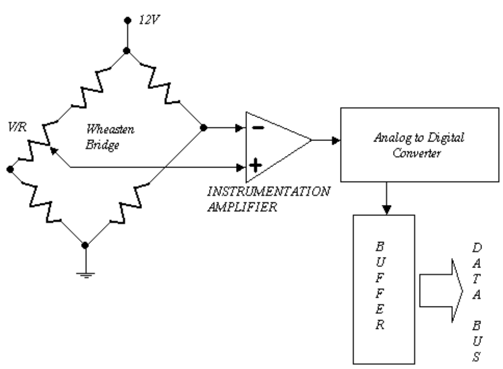

Figure 4: Block Diagram of the Valve Position Sensor

3.4 Stepper Motor Drive

The inlet valve of the turbine is moved by a hydraulic mechanism. A stepper motor controls the flow of the pressurized fluid, which actuates mechanical system. The software decides the number of steps to rotate and the direction of rotation. These data is fed to the up-down counter in this driver circuit. The up-down counter gives the pulse and the driver circuit of the stepper motor gives the desired pattern of pulses to the stepper motor.
The driver circuit is compatible with both unipolar and bi-polar stepper motors.

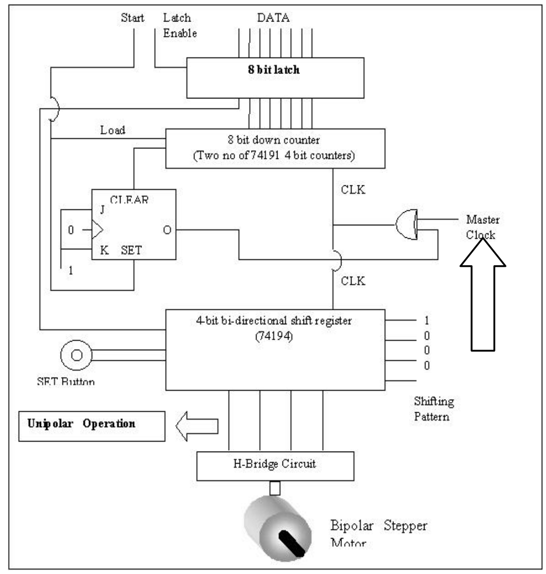

Figure 5: Stepper Drive Control Block Diagram

3.4.1. Latest Modifications.

1. Reduce the circuit complexity
   - Remove the 4-bit shift register and instead introduced a 2-bit synchronous counter stage.
   - Eliminate the redundancy of buffers at the output stage and transistor current amplifications were coupled to the TTL outputs.
   - Stepper power down feature. This will operate when the stepper is at rest.
2. Automated manual starting (Self mode)
   - In the former design of the stepper driver, power failures causes the circuit to interrupt and completely malfunction the driving operation even though the power is ON again.
   - Manually operated starting and setting buttons were automated using synchronous counter design.
3. Optimization of the circuit design and minimize the component cost.
   - Maximum utilization of multiple gate ICs and Flip-flops.
   - Optimum performance is achieved by synchronous counter design and NAND bridge at the output stage.
   - Minimum numbers of ICs are being used.
4. Improve the reliability by PCB designs.
   - All strip board designs of circuits were integrated to a single PCB.

Coils			
A	B	C	D
1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1

5. Inclusion of stepper status check
  - Completion of the rotation is acknowledged to the computer by status bus.

6. LED indicators
  - Power ON indicators
  - Direction of rotation

3.5 The Main Board

This is the platform used to integrate all the functional input/output devices of the system. Like a PC motherboard, this provides easy "plug and play" facility and avoids clashes when using the common data bus to read or write to those devices. This uses a 4X16 decoder to switch to the devices. Virtually, 16 devices could be plugged-in to the main board, but one address is kept nullified. It is used as a "data flash" of the data bus. There are also two additional connectors. One of them has 16-bit and the other has 8-bit data bus width. So these connections can be used for future developments such as Protection alarm systems

3.5.1. Modifications

- All circuit board designs (Input and output) were integrated and controlled though a single PCB (i.e. the Main board) with more reliability
- Status signals are used to check the devices. This will help to take better measurements from the sensors without any malfunction.
- Due to noise of the control signals De-multiplexer automatically switched error signals to devices. To avoid this 4 resisters are connected with the control bus lines.

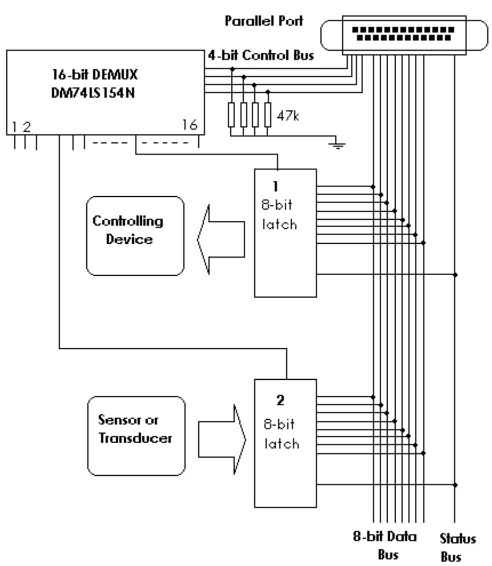

Figure 6: The External Bus Arrangement

3.6 Circuit Breaker Signal

The circuit breaker status is a crucial input signal so it is scanned frequently (with a clock of 20 Hz). After synchronizing, the user is allowed to increase power when the circuit breaker is closed. When the grid fails, the circuit breaker is automatically opened; so the system senses it at no time and the Emergency Shutdown routine is run immediately.

4.0 THE SOFTWARE

The hardware is connected to the computer via the parallel port. The parallel port of the PC is accessed by using win95io.dll. It is a dynamic link library written by using C++. The GUI (Graphical User Interface) is built by using Visual Basic 6.0 (Enterprise Edition). The operating system must be Windows95, 98, 2000. The win95io.dll does not support Windows NT.

The software uses the data port to input and output data. Four output pins of the control port are used to address the devices plugged into the main board. There are 25 pins in the parallel port (known as printer port). Pin numbers 2 to 9 are data lines and they are used to input and output data (bi-directional). The direction pin configures the direction of the data. When it is set high, data input is done. To output data the direction pin is set to low.

This Software uses a multithreading technique to do parallel processing where it is necessary. It uses several Timers to get data, run the internal subroutine loops, draw graphs and update the records of the operation. For example the circuit breaker status, which is one of the most important inputs to the system, is refreshed using an independent clock with an interval of 50ms (20 Hz).

The system software also includes device driver software, which is required to convert the inputs of various input devices such as frequency counters into numerical values. Those numerical values are used in the operational calculations in the system software.

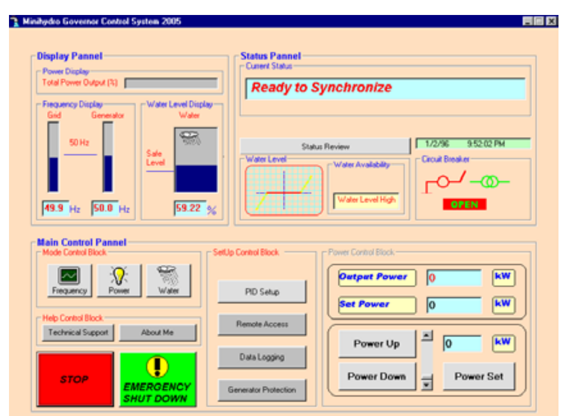

Figure 7: Snapshot of the Graphical User Interface

The device driver software has the option of calibration of the input and output devices.

The GUI of the system represents the actual run time values of the input modules, output modules and it also comprises of graphical representation of some of the input-output data.

The software avoids any misconduct of the user. The protection rules, such as the emergency operation at a grid failure, water supply problems etc. are embedded to the system.

5.0 Future Developments

This governor control system possesses several advance features over its traditional counterparts. The PC use has improved its presentation skills tremendously. This arrangement allows the user to tune up the system very easily. The graphical representation and the status registry is good identification of the smooth run of the plant. There are two major features that can be further developed in this governor control system. One is Remote Data Logging facility. The other one is Remote Monitoring facility. After implementing these two features the owners of the plant can remotely log in to the control system of that particular plant, may be through the Internet and observe the operation of the plant in real time.

6.0 CONCLUSIONS

This design of the governor control system has proven its ability to replace any of its counterparts. All the laboratory tests gave promising results, now we plan to put this governor into operation to test it in the real world.

The overhead of calculation to the PC should be reduced, and instead we are planning use a Micro Controller. The PC should be used only for data storage, monitoring and as an interface only. This will not be a big problem, as far as we can use a C++ to Assembly Cross-Compiler, to convert the system software to Assembly Code.

Most of the mini-hydro power plants have two or three turbines. All of these units require independent governor control systems. With Micro Controller version, we can use a number of such governor control systems, and the display and data storage can be done using a single computer as the main control computer. By referring to the turbine efficiency charts, we can develop a procedure to achieve the most economic utilization of the water available.

This Governor Control System can be used with any type of turbine or hydro power plant of any capacity (even in major-hydro). The total cost of this device is less than Rs.20000/= plus the cost of the computer. Compared with the market price of a Governor this cost is only a fraction of it. The only persisting challenge is the development of this product according to the current market standards.

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