ELECTRONIC GOVERNOR AND CONTROL SYSTEM OF A   MINI-HYDRO POWER PLANT

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1.0 Introduction

The governor of a grid connected mini-hydro power plant first builds the generator frequency up to the grid frequency. It also controls the output power utilizing the available water supply to the turbine. This entire operation is 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.

The main intention of this project is to design a PC based controller accessing that point of control mentioned earlier, plus the protection system of the power plant.

2.0 Basic Operation

In our design, a PC based PID (Proportional, Integral and Derivative) controller, which has a precise control over a stepper motor that addresses the actuator to control the water flow to the turbine. Two frequency counters those are used to get the frequencies of the generator and the grid are two of the main input device of the system. The water level is the next input to make the decision to open or close the gate.

The PC model of the PID controller was programmed by C++ and the interface was build by using Visual Basic. The 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. 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 we normally have in the control panel of a power plant. This version of the governor has very advance features over the conventional governors.

3.0 Functional Units

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

3.1 Frequency Counters

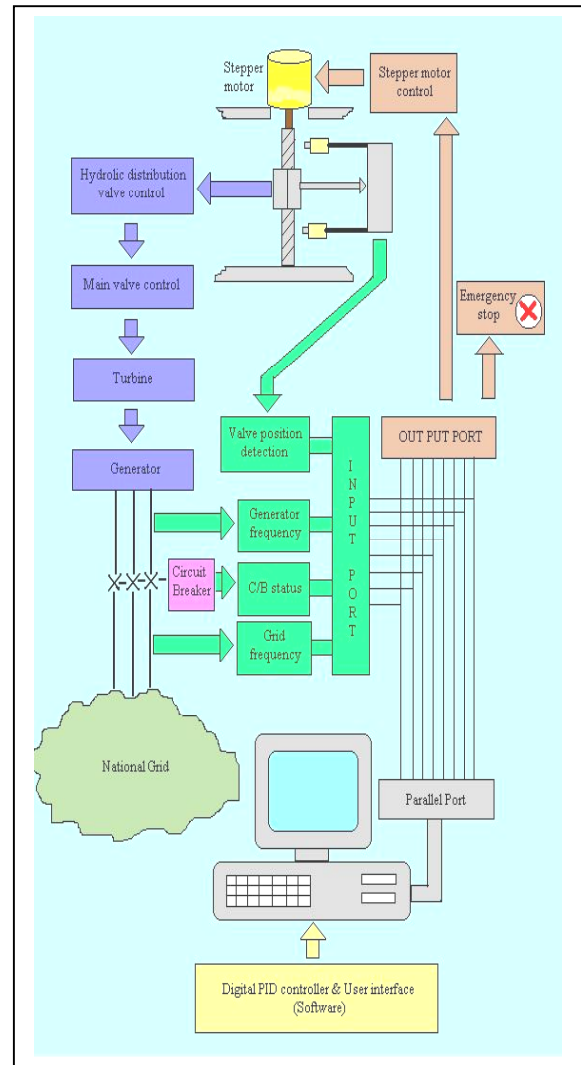The Generator and Grid frequencies are two of the main inputs of the system.

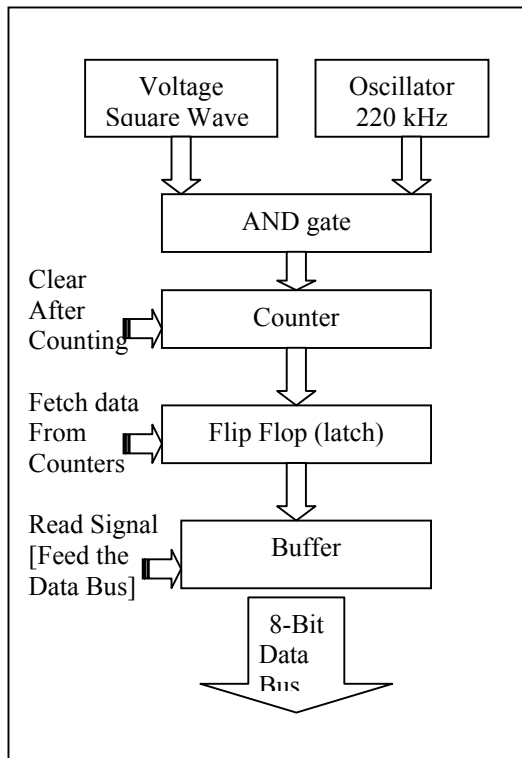Figure1: Basic block diagram of the system.

Figure 3.1: Block Diagram

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. This small but sinusoidal signal is then converted to a square wave by using a Schmidt trigger. This unit also isolates the frequency counters and rest of the circuitry from the large voltage samples of grid and generator.

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 number of zero-crossings of the sampled signal. Which is the number of output pulses of the AND gate, up to a maximum of 64k. 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 software acts like the operating system of a computer that integrates all the devices and communicates with each and every device while doing the necessary processing tasks. The data bus is 8bit and the frequency output is 16bit. Therefore the full word length of the frequency counter output is divided to two fragments of 8bit each.

The 8bit fragment of the number containing most significant 8bits are weighted and added to the lower 8bits. Then that number is converted to frequency units in hertz. The counter is calibrated to have a premium accuracy near 50Hz, where small frequency fluctuations should also be considered at the point of synchronizing.
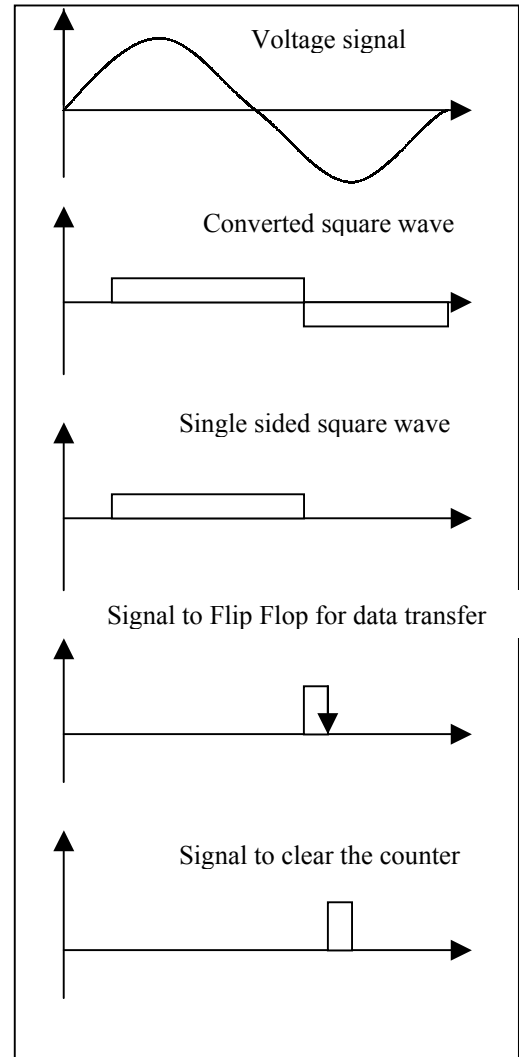

Figure 3.2: Frequency Counter Signals

Oscillator circuit is used to generate clock pulse of 220kHz to use in the frequency counters and in the stepper motor driver circuit.

3.2 Stepper Motor Driver

The inlet valve of the turbine is moved by a hydraulic mechanism. That is by controlling the flow of the pressurized fluid, by using a stepper motor. 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 uni-polar and bi-polar stepper motors.

3.3 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 flush" of the data bus.

Pin No	Control No	Device Connected
1	43	Grid Freq High 8bit (Input)
2	42	Grid Freq Low 8bit (Input)
3	9	Stepper Load Signal (Out)
4	40	Circuit Breaker Signal (In)
5	47	Generator Freq High 8bit
6	46	Generator Freq Low 8bit
7	13	Stepper Latch (Out)
8	12	Emergency Relay (Out)
9	35	Limit Switches (In)
10	34	Water Level (Input)
11	33	
12	GND	
13	32	
14	7	Data Flush (Out)
15	38	
16	37	

There is provision to plug few more devices and they can be used for protection alarms or any other device.

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 WindowsNT.

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 in to the main board.

There are 25 pins in the parallel port (known as printer port). Pin number 2 to 9 are data lines and they are used to input and output data (bidirectional). 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.

Pin assignments of the parallel port.

Pin No:	Port	Printer Port Signal
2	Data	Data 0 (LSB)
3	Data	Data 1
4	Data	Data 2
5	Data	Data 3
6	Data	Data 4
7	Data	Data 5
8	Data	Data 6
9	Data	Data 7 (MSB)
1	Control	Strobe (Inverted logic)
14	Control	Auto Feed (Inverted)
16	Control	INIT
17	Control	Select In (Inverted)

The software gets frequency inputs and uses those values in the PID loop. The PID (proportional integral derivative) controller is modeled using the software that decides the number of steps to open or close valves to build the frequency of the generator when synchronizing the generator.

4.1 PID Controller Model
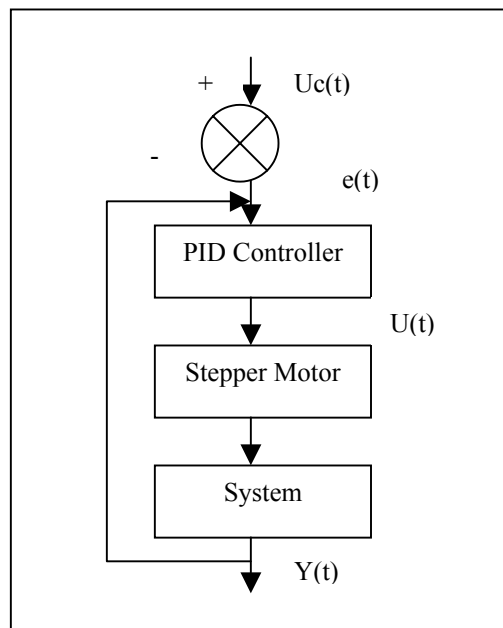
Uc(t)   - Grid Frequency
Y(t)   - Generator Frequency
U(t)   - PID output

PID Controller Function:-

$$u(t)=K[e(t)+1/Ti\int e(x)\ dx + Td\ de(f)/dt\ ]$$

$$U(s) =K[E(s)+1/s\ Ti\ E(s)+s\ Td\ E(s)]$$

The software Implimentation

P = K * (b * Fgrid - Fgenerator)
 I = Iold + K * h * (Fgrid - Fgenerator) / Ti
D = (Td / (Td + N * h)) * Dold
       -K*Td* N * (Fgenerator - Fgeneratorold)
V = P + I + D

The software allows changing values of the PID constants. Therefore the tuning of the turbine can be easily done with the software.

There are three modes of operation. Those are Frequency Mode- Used for synchronizing
Power Mode-   Power is delivered utilizing the water available.
Water Level Mode-

4.2 Flow Chart

For tuning purposes the Test Mode has been introduced.

The features of this system

1.Better controllability
2.Enhancements in monitoring with GUI
3.Easy tuning
4.Automatic data logging facility