DEVELOPMENT OF PLC BASED CONTROLS FOR A HYDROELECTRIC POWER PLANT

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

ELECTRICAL ENGINEERING

(With Specialization in Measurement and Instrumentation)

By

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JUNE, 2006

I D NO. MT-328/2006-23/PSSK-HKV

CANDIDATE'S DECLARATION

I hereby declare that the work presented in the dissertation entitled **"Development of PLC Based Controls for a Hydroelectric Power Plant"** submitted in the partial fulfillment of the requirement of the award of degree of **Master of Technology** in **Electrical Engineering** with specialization in **Measurement and Instrumentation** in the **Department of Electrical Engineering, Indian Institute of Technology Roorkee** is an authentic record of my own work carried out from July 2005 to June 2006 under the guidance and supervision of **Dr.H.K.Verma (Professor, EED, IITR)**

I have not submitted the matter embodied in the report for award of any other degree or diploma.

Date: 26 June, 2006

Place: Roorkee

(P S SAI KRISHNA)

This is to certify that the above statement made by the candidate is true to the best of my knowledge and belief.

26/6/06

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ACKNOWLEDGEMENTS

I express my deep sense of gratitude and indebtedness to my guide **Prof.H.K.Verma,** Department of Electrical Engineering, Indian Institute of Technology Roorkee, India for his guidance and constructive suggestions for successful completion of the thesis.

Words are inadequate to express my thanks to **Mr. Arun Kumar, Head of the department, R.P Saini (Scientific officer) and S.N.Singh (Scientific officer) of Alternate Hydro Energy Center, IIT Roorkee** for providing the necessary facilities to carry out the thesis work.

My sincere thanks and special appreciation goes to **Sasank Patnaik (JRF)** at Alternate Hydro energy center for his constant help, suggestions and discussion and for creating a friendly environment in the department.

I am also thankful to the **Suresh Chand (T.A), Avatar Singh Addi (T.A), Shyam Kumar (T.A) and Khub Chand (Lab Assistant)** of Hydro-mechanical lab at Alternate hydro Energy center for their constant help and motivation while carrying out my thesis work.

Last but not the least, my heartiest gratitude to my **parents and family members** for their continuous encouragement and blessing. Without their support this work would not have been possible.

ABSTRACT

A hydro power station needs simultaneous measurement and control of a number of variables located in different places in the station using suitable instruments placed close to the respective variables. The measurement data from these instruments can be acquired and control implemented simultaneously, centrally and reliably by networking them with a computer using RS-485 for communications [1].

The thesis work is carried out taking a hydro-turbine generator test rig in the laboratory of Alternate Hydro Energy Centre as the test system of 1.5 kW capacity.

The measurement data is acquired from the remote data acquisition modules namely analog input module and frequency/counter module. Speed and load control are implemented using digital output module whereas the excitation control is implemented using analog output module. All these modules are connected to the PC by means of RS-485 network. The RS-232 port of the PC is converted to RS-485 port using a RS-232 to RS-485 converter module.

Data acquisition and control logic is implemented in Labview by calling the appropriate SubVI's corresponding to the remote data acquisition modules. This enables online monitoring of five parameters speed, inlet head, outlet head, valve position, differential pressure at Venturi and consequent control of three parameters namely speed, load and excitation.

LIST OF FIGURES

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1. INTRODUCTION

The schematic of the hydro-turbine generator test setup is shown below in figure 1-1.

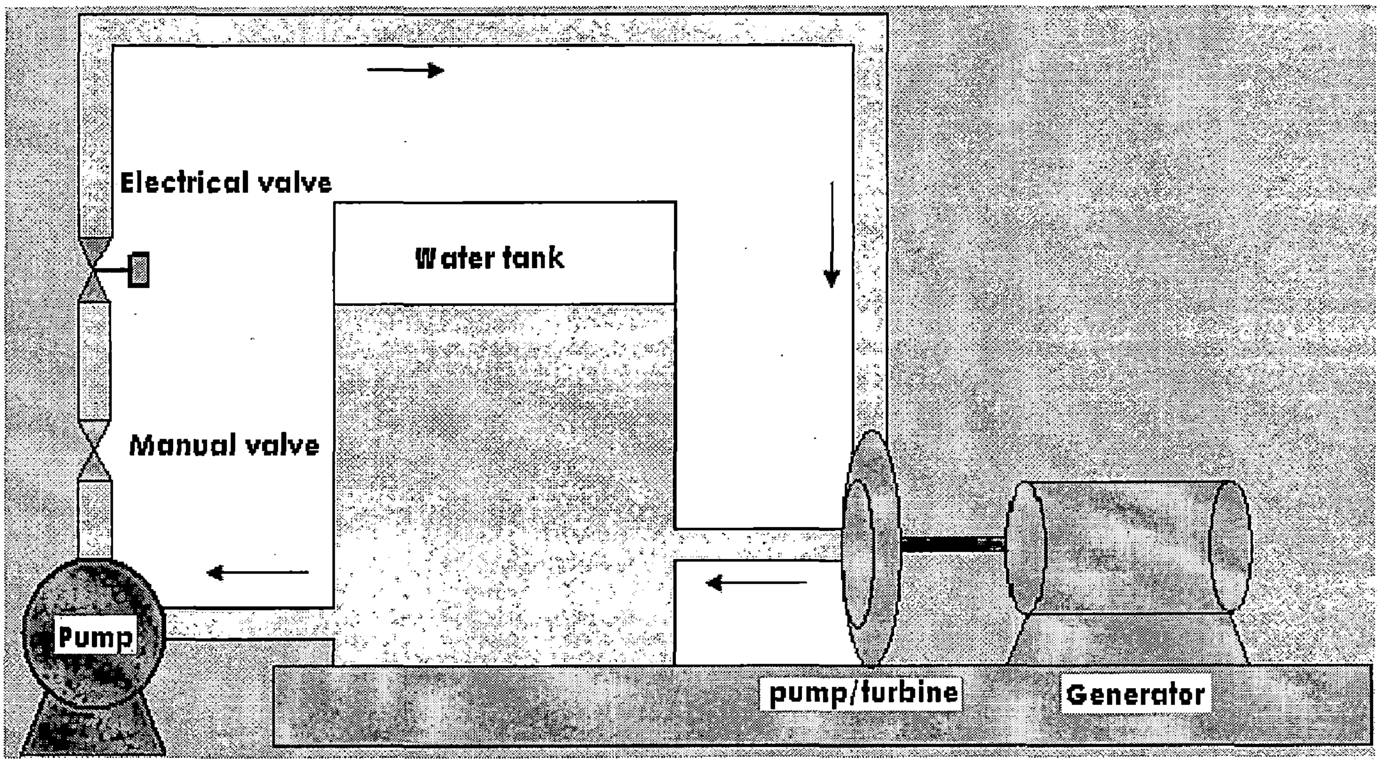


Figure 1-1: Hydro-turbine generator test rig

It consists of a pump which creates the necessary head and discharge for the turbine. In its suction is a water tank wherein water is drawn by the impeller and pumped into a pump-turbine (It acts as a pump depending on the direction of water flow). The water flow to the turbine can be adjusted by means of a manual control valve or an electrical valve. If electrical control valve is used then the manual valve is kept fully open

The Generator is coupled to the turbine by means of a shaft. The generator terminals are in turn connected to load (bulb load) through the Load control circuit.

The load consists of 5 rows of lamps with 3 lamps in each row and they are arranged such that all the 5 bulbs in one column which are connected to a phase, as the generator is of three phase all the lamps are accommodated.

The objective of the thesis work is to develop a Labview based automation system with following capabilities:

- Online monitoring of parameters like speed, inlet head, outlet head, valve position, D.P (Venturi tube) and thereby flow
- Speed control
- Load control
- Excitation Control
- Front panel GUI and control logic using Labview Real time professional 6.0.2

The block diagram of the setup is shown in figure 1-2.

All these modules are connected to the PC by means of RS-485 network. The RS-232 output from the PC is converted to RS-485 using a RS-232 to RS-485 converter module.

Analog Input Module:

It is a data acquisition module which accepts Analog inputs only. There are 8 channels present in the module which can configured. Only 4 channels are used for acquisition of measurement data they are as under:

- Inlet head transmitter input which is a current signal in the range 4-20 mA
- Outlet head transmitter input which is a current signal in the range 4-20 mA
- Valve position input which is a voltage signal
- D.P transmitter output which is current signal in the range 4-20 mA.

Frequency/Counter Module:

It accepts pulse inputs. It has two channels and options for their use as

- frequency input channel 0, frequency input channel 1 in isolated and non isolated mode
- Counter input channel 0 and counter input channel 1 in isolated and non isolated mode

Here a total of 4 channels can be used which can be a combination of above options.

In the present work only one frequency input channel is used in non-isolated mode for frequency measurement of the pulses from the speed sensor.

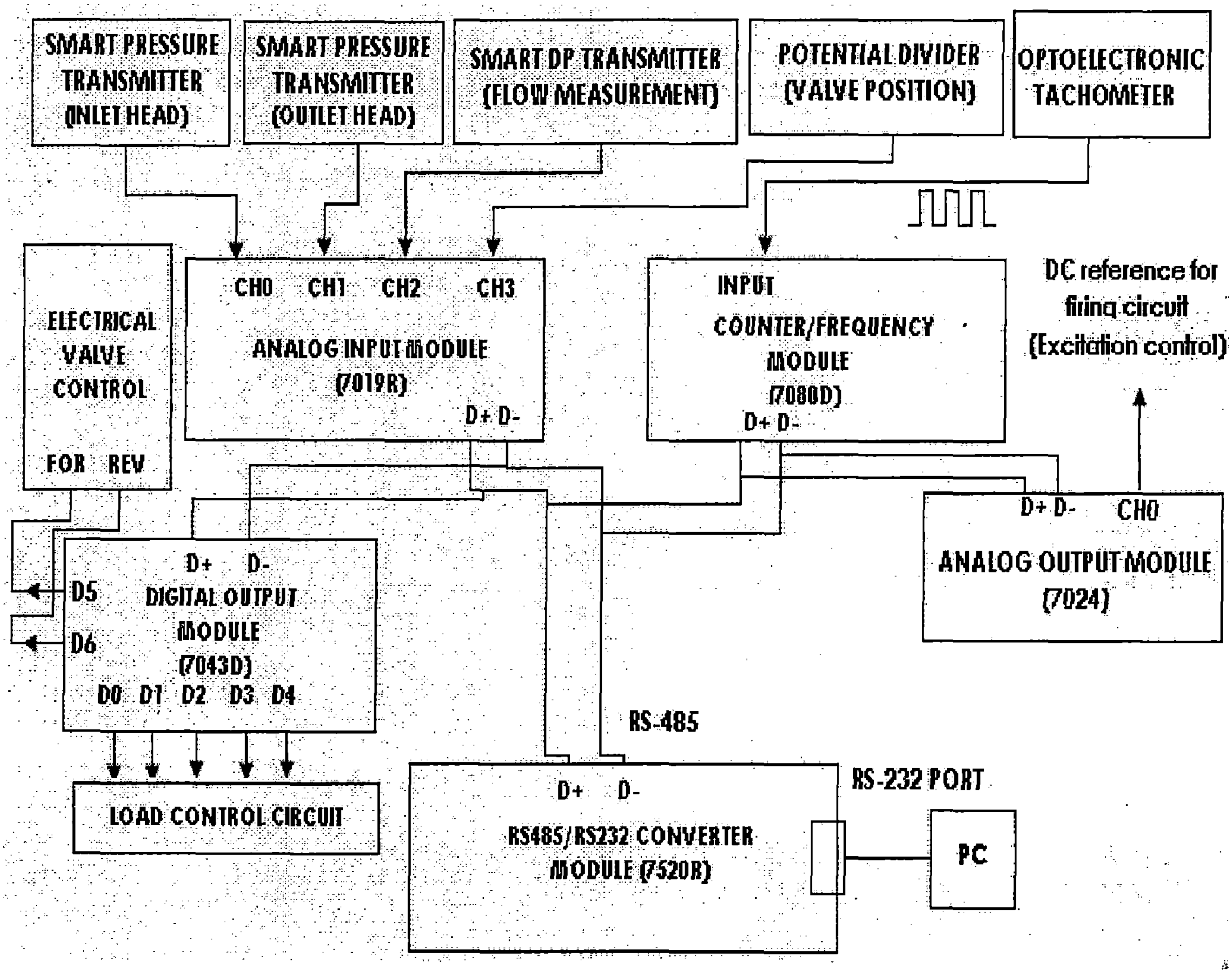


Figure 1-2: Block diagram of measurement and control setup

Digital Output module:

It has open collector digital outputs with 16 output channels out of 5 are used for Load control using contactors and 2 are used for speed control by electrical actuator

Analog output Module:

It has 4 analog output channels whose outputs can be configured as either as voltage or current signal. In the present work only one channel is used for analog output with 0 to 5V range. This voltage is a DC reference for the firing angle circuit for a half controlled Thyristor bridge.

Chapter 2 explains serial port communication using RS-232, RS-485 and necessary hardware. Chapter 3 gives specifications of all the remote data acquisition modules and details of how to configure these modules using DCON utility software. Chapter 4 gives the details of hydro-turbine generator test rig and instruments used for measuring flow, D.P, inlet and outlet head. Chapter 5 explains the basic introduction to Labview and details of how to go for data acquisition and control. Chapter 6,7 and 8 give the details of load, speed and Excitation controls using DAQ modules and Labview.

Chapter 9 gives the conclusion of the work and future work that can be carried out on the set up.

2. SERIAL PORT COMMUNICATION

2.1 Introduction:

All personal computers are typically equipped with two serial ports and one parallel port. Although these two types of ports are used for communicating with external devices, they work in different ways. A parallel port sends and receives data eight bits at a time over 8 separate wires. This allows data to be transferred very quickly; however, the cable required is more bulky because of the number of individual wires it must contain. Parallel ports are typically used to connect a PC to a printer and are rarely used for much else.

On the other hand a serial port sends and receives data one bit at a time over one wire. While it takes eight times as long to transfer each byte of data this way, only a few wires are required. In fact, two-way (full duplex) communications is possible with only three separate wires - one to send, one to receive, and a common signal ground wire.

2.2 Bidirectional Communication:

The serial port on a PC is a full-duplex device which means that it can send and receive data at the same time. In order to be able to do this, it uses separate lines for transmitting and receiving data.

Once the start bit has been sent, the transmitter sends the actual data bits. There may either be 5, 6, 7, or 8 data bits, depending on the number of bits it is configured. Both receiver and the transmitter must agree on the number of data bits, as well as the baud rate. Almost all devices transmit data using either 7 or 8 data bits. After the data has been transmitted, a stop bit is sent. A stop bit has a value of 1 - or a mark state - and it can be detected correctly even if the previous data bit also had a value of 1. This is accomplished by the stop bit's duration. Stop bits can be 1, 1.5, or 2 bit periods in length, here 1.5 means that the stop bit is ON for a duration one and a half that of a normal data bit duration.

Besides the synchronization provided by the use of start and stop bits, an additional bit called a parity bit may optionally be transmitted along with the data. A parity bit affords a small amount of error checking, to help detect data corruption that might occur during transmission.

2.3 RS-232 Standard:

RS-232 stands for Recommend Standard number 232 and C is the latest revision of the standard. The serial ports on most computers use a subset of the RS-232C standard. The full RS-232C standard specifies a 25-pin "D" connector of which 22 pins are used. Most of these pins are not needed for normal PC communications. Most new PCs are equipped with male D type connectors having only 9 pins [6].

2.3.1 Electrical Voltages:

The RS232 signals are represented by voltage levels with respect to a system common (power / logic ground). The "idle" state (MARK) has the signal level negative with respect to common, and the "active" state (SPACE) has the signal level positive with respect to common. RS232 has numerous handshaking lines primarily used with modems, and also specifies a communications protocol [6].

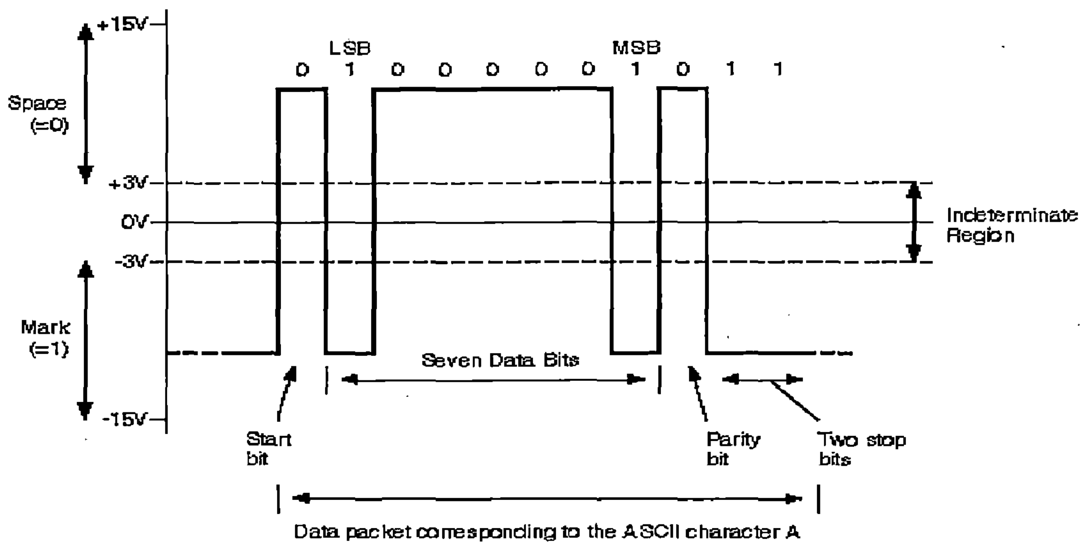


Figure 2-1: Data signal in RS-232 format

The figure 2-1 above shows the data format of RS-232.

RS232 data is bi-polar, +3 TO +15 volts indicates an "ON or 0-state (SPACE) condition" while A -3 to -15 volts indicates an "OFF" 1-state (MARK) condition. Modern computer equipment ignores the negative level and accepts a zero voltage level as the "OFF" state. In fact, the "ON" state may be achieved with lesser positive potential. This means circuits powered by 5 VDC are capable of driving RS232 circuits directly, however, the overall range that the RS-232 signal may be transmitted/received may be reduced considerably. The output signal level usually swings between +12V and -12V. The "dead area" between +3V and -3V is designed to absorb line noise.

2.3.2 DCE and DTE devices:

DTE stands for Data Terminal Equipment, and DCE stands for Data Communications Equipment. These terms are used to indicate the pin-out for the connectors on a device and the direction of the signals on the pins. Computer is a DTE device, while most other devices are usually DCE devices.

The RS-232 standard states that DTE devices use a 25-pin male connector, and DCE devices use a 25-pin female connector. One can therefore connect a DTE device to a DCE using a straight pin-for-pin connection. However, to connect two like devices, we must instead use a null modem cable. Null modem cables cross the transmit and receive lines in the cable. The listing shown in figure 2-2 and 2-3 below are connections and signal directions for both 25 and 9-pin connectors.

The **TD (transmit data)** wire is the one through which data from a DTE device is transmitted to a DCE device.. The TD line is kept in a mark condition by the DTE device when it is idle. The **RD (receive data)** wire is the one on which data is received by a DTE device, and the DCE device keeps this line in a mark condition when idle. **RTS** stands for **Request to Send**. This line and the CTS line are used when **"hardware flow control"** is enabled in both the DTE and DCE devices. The DTE device puts this line in a mark condition to tell the remote device that it is ready and able to receive data.

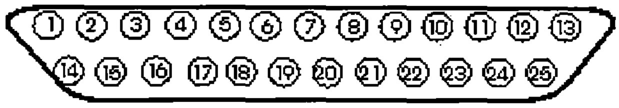
	25 Pin Connector on a DTE device (PC connection)
Male RS232 DB25	
Pin Number	**Direction of signal:**
1	Protective Ground
2	Transmitted Data (TD) Outgoing Data (from a DTE to a DCE)
3	Received Data (RD) Incoming Data (from a DCE to a DTE)
4	Request To Send (RTS) Outgoing flow control signal controlled by DTE
5	Clear To Send (CTS) Incoming flow control signal controlled by DCE
6	Data Set Ready (DSR) Incoming handshaking signal controlled by DCE
7	Signal Ground Common reference voltage
8	Carrier Detect (CD) Incoming signal from a modem
20	Data Terminal Ready (DTR) Outgoing handshaking signal controlled by DTE
22	Ring Indicator (RI) Incoming signal from a modem

Figure 2-2: 25 pin connector on DTE device

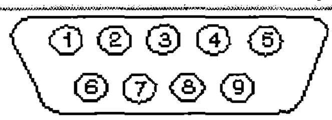
	9 Pin Connector on a DTE device (PC connection)
Male RS232 DB9	
Pin Number	**Direction of signal:**
1	Carrier Detect (CD) (from DCE) Incoming signal from a modem
2	Received Data (RD) Incoming Data from a DCE
3	Transmitted Data (TD) Outgoing Data to a DCE
4	Data Terminal Ready (DTR) Outgoing handshaking signal
5	Signal Ground Common reference voltage
6	Data Set Ready (DSR) Incoming handshaking signal
7	Request To Send (RTS) Outgoing flow control signal
8	Clear To Send (CTS) Incoming flow control signal
9	Ring Indicator (RI) (from DCE) Incoming signal from a modem

Figure 2-3: 9 pin connector on DTE device

If the DTE device is not able to receive data (typically because its receive buffer is almost full), it will put this line in the space condition as a signal to the DCE to stop sending data. When the DTE device is ready to receive more data (i.e. after data has been removed from its receive buffer), it will place this line back in the mark condition.

The complement of the RTS wire is CTS, which stands for Clear To Send. The DCE device puts this line in a mark condition to tell the DTE device that it is ready to receive the data. Likewise, if the DCE device is unable to receive data, it will place this line in the space condition. Together, these two lines make up what is called RTS/CTS or "hardware" flow control.

The Software Wedge supports this type of flow control, as well as Xon/XOff or **"software" flow control.** Software flow control uses special control characters transmitted from one device to another to tell the other device to stop or start sending data. With software flow control the RTS and CTS lines are not used.

DTR stands for **Data Terminal Ready**. Its intended function is very similar to the RTS line. DSR (Data Set Ready) is the companion to DTR in the same way that CTS is to RTS. Some serial devices use DTR and DSR as signals to simply confirm that a device is connected and is turned on. The Software Wedge sets DTR to the mark state when the serial port is opened and leaves it in that state until the port is closed. The DTR and DSR lines were originally designed to provide an alternate method of hardware handshaking. It would be pointless to use both RTS/CTS and DTR/DSR for flow control signals at the same time. Because of this, DTR and DSR are rarely used for flow control.

CD stands for **Carrier Detect.** Carrier Detect is used by a modem to signal that it has a made a connection with another modem, or has detected a carrier tone.

The last line is **RI** or **Ring Indicator**. A modem toggles the state of this line when an incoming call rings your phone. The Carrier Detect (CD) and the Ring Indicator (RI) lines are only available in connections to a modem. Because most modems transmit status information to a PC when either a carrier signal is detected (i.e.

when a connection is made to another modem) or when the line is ringing, these two lines are rarely used.

2.3.3 Null Modem cable and Adapters:

If we connect two DTE devices (or two DCE devices) using a straight RS232 cable, then the transmit line on each device will be connected to the transmit line on the other device and the receive lines will likewise be connected to each other. A Null Modem cable or Null Modem adapter simply crosses the receive and transmit lines so that transmit on one end is connected to receive on the other end and vice versa. In addition to transmit and receive, DTR & DSR, as well as RTS & CTS are also crossed in a Null Modem connection.

2.3.4 RS-485 Standard:

It is a standard for electrical characteristics of generators and receivers used in balanced digital multipoint systems and is meant for multidrop configuration. When communicating at high data rates, or over long distances in real world environments, single-ended methods are often inadequate. **Differential data transmission** (balanced differential signal) offers superior performance in most applications. Differential signals can help nullify the effects of ground shifts and induced noise signals that can appear as common mode voltages on a network.

Data rates of up to 100K bits / second and distances up to 4000 Ft. can be accommodated with RS485. **RS485** meets the requirements for a truly multi-point communications network, and the standard specifies up to 32 drivers and 32 receivers on a single (2-wire) bus. With the introduction of "automatic" repeaters and high-impedance drivers / receivers this "limitation" can be extended to hundreds (or even thousands) of nodes on a network. The voltage level are specified as Logic 1 as Va-Vb: +2 to +6 Volts and Logic 0 as Va-Vb: -2 to -6 Volts

2.3.4 UART:

The core of any serial port is UART, or Universal Asynchronous Receiver-Transmitter. A UART is generally an integrated circuit. It contains the software that converts the parallel data stream to of 8-bytes to into a serial format of single bits, or vice versa [6].

When transmitting data over a serial line, the data is transmitted one bit at a time. When receiving data from a serial line, the UART converts serial back to parallel data for computer CPU use. To transmit data, the UART takes it, breaks it into its constituent bits, and packages it so that the byte can be successfully identified and reassembled by the receiving serial port's UART. This process is called "framing" of byte. The UART then transmits the byte through the wires of serial connection. The UART also manages the way the data is handled between its transmit and receive buffers and the computer's CPU.

3. REMOTE DATA ACQUISITION MODULES

3.1 Introduction:

7000 series is a family of remote controllable data acquisition modules. They provide A/D, D/A, Timer/Counter, MMI, and other functions. These modules can be controlled remotely by a set of commands [7].

3.2 Common features of 7000 series Modules [7]:

3.2.1 Communication :

- Asynchronous half duplex 2-wire RS-485 network.
- Maximum distance without repeater is 4000 feet (1 Km).
- Speed is 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200.
- Connecting 256 modules in one RS-485 network without a repeater.
- Multiple Baud rate and multiple data format can share the same RS-485 bus.
- Different Baud rates and same module address can share the same RS-485 bus.
- Connecting 256*8=2048 modules max in one RS-485 bus with repeater.
- Data format= 1 Start + 8 Data + 1 Stop + no parity = 10-bit.
- Two extra checksum bytes can be enable/disable.
- Built in transient voltage suppresser and PTC protector.
- Sharing the same RS-485 bus with the RS-485 or RS-232 device which communicates in multiple data format (not 10 bit) and multiple baud rate (using RS-232 to RS-485 converter.

3.2.2 Power :

- +10V ~ +30V DC.
- Power reverse protection,

3.2.3 System :

- Dual watchdog inside, power on start value and safe value for host failure.
- Operating temperature: -25 to 75 °C.
- Storage temperature: -25 to 80 °C.
- Humidity: 5 to 95%, non condensing.

3.3 Conventional two wire RS-485 network:

- It uses DIP switch selectable converter to convert host RS-232 to two wire RS-485, the baud rate and data format must be set to a fixed value for the whole network.
- The number of independent RS-485 networks increase as the data format/baud rate changes.
- Modules closer to the host PC will communicate with higher speeds whereas those away from it communicate with a lower speed as because only one speed is possible in RS-485 network.

3.4 7000 series RS-485 network:

It is a multiple Baud rate and multiple data format network system. It has a "self tuner" inside which can detect the baud rate and data format automatically and control the direction of Rs-485 network precisely.

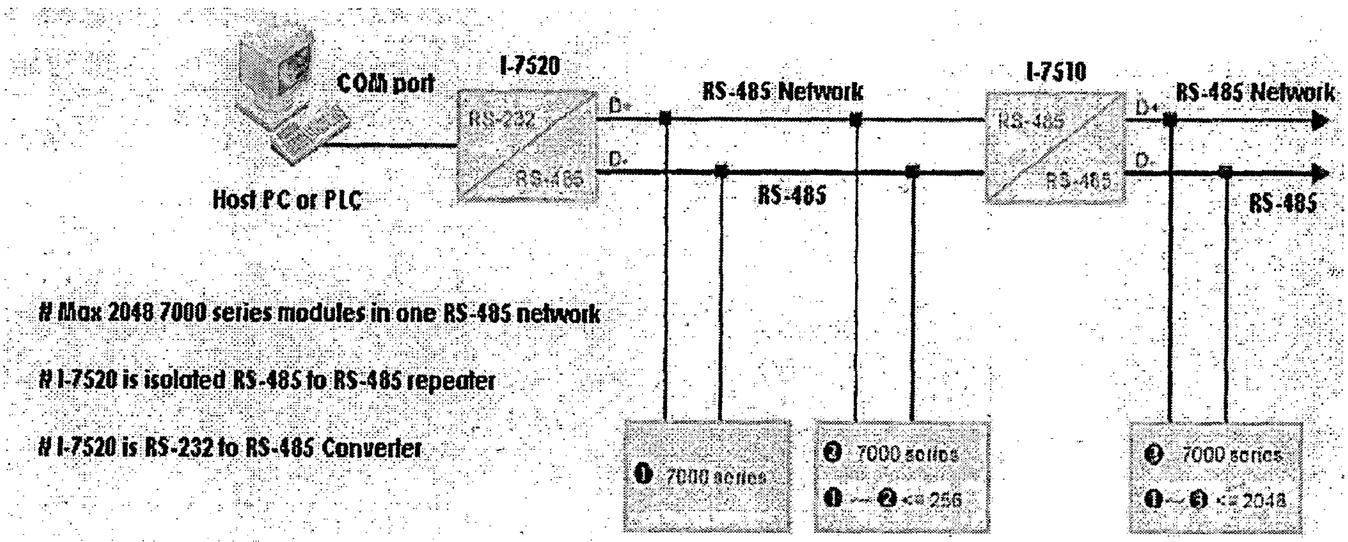


Figure 3-1: 7000 series RS-485 network

The schematic of an I7000 series RS-485 network is shown in figure 3-1.

Operation:

- The host PC sends out commands via COM1 or COM2.
- The 7520R module converts the RS-232 signal to RS-485 signal.
- All the modules connected to the RS-485 network receive command at the same time. Then all the modules will begin extracting the destination address and compare it to its local module address.
- The module with the matched address will continue to execute the host command while other modules will bypass it.
- After executing the host command, the destination module will send the result back to the RS-485 network. The host PC will interpret the result and take necessary action.

3.5 Configuring the modules using DCON Utility [7]:

The Modules are interconnected with D+ and D- lines being connected to the corresponding terminals of 7520R module. The power supply and ground are also connected in the same way. Now the DCON utility software is used to search for the module. The results of the search include the address 1 as default and default configuration from the manufacturer.

The address and configuration can be changed by using the menu. In this way all the modules are connected one by one, suppose there are 4 modules the first module when connected is given address 4 and others are given 3, 2, 1 one after the other .

After the configuration of all the modules when search option is pressed in the DCON utility all the modules with their assigned addresses appear at a time with different address.

3.6 RS-232 to RS-485 Converter (7520R Module) [7]:

Specifications:

- Protocol: two-wire RS-485, (D+, D-), protocol.
- Connector: plug-in screw terminal block.
- Speed: "Self tuner" inside, auto switching Baud rate from 300 to 115200 BPS.
- 256 modules max in one RS-485 network without a repeater.
- 2048 modules max in one RS-485 network with repeater.
- Isolation Voltage: 3000V.
- Isolation site: RS-485.
- Repeater request: 4000 feet or over 256 modules.
- Power requirements: +10V to +30V DC power consumption: 2.2 W (max)

3.7 Digital Output module (7043D) [7]:

Specifications:

- Output Channels: 16
- Isolation: Non-isolation
- Load voltage: Max +30V
- Maximum Load current: 100 mA
- Power Input : +10 V DC to +30 V DC, Consumption: 1.1 W

3.8 Analog Input Module (7019R) [7]:

Specifications:

- Input Channels: 8 differential.
- Input Type: mV, V, mA (jumper selectable).
- Thermocouple Type: J, K, T, E, R, S, B, N, C, L, M.
- Sampling Rate: 8 samples/sec.

- Bandwidth: 5.24 Hz.
- Accuracy: +/- 0.15 %.
- Zero drift:10 μV/°C.
- Span drift: 25 ppm/°C.
- CMRR@50/60Hz: 86dB min.
- Input Impedance: 2MΩ.
- Voltage Overload Protection: +/- 240V.
- Isolation: 3000V.
- Wire Opening Detection: Yes.
- Power requirement: +10 to +30V DC, 1.2 W.

3.9 Counter/Frequency module [7]:

Specifications:

Counter input

- Channels: Two independent 32 bit counters, counter 0&1.
- Input Signal: Isolated or non Isolated Programmable.
- Isolation Input levels: Logic level 0: +1 V max, Logic level 1 : +3.5 to +30 V.
- Isolation voltage: 3750 V rms.
- Non-isolation Input threshold level: programmable; Logic level 0: 0 to +5 V (default 0.8 V); Logic level 1: 0 to +5 V (default 2.4 V).
- Maximum Count: 32 bit (4,294,967,295).
- Programmable digital noise filter: 2 μs to 65 ms.
- Alarming: Alarm on Counter 0 or Counter 0&1, Programmable.
- Counter preset value: Programmable.

Display

- LED Indicator: 5 digit readout, Channel 0 or Channel 1.

Frequency measurement

- Input frequency: 1Hz to 100 KHz max.
- Programmable built in gate time: 1/0.1 sec.

Digital output:

- 2 channels open collector to 30V, 30mA max load.
- Power dissipation: 30mW.

Power

- Power requirements: +10 to +30 V (non-regulated).
- Power consumption: 2.2W.

3.10 Analog output module (7024) [7]:

- Output Channel : 4
- Output Type : mA, V
- Accuracy : ±0.1% of FSR
- Resolution : ±0.02% of FSR
- Zero Drift :

  Voltage output : ±30μV/°C

  Current output : ±0.2μA/°C
- Span Temperature Coefficient : ±20ppm/°C
- Programmable Output Slope : 0.125 to 2048 mA/Second, 0.0625 to 1024 V/Second
- Voltage output: 5mA max
- Current Load Resistance: External 24V:1050 ohms
- Isolation: 3000VDC
- Power supply:

  Input: +10 to 30VDC

  Consumption: 2.3W

4. INSTRUMENTATION FOR HYDRO-TURBINE GENERATOR:

4.1 Complete setup:

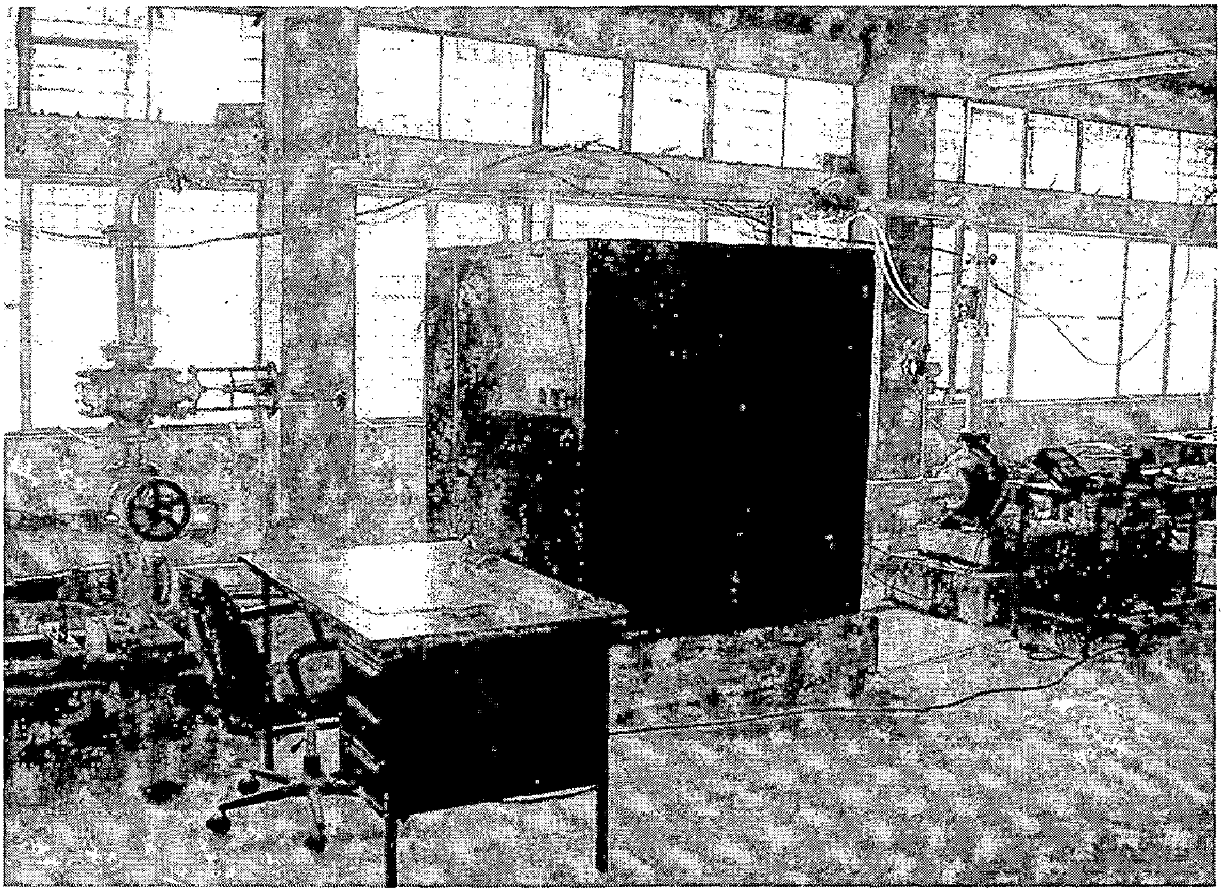


Figure 4-1: Photograph of Complete setup

The schematic of the test rig has already been explained in introduction chapter 1. The following section gives the specifications of turbine and generator in the test rig. Figure 4-1 shows the photograph of the complete setup.

4.2 Pump:

Specifications:

Total head: 32.8 meters

Flow rate: 14.5 liters/sec

Pump input: 8.18kW

Speed: 1450 rpm

The input pump is a constant speed motor pump of 30 H.P and can produce a maximum head of 60 meters and maximum flow of 23.5 Litters.

4.3 Generator:

Terminal voltage: 415V

Reactive power: 12.5kVA

Active power: 10Kw

Power factor: 0.8

Frequency: 50 Hz

Speed: 1500 rpm

Excitation: 23.5V DC, 2.32 Amps

4.4 Smart Pressure Transmitter

4.4.1 Introduction:

The Smar made Smart D.P transmitter is used for the measurement of D.P across the Venturi tube. The main objective of D.P measurement is to make flow measurement online by calibrating the transmitter so that the output current of the transmitter is proportional to the Flow.

The calibration is done using Ultrasonic Flow meter as discussed in **chapter.**

The Smar made Absolute pressure Transmitter is used for the measurement of Inlet and Outlet head of the turbine

4.4.2 Principle of operation:

The SMAR D.P transmitter model LD301 uses, as its measuring principle, the well known and field proven technique of capacitance sensing, enhanced by a microprocessor based electronics [4]. Designed for process control applications, these 2-wire transmitters generate a 4-20 mA signal proportional or characterized to the applied differential pressure. This signal can be transmitted over a pair of twisted wires through long distances (limited only by the wire resistance and load). Digital communication for remote calibration and monitoring is also provided, superimposing a digital signal on the same pair of wires that carries the 4-20 mA signal.

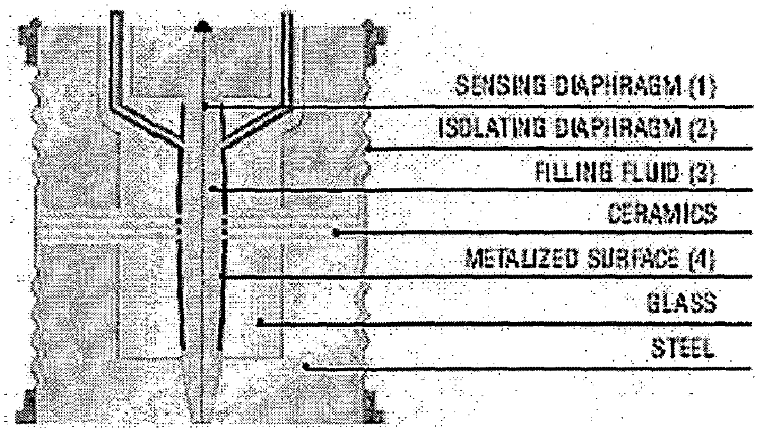


Figure 4-2: Diaphragm of Smart Transmitter

4.4.3 Construction and Working:

The transmitter consists of two main parts. The sensor (a capacitance variation cell) and the electronic circuit. The sensor is schematically shown in the figure 4-2.

A sensing diaphragm (1) is shown at the center of the cell. This diaphragm deflects, as a result of the difference between the pressures applied to the left and right sides of the sensor. These pressures are directly applied to the isolating diaphragms (2), that provide isolation and resistance against process fluid corrosion. The pressure is transmitted to the sensing diaphragm through the filling Fluid (3). The sensing diaphragm is also a moving capacitor plate, and the two metallized surfaces (4) are fixed plates. The sensing diaphragm deflection results in a variation on the capacitances between the moving and fixed plates.

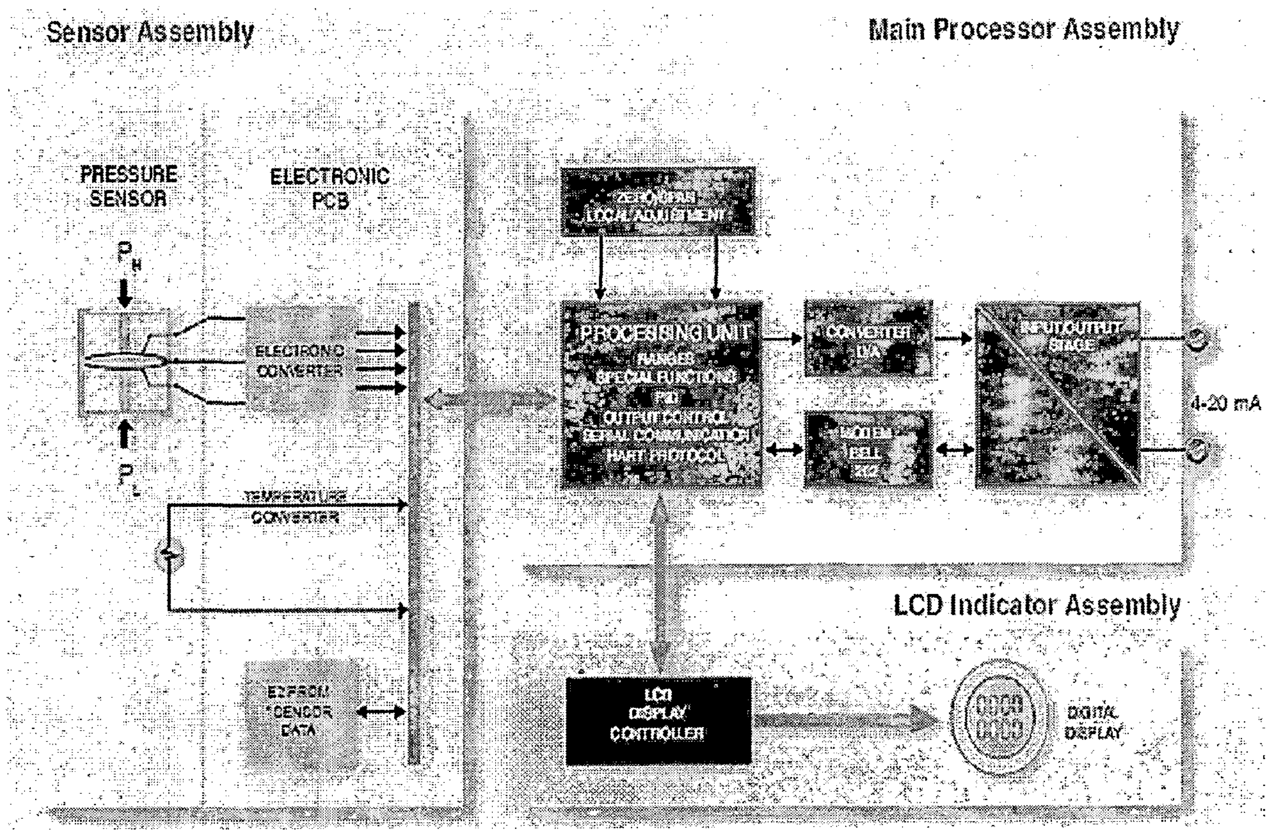


Figure 4-3: Sensor assembly and associated Electronics

The Electronic Circuit measures the variation of the capacitance between the moving and fixed plates, and generates a 4-20 mA signal, that can be proportional to the differential pressure applied or characterized (square root, special function, etc.) to it. Being microprocessor based, the electronic circuit is extremely versatile and accurate. Transmitter performance is improved by continuous monitoring of the sensor temperature and corresponding corrections.

The transmitter can also operate as a combination of transmitter plus controller. In this case, the 4-20 mA signal is used as the output of a PID control function which is optional, while the digital signal may be used for remote monitoring and operation.

4.4.4 Features:

- 0.075% Accuracy
- 120:1 Rangeabilty

- Direct digital capacitance sensing (No A/D conversion)
- 4-20 mA output and direct digital communication (HART Protocol)
- Remote and Local calibration
- Online and offline programming
- Password protection
- Multi-drop operation mode
- Optional 4-1/2 digit numerical and 5 character alphanumerical LCD indicator
- Capable of handling most process fluids
- Explosion and weather proof housing
- Optional PID control function
- User selectable units
- Constant Signal Generation for loop tests

4.4.5 Electrical Connections:

There are two different types of terminals i.e. the terminals and the communication terminals that allow respectively to measure the current in the 4-20 mA loop without opening and communicating with the transmitter.

To measure it connect a multimeter in the mA scale in the "–" and "+ " terminals and to communicate we can use a HART configerator in "COMM " and "-" terminals.

Figure 4-4 and 4-5 shows how the connections are made.

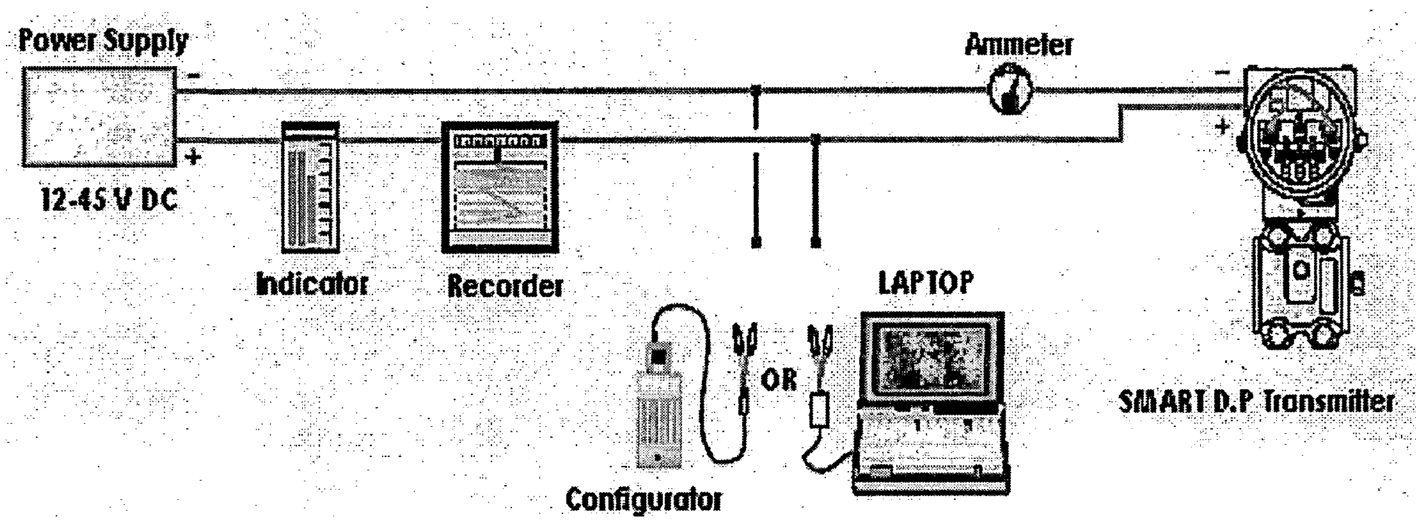


Figure 4-4: Connection diagram of smart transmitter

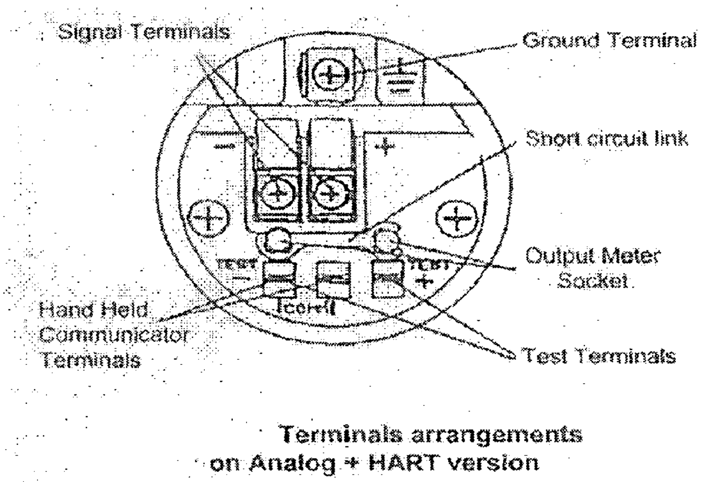


Figure 4-5: Transmitter terminals

It is made sure that the transmitter is in the operating area as shown in figure 4-6. It is understood that Communication requires a minimum of 250Ω resistor.

Care should be take to make sure that power supply is sufficient when many transmitters are connected as the voltage drop across the load resistance would be high.

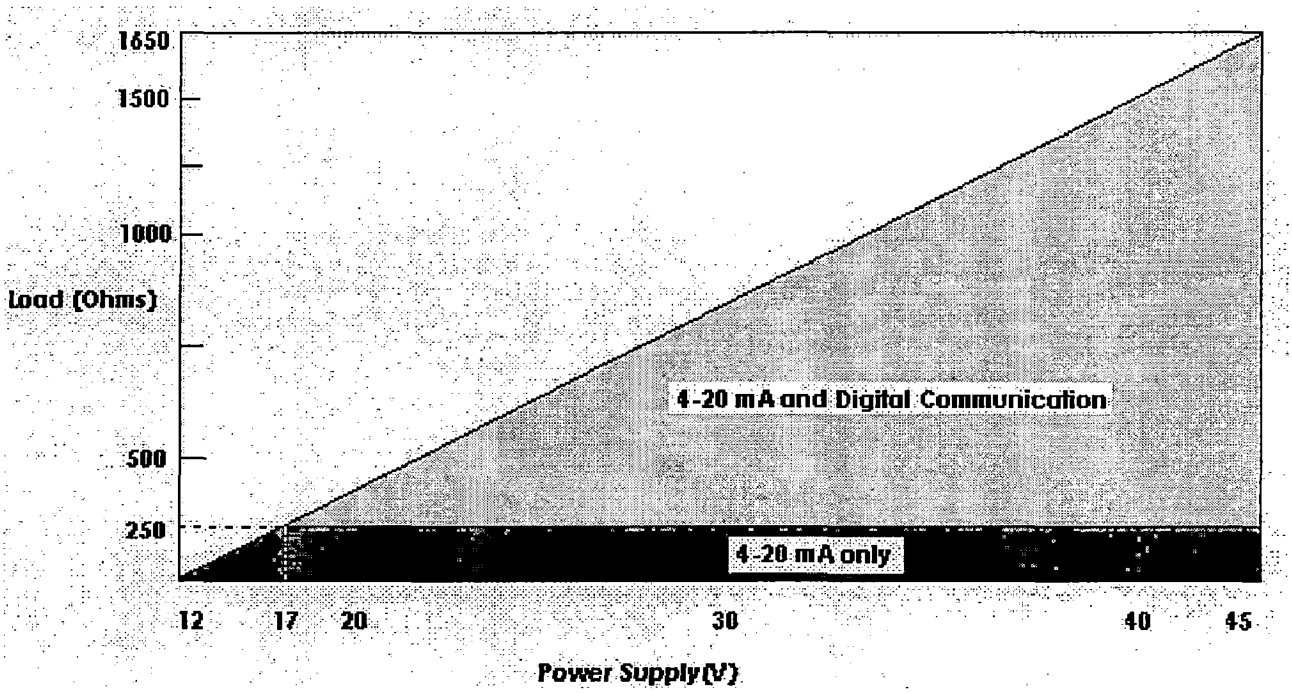


Figure 4-6: Load Curve

4.4.6 Mounting and calibration of D.P Transmitter:

Mounting:

The overall accuracy of D.P measurement depends on several variables like environmental conditions like temperature, humidity and vibration. The transmitter has a built in temperature sensor to compensate for temperature variations. Humidity protection is provided by means of O-rings for electronic housing.

The transmitter is mounted on the pipeline entering the turbine and care is taken so that that the two pressure input connections are at the same level with respect to a standard or datum head, to ensure this spirit level is used to check whether the transmitter is mounted properly or not .

When the bubble of the spirit level is at the center it is understood that the transmitter is mounted correctly and also the D.P indicated should be zero under no flow condition.

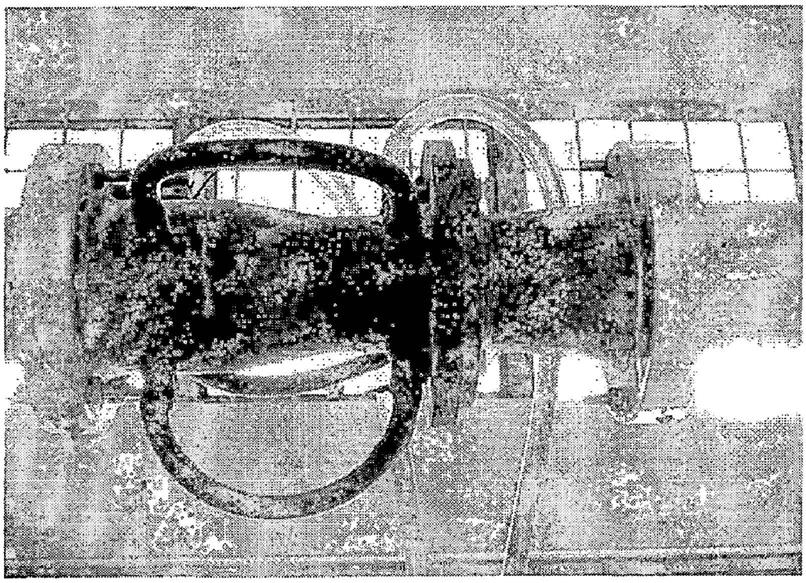


Figure 4-7: Venturi tube

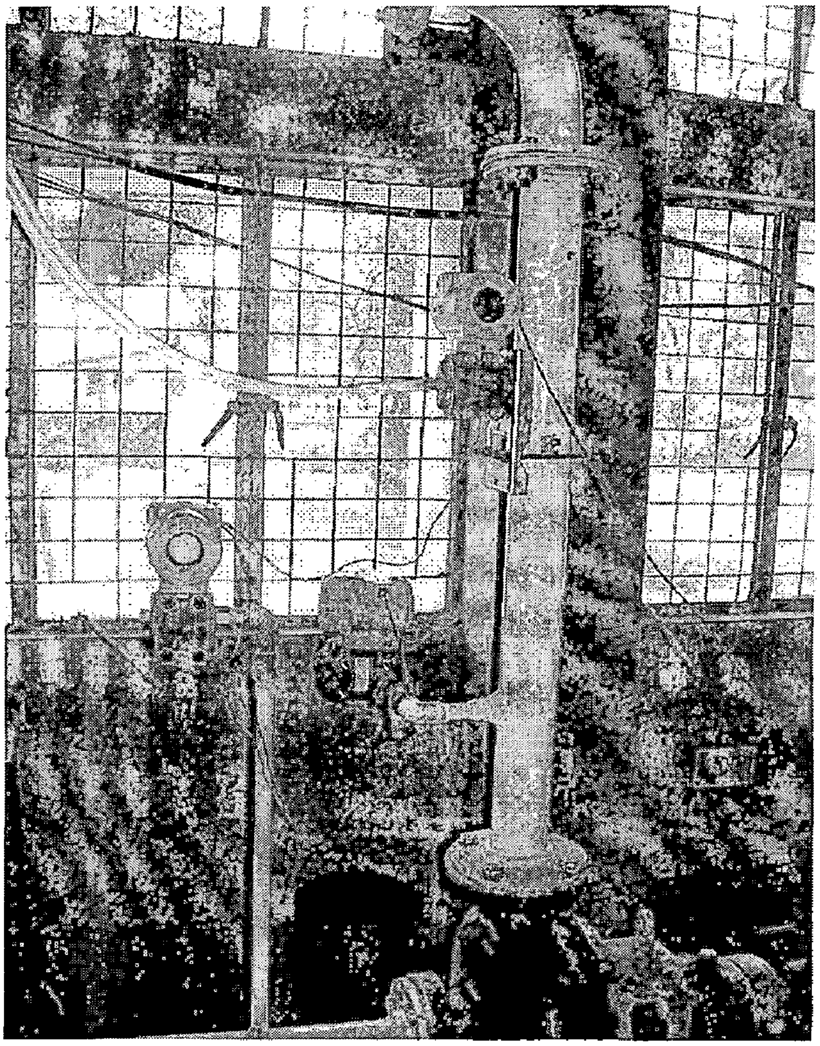


Figure 4-8: Smart differential transmitter

After mounting it correctly the connections from the Venturi tube to the D.P transmitter are made only after the air bubbles are removed in the two lines. Figure 4-7 and 4-8 shows the actual installation.

4.4.7 Calibration:

There are two types of calibrations:

1. Calibration with Reference: This is used to adjust the transmitter's working range using a pressure standard as reference
2. Calibration without Reference: This is used to adjust the transmitter working range simply by having limit values informed by the user.

When the transmitter is used for the first time it is adjusted to the working range as suitable to the D.P measurement. There is no need of recalibration, i.e. the second type of calibration is used.

- The D.P transmitter used and now its working range is adjusted from 0 to 3000 mm water column so that the transmitter outputs 4 mA for 0 mm water column and 20mA for 3000 mm water column.
- The transmitter output current is to be made proportional to flow and hence a set of reading with D.P Vs Discharge are noted down.
- The transmitter is now configured to give an output in terms of square-root of differential pressure that means that the output current is proportional to square-root of D.P. A plot between the square root D.P and discharge is drawn and it is seen that it is a straight line.
- Obtaining the equation of the linear curve as y=mx+c, fit the corresponding relation ship between them is fed into the Labview program, Now the online measurement of flow can be done using in Labview

Figure 4-9 and 4-10 shows the Sqrt(D.P) Vs Discharge plot.

4.4.8 SQRT (D.P) Vs Flow readings

SQRT(Differential Pressure)	Flow (Liters/Sec)
0	0
2.5	1.2
5.0	2.1
7.5	3.5
10.0	4.8
12.5	5.9
15.0	7.0
17.5	8.2
20.0	9.5
22.5	10.5
25.5	12.1
28.7	13.5
32.7	15.4
37.7	17.8
40.3	18.8
42.9	19.8
44.7	21.0
47.2	22.46
48.4	23.0
49.4	23.4
50.0	23.8

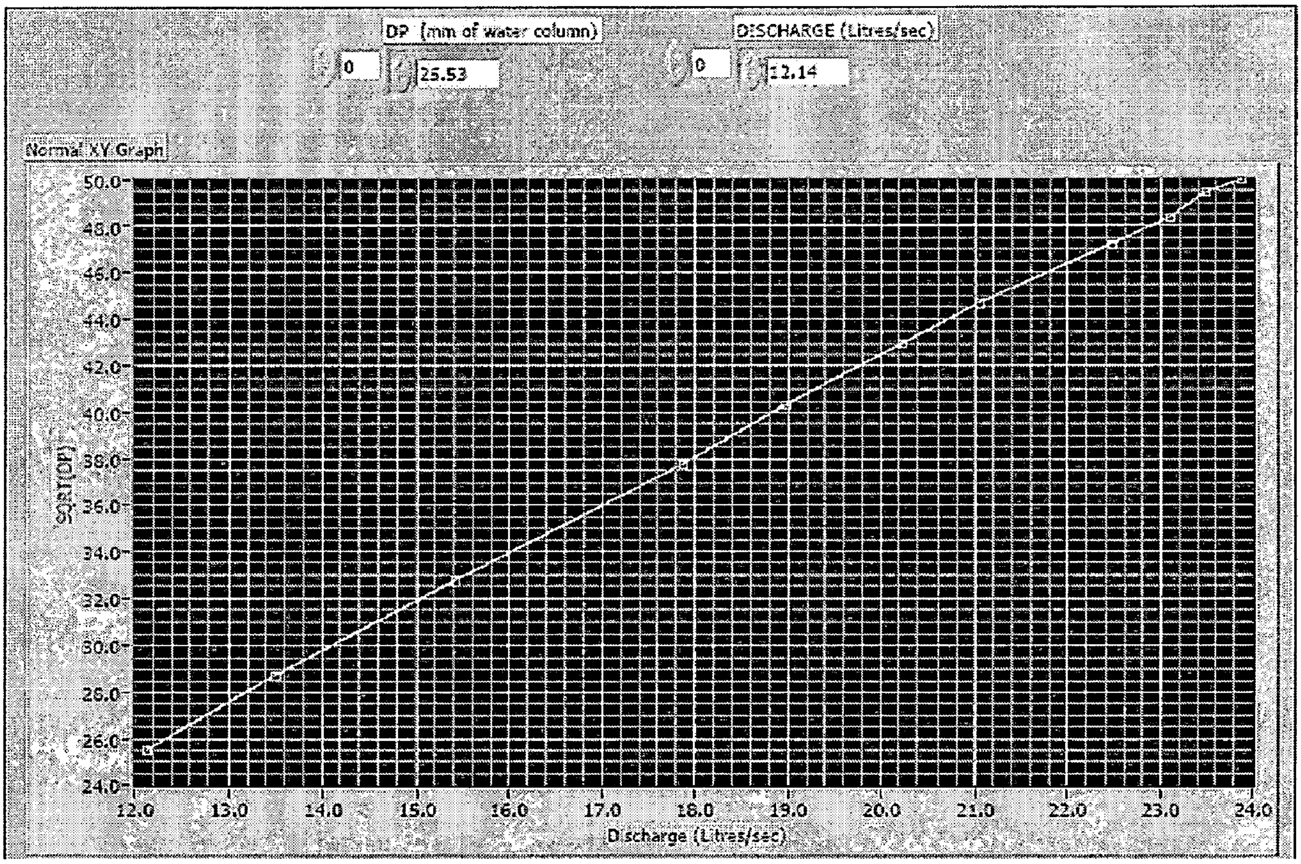


Figure 4-9: DP Vs SQRT (Discharge)

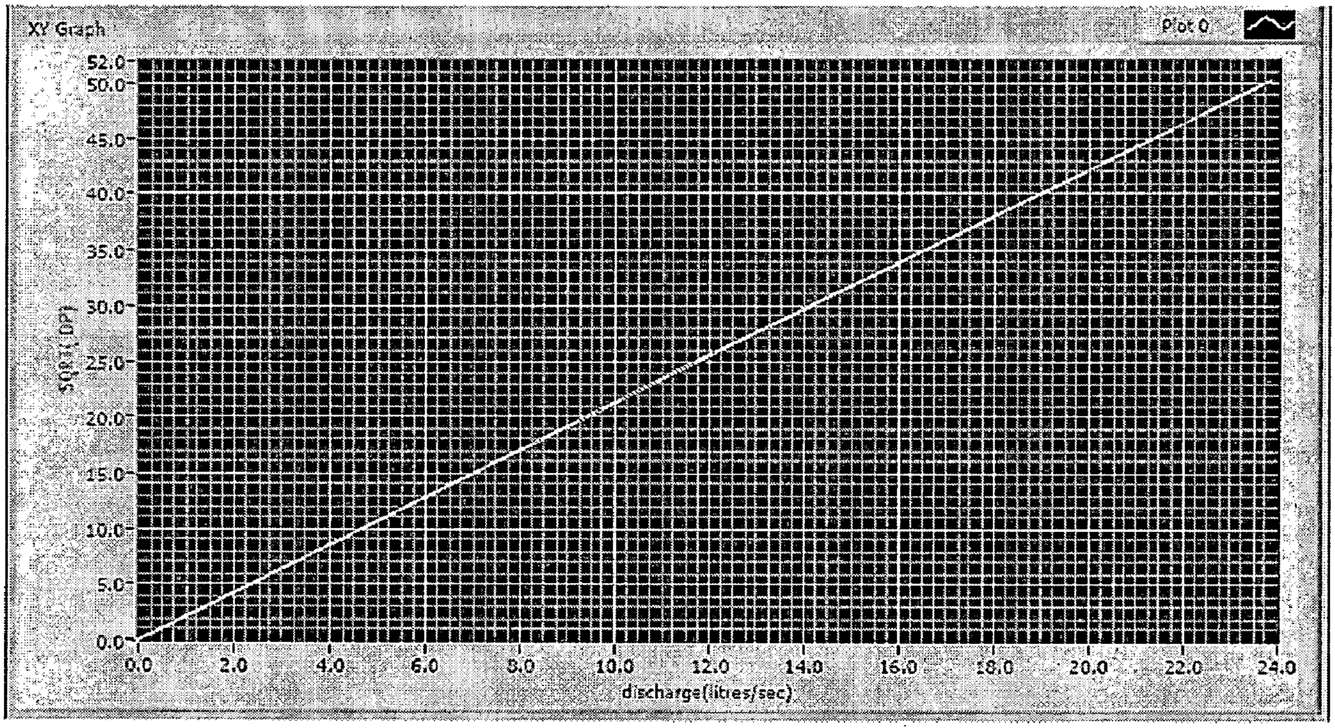


Figure 4-10: DP Vs SQRT (Discharge) linear fit

4.4.9 Mounting and calibration of Absolute Pressure Transmitter:

Mounting:

A chamber is welded on one side of the sensor and then vacuum sealed. Pressure is applied to the other side of the sensor.

The mounting of an absolute pressure transmitter is simpler compared to a D.P transmitter. Here the only thing to be taken care of is the height above or below which the transmitter is mounted with respect to the point of Head measurement , usually it is mounted in line with that the pipe carrying the fluid , this is due to the fact that a small error depending on the head above or the pressure tapping point makes a small difference which is usually negligible for high head applications.

For water as fluid the head of 10 meters is equivalent to an absolute pressure of 1 Kg/cm^2.

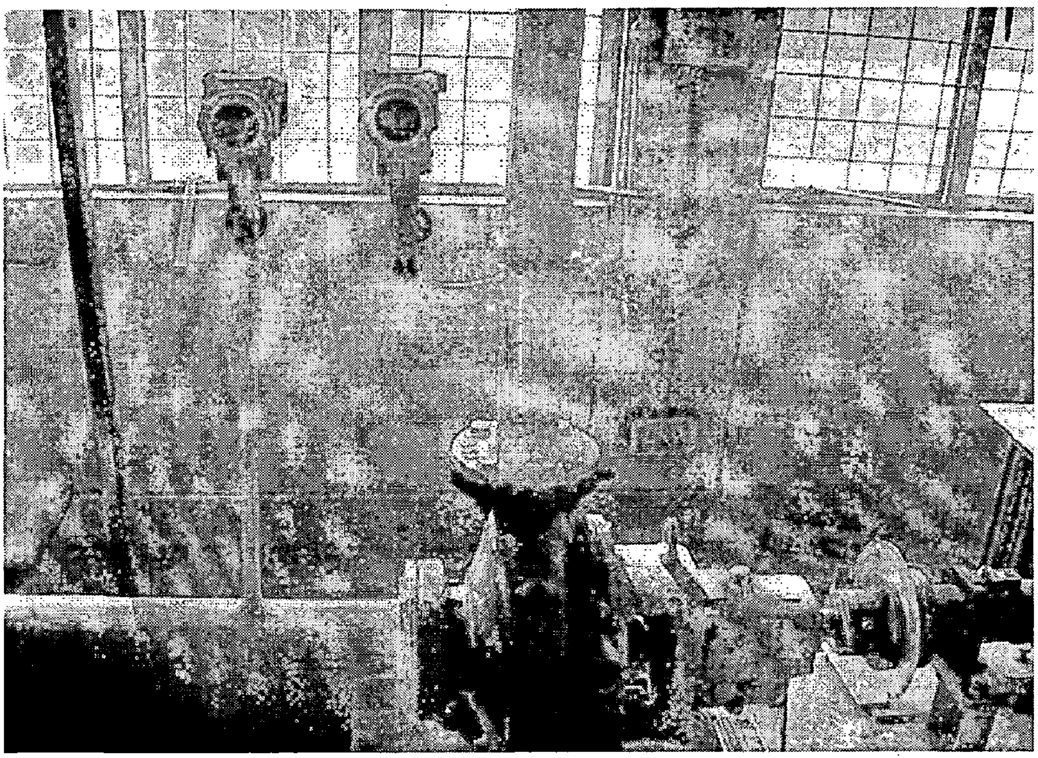


Figure 4-11: Inlet and outlet head transmitters

The mounting of Inlet and Outlet head transmitters is shown in figure 4-11.

Calibration:

(1) Inlet head Transmitter:

The pump produces a maximum head of 40 meters i.e. 4 Kg/cm^2. A transmitter with a range of 0 to 10 Kg/cm^2 is available.

Calibration without reference method is used wherin the working range of the transmitter is adjusted from 0 to 5 Kg/cm^2 so that 4 mA is transmitted corresponding to 0 Kg/cm^2 and 20 mAis transmitted corresponding to 5 Kg/cm^2 is used.

(2) Outlet Head transmitter:

The head at the discharge of the turbine is at most 0.5 Kg/cm^2. Transmitter with 0 to 1 Kg/cm^2 is available.

Calibration without reference method is used wherin the working range of the transmitter is adjusted from 0 to 0.5 Kg/cm^2 so that 4 mA is transmitted corresponding to 0 Kg/cm^2 and 20 mA is transmitted corresponding to 0.5 Kg/cm^2 is used.

4.5 Ultrasonic Flow Meter:

4.5.1 Introduction:

The 1010P universal portable flow meter is an extremely versatile transit time flow meter. The 1010P system provides a menu driven interface for site programming, During the installation procedure, you tell the system what you need it to do. It will then verify the pipe and liquid conditions, and, based on your selections, optimize its operation automatically. However, the system cannot protect itself from any critical data entry errors that you input. Its performance depends on the accuracy of the information that is provided to it. For normal operation, the flow computer only needs a receive signal of sufficient amplitude to activate its automatic gain-controlled detection circuits. Severely adverse application conditions may reduce system performance, or cause apparent operational failures [5].

4.5.2 Principle of Operation:

Sound waves travel in fluids at a specific velocity depending n the type of the fluid. If the fluid is moving , the sound wave travels at a velocity equal to the sum of the speed of sound in the fluid and the velocity of the fluid itself relative to the transducer. A sound wave traveling in the same direction as the fluid flow (downstream) will arrive sooner than the sound wave traveling against the flow.

A transit time flow meter operates by measuring both absolute time travel of each sound wave and the difference in time required for the waves to travel between an externally mounted down stream and upstream transducer. Based on the transit time of the two sound waves, the floe meter calculates the fluid velocity.

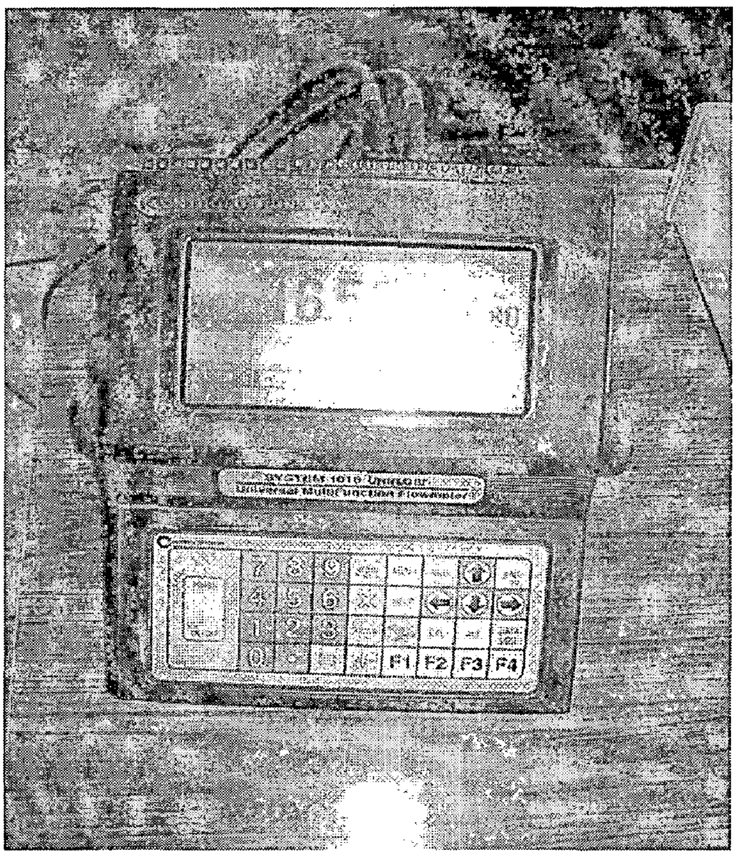


Figure 4-12: Ultrasonic flow meter

4.5.3 Flowmeter Installation Steps:

Steps to complete the installation procedure:

- Collecting the site data (pipe and liquid data, part numbers etc).
- Choosing a mounting location for flow transducers.

- ➢ Prepare pipe for transducer mounting.
- ➢ Accessing the installation menu and creating a site.
- ➢ Entering the pipe parameters.
- ➢ Invoking the transducer install procedure
- ➢ Mounting the flow transducers on the pipeline.
- ➢ Complete the transducer install menu operation.

4.5.4 Installation of Flow Transducers:

The installation of the transducers is based on the information provided to the flow computer. The installation steps can be summarized as under:

- ➢ Selecting a mounting option for the application
- ➢ Selecting a location on the pipe
- ➢ Preparing the pipe to accept the transducers

4.5.5 Identification of Transducer and mounting Hardware:

1010 series flow meters and mounting frames have color codes for easy identification , they are as under:

Gold..........................Size 'A'

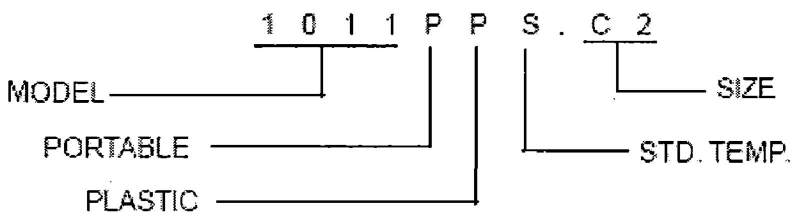
Blue.......................... Size 'B'

Red ....Size 'C'

Green.........................Size 'D'

Black.........................Size 'E'

The transducer part number is located on its front face and provides a more detailed information as shown below for example part number 1011PPS-C2 means:



4.5.6 Selecting a location on the pipe for Clamp-on Transducers:

- The transducers should be located downstream from the center of the longest available straight run. A location ten pipe diameters or greater downstream from the nearest bend will provide the best flow profile conditions.
- The transducer should not be installed at the downstream from a throttling valve, a mixing tank, the discharge of a positive displacement pump or any other equipment that could possibly aerate the liquid. The best location will be as free as possible from flow disturbances, vibration, sources of heat, noise, or radiated energy.
- Avoid mounting the transducers on a section of pipe with any external scale. Remove all scale, rust, loose paint, etc., from the location.
- Do not mount the transducers on a surface aberration (pipe seam, etc.).
- Do not mount transducers from different ultrasonic flowmeters on the same pipe.
- Never mount transducers under water.

4.5.7 Mounting Mode:

The clamp-on transducers support Direct or Reflect mounting modes. The flow computer recommends a mounting mode after analyzing your pipe and liquid data entries.The transducer mounted in the reflect mode and direct mode are as shown in the figure 4-13 and 4-14 below.

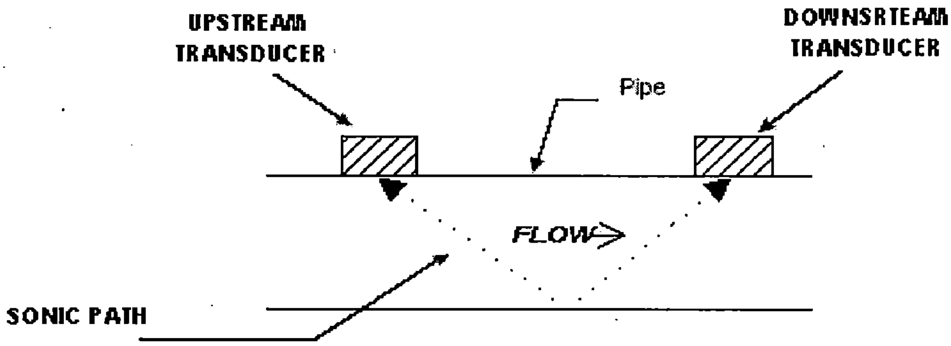


Figure 4-13: Reflect mount for Clamp-on transducer

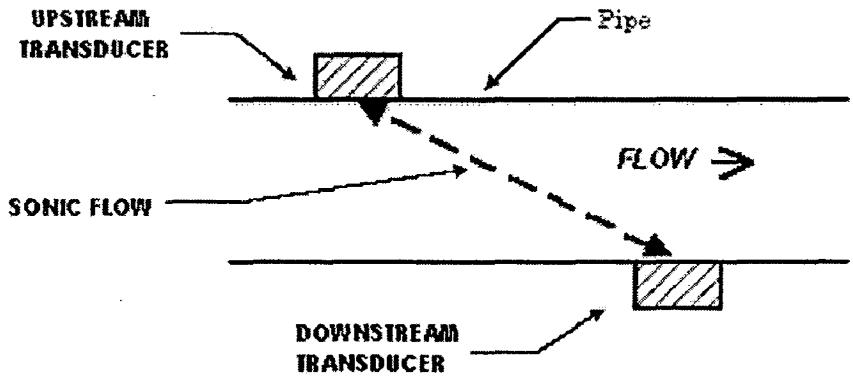


Figure 4-14: Reflect mount for Clamp-on transducer

There are two modes one is the reflect mode and the other is the direct mode, in the direct mode the transducers are mounted opposite to each other on the same pipeline. The advantage of having reflect mode is that it resists the abnormal flow conditions such as cross-flow within the flow stream and also it may not be always possible to go for direct mount as accessibility to other side of the pipe line is not possible in all situations

4.5.8 Configuring the flow meter with site Data:

The following site data is to be entered into the flowmeter when prompted to do so.

Pipe table parameters:

Pipe class: ASA Stainless steel

Pipe name: 1RS 10

Outer diameter: 1.315 inches

Wall thickness: 0.109 inches

Liner material: none

Liner thickness: 0.0

Transducer type:

Transducer model: 1010 Universal

Transducer size: C2

Transducer mount mode: reflect

Spacing offset: minimum

Number index: 13

Spacing method: Spacer bar

Application data

Liquid class: Water 20°C/68°F

Temperature range: -40°C to120°C

After feeding this data the flowmeter prompts the user if Install completed? If yes then it calculates the spacing between the transducers, it is 4.9 mm in this case.

4.5.9 Preparing the Pipe for mounting Transducers:

- Pick a mounting location with the longest straight run. You must have easy access to at least one side of your pipe. The mounting location must remain full, even at zero flow.
- The mounting mode is selected as Reflect.
- After receiving the spacing dimensions from the Installation Menu, prepare the pipe surface. De-grease the surface, if necessary, and remove any grit, corrosion, rust, loose paint, etc. Use abrasive material provided to provide a clean contact surface for the transducers.
- An EZ clamp and spacer bar is used to set the correct position of the transducers. The spacer bar eliminates the manual spacing measurements and provides rigidity for mounting the transducers when mounting the transducers while maintaining the axial alignment.

4.6 Electrical Actuator:

4.6.1 Introduction:

The AVCON make 2- way motorized control valve is used most commonly for either ON/OFF or control service [3]. Figure 4-15 shows the actuator.

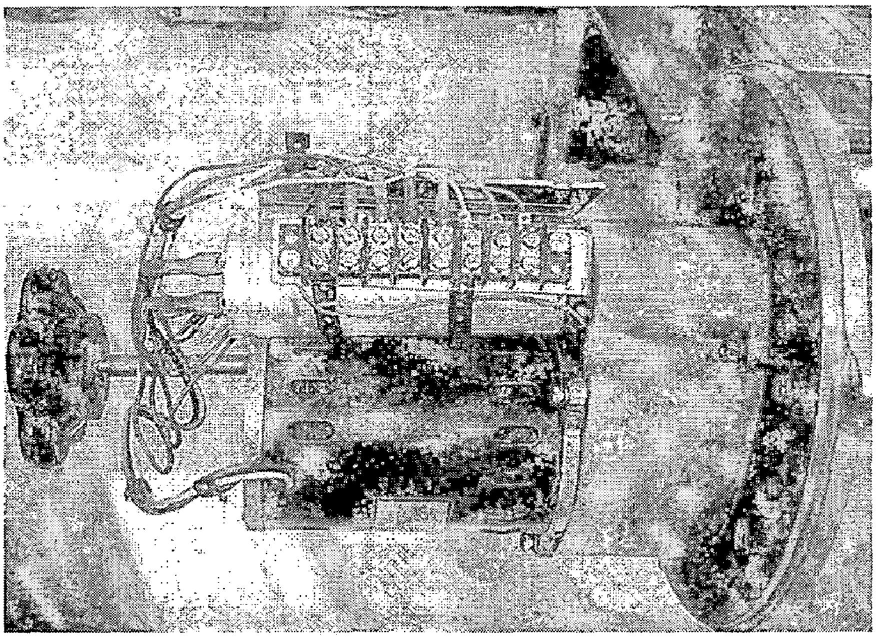


Figure 4-15: Electrical Actuator

4.6.2 Principle of Operation:

An electrical actuator is basically an On-Off type controller which is operated with the conventional 230V, 50Hz supply. It is connected to a Globe valve whose stem is connected to the actuator so that when the actuator is powered then the valve opens or closes until the supply is fed.

The actuator has two limit positions based on the two limit switches, one is called the open limit switch and other close limit switch. These two limit switches limit the operation of the motor until two extreme positions the valve can move i.e. Full open and Full close position.

This is done by means of open and close limit switches which have Normally open (NO) and Normally closed (NC) contacts, the supply to the motor of the actuator is routed through the NC contact. So whenever the valve reaches the predefined extreme limits then either the Open/Close limit switch is activated and the supply through the NC contact is cut off as this contact changes to NO.

In this way the valve is operated either in the forward or reverse direction to open or close the valve respectively.

4.6.3 Electrical Connections:

The actual electrical connections of the manufacturer is as shown in figure 4-16 below[3].

This Electrical connection pertains to the 4-20 mA servo-control for the actuator wherein the 4 mA corresponds to full close and 20 mA corresponds to the full open position.

Due to the improper operation of the 4-20 mA controller the wiring diagram has been modified after completely removing the servo-controller.

The modified connection diagram of the actuator is shown in figure 4-17 below.

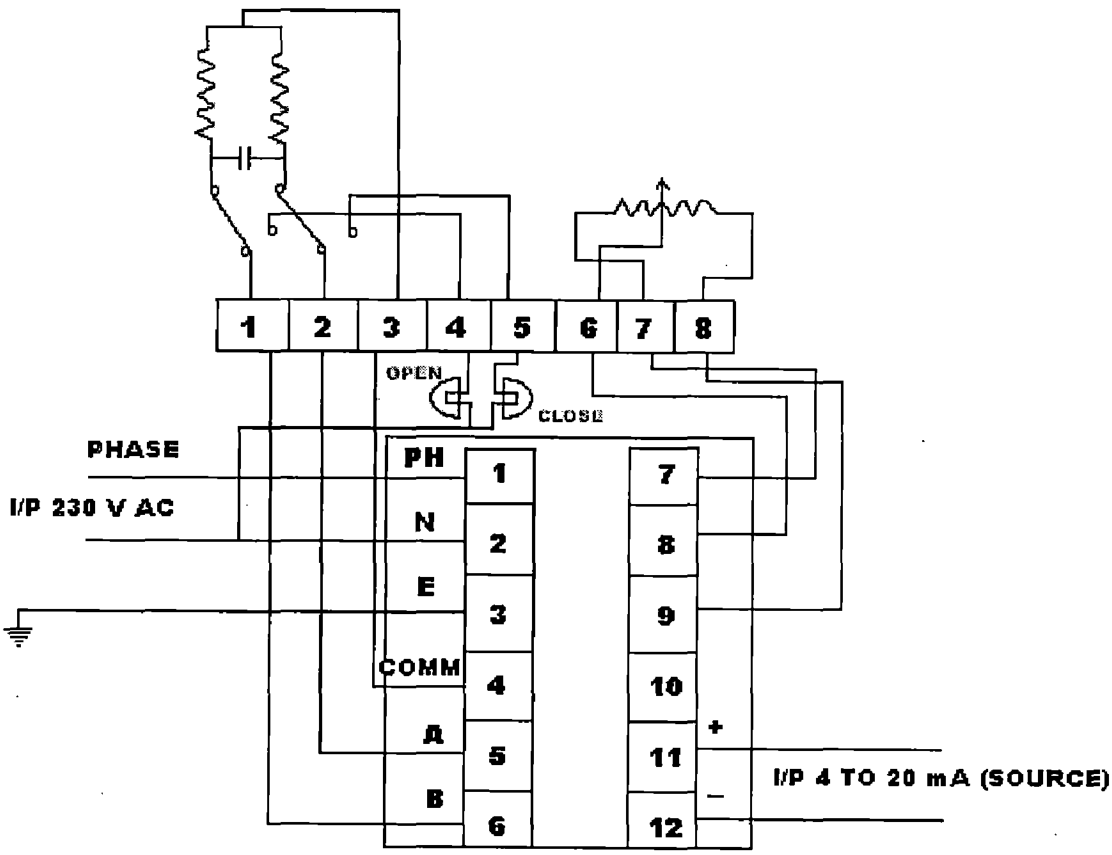


Figure 4-16: Actual electrical connections

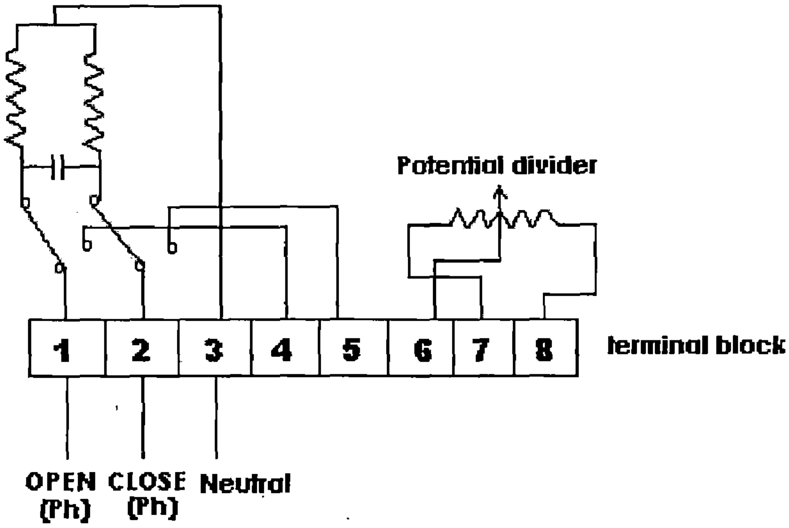


Figure 4-17: Modified electrical connections

4.6.4 Tuning and Adjustment:

The tuning and adjustment is nothing but setting the actuator to be driven within the open and close limits. The following are the steps to be carried out:

- At first the valve is bought to the two extreme conditions. At one extreme the resistance of the variable point 6 in the potential divider with respect fixed point 7 is found to be 90 ohms at full close position.
- At another extreme the resistance of the variable point 6 in the potential divider with respect fixed point 7 is found to be 430 ohms at full close position.
- A 2V DC source is connected to the fixed POT terminals 7 and 8 and respective voltages at the two extreme voltage is measured , this voltage is further used for online indication of valve position using LABVIEW.
- Manually get the valve to the middle position, connect the phase supply to the terminal 1 and neutral to 3 and check whether the valve is opening. Also check whether the open limit switch is working in the extreme condition i.e. the motor of the actuator should stop automatically when open limit switch acts.
- Now connect the phase supply to the terminal 2 and neutral to 3 and check whether the valve is closing. Also check whether the close limit switch is

working in the extreme condition i.e. the motor of the actuator should stop automatically when close limit switch acts.

- The Limit switch positions on the actuator should not be disturbed otherwise the valve may be damaged or the actuator motor winding may burn out.

5. VIRTUAL INSTRUMENTATION USING LABVIEW:

Labview is a development programming based on graphical programming. LABVIEW uses terminology, icons and ideas familiar to engineers, scientists, and technicians. It relies on graphical language rather than text based languages to describe programming actions. It is also fully integrated to communicate with external hardware, GPIB, RS232, RS485 and plug in data acquisition boards like PCI, PCIMCIA, USB, IEEE-1394, ISA etc. LABVIEW also has built in software standard libraries for TCP/IP networking and ACTIVEX controls etc. the programs that are made in LABVIEW are called virtual instruments [8].

5.1 Virtual Instruments versus Traditional Instruments

Stand-alone traditional instruments such as oscilloscopes and waveform generators are very powerful, expensive, and designed to perform one or more specific tasks defined by the vendor. However, the user generally cannot extend or customize them. The knobs and buttons on the instrument, the built-in circuitry, and the functions available to the user, are all specific to the nature of the instrument. In addition, special technology and costly components must be developed to build these instruments, making them very expensive and slow to adapt. Virtual instruments, by virtue of being ***PC-based***, inherently take advantage of the benefits from the latest technology incorporated into off-the-shelf PCs [9]. These advances in technology and performance, which are quickly closing the gap between stand-alone instruments and PCs, include powerful processors such as the Pentium-IV and operating systems and technologies such as Microsoft Windows XP, .NET, and Apple Mac OS. Traditional instruments also frequently lack portability, whereas virtual instruments running on notebooks automatically incorporate their portable nature.

5.2 VI's Software

Software is the most important component of virtual instruments. With the right software tool, engineers and scientists can efficiently create their own:

i. **Front Panel** – How the user interacts with the VI.

ii. **Block Diagram** – The code that controls the program.

iii. **Icon/Connector** – Means of connecting a VI to other VIs.

5.2.1 Front Panel

The Front Panel is used to interact with the user when the program is running. Users can control the program, change inputs, and see data updated in real time. Every front panel control or indicator has a corresponding terminal on the block diagram. When a VI is run, values from controls flow through the block diagram, where they are used in the functions on the diagram, and the results are passed into other functions or indicators. The front panel is the user interface of the VI. Controls are knobs, pushbuttons, dials, and other input devices. Indicators are graphs, LEDs, and other displays.

Controls simulate instrument input devices and supply data to the block diagram of the VI. Indicators simulate instrument output devices and display data the block diagram acquires or generates.

Fig.5.1 show the typical block diagram created in LabVIEW environment. It shows the control and indicator palette. Control palette is shown by the two knobs while the indicator palette is shown by the waveform graph.

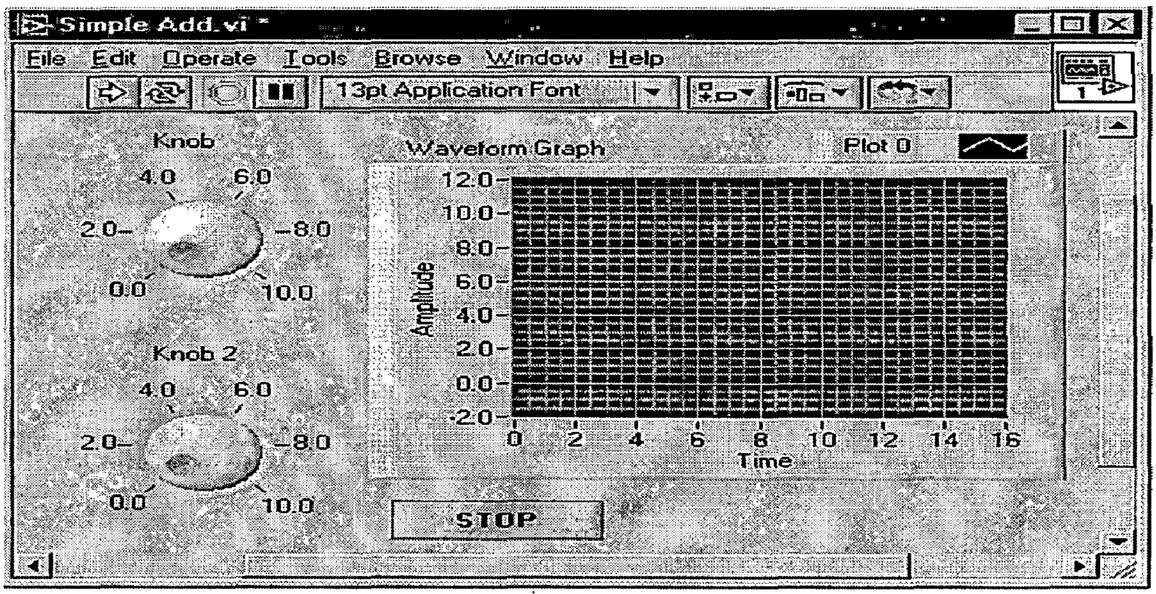


Figure 5-1: Typical VI's Front Panel

5.2.2 Block Diagram

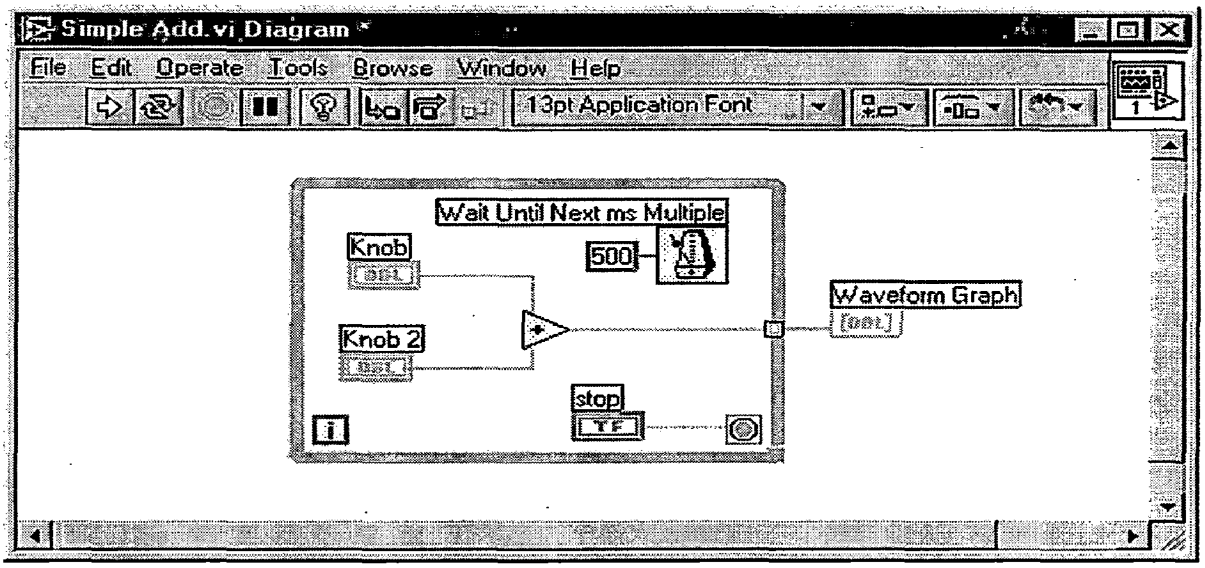


Figure5-2 : block diagram

The block diagram contains this graphical source code. Front panel objects appear as terminals on the block diagram. Additionally, the block diagram contains functions and structures from built-in LabVIEW VI libraries. The VI receives instructions from a block diagram, which you construct in G.

A corresponding terminal of front panel is shown in figure 5.2 The knobs and waveform are shown as the two terminals on the block diagram Fig Typical VI's Block Diagram.

Wires connect each of the nodes on the block diagram, including control and indicator terminals, functions, and structures.

5.2.3 Icon/ Connector

Every VI displays an icon, in the upper right corner of the front panel and block diagram windows. An icon is a graphical representation of a VI. It can contain text, images, or a combination of both. If you use a VI as a sub-VI, the icon identifies the sub-VI on the block diagram of the VI. The connector shows terminals available for transfer or data to and from the sub-VI. There are several connector patterns to choose from.

5.2.4 Role of LabVIEW in Virtual Instrumentation

LabVIEW is an integral part of Virtual Instrumentation because it provides an easy-to-use application development environment designed specifically with the needs of engineers and scientists in mind. LabVIEW offers powerful features that make is easy to connect to a wide variety of hardware and other software. Hence, finally some of the chief features of Virtual Instruments can be summarized as:

i. Graphical Programming
ii. Connectivity and Instrument Control
iii. Open Environment
iv. Reduces Cost and Preserves Investment
v. Multiple Platforms
vi. Distributed Development
vii. Analysis Capabilities
viii. Visualization Capabilities
ix. Flexibility and Scalability -- Key Advantages

5.3 Data Acquisition and Control using Labview:

5.3.1 Introduction:

Every control system requires the monitoring of parameters to take a control action, therefore data acquisition is important. The real time parameters can be monitored by

means of Labview drivers which are basically responsible for to get the online data into the Labview program

The drivers for the I-7000 Series Modules, provide one or more DLL files (and VXD/SYS files) to be used by higher-level computer languages. The DLL files are written in Visual C++ and provides lots of functions to perform a variety of Analog input/output, Digital input/output, Counter/Timer and RS-232/RS-485 Communication operations with the hardware of the I-7000 Series Modules. The

DLL files are in standard Win32 DLL format, and can be used with Windows 95/98/NT/2000. With these functions of DLL files, user no longer needs to process the lower-level hardware controls. The DLL files can be easily used by higher-level computer language. For example, it provides a large variety of demo programs that are written in Visual C++, Delphi, Borland C++ Builder , Visual Basic and LabVIEW.

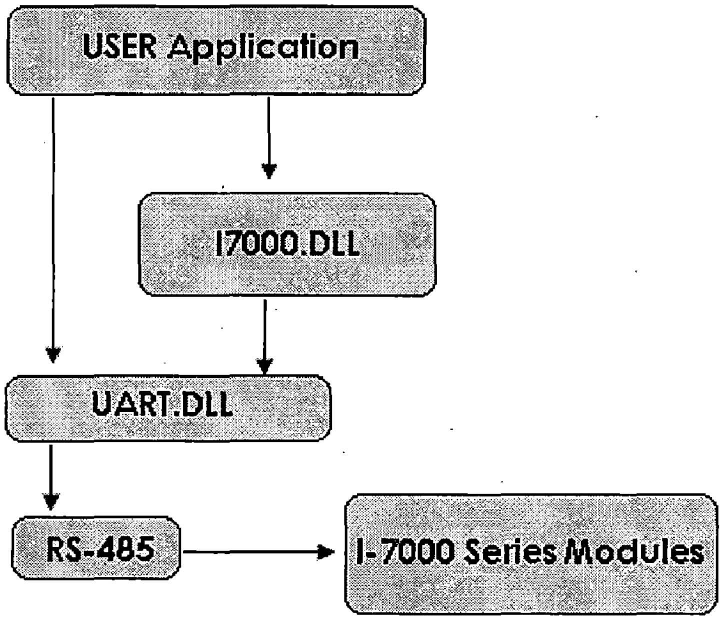


Figure 5-3: UART.dll and I-7000.dll

The figure 5-3 above shows the schematic of how the dll files are called from the source program in Labview The **UART.DLL & I7000.DLL** are the dynamic linking library (DLL) designed for Windows 95/98 and Windows NT 3.51/4.0/2000/XP applications. The user can use many programming languages as mentioned to develop his application with UART.DLLandI7000.DLL.

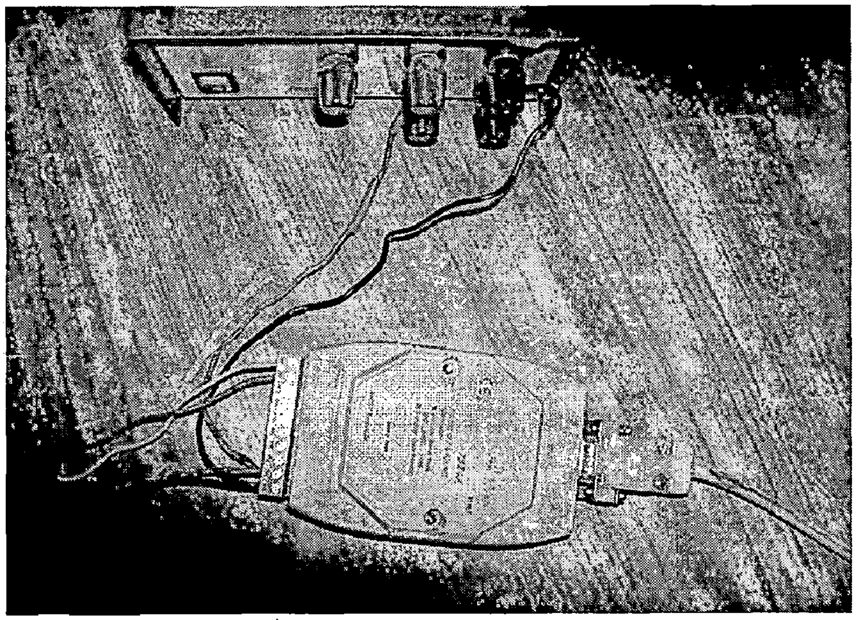


Figure 5-4 : RS-232 to RS-485 Converter

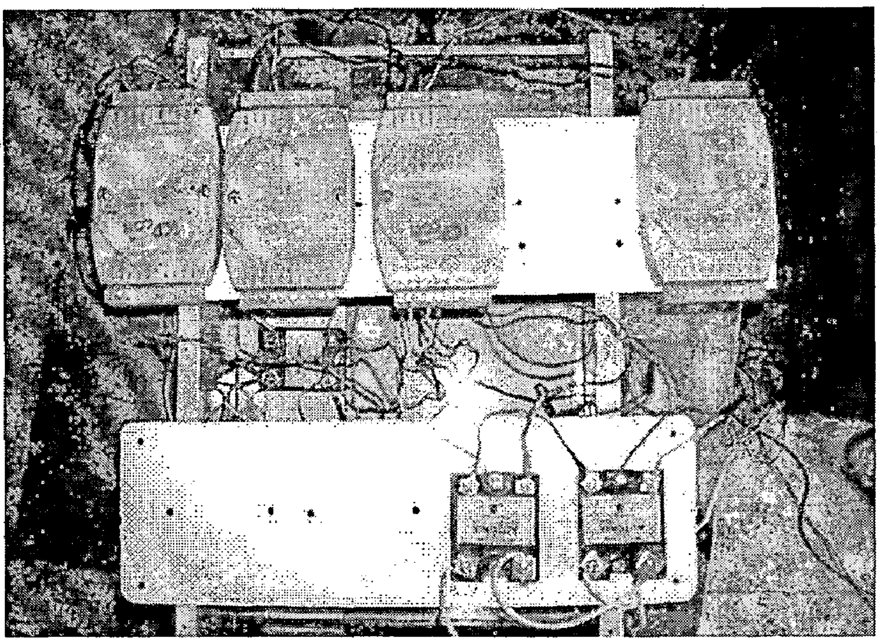


Figure 5-5: Remote data acquisition modules

5.3.2 Configuring the DAQ modules using Labview:

In order to acquire data from different I-7000 series modules the drivers of the particular module have to be called into the Labview program. Drivers are nothing but sub VI's in Labview which can be accessed by popping up "select a VI" option in the block diagram. The subVI's are present in a *.llb file such as

UART.llb, I7000.llb, and I7080.llb. The figure 5-4 and 5-5 shows the interconnections of modules

a) Configuring Digital Output module(7043D):

The input to the subVI to perform digital output function is an array (W7000) of parameters to be passed to the sub VI icon in the block diagram. W7000 is called the word input/output table. The structure of the array is as under:

w7000[0]: RS-232 port number ,1/2/3/4

w7000[1]: module address, from 0x00 to 0xFF

w7000[2]: module ID, 7043

w7000[3]: 0=checksum disable, 1=checksum enable

w7000[4]: Timeout constant, normal=100

w7000[5]: 16-bit digital output data

w7000[6]: 0: no save to szSendTo7000&szRecieveFrom7000

1: szSendTo7000=Command string send to 7000

szRecieveFrom7000=result string receive from 7000

The digital output is given an addressed as 3 with module ID 7043

b) Configuring Analog Output module(7024):

w7000[0]: RS-232 port number ,1/2/3/4

w7000[1]: module address, from 0x00 to 0xFF

w7000[2]: module ID, 7024

w7000[3]: 0=checksum disable, 1=checksum enable

w7000[4]: Timeout constant, normal=100

w7000[5]: channel number (0-3)

w7000[6]: 0: no save to szSendTo7000&szRecieveFrom7000

1: szSendTo7000=Command string send to 7000

szRecieveFrom7000=result string receive from 7000

The module is addressed 4 with module ID 7024. The channel is configured for analog output in the range 0 to 5V by providing a separate input to the Sub VI in the block diagram of the Labview program.

c) Configuring Analog Input module(7019R):

w7000[0]: RS-232 port number ,1/2/3/4

w7000[1]: module address, from 0x00 to 0xFF

w7000[2]: module ID, 7019

w7000[3]: 0=checksum disable, 1=checksum enable

w7000[4]: Timeout constant, normal=100

w7000[5]: channel number (0-3)

w7000[6]: 0: no save to szSendTo7000&szRecieveFrom7000

1: szSendTo7000=Command string send to 7000

szRecieveFrom7000=result string receive from 7000

The module is addressed 1 with module ID 7019 , all the input channels data can now be called into the Labview program.

d) Configuring Frequency/Counter module(7080D):

w7000[0]: RS-232 port number ,1/2/3/4

w7000[1]: module address, from 0x00 to 0xFF

w7000[2]: module ID, 7080

w7000[3]: 0=checksum disable, 1=checksum enable

w7000[4]: Timeout constant, normal=100

w7000[5]: 0: to read 7080's counter 0

1: to read 7080's counter 1

w7000[6]: 0: no save to szSendTo7000&szRecieveFrom7000

1: szSendTo7000=Command string send to 7000

szRecieveFrom7000=result string receive from 7000

w7000[7]: high word of counter value

w7000[8]: low word of counter value

The module is addressed 2 and module ID 7080, the channel 0 is configured for frequency measurement in non-isolated mode using DCON utility.

The Labview front panel with necessary menu to enter the configuration data is shown in figure 5-6 and 5-7 below.

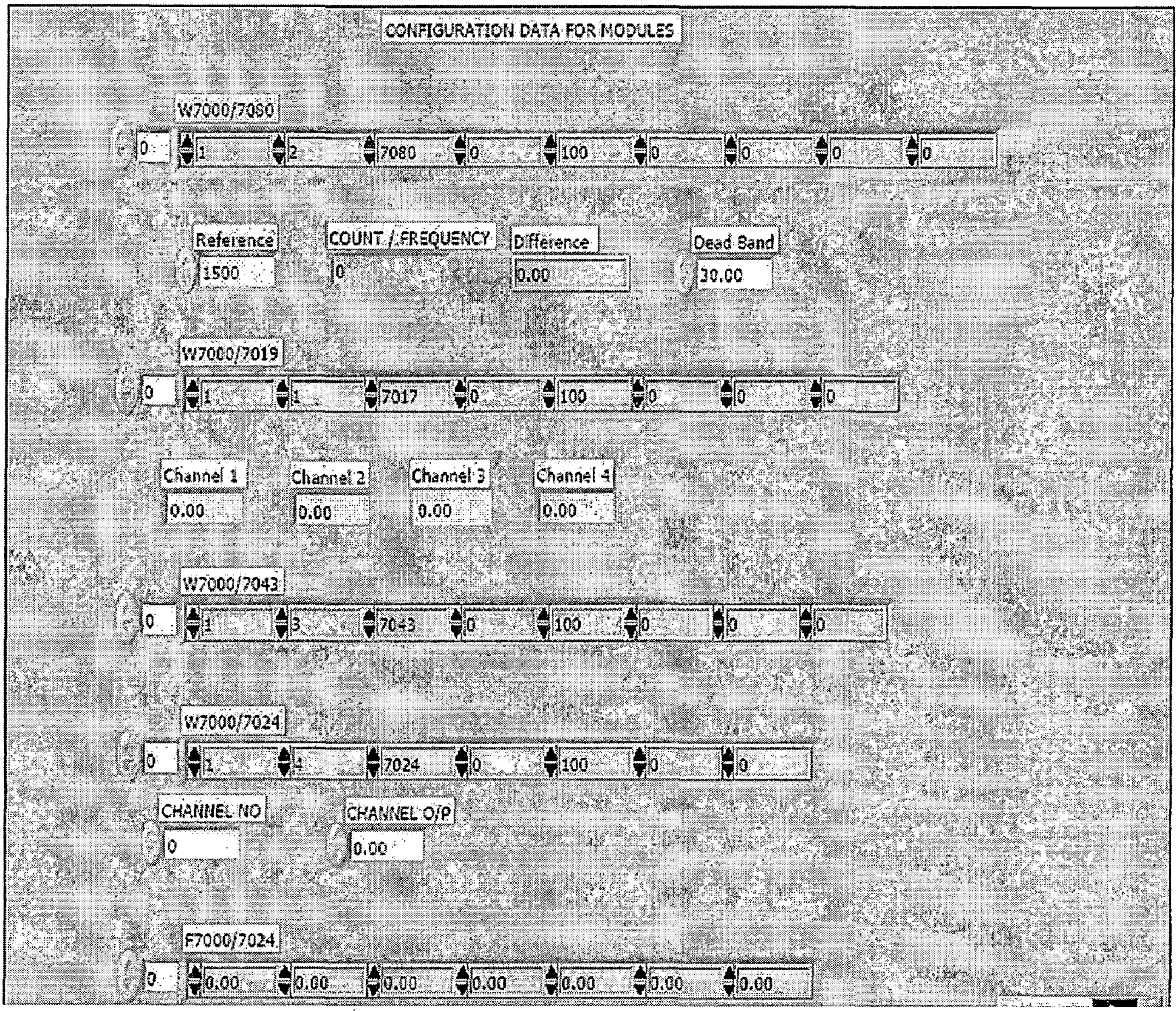


Figure 5.6: Configuring modules in Labview

The modules are configured by entering the values of different parameters in the array W7000 of each module.

The data to be entered in to the array is given in the above explanation of configuring the modules.

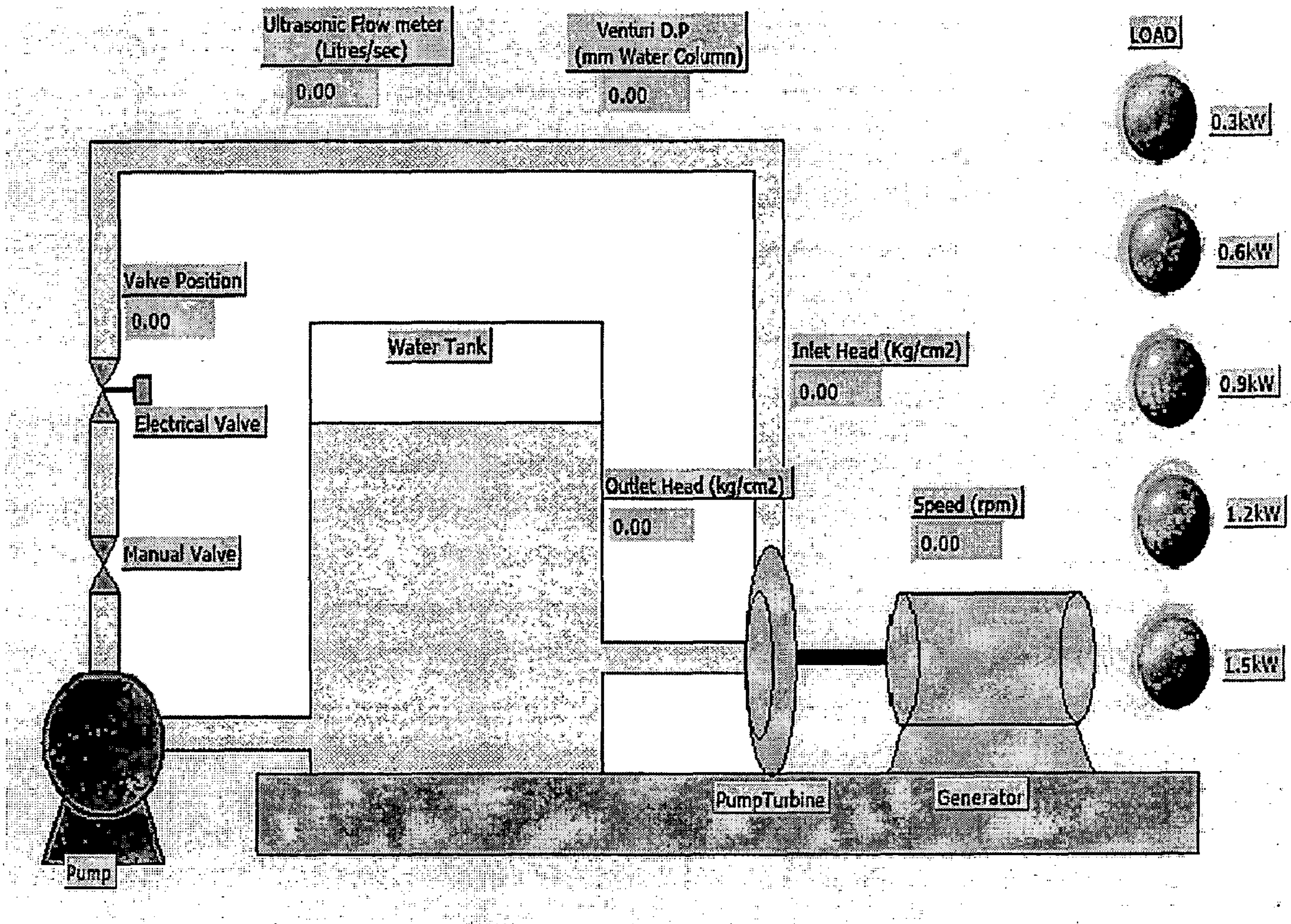


Figure 5-7: Front panel in Labview

The front panel in Labview is shown above. The operation of the Labview front panel is as below.

All the parameters of the test rig are obtained on the front panel. The load control can be achieved by pressing the push buttons on the front panel, these push buttons turn bright whenever load is activated. The load is then increased in steps from 0.3 kW to 1.5 kW and similarly we can unload the machine by again pressing the load push buttons, this time the pushbuttons stop glowing indicating that the load has been disconnected.

The digital indicators also act as ***virtual annunciators*** by ***turning red*** whenever abnormal conditions are encountered; this feature is achieved by use of property nodes in Labview.

6. LOAD CONTROL

6.1 Introduction:

The generator is fed with lamp load (resistive load) in five steps. The maximum load the generator can take is 1.5 kW, so each step loads the generator by 0.3kW.

6.2 Load Wiring :

The load consists of five rows of bulbs with each row consisting of 3 bulbs 100W each. The wiring is done such that at a time load on the three phases is the same. As seen from seen from figure 6-1 and 6-2 the load consists of 5 lamps each connected to R , Y, and B phases connected through the contactors.

There is a provision for the bulbs to be operated manually by means of a switch. The figure below shows the photograph of load wiring diagram with contactors.

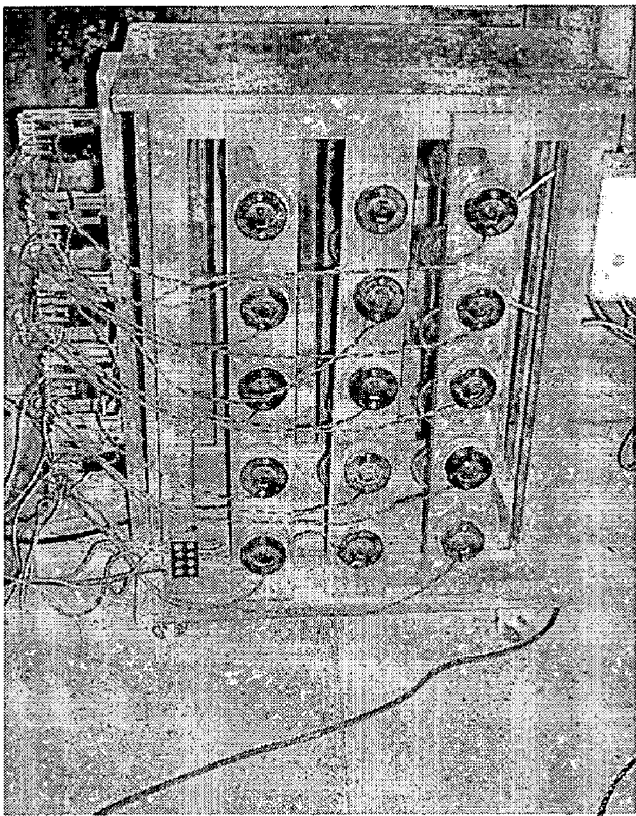


Figure 6-1: Photograph of load wiring

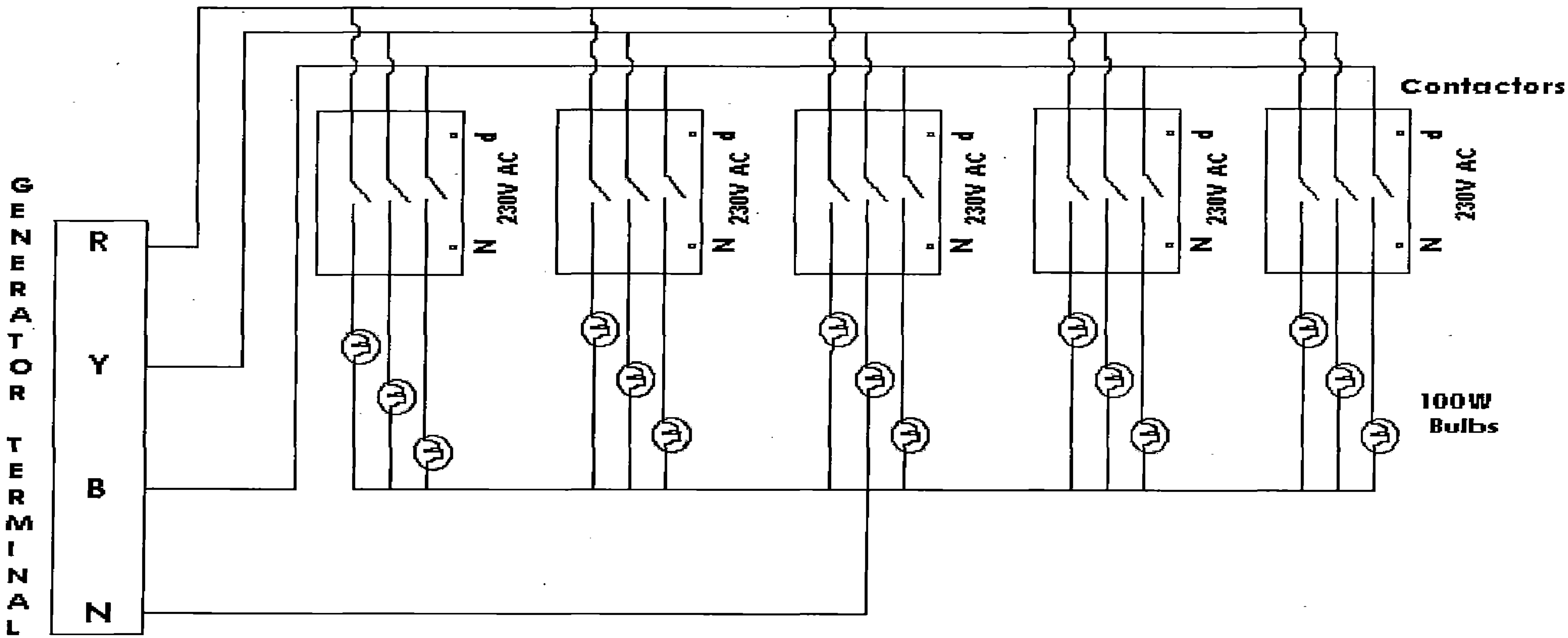


Figure 6-2: Lamp Load

6.3 Load control using digital output module and Labview:

The load control is accomplished in Labview by pressing the push buttons in the Labview GUI which in turn activates the digital output module.

The figure 6-3 below shows the load control circuit.

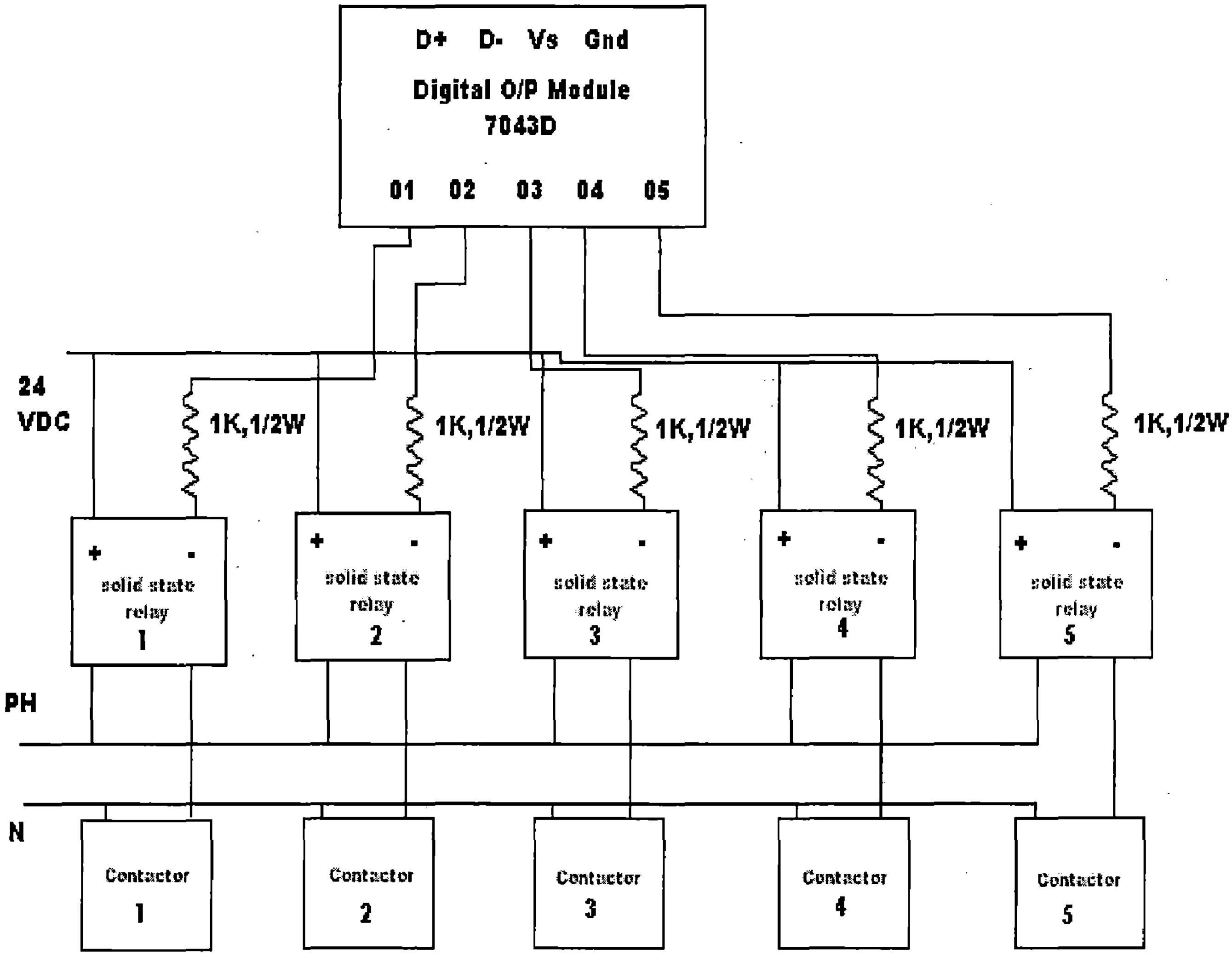


Figure 6-3: Load control circuit

When the load switches on the front panel of the VI is pressed the corresponding terminal of the digital o/p module is activated and the solid state relay picks up. Consequently the phase supply to the load contactor which is connected to the solid state relay output picks up and extends the supply to the resistive load i.e. bulb load.

Three bulbs in a row with each one of them connected to the three phases of the generator terminal are fed at a time. In this way the generator is loaded by means of front panel pushbuttons in Labview GUI.

7. SPEED CONTROL

7.1 Introduction:

The speed control or speed governing is done in order to maintain the speed of the generator within a specified band which is user selectable, this means that we are indirectly maintaining the frequency of the generator within specified limits.

The generator is a 4 pole machine with rated speed of 1500 rpm.

7.2 Optoelectronic Speed Sensor:

a) Slotted Disc: A slotted disc fabricated with brass having an outer diameter of 21cm and it has 60 tooth is used. This disc is mounted on the generator shaft whose speed is to be measured. As the generator shaft rotates the disc also rotates with the same rpm.

b) Speed sensor MOC7811:

The speed sensing is done using a optocoupler MOC7811. It has a LED on one side and a phototransistor on the other side. The placement of the sensor is such that the movement of the disc interrupts the light path between the two.

Since the disc is slotted the rotation of the disc causes the interruption of light at time intervals proportional to the speed of the generator.

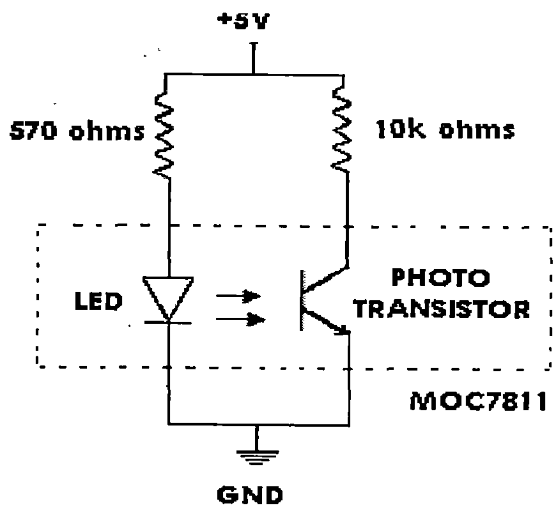


Figure 7-1: optoelectronic Speed sensor

The speed sensor circuit is shown in figure 7-1 above.

LED current should be in the range of 5 mA to 10 mA. Therefore a series resistance of 570Ω is placed and on phototransistor side a 10K resistance.

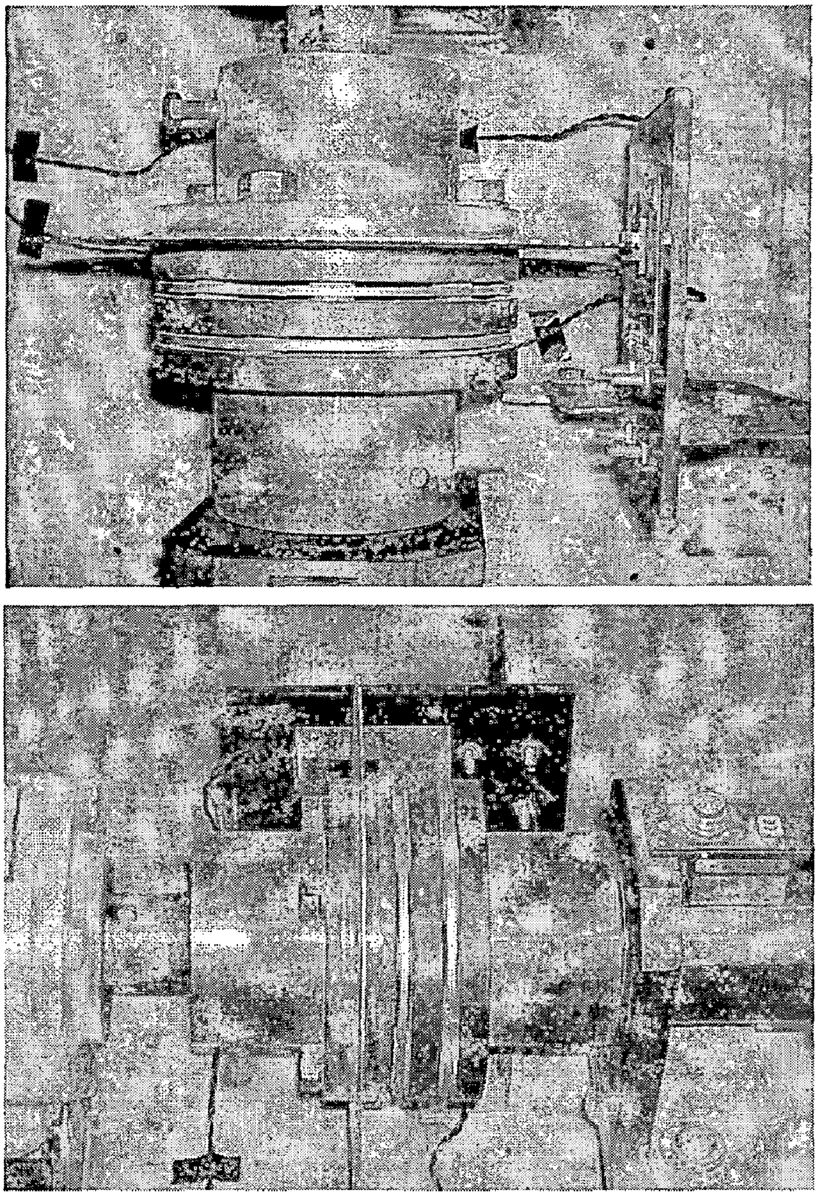


Figure 7-2: Photograph of speed sensor and Disc

7.3 Signal Conditioner for Speed Sensor:

The output of the speed sensor is a distorted square wave and hence signal conditioning is necessary to get a perfect square wave. In order to do this LM339 i.e. quad differential comparator is used. The output is open collector type and hence a resistance of 10k is connected to the O/P terminal via 5V supply.

LM339 is preferable because its output is TTL compatible and is easy for interfacing with the frequency/counter module.

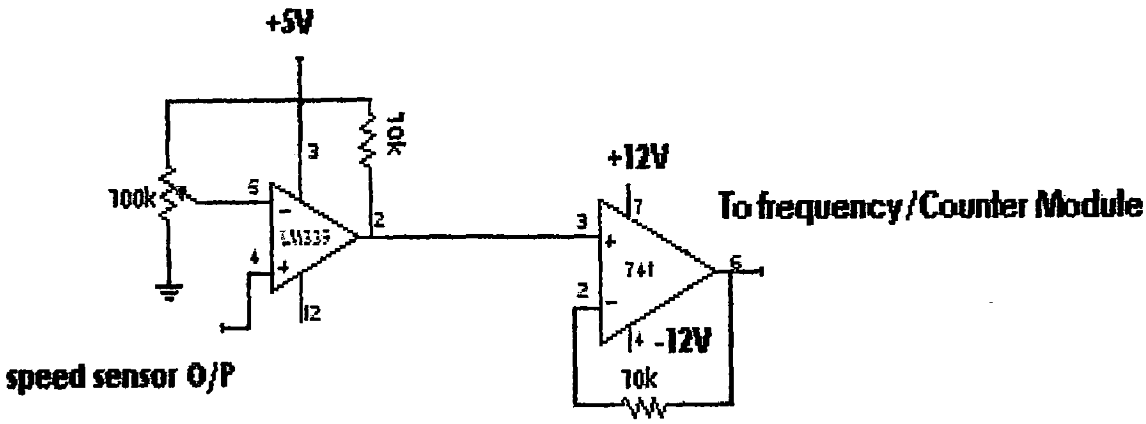


Figure 7-3: Signal conditioner for speed sensor

The output of the LM339 is connected to an 741 op-amp in order to avoid loadingby the frequency/counter module. the o/p is then connected to 7080 frequency/counter module to measure the frequency of the square waves generated

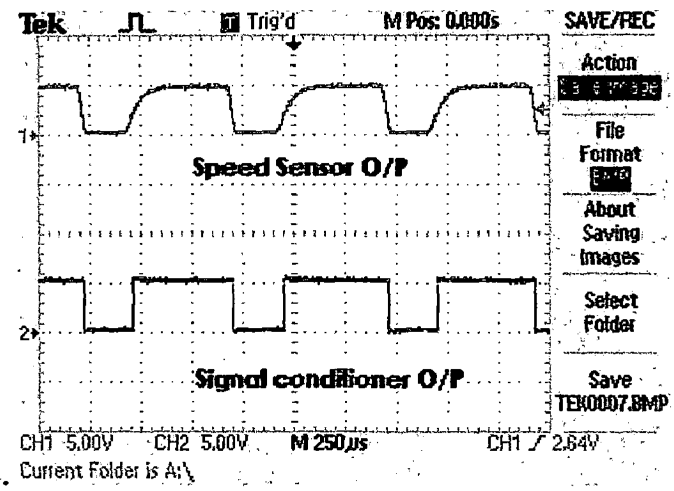


Figure 7-4: Sensor and signal conditioner waveforms

The frequency is nothing but the pulse count per sec or rpm of the generator. This count when divided by 30 gives the frequency of the generator. The output count of the speed sensor is compared with that of the count obtained by multiplying the frequency of the generator as obtained from the Incomer panel by 30. The readings are tabulated as under.

Frequency (Incomer panel) **f** (Hz)	Estimated pulse count per sec = f*30	Actual Pulse Count per sec
25.80	774	774
26.40	792	791
33.60	1008	1009
39.09	1172	1172
40.94	1228	1228
43.80	1314	1314
45.50	1365	1366
48.76	1462	1462
50.94	1528	1526
52.40	1575	1575
53.80	1614	1615
55.10	1653	1655

A graph is drawn between the frequency (Generator incomer panel of test rig) and actual pulse count in Labview and it is seen that it is a exactly a straight line.

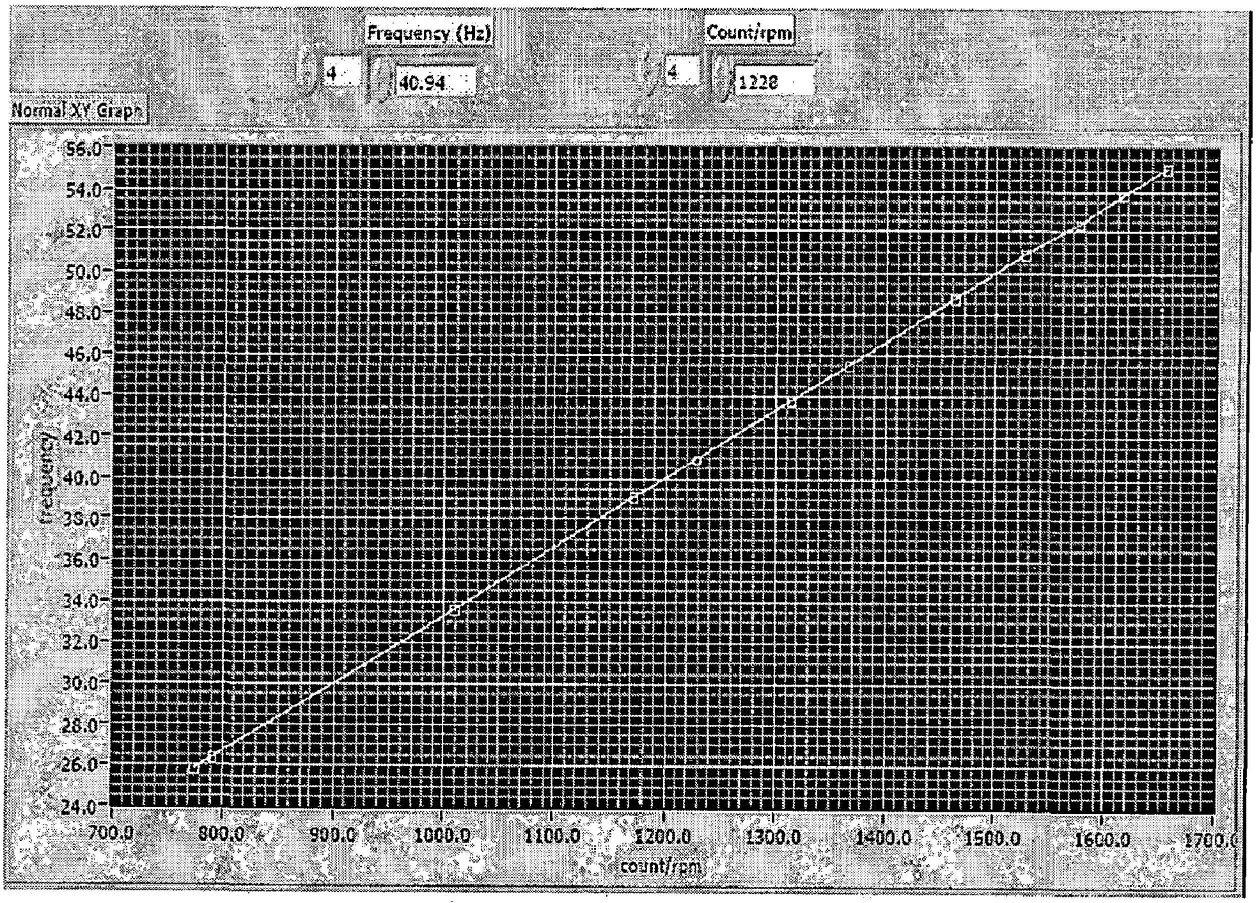


Figure 7-5: Graph between frequency and actual pulse count per sec

7.4 Speed control using Digital output module and Labview:

The speed control is basically an ON/OFF TYPE control i.e. the control valve or electrical actuator is either driven in the forward or reverse direction depending on the error in speed from the set point. The important feature of the control is having a dead band selectable by the user which a range of rpm over which the controller should not respond. Having a ON/OFF control with dead band eliminates oscillations in the control output. The main consideration in choosing the dead band depends on how much speed is effected after turning off the supply to the actuator in either forward or reverse direction. This is due to the fact that the actuator may have inertia which keeps it driving the valve even if the supply to it is cut off.

The figure 7-6 below shows the control circuit for speed control of generator.

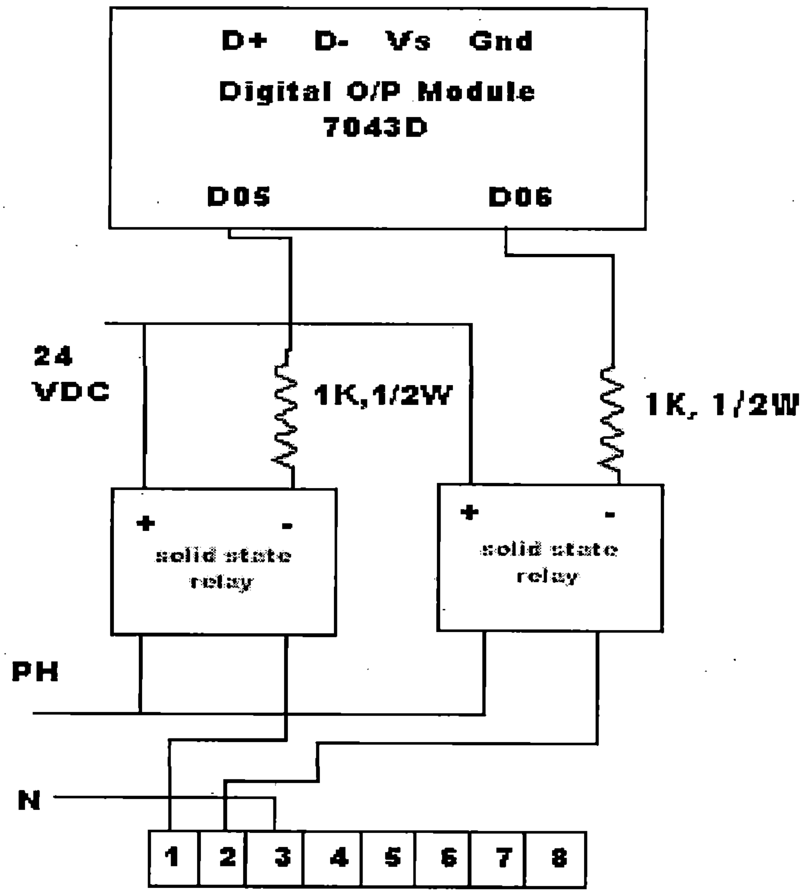


Figure 7-6: Speed Control circuit

As it can be seen from the circuit diagram the digital output module (open collector output module) drives a solid state relay i.e. whenever its digital output is ON the ground is extended and the relay becomes ON and the its output becomes NC. The phase supply to the electrical actuator is extended through this relay output terminals. Therefore whenever the electrical actuator is to be operated in forward or reverse direction the corresponding relay is driven by the solid state relay and this is done control logic in Labview automatically by sensing the error in speed.

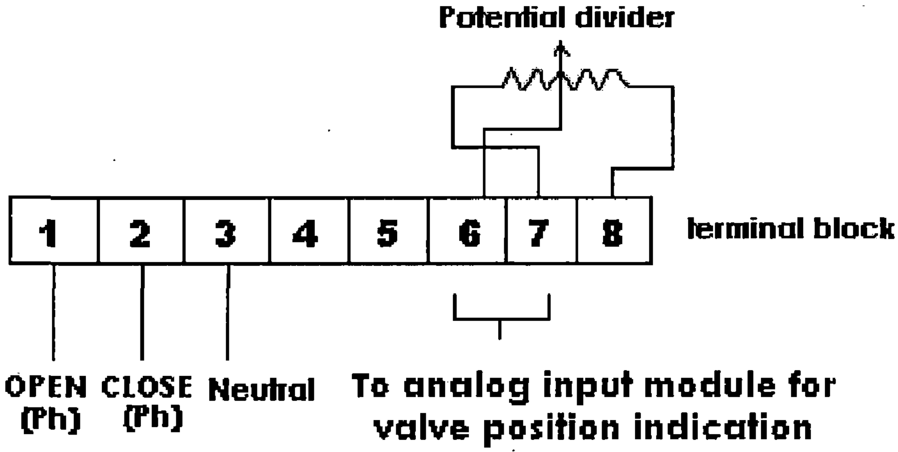


Figure 7-7: Valve position indication

Another important provision made in Labview is to set the software limits 0% and 100% for the actuator operation even though the limit switches are present. This is done by energizing the potential divider on the terminal strip of actuator by a 2V DC and taking the output between two points 6 and 7. the voltage across these points are fed to an analog input module and valve position indication is achieved. The figure 7-7 shows the scheme for valve position indication.

7.5 Results of Speed Control:

The plot of Speed reference i.e. 1500 rpm and online Speed at load variation from 0 to 100% and 100 to 0% in steps of 20% is shown at dead bands 1485 to 1515 rpm and 1480 to 1520 rpm is shown below in figure 7.7 and . It is an online **waveform chart** in Labview.

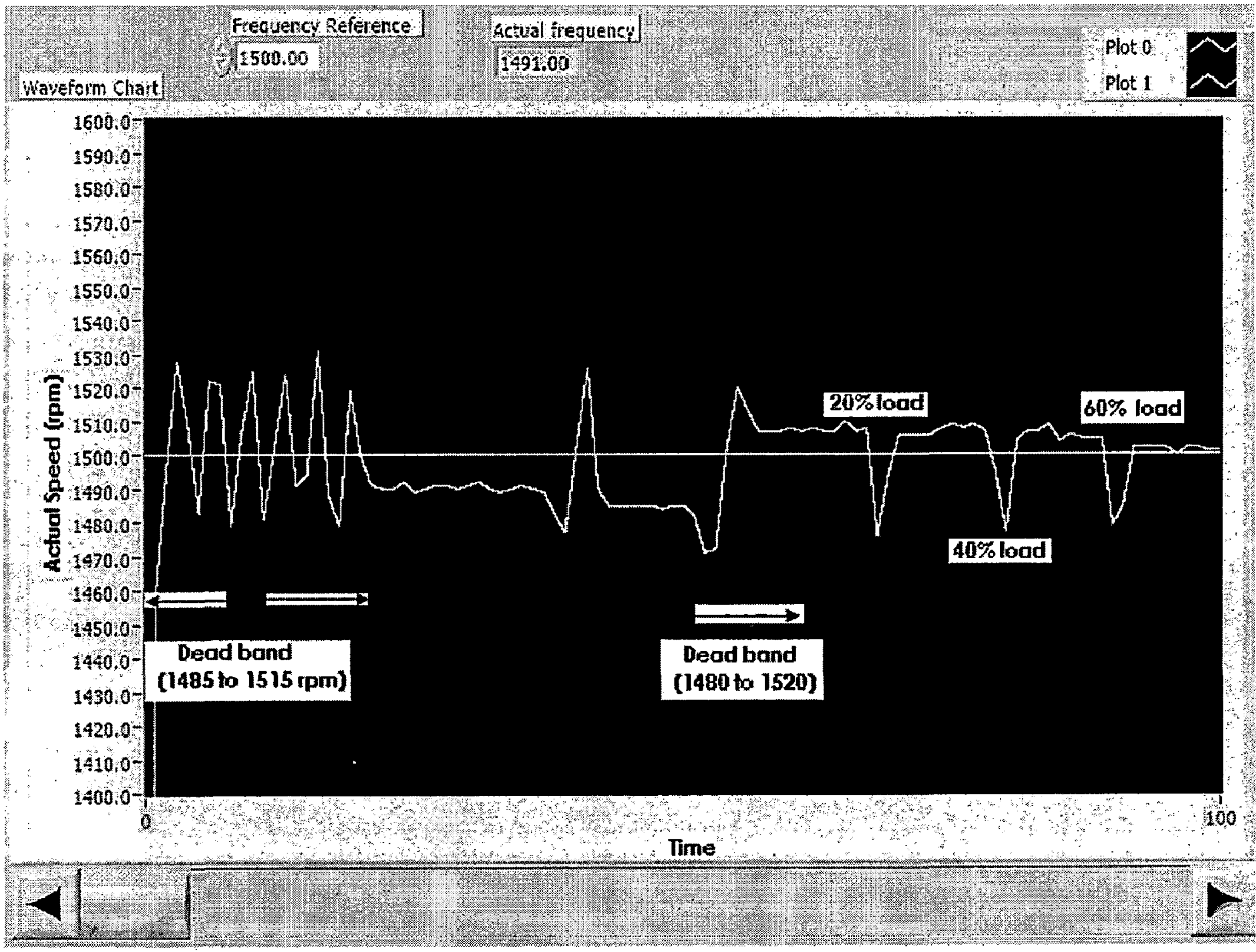


Figure 7-8: online waveform chart in Labview 1

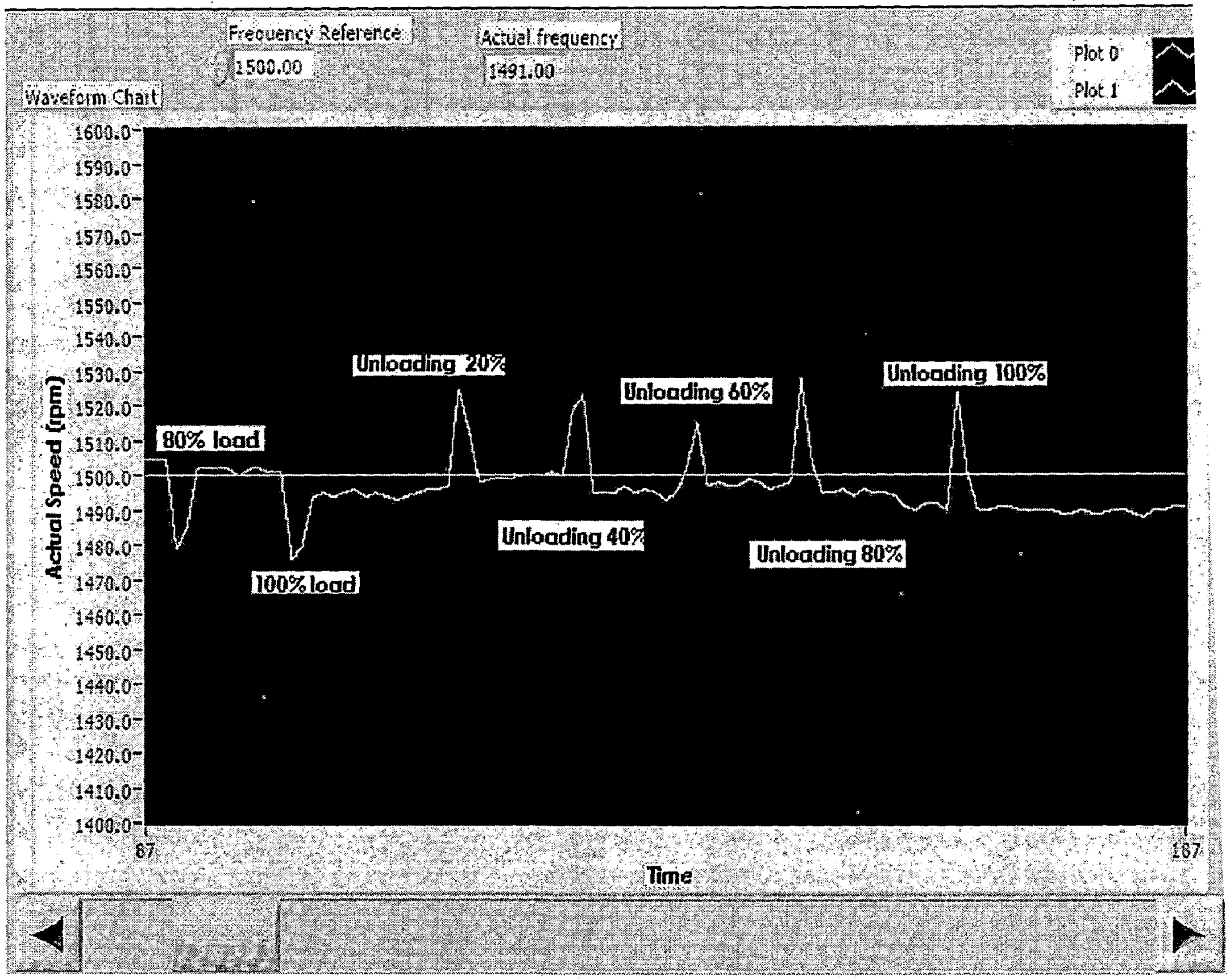


Figure 7-9: Online waveform chart in Labview 2

As seen from the above waveforms it is observed that the controller oscillates when the dead band is between 1485 and 1515 rpm, but it performs satisfactorily if the dead band is between 1480 to 1520 rpm.

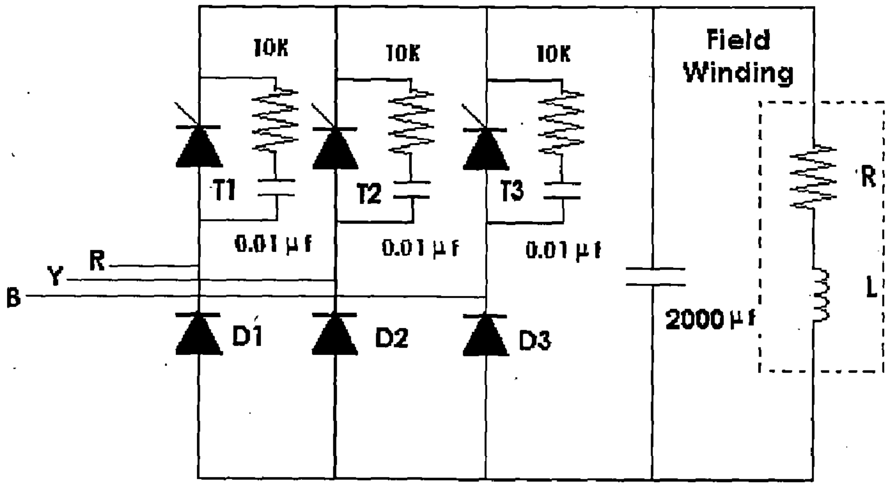
8. EXCITATION CONTROL

8.1 Introduction:

The basic function of the Excitation system is to supply and automatically adjust the field current of the synchronous generator to maintain the terminal voltage constant as the output varies within the continuous capability of the generator.

A Thyristor based excitation system is implemented as a part of thesis work. It is a three phase half controlled bridge rectifier. This system supply excitation current directly to the field winding of the generator. The power to the rectifier is from the generator terminals through a transformer (called excitation transformer) to step down voltage to appropriate level.

8.2 Three Phase half controlled bridge rectifier:



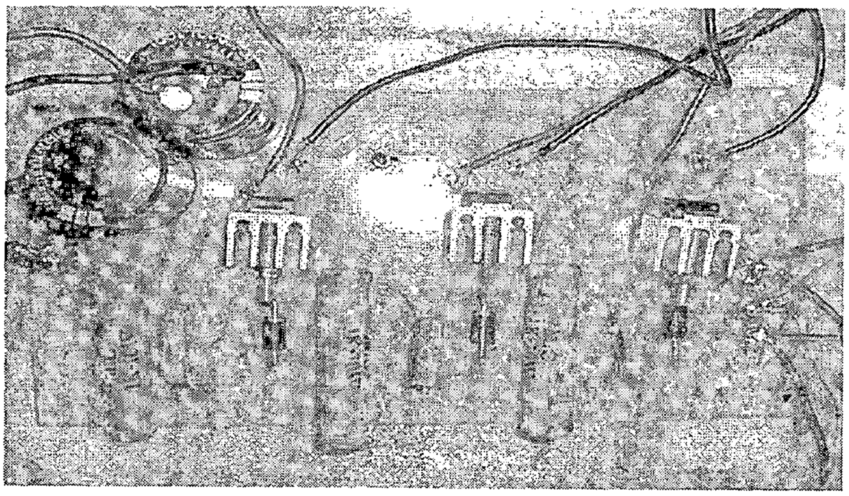


Figure 8-1: Three phase half controlled bridge

Figure 8-1 shows a half controlled rectifier bridge consisting of three diodes and three Thyristors which form a three phase bridge, since only half cycle can be controlled in each phase it is called half controlled bridge. The output of the bridge is connected to a filter capacitor of 2000μF, this is used to minimize the ripples and provide constant DC voltage in the output load which is the field winding of the generator. A 10K resistance and a capacitor of 0.01μF is placed in parallel to the Thyristor to limit the dv/dt rating.

8.3 Firing circuit for the half controlled rectifier:

A firing circuit provides necessary timing pulses to fire/start a Thyristor from OFF state to ON state. Figure 8.2 shows the circuit diagram for the firing circuit.

The output of the transformer is is fed to the firing circuit to generate the necessary firing pulses for the three Thyristor.

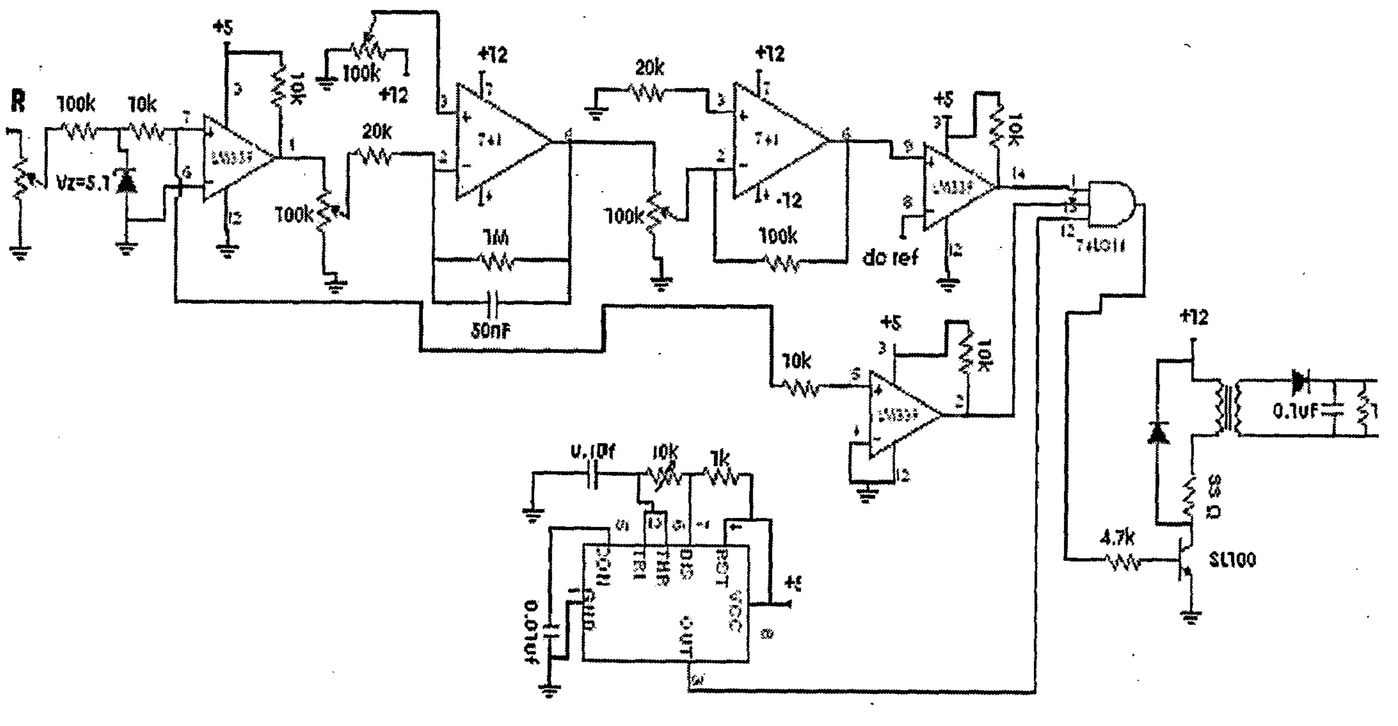


Figure 8.2: firing circuit for a single phase

The input from the transformer to the firing circuit is reduced by means of a potential divider and a zener diode is used to clip peak voltages of above 5volts.

The output of the zener is then fed to the LM339 comparator which acts as a zero crossing detector. The output of the zero crossing detector is a square wave with amplitude 0-5V. LM339 being an open collector output type a resistor of 10k is connected from supply of 5V to the out put terminal.

The square wave 0-5V is then converted into a triangular wave by means of an integrator circuit. The DC level of the triangle wave generator can be adjusted by means of a potential divider connected to the +ve terminal of the integrator The output of the integrator is fed to an inverting amplifier with adjustable gain. The triangular wave form is a combination of two ramp waveforms one with increasing slope and other with decreasing slope, positive ramp is taken for comparison with a standard DC reference. The output of the integrator is fed to a LM339 comparator which compares the positive ramp of the triangular wave with DC reference voltage and the output is a square wave whose period is proportional to the DC reference(0-5V).

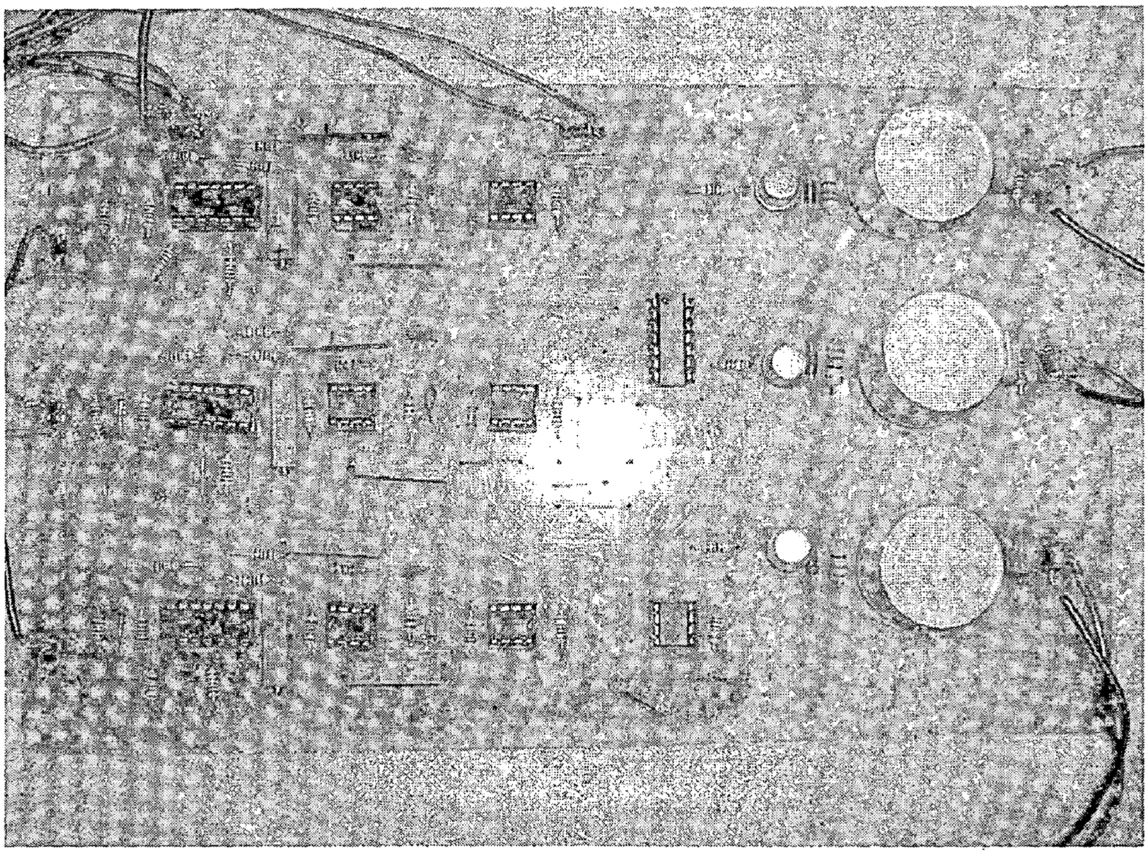


Figure 8-3: Photograph of complete firing Circuit

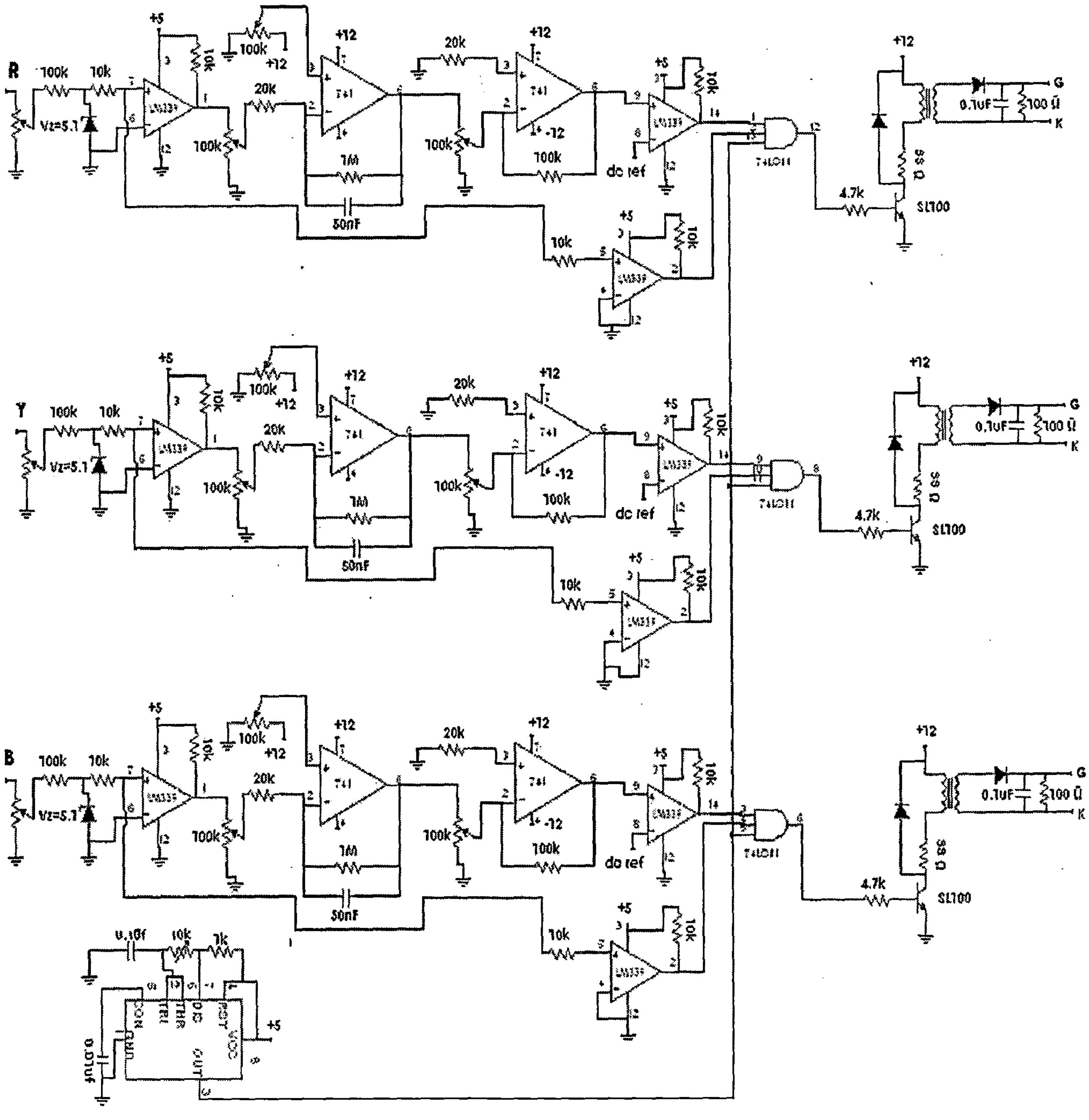


Figure 8-4: complete firing circuit schematic

For a 0V DC the output square wave has half the period of the input waveform ie sine wave and for 5V DC the output square wave has zero time period. Now the output of the comparator (final comparator) and another zero crossing detector and

555 timer output is fed to an AND gate IC 74LS11. The output of the AND gate is square wave pulses which are fed to the drive circuit.

The drive circuit consists of a SL100 transistor with a pulse transformer in its collector the purpose of the pulse transformer is to couple the pulses to the output without any distortion. **The output consists of a resistor of 100Ω**and a capacitor of 0.1μf. The complete circuit diagram for the three phase circuit is shown in figure 8-4.

8.4 Part List:

IC's : LM339, μA741, 74LS11, LM555

SCR : Tyn612

Resistors: 100Ω, 1KΩ, 10K, 100KΩ, 4.7KΩ, 2.2KΩ, 20KΩ

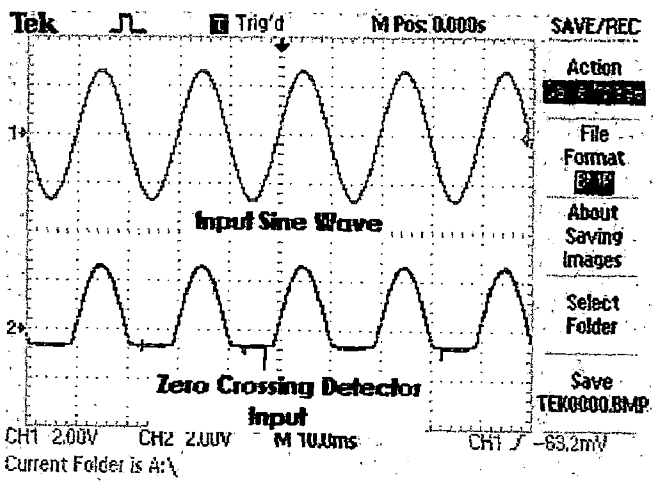
Capacitors: 0.01μf, 0.1μf

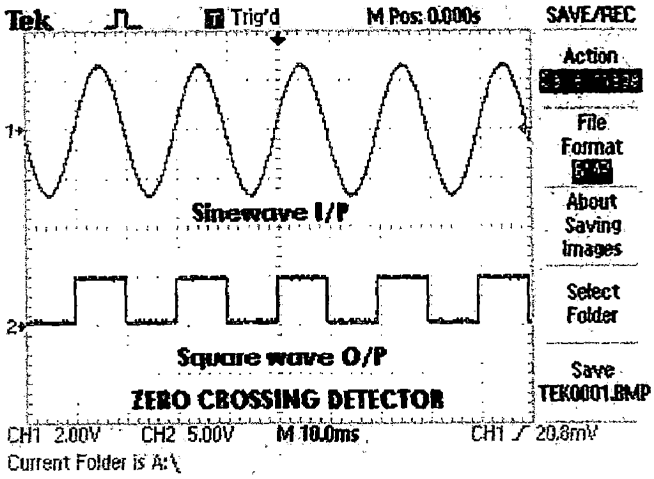
Diodes: IN5148, IN4009, Zener diode (5.1V)

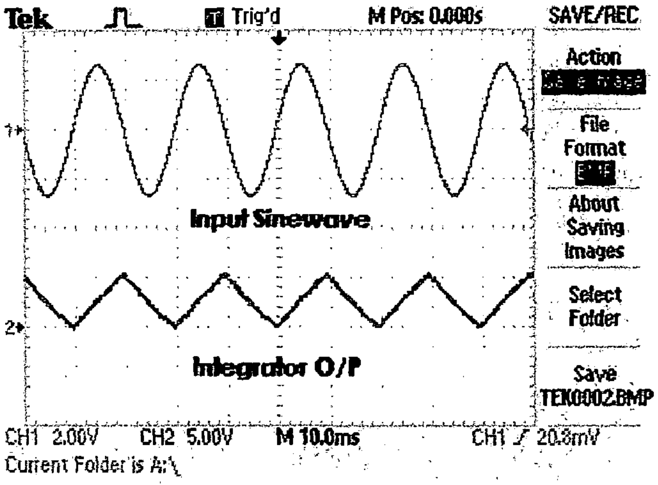
Transistor: SL100

Potentiometers: 10K, 100K

Waveforms of input, zero crossing detector (LM339), Integrator and pulse transformer output are shown below.




Tek
Trig'd
M Pos: 0.000s
SAVE/REC
Action
File Format
About Saving Images
Select Folder
Save TEK0001.BMP
Sinewave I/P
Square wave O/P
ZERO CROSSING DETECTOR
CH1 2.00V CH2 5.00V M 10.0ms CH1 ∕ 20.8mV
Current Folder is A:\


Tek
Trig'd
M Pos: 0.000s
SAVE/REC
Action
File Format
About Saving Images
Select Folder
Save TEK0002.BMP
Input Sinewave
Integrator O/P
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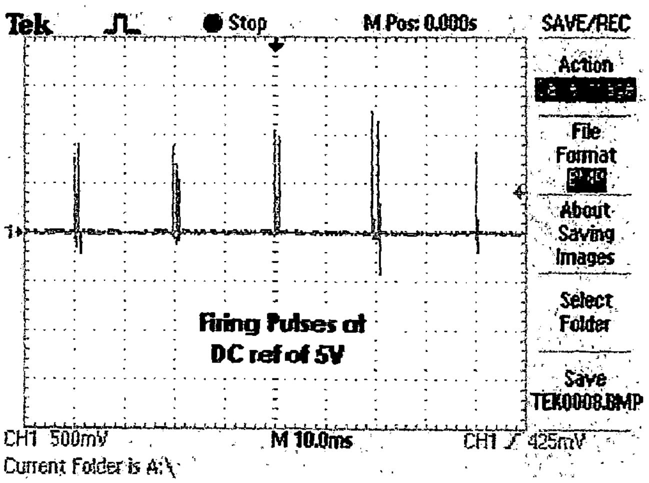
Current Folder is A:\


Tek
Stop
M Pos: 0.000s
SAVE/REC
Action
File Format
About Saving Images
Select Folder
Save TEK0008.BMP
Firing Pulses at
DC ref of 5V
CH1 500mV M 10.0ms CH1 ∕ 425mV
Current Folder is A:\

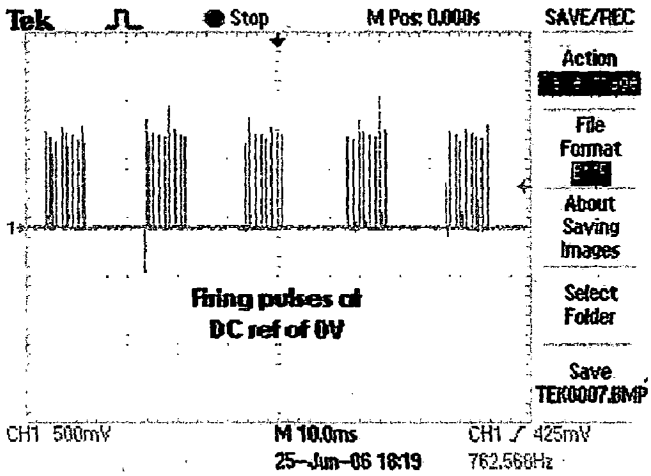


Figure 8-5: Waveforms of firing Circuit

8.4 Excitation control using Labview and Analog output module:

As seen from the firing circuit of the Thyristor the output DC of the three phase half controlled bridge can be controlled by varying the firing angle from 30° to 150°. This is achieved by varying the DC voltage from the analog output module. The excitation control is enabled at startup when the generator speed reaches 1500 rpm. The dc reference voltage is varied from maximum firing angle to minimum firing angle.

9. CONCLUSION AND FUTURE WORK

9.1 Conclusion:

A data acquisition and control system is developed using remote data acquisition modules and Labview real time professional. The experimentation performed on the hydro-generator test rig include:

- Online monitoring of speed, flow, inlet head, outlet head, terminal voltage and valve position.
- Speed control, Load control, and Excitation control.
- VI annunciator to indicate abnormal conditions.

The load on the generator is fed in five steps adding a load of one-fifth of generator capacity in each step.

Speed control performed using Electrical actuator is limited to ON/OFF control with specified dead band which is user selectable.

Excitation control is performed by variation of firing angle from 30° to150° such that the terminal voltage of the generator is 400V after reaching the predefined speed.

The load (lamp load) being resistive the drop in the terminal voltage was found to be negligible.

9.2 Future work:

The work can be further extended by:

- Making a provision for torque measurement so that the efficiency of the turbine alone can be calculated online.
- Electrical parameters such as line and phase voltages, currents, power factor, active and reactive power have to be monitored online. For this a power line analyzer with Labview driver has to be used. Once electrical power output is available , the efficiency of the turbine generator can be measured online [2].

- The VI annunciator can be made further effective by making a provision for monitoring electrical faults or abnormalities. This can be done using a digital input module with necessary hardware to take the status of different protective relays from their contacts.
- Excitation control can be performed using a PID control block in Labview if there is an appreciable change in the terminal voltage, this is possible when inductive load is fed to the generator.

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