DEVELOPMENT OF AN INTEGRATED DATA ACQUISITION SYSTEM FOR HYDRO TURBINE GENERATOR UNIT USING LABVIEW

A DISSERTATION

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

of

MASTER OF TECHNOLOGY

in

ALTERNATE HYDRO ENERGY SYSTEMS

By

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CANDIDATE'S DECLARATION

I hereby declare that the work presented in this dissertation entitled **"Development of an Integrated Data Acquisition System for Hydro Turbine Generator Unit using LabVIEW"** submitted in the partial fulfillment of the requirement of the award of degree of **Master of Technology** in **Engineering** with specialization in **Alternate Hydro Energy Systems** in the Department of **Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, Roorkee** is an authentic record of my own work carried out from July 2009 to June 2010 under the guidance and supervision of **Shri S.N. Singh, Sr. Scientific officer, Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, Roorkee.**

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

Date: June28, 2010

Place: Roorkee

(Rajkumar Viral)

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

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Date: June28, 2010
Place: Roorkee

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ABSTRACT

The rapid evolution of Renewable Energy Sources (RESs) during the last two decades resulted in the installation of many renewable energy power systems all over the world such as small hydro, wind, solar, biomass based etc. The increasing application of these RESs requires use of data acquisition in order to collect data, regarding the installed system operation monitoring, control of its operation and performance evaluation purposes. In this dissertation, the development of a computer based data acquisition system for monitoring parameters and performance of Hydro Turbine Generator Unit (HTGU) is presented.

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 implemented simultaneously, centrally and reliably by networking them with a computer.

The proposed system consists of a set of transducers for measuring both non-electrical (e.g. turbine head, discharge, power, speed etc.) and electrical parameters (generator voltage, current, power, speed etc.).The collected data are first conditioned using precision electronic circuits and then interfaced to a Personal Computer (PC)/Laptop using data-acquisition modules. The National Instrument (NI) LabVIEW program is used to further process, display and store the collected data in the PC/laptop. The modern feature of this data acquisition system is to access and monitor the system using more user friendly graphical interface software.

In context to above, using SHPs is an attractive and significant alternative among in renewable energies. Usually the SHPs situated in remote locations in hilly regions. Besides, that their monitoring is not quite easy.

This dissertation is first focuses on the brief description of development of SHPs and application of Data Acquisition System (DAS). Then, it acquaints the readers with the HTGU experimental setup along with the data collection and interfacing process, data representation in LabVIEW, the experimental results, conclusion and discussion.

This dissertation work helps to monitor all parameters of Small Hydropower Station in a single window on desktop. The proposed architecture permits the rapid system development and has the advantage of flexibility in the case of changes, while it can be easily

extended for monitoring and control I/O (Input/output) of HTGU based Small Hydro Power (SHP) station operation by some essential hardware modifications. This may be also led to help in monitoring the SHPs remotely/wirelessly.

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CHAPTER-1

INTRODUCTION AND LITERATURE REVIEW

1.1 GENERAL

The increasing demand and application of Renewable Energy Systems (RESs) during the last three decades resulted in the installation of many RES power systems such as small hydro, wind, solar, biomass based etc. Hence widespread application of RESs requires the use of data acquisition in order to collect data, regarding the installed system operation monitoring, control of its operation and performance evaluation purposes. Among renewable energy sources, the Small Hydropower Projects (SHPs) are advantageous owing to short gestation period, inexpensive operation & maintenance and most importantly environment friendly. Moreover, SHP is the oldest and yet the most reliable of all RESs [1].

The CEA estimates that the economically exploitable potential of the river systems in India stands at 148.7 GW, while its capacity under operation is 35.9 GW (including large hydro projects). The assessed potential of SHPs spanning almost all the states in the country is 14.3 GW. The hilly states of India mainly Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir and Uttarakhand have the highest potential of about 6.6 GW of SHPs cumulatively [2].

With the rapid developments of internet and computer technologies, accessing and operating of real time applications is becoming reality. Many modern Data Acquisition System (DAS) have developed and available now to evaluate the parameter and performance of such kind of machines (turbine, pumps and generator etc.), when they are in operation.

In context to above, using Hydro Turbine Generator Unit (HTGU) is one of the most important part of any Hydro power plant whether its Small or large. As compare to large hydro small hydro have relatively simple machines (HTGU) with no special designing and are readily available in most developing countries. Besides, their installation, commissioning and maintenance are easy and cheap [3]. Most of the SHPs are situated in remote and distant areas, due to that their testing, maintenance and monitoring problem is widespread and its a time consuming process. Here attempt to develop such a DAS which can help in above mentioned problems.

1.2. INTEGRATED DATA ACQUISTION SYSTEM (IDAS)

The computer revolution and widespread availability of personal desktop computers have spurred interest in telemetry receiving systems with the capability of recording information digitally. Data acquisition begins with the physical phenomenon to be measured. This physical phenomenon could be the temperature of a room, the intensity of a light source, the pressure inside a chamber, the force applied to an object, or many other things. An effective DAQ system can measure all of these different phenomena [4].

An effective data acquisition system can measure all of these different properties or phenomena. In computer data processing, data acquisition is the sampling of the real world to generate data that can be manipulated by a computer. Sometimes abbreviated DAQ or DAS, data acquisition typically involves acquisition of signals and waveforms and processing the signals to obtain desired information. The components of data acquisition systems include appropriate sensors that convert any measurement parameter to an electrical signal, then conditioning the electrical signal which can then be acquired by data acquisition hardware.

1.2.1 Need of Data Acquisition Systems

Data acquisition systems have evolved over time from electromechanical recorders containing typically from one to four channels to all-electronic systems capable of measuring hundreds of variables simultaneously. Early systems used paper charts and rolls or magnetic tape to permanently record the signals, but since the advent of computers, particularly personal computers, the amount of data and the speed with which they could be collected increased dramatically. However, many of the classical data-collection systems still exist and are used regularly.

The purpose of data acquisition is to measure an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound. PC-based data acquisition uses a combination of modular hardware, application software, and a computer to take measurements. While each data acquisition system is defined by its application requirements, every system shares a common goal of acquiring, analyzing, and presenting information.

Early, expensive mainframe computers were used extensively for gathering multiple channels of data, primarily in large industrial or scientific applications. They were seldom used in small projects because of their relatively high cost. But the introduction of small rack-mounted minicomputers that developed in the 1960's and later desktop personal-type computers that housed microprocessors and proliferated in the 1970's justified their use for smaller projects. Soon, data acquisition plug-in cards (as well as hundreds of other types of plug-in cards) for these small computers were a common means to collect and record data of all types [5].

All PC-based data acquisition systems will record extremely accurate, repeatable, reliable, and error-free data provided they are connected and operated according to the manufacturer's recommended practices. These practices include selecting the correct sensors for the application, the proper wire and shielded cable; capturing the signals in proper magnitude, range, and frequency; and paying close attention to grounding and shielding – particularly eliminating ground loops. Additional items include choosing the correct impedance and using doubled-ended (differential) inputs instead of single-ended where possible. The environment should also be considered, especially for extremes of ambient temperature, shock, and vibration. And herein lies the major goal of this publication – to inform users of the most needed recommended practices based upon a fundamental knowledge of the internal workings of data acquisition system instrumentation [6].

1.2.2 Application of IDAS in Small/Mini/Micro Hydro Power Plants

They require control and monitoring systems to limit the huge variation in input flows expected in rivulets over which these are established to produce a constant power supply in every power house. A Power Plant Monitoring System is extremely important for assuring normal operation of the whole power plant as well as initiating alarms to avoid further development of unattended fault within the power generating system. The task of monitoring a power plant is to detect faults at an early stage and avoid damages to the major components of the plant e.g. turbine, generator. There are many parameters of monitoring in a power house. Like generations, instantaneous voltage or generating voltage, current, power factor, temperature, revolutions per minutes of generator shaft because of frequency should be matched with the grid and it should be precisely monitored, kVA generations, load factor, kVAr generations. So knowing of current status of various parameters in system, the monitoring of all quantity is necessary. It helps for controlling of all equipments.

Usually, there are number of sensors in a power plant for measurement purpose, such as, pressure transmitters, flow meter, temperature transmitters, level transmitter, and so on. Until now, wired networks are used to connect sensors to transfer sampled process data to control systems. Many modern data acquisition system have developed and available now to evaluate the parameter and performance of such kind of machines (turbine, pumps and generator etc.), when they are in operation.

1.3 OBJECTIVE OF THE DISSERTATION

The objective of the dissertation is to develop a fully integrated DAS for HTGU which can able to measure the following parameters and display them on PC/Laptop:

(a) **Electrical parameters-** Generator Voltage, Current, Power, Power Factor, Frequency, Speed etc.

(b) **Non-electrical parameters-** Speed, Temperature, Pressure, Discharge, % of gate valve opening of turbine etc.

1.4 LITERATURE REVIEW

Losordo Thomas M. et al. in [7] had developed an automated water quality data acquisition system at the University of California, Davis (UCD). The self-contained microprocessor based system consists of a micro logger, a weather station and a unique water sampling raft. The system can monitor and record the following information on a routine basis: (a) weather data including solar irradiance, photo synthetically active radiation, wind speed, wind direction, air temperature, relative humidity and rainfall; (b) pond environmental data, taken at up to eight depths to a maximum of 175 cm, including dissolved oxygen, temperature, pH and photo synthetically active radiation.

Kusic G.L. et al. in [8] proposed a Remote Terminal Unit (RTU) for the generation of hydro systems which convert the raise/lower megawatts (MW) into timed relay contact closures to the governor which result in wicket gate open/close movement to change the generator output power. The output power of each generator is monitored by the digital Automatic Generation Control (AGC) which closes a feedback loop around the governor-turbine-generator to assure the desired power level is attained. This paper describes the feedback loop design, which is essentially a sampled-data control. Additional feedback loops due to the Area Control Error (ACE) and load regulation are also analyzed. A method is presented for allocating water usage between reservoirs on a generator command-time basis. The theoretical designs are verified by on-line measurements presented in the paper as in Fig.1 (a).

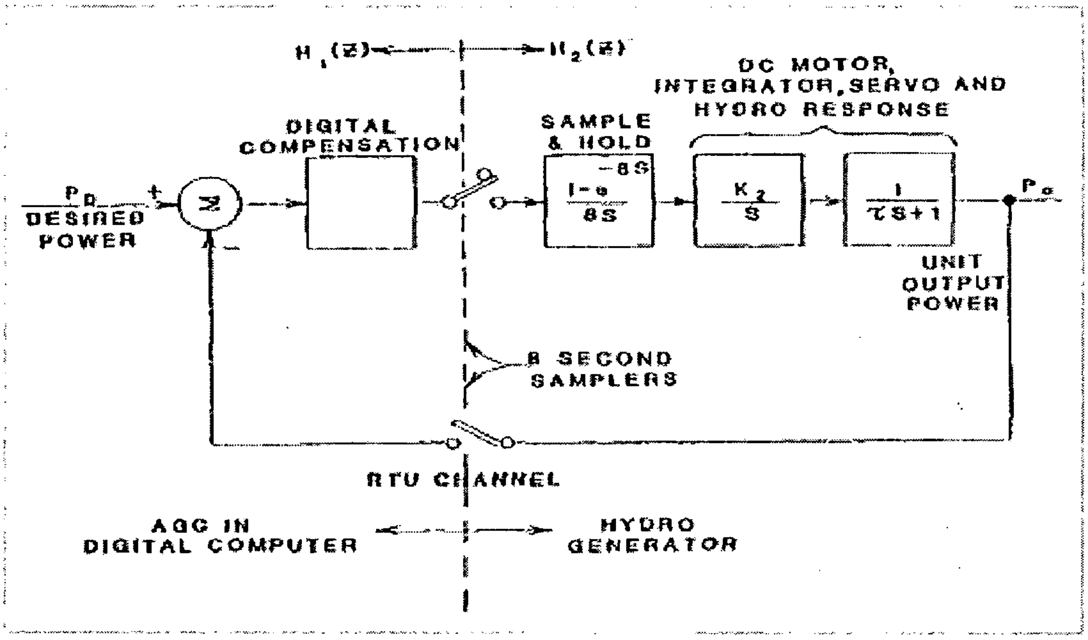

Fig. 1(a) Digital Control of a Hydro Generating Unit

Ibáñez Jesús et al. in [9] developed a high performance acquisition and processing DSP board (DASPU) for low frequency dynamic signals, based on the Texas Instruments TMS320C30 processor. It is specially suited for monitoring low speed rotating machinery: hydraulic generating sets, turbines, thermal power plants, etc. Up to 16 transducers can be connected to each DASPU and up to 32 DASPUs can be connected, via a communications network, to a remote host. Therefore, the proposed unit provides the flexibility and high performance characteristics required in monitoring and predictive maintenance systems. The presented DSP based monitoring system is currently working in one hydroelectric power plant in Spain.

A different approach has been proposed by **Wichert et al.** in [10], as shown in Fig. 1(b). A commercial data-logging unit has been used to measure a set of meteorological and operational parameters of a hybrid photovoltaic–diesel system. The collected data are transmitted to a PC through an RS-232 serial interface, where they are processed using the LabVIEW data acquisition software.

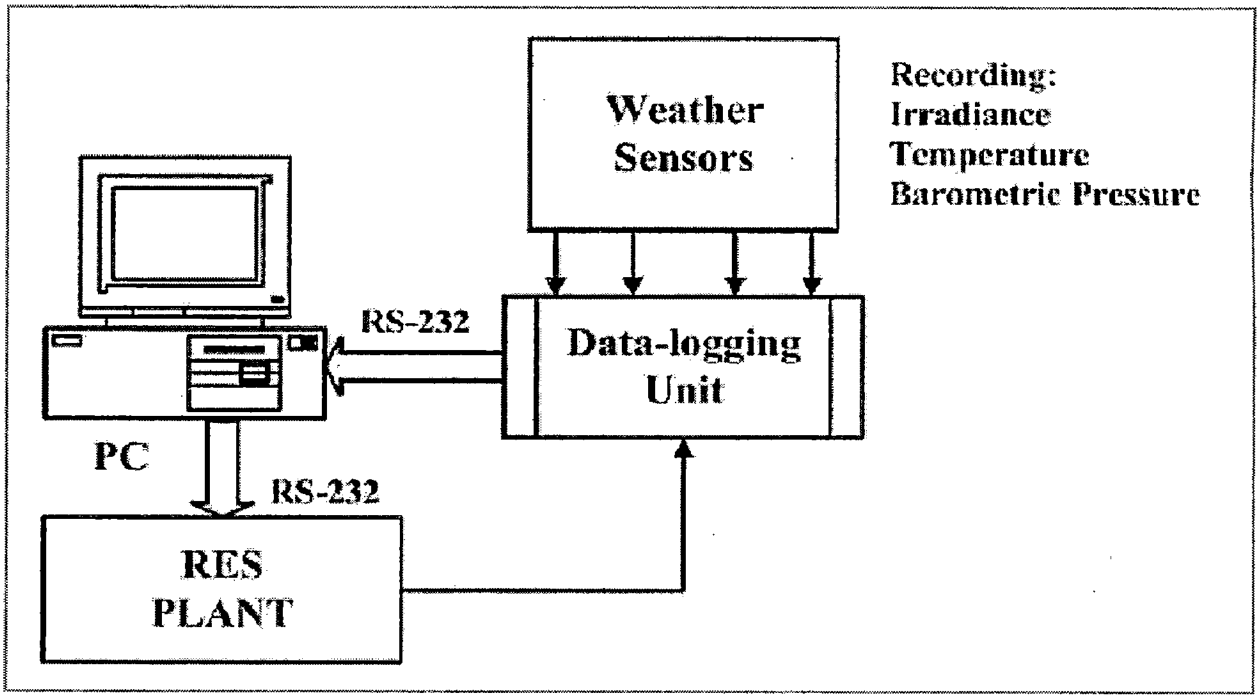

Fig. 1(b) Data-acquisition architectures for RES systems of a data logging unit connected to a PC

Koutroulis and Kalaitzakis in [11] describe a computer-based data-acquisition system for monitoring both meteorological data and renewable energy sources system operational parameters is proposed. A block diagram of the proposed system is shown in Fig. 1(c).

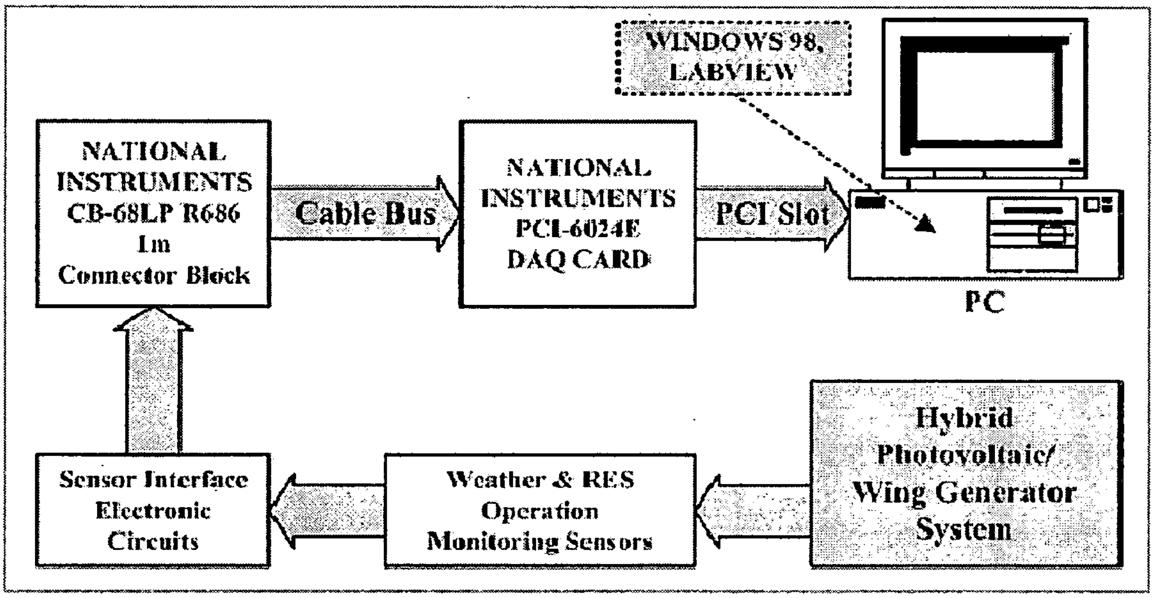

Fig. 1(c) Data-acquisition architectures for computer based renewable energy source systems

Chen x.y. and wu w. in [12] had developed, according to diversity and complexity of hydro-generator sets faults, a type of remote monitoring and diagnosis system is brought forward which is based on wavelet packet decomposition, BP Neural Network and MATLAB Web Server. Firstly, wavelet packet decomposition is introduced to acquire energy of hydro-generator sets signal's frequency band to be feature parameter. Secondly, BP Neural Network algorithm is analysed.

Momentum term is introduced to improve BP Neural Network learning rate. It reduces BP Network input dimension and improves BP Neural Network performance by use of extracting some energy features as BP Network input variables. Thirdly, it is the first time to adopt MATLAB Web Server to hydro-generator sets faults diagnosis to implement distributed remote monitoring and diagnosis system. Therefore, remote diagnosis application is independent from operating system (OS) used on server side. Most of all, clients can finish remote diagnosis by web browser and without installation of Matlab software. Fig.1 (d) illustrates the structure of this system.

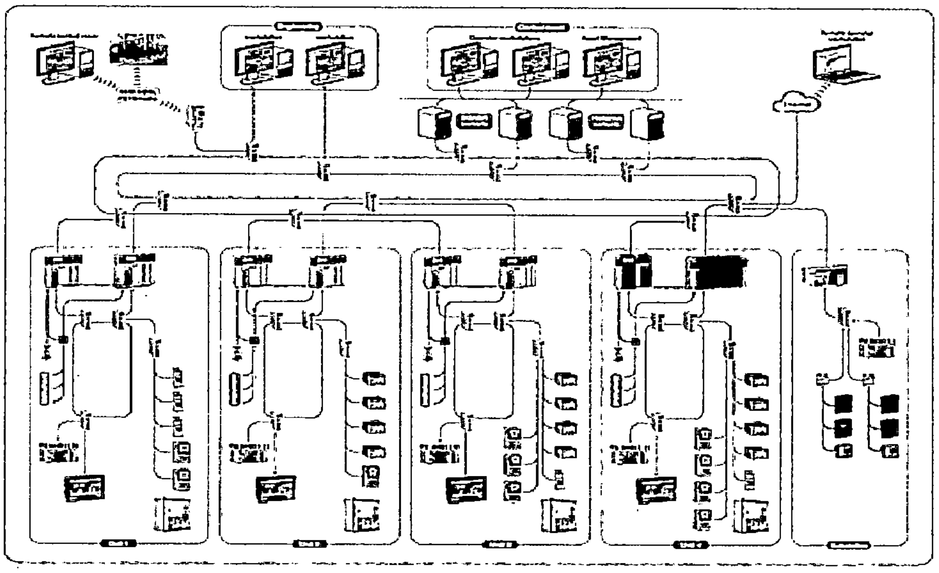

Fig. 1(d) Process control architecture in large hydro plant

Aristizábal A. J et al. introduced *a* system for monitoring the performance of PV power plants using the Virtual Instrumentation concept. Portable equipment for monitoring the performance and the quality of the power generated by PV power plants was implemented using the Virtual Instrumentation concept. For that, a NISCXI system was used as hardware and the LabVIEW graphical programming package 7.1 as software.Fig.1 (e) illustrated the Block diagram of the interconnected PV plant, showing the devices used for monitoring the performance and parameters determining the quality of the electrical power generated. [13].

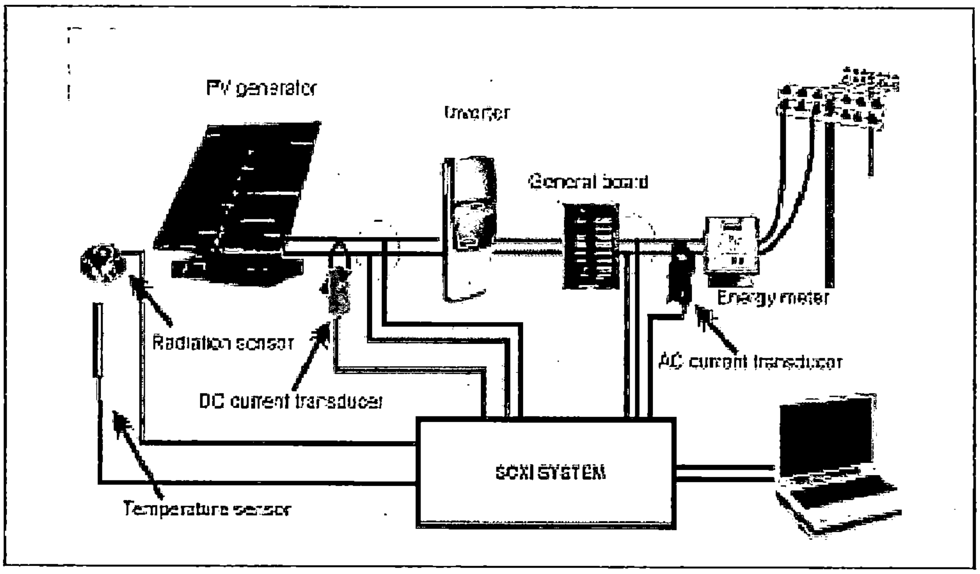

Fig.1 (e) The Block diagram of the interconnected PV plant, showing the devices used for monitoring the performance and parameters determining the quality of the electrical power generated.

Arshak et al. in [14] presents a review of developed simulated models for a wireless data acquisition system. The system reads analogue information provided by two sensors used for medical purposes. The real data have been recorded by two, pH and pressure sensors used in diagnosing conditions of the esophagus that are employed to examine the system performance. The created model contains four main simulated units using SIMULINK. The first unit contains the output signal, which is encoded to digital signal based on adapting one of the pulse coding modulation (PCM) algorithms. The second unit simulates the processor function that is responsible for framing, mixing and compressing the incoming bit streams from both sensors. The third unit, where the digital data are modulated and sent through different noisy channels, represents an efficient FSK transmitter/receiver model. At the receiver end, the signal is demodulated and processed inversely to extract the original analogue signal read by the two sensors.

In this work, the performance of the systems using different PCM methods will be studied comparatively in order to control the transmission and reduce the amount of data frames sent. This will lead to a significant reduction in power consumption. In addition, the performance of the RF unit through additive White Gaussian noise (AWGN) channel was examined by estimating the average bit error rate (BER) for different carrier frequencies.

The effect of the multipath fading, inband/outband interference, and adjacent channel power ratio (ACPR) has also been investigated during system assessment.

Demirtas Mehmet et al. in [15] describe the design and implementation of a data acquisition card for the hybrid energy system. Parameters of the solar and the wind sources such as the current, the voltage, the direction of wind, the operation conditions and the position of the solar system can be changed and illustrated on an LCD and displayed on a PC using the card developed. The hybrid system including a PIC 18F452 and a 18F2550 microcontroller has been tested on a 2.5 kW solar panel and a 2.5 kW wind turbine. It has been observed that this hybrid system works successfully and gives good performance such as low cost and easy programming.

Qadri Muhammad Tahir et al. in [16] discuss the approach of real-time controlling of the energy management system using the data acquisition tool of LabVIEW. The main idea of this inspiration was to interface the Station (PC) with the system and publish the data on internet using LabVIEW. In this venture, controlling and switching of 3 phase AC loads are effectively and efficiently done. The phases are also sensed through devices. In case of any failure the attached generator starts functioning automatically. The computer sends command to the system and system responds to the request. The modern feature is to access and control the system world-wide using world wide web (internet). This controlling can be done at anytime from anywhere to effectively use the energy especially in developing countries where energy management is a big problem. In this system totally integrated devices are used to operate via remote location.

Schneider-Electric France (Plant automation & energy management specialist comp.) in [17], developed Solution for micro hydro power plants, lower than 1MW: 1 turbine generator unit or several small generators (multi site) and local control. Its main applications are in

(a). Turbine-Generator unit management
(b). Protection of generator set
(c). Synchronization to grid network
(d). HMI and remote monitoring

The architecture of a Micro Hydro power plant is shown in Fig.1 (e) below: This architecture permits the following control:

(a). Remote control Web navigator

(b). SMS alarm system

(c). Magelis XBT GT HMI

(d). W@de W325 telemetry controller

(e). GPC, synchroniser, protection & monitoring module

(f). Instrumentation: flow, water level, pressure

(g). Valves, gates, deflectors, injectors

(h). Ventilation, bearing greasing system: TeSys U & TeSys T motor starters and Altivar drives

(i). Auxiiaries, contactor and circuit breakers

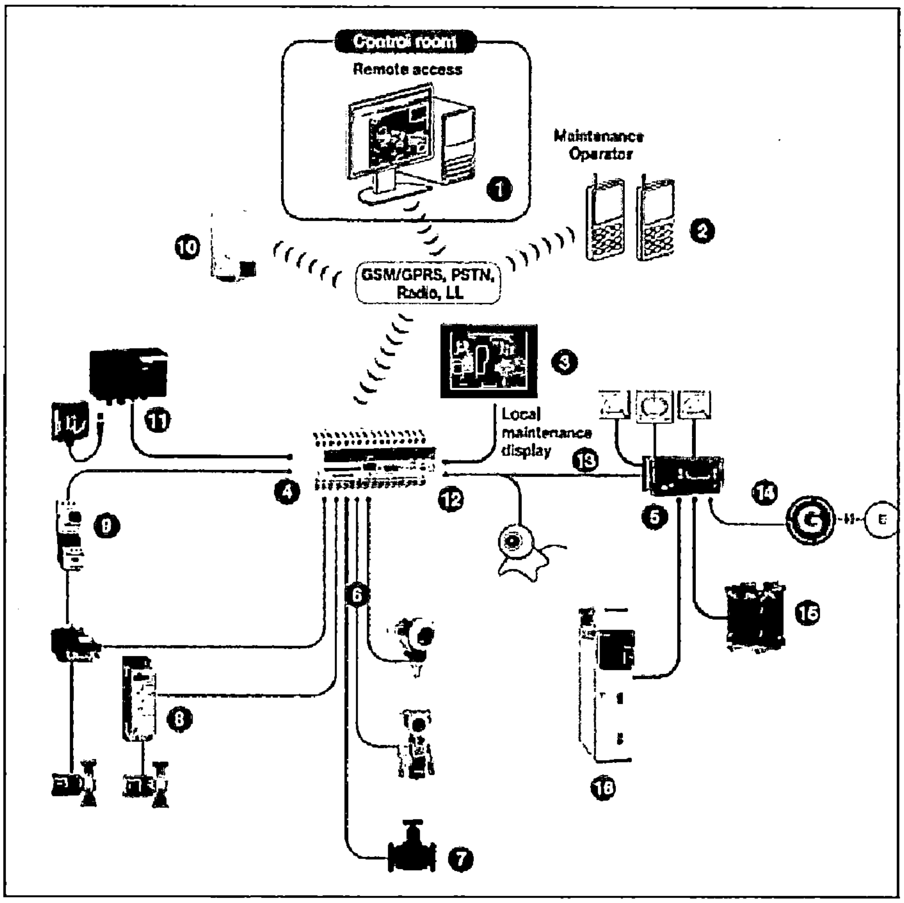

Fig.1 (f) Architecture of a Micro Hydro Power plant

(j). W@de W310 standalone data acquisition module

(k). Ositrack RFID module

CHAPTER-2
DATA ACQUISITION SYSTEM (DAS)

2.1 GENERAL

The computer revolution and widespread availability of personal desktop computers have spurred interest in telemetry receiving systems with the capability of recording information digitally. Data must then be stored in a memory device in the field and later transferred to a "main computer" back in the office. Today, digital computers and other microprocessor-based devices have replaced analog recording and display technologies in all but the simplest data acquisition applications.

Data acquisition begins with the physical phenomenon to be measured. This physical phenomenon could be the temperature of a room, the intensity of a light source, the pressure inside a chamber, the force applied to an object, or many other things. In computer data processing, data acquisition is the sampling of the real world to generate data that can be manipulated by a computer. Sometimes abbreviated DAQ or DAS, data acquisition typically involves acquisition of signals and waveforms and processing the signals to obtain desired information [4].

2.2 FUNDAMENTAL OF DATA ACQUISTION SYSTEMS

Data Acquisition Systems, as the name implies, are products and/or processes used to collect information to document or analyze some phenomenon. In the simplest form, a technician logging the temperature of an oven on a piece of paper is performing data acquisition [18].

In other words, Data acquisition is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound. PC-based data acquisition uses a combination of modular hardware, application software, and a computer to take measurements. While each Data Acquisition (DA or DAQ) system is defined by its application requirements, every system shares a common goal of acquiring, analyzing, and presenting information. Data acquisition systems incorporate signals, sensors, actuators, signal conditioning, DAQ devices, and application software [4].

Acquired data are displayed, analyzed, and stored on a computer, either using vendor supplied software, or custom displays and control can be developed using various general purpose programming languages such as BASIC, C, Fortran, Java, Lisp, Pascal. Specialized programming languages used for data acquisition include EPICS, used to build large scale data acquisition systems, LabVIEW, which offers a graphical programming environment optimized for data acquisition, and MATLAB which provides a programming language, and also built-in graphical tools and libraries for data acquisition and analysis [6].

Today, most scientists and engineers are using personal computers with Peripheral Component Interconnect (PCI), Peripheral eXtentions Interconnect (PXI)/Compact PCI, Personal Computer Memory Card International (PCMCIA), Universal Serial Bus (USB), IEEE1394, Industry Standard Architecture (ISA), or parallel or serial ports for data acquisition in laboratory research, test and measurement, and industrial automation.

Many applications use plug-in boards to acquire data and transfer it directly to computer memory. Others use DAQ hardware remote from the PC that is coupled via parallel or serial port [19].

Obtaining proper results from a PC-based DAQ system depends on each of the following system elements are given below and shown in Fig. 2.1(a), (b) and (c).

(a). The Personal Computer

(b). DAQ Hardware

(c). DAQ Software

(d). Sensors/Transducers

(e). Signal Conditioning Units

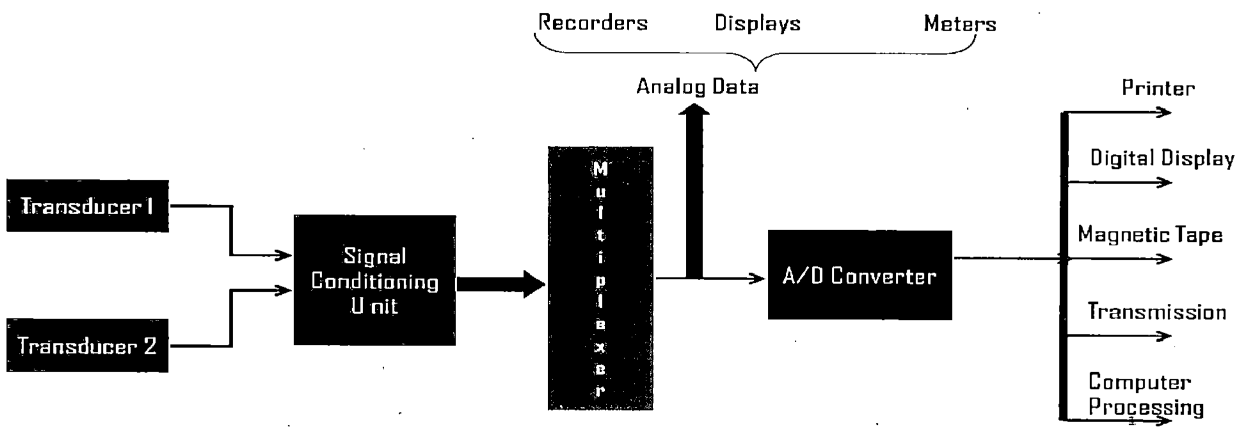

Fig.2.1 (a) Generalized Block diagram of DAQ System and its component

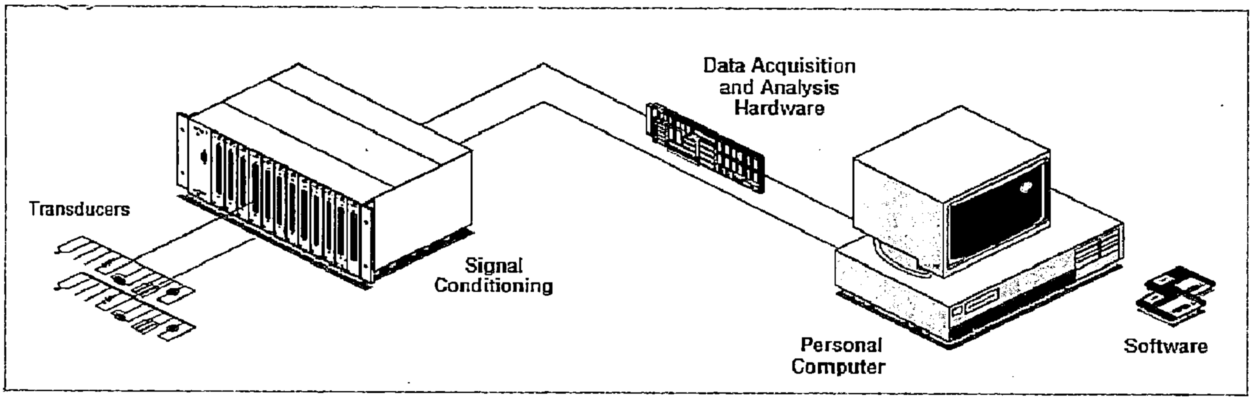

Fig.2.1 (b) Typical PC-Based DAQ System and its component [19]

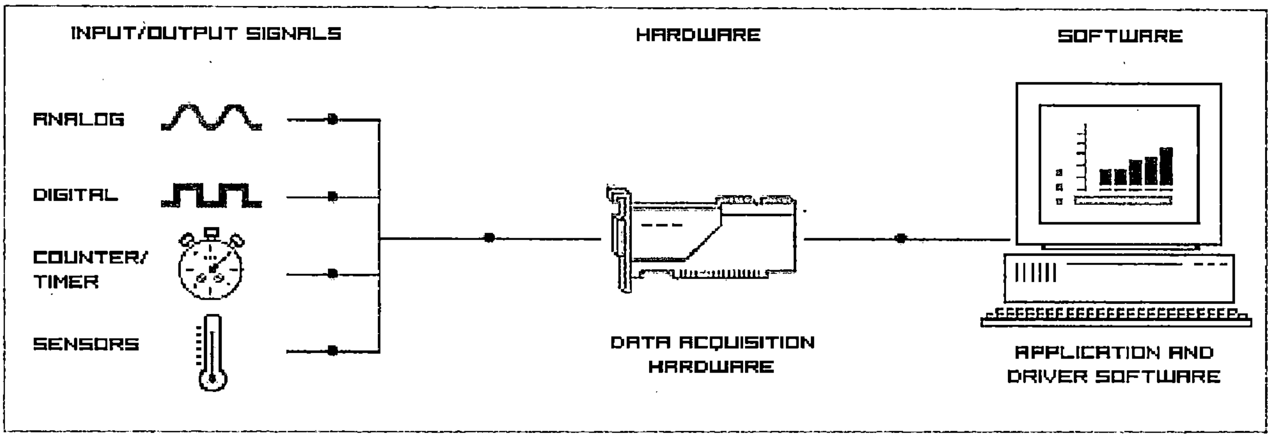

Fig.2.1 (c) Another view of PC-Based DAQ System [19]

In detail all the components of the PC-Based DAQ System may be explain as:

2.2.1 The Personal Computer

The Computer we use for our DAQ system can drastically affect the maximum speeds at which we can continuously acquire data. As computers continuously improve, our DAQ system can take advantage of the computer's enhanced capabilities, including improved real-time processing, the ability to use complex video graphics, and higher streaming-to-disk throughput. Today's technology boasts Pentium IV and Power PC class processors coupled with the high-performance bus architectures. The PCI bus and USB port are standard equipment on most of today's desktop computers and yield up to 132 Mbytes/s theoretical data transfer capabilities. External and portable PC buses such as PCMCIA, USB, and FireWire offer a flexible alternative to desktop PC-based DAQ systems while achieving up to 40 Mbytes/s transfer rates.

For remote or distributed DAQ applications, we can place measurement nodes near sensors and signal sources and use standard networking technology, such as Ethernet, serial, or wireless. When choosing a DAQ device and bus architecture, keep in mind the data transfer methods supported by our chosen device and bus and the transfer rates. The data transfer capabilities of our computer can significantly affect the performance of our DAQ system. Twenty years ago, PCs capable of transferring at rates around 5 MHz, whereas today's computers can transfer significantly faster [6].

As PC speed continuously increases, DAQ system speed increases as a result. Today's PCs are capable of programmed I/O and interrupt data transfers. Direct memory access (DMA) transfers increase the system throughput by using dedicated hardware to transfer data directly into system memory. Using this method, the processor is not burdened with moving data and is therefore free to engage in more complex processing tasks.

Traditional platforms include Mac OS, which is known for its simple graphical user interface and Windows 2000 or XP which include native plug and play and power management. Furthermore, real-time operating systems provide reliability and robustness that may appeal to our particular application [20].

2.2.2 DAQ Hardware

Depending on our application, there are several different classes of PC-based data acquisition devices that we can use are:

(a). Analog Input/Output
(b). Digital Input/Output
(c). Counter/Timers
(d). Data Acquisition – a combination of analog, digital and counter operations [5].

2.2.3 DAQ Software

Software transforms the PC and DAQ hardware into a complete DAQ, analysis, and display system. DAQ hardware without software is useless – and DAQ hardware with poor software is almost useless. The majority of DAQ applications use driver software. These are the example of software used for DASs -Test Point, Snap Master, LabVIEW, DADISP, DASYLAB, e-TAP, MATAB, D-CON, etc, some software packages are as shown in shown in Fig. 2.2.

2.2.3.1 Functions

Driver Software functions for controlling DAQ hardware can be grouped into analog I/O, digital I/O and timing I/O. Although most drivers will have this basic functionality, we will want to make sure that the driver can do more than simply get data on and off the board. The driver should have the functionality to [21, 22]:

(a). Acquire data at specified sampling rates.
(b). Acquire data in the background while processing in the foreground (continuous data acquisition).
(c). Use programmed I/O, interrupts and DMA to transfer data.
(d). Stream data to and from disk.
(e). Perform several functions simultaneously.
(f). Integrate more than one DAQ board.
(g). Integrate seamlessly with signal conditioning equipment.

These and other functions of the DAQ driver save the user considerable development time.

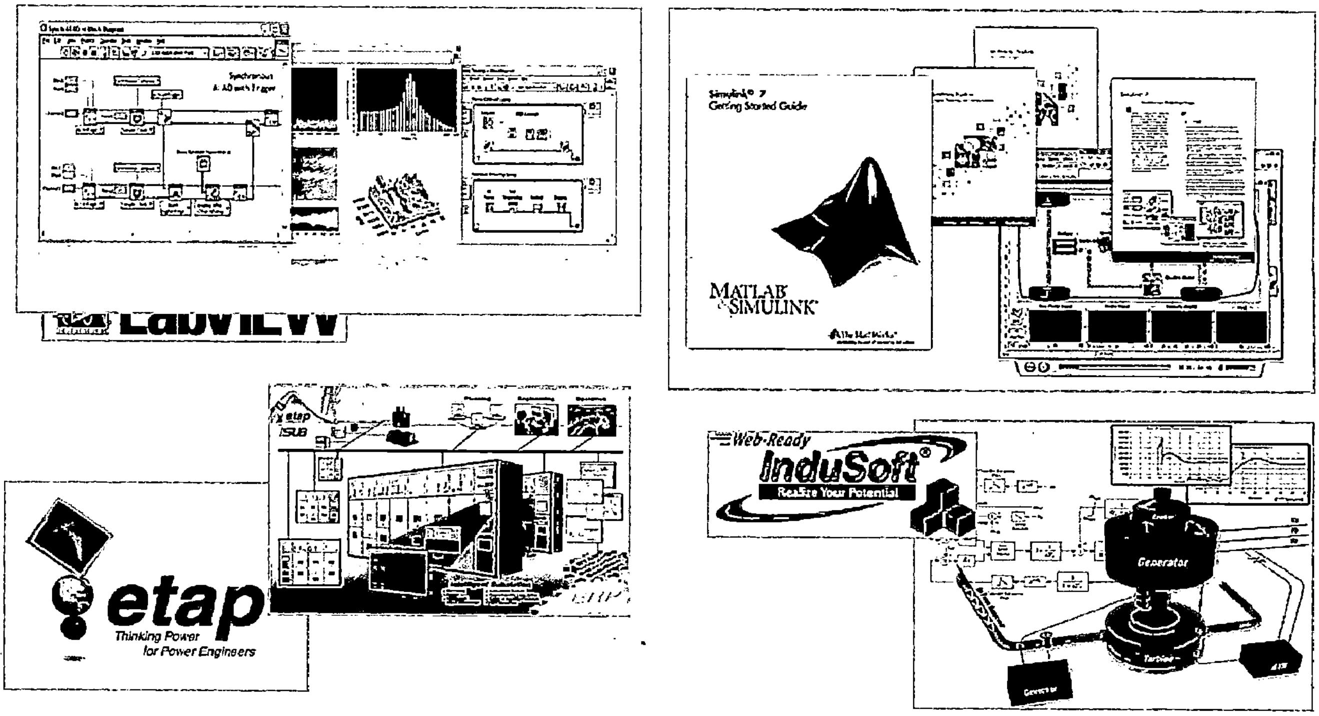

Fig.2.2 Some Software used for industrial automation and Control

2.2.4 Sensors/Transducers

A sensor converts the physical phenomena of interest into a signal that is input into our data acquisition hardware. Transducers are synonymous with sensors in DAQ systems. There are two main types of sensors based on the output they produce: digital sensors and analog sensors [23].

Digital sensors produce an output signal that is a digital representation of the input signal, and has discrete values of magnitude measured at discrete times. A digital sensor must output logic levels that are compatible with the digital receiver. Examples of digital sensors include switches and position encoders [5].

Analog sensors produce an output signal that is directly proportional to the input signal, and is continuous in both magnitude and in time. Most physical variables such as temperature, pressure, and acceleration are continuous in nature and are readily measured with an analog sensor. For example, the temperature of an automobile cooling system and the acceleration produced by a child on a swing all vary continuously.

The sensor we use depends on the phenomena we are measuring. Some common analog sensors and the physical variables they measure are listed below in Table 2.1 [24].

Table 2.1 Electrical Characteristics and Basic Signal Conditioning Requirements of Common Transducers

Sensor	Electrical Characteristics	Signal Conditioning Requirement
Thermocouple	Low-voltage output Low sensitivity Nonlinear output	Reference temperature sensor (for cold-junction compensation) High amplification Linearization
RTD	Low resistance (100 ohms typical) Low sensitivity Nonlinear output	Current excitation Four-wire/three-wire configuration Linearization
Strain gauge	Low resistance device Low sensitivity Nonlinear output	Voltage or current excitation High amplification Bridge completion Linearization Shunt calibration
Current output device	Current loop output (4 - 20 mA typical)	Precision resistor
Thermistor	Resistive device High resistance and sensitivity Very nonlinear output	Current excitation or voltage excitation with reference resistor Linearization
Active Accelerometers	High-level voltage or current output Linear output	Poour source Moderate amplification
AC Linear Variable Differential Transformer (LVDT)	AC voltage output	AC excitation Demodulation Linearization

Some of the Common Analog Sensors are shown in Fig.2.3. When choosing the best analog sensor to use, we must match the characteristics of the physical variable we are measuring with the characteristics of the sensor. The two most important sensor characteristics are [5]:

(a). The sensor output

(b). The sensor bandwidth

2.2.4.1 Sensor Output

The output from a sensor can be an analog signal or a digital signal, and the output variable is usually a voltage although some sensors output current.

(a). Current Signal - Current is often used to transmit signals in noisy environments because it is much less affected by environmental noise.

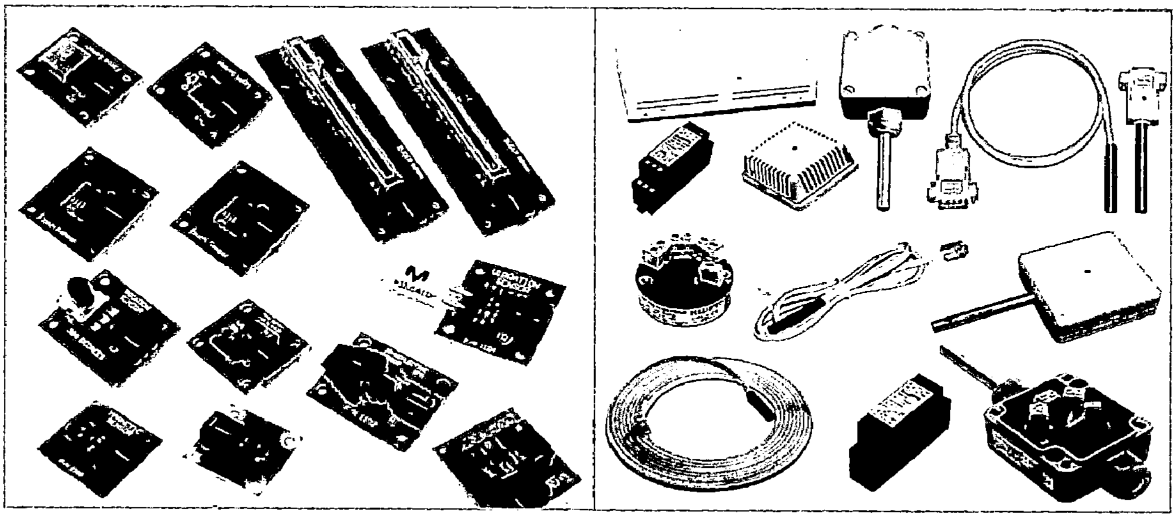

Fig. 2.3 Common Analog Sensors and other sensors

The full scale range of the current signal is often either 4-20 mA or 0-20 mA. A 4-20 mA signal has the advantage that even at minimum signal value, there should be a detectable current flowing.

Before conversion by the analog input subsystem, the current signals are usually turned into voltage signals by a current-sensing resistor. The resistor should be of high precision, perhaps 0.03% or 0.01% depending on the resolution of our hardware.

Additionally, the voltage signal should match the signal to an input range of the analog input hardware. For 4-20 mA signals, a 50 ohm resistor will give a voltage of 1 V for a 20 mA signal by Ohm's law.

(b). Voltage Signals - The most commonly interfaced signal is a voltage signal. For example, thermocouples, strain gauges, and accelerometers all produce voltage signals.

2.2.4.2 Sensor Bandwidth

The bandwidth is given by the range of frequencies present in the signal being measured. We can also think of bandwidth as being related to the rate of change of the signal. A slowly varying signal has a low bandwidth, while a rapidly varying signal has a high bandwidth. To properly measure the physical phenomena of interest, the sensor bandwidth must be compatible with the measurement bandwidth [23, 24].

We might want to use sensors with the widest possible bandwidth when making any physical measurement. This is the one way to ensure that the basic measurement system is capable of responding linearly over the full range of interest. However, the wider the bandwidth of the sensor, the more we must be concerned with eliminating sensor response to unwanted frequency components.

2.2.5 Signal Conditioning Unit

Sensor signals are often incompatible with data acquisition hardware. To overcome this incompatibility, the sensor signal must be conditioned. The type of signal conditioning required depends on the sensor we are using [25]. For example, a signal might have small amplitude and require amplification, or it might contain unwanted frequency components and require filtering. Common ways to condition signals include

(a). Amplification

(b). Filtering

(c). Electrical isolation

(d). Multiplexing

(e). Excitation source

2.2.5.1 Amplification

Low-level – less than around 100 millivolts – usually need to be amplified. High-level signals might also require amplification depending on the input range of the analog input subsystem. For example, the output signal from a thermocouple is small and must be amplified before it is digitized. Signal amplification allows we to reduce noise and to make use of the full range of our hardware thereby increasing the resolution of the measurement.

2.2.5.2 Filtering

Filtering removes unwanted noise from the signal of interest. A noise filter is used on slowly varying signals such as temperature to attenuate higher frequency signals that can reduce the accuracy of our measurement. Rapidly varying signals such as vibration often require a different type of filter known as an antialiasing filter. An antialiasing filter removes undesirable higher frequencies that might lead to erroneous measurements [26].

2.2.5.3 Electrical Isolation

If the signal of interest contains high-voltage transients that could damage the computer, then the sensor signals should be electrically isolated from the computer for safety purposes. We can also use electrical isolation to make sure that the readings from the data acquisition hardware are not affected by differences in ground potentials.

2.2.5.4 Multiplexing

A common technique for measuring several signals with a single measuring device is multiplexing. Signal conditioning devices for analog signals often provide multiplexing for use with slowly changing signals such as temperature. This is in addition to any built-in multiplexing on the DAQ board. The A/D converter samples one channel, switches to the next channel and samples it, switches to the next channel, and so on.

Because the same A/D converter is sampling many channels, the effective sampling rate of each individual channel is inversely proportional to the number of channels sampled.

2.2.5.5 Excitation Source

Some sensors require an excitation source to operate. For example, strain gauges, and Resistive Temperature Devices (RTDs) require external voltage or current excitation. Signal conditioning modules for these sensors usually provide the necessary excitation. RTD measurements are usually made with a current source that converts the variation in resistance to a measurable voltage.

Some of the signal conditioning hardware options are display in Fig. 2.4

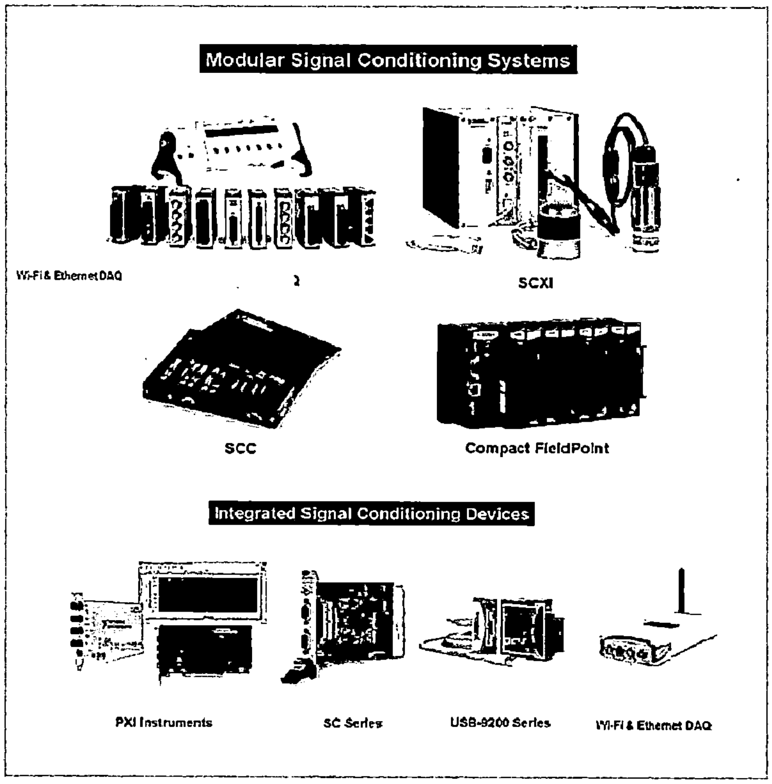

Fig. 2.4 Signal conditioning hardware options

2.3 COMMON TERMS ABOUT DASs

In the line of above, there are some common data acquisitions terms are given below [19]:

(a). Analog-to-digital converter (ADC)

An electronic device that converts analog signals to an equivalent digital form. The analog to-digital converter is the heart of most data acquisition systems.

(b). Digital-to-Analog Converter (D/A)

An electronic component found in many data acquisition devices that produce an analog output signal.

(c). Digital Input/output (DIO)

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No.AHEC/U-15/ 2694 Dated : July 12, 2010

M.TECH. DISSERTATION VIVA-VOCE EXAMINATION NOTICE

M. Tech. Dissertation Viva-Voce examination in respect of **Shri Raj Kumar Viral** will be held in the conference room of AHEC on **July 14, 2010 (Wednesday)** at 9.00 AM. All interested are kindly requested to attend the same.

DISSERTATION TOPIC : **DEVELOPMENT OF AN INTEGRATED DATA ACQUISITION SYSTEM FOR HYDRO TURBINE GENERATOR UNIT USING LABVIEW**

DISSERTATION SUPERVISOR (S)

CC :

1. Head & Chairman, CRC for information please.
2. ~~O.C. M.Tech. Course (AHES & CRL).~~
3. CRC Nominee (Dr. D.K. Khatod, Asstt. Professor, AHEC)
4. Dean, Academic Programme.
5. All faculty members (AHEC).
6. The external examiner (Dr. M.K. Pathak, Asstt. Professor, EED, IIT Roorkee).
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No.AHEC/U-15/ 2690 Dated : July 12, 2010

CONFIDENTIAL

Dr. M.K. Pathak,
Asstt. Professor,
EED, IIT Roorkee

SUBJECT: EXAMINATION OF DISSERTATION FOR AWARD OF MASTER OF TECHNOLOGY DEGREE IN ALTERNATE HYDRO ENERGY SYSTEMS.

Dear Sir,

You are invited to act as External Examiner for the dissertation submitted by **Shri Raj Kumar Viral.**

It shall be appreciated if you could kindly accept this offer and participate in the evaluation process of the dissertation entitled :

"DEVELOPMENT OF AN INTEGRATED DATA ACQUISITION SYSTEM FOR HYDRO TURBINE GENERATOR UNIT USING LABVIEW"

There will be a Viva-Voce examination and you may kindly intimate the Internal Examiner **Dr. D.K. Khatod, Asstt. Professor**, AHEC a suitable date.

The dissertation work is a partial requirement for the award of Mater of Technology Degree. It is normally completed in a period of 15 months. It carries 36 credits.

I would be grateful if you may kindly communicate your acceptance.

Encl : The dissertation.

Yours faithfully,

HEAD

Copy to : Internal Examiner (s)

Dr. D.K. Khatod, with a copy of dissertation and request to please arrange for the Viva-Voce examination in consultation with the External Examiner and Chairman of the Board of Examiner.

HEAD

(d).Differential Input (DI)

Refers to the way a signal is wired to a data acquisition device. Differential inputs have a unique high and unique low connection for each channel.

(e). General Purpose Interface Bus (GPIB)

Synonymous with HPIB (for Hewlett-Packard), the standard bus used for controlling electronic instruments with a computer. Also called IEEE 488 in reference to defining ANSI/IEEE standards.

(f). Resolution

The smallest signal increment that can be detected by a data acquisition system. Resolution can be expressed in bits, in proportions, or in percent of full scale. For example, a system has 12-bit resolution, one part in 4,096 resolutions, and 0.0244 percent of full scale.

(g). RS232

A standard for serial communications found in many data acquisition systems. RS232 is the most common serial communication, however, it is somewhat limited in that it only supports communication to one device connected to the bus at a time and it only supports transmission distances up to 15.243m (50 feet).

(h).*RS485*

A standard for serial communications found in many data acquisition systems. RS485 is not as popular as RS232, however, it is more flexible in that it supports communication to more than one device on the bus at a time and supports transmission distances of approximately 1524.39m (5,000 feet).

(i). Sample Rate

The speed at which a data acquisition system collects data. The speed is normally expressed in samples per second. For multi-channel data acquisition devices the sample rate is typically given as the speed of the analog-to-digital converter (A/D). To obtain individual channel sample rate, we need to divide the speed of the A/D by the number of channels being sampled.

(j). Single-Ended Input (SE)

Refers to the way a signal is wired to a data acquisition device. In single-ended wiring, each analog input has a unique high connection but all channels share a common ground connection. Data acquisition devices have either single-ended or differential inputs. Many support both configurations.

2.4 DAQ SPECIFICATIONS

A "typical specification" provides good insight into how the product will perform because it represents how a vendor expects a product to perform under normal operating conditions. The comprehensive description of the specifications is intended to make it easier to interpret and understand the material in our Instrumentation. All specifications represent typical performance at 25°C unless otherwise noted. All specifications are applicable for all DAQ products.

(a). Analog Input
(b). Analog Output
(c). Digital I/O
(d). Digital Relays
(e). Timing I/O
(f). Triggers
(g). Excitation
(h). Digital Signal Processor
(i). RTSI

2.5 TYPES OF DASs

DASs may be classified as follows:

1. On the basis of their Installation [25]
2. On the basis of their use [26]

2.5.1. On the basis of their Installation

Three general usage types:

(a). Laboratory
(b). Distributed
(c). Portable

Laboratory and ***distributed*** DAQ systems are normally put in a permanent location as these are comprised of relatively large or bulky hardware and connect to desktop PCs in some way. These systems depend upon the PC to access, process, and analyze input data and prepare it for some type of presentation. ***Portable*** DAQ systems, on the other hand, are small, lightweight units that are easily carried by hand and work with laptops or, even, no computer at all when installed at a location or site to only record data.

Laboratory and ***distributed*** data-acquisition systems typically adhere to industry-based packaging standards. For instance, some laboratory systems are mounted in standard 19-inch racks while distributed systems often use track mountings. A subset of these systems includes a host computer that accommodates data-acquisition plug-in boards. ***Portable*** systems, in contrast, have no real standardized form they may come in various sizes and shapes, but they are typically small and light. Further, portable systems are additionally classified as either stand-alone units or those which connect to a PC. Stand-alone units are self-contained data loggers and do not need a PC connection to function.

Further, inputs may or may not be isolated, and either single-ended or differential, or both of the three types, ***portable*** systems are gaining a larger market share as the other (legacy) systems age, and these portable systems are increasingly outperforming them. Further, the new portable systems can be easily configured for laboratories and distributed systems as well as portable applications. When considering a data acquisition system to purchase, however, the most important functional parameters that differentiate them include accuracy, resolution, and sampling rate [23].

2.5.2 On the basis of their applications

Four types are generally used:

(a). Wireless Data Acquisition Systems

(b). Serial Communication Data Acquisition Systems

(c). USB Data Acquisition Systems

(d). Data Acquisition Plug-in Boards

In detail they may be summarized as follows.

2.5.2.1 Wireless Data Acquisition Systems

Wireless data acquisition systems can eliminate costly and time consuming field wiring of process sensors. These systems consist of one or more wireless transmitters sending data back to a wireless receiver connected to a remote computer. Wireless transmitters are available for ambient temperature and relative humidity, thermocouples, RTDs, pulse output sensors, 4 to 20 mA transmitters and voltage output transducers [13]. Receivers can be connected to the USB or Ethernet port on the PC as shown in Fig. 2.5 (a).

2.5.2.2 Serial Communication Data Acquisition Systems

Serial communication data acquisition systems are a good choice when the measurement needs to be made at a location which is distant from the computer. There are several different communication standards, RS232 is the most common but only supports transmission distances up to 15.24m (50 feet). RS485 is superior to RS485 and supports transmission distances to 1524.39 m (5,000 feet) as shown in Fig.2.5 (b).

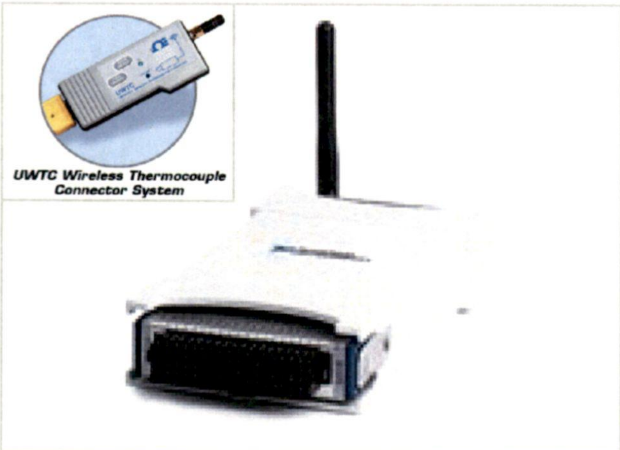


Fig. 2.5(a) Wireless DAS

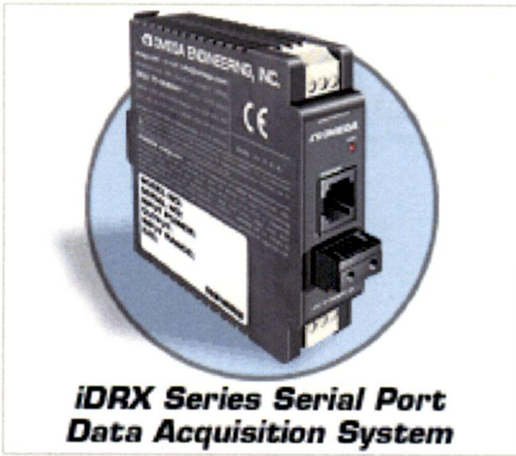


Fig. 2.5(b) Serial Communication DAS

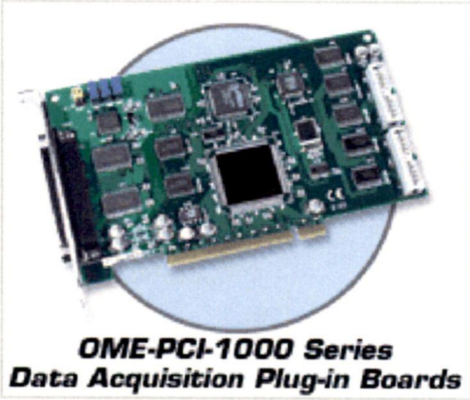
2.5.2.3 USB Data Acquisition Systems

The Universal Serial Bus (USB) is a new standard for connecting PCs to peripheral devices such as printers, monitors, modems and data acquisition devices. USB offers several advantages over conventional serial and parallel connections, including higher bandwidth (up to 12 Mbits/s) and the ability to provide power to the peripheral device. USB is ideal for data acquisition applications. Since USB connections supply power, only one cable is required to link the data acquisition device to the PC, which most likely has at least one USB port as shown in Fig.2.5(c).

Fig. 2.5 (c) USB Data Acquisition Systems

2.5.2.4 Data Acquisition Plug-in Boards

Computer data acquisition boards plug directly into the computer bus. Advantages of using boards are speed (because they are connected directly to the bus) and cost (because the overhead of packaging and power is provided by the computer). Features provided by the cards can vary due to number and type of inputs (voltage, thermocouple, on/off), outputs, speed and other functions provided. Each board installed in the computer is addressed at a unique Input/Output map location. The I/O map in the computer provides the address locations the processor uses to gain access to the specific device as required by its program as shown in Fig.2.5 (d).



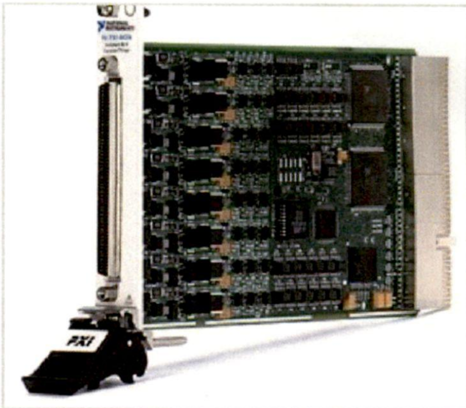


Fig. 2.5(d) Data Acquisition Plug-in Boards

2.6 FUTURE'S DASs

As mentioned previously, **USB 2.0** is continuing to see expanding usage in portable measurement applications. However, other PC bus technologies will also see broad adoption in future data acquisition applications. One example is the next generation of USB, which has been announced by Intel and others, and whose specification is currently being finalized. **USB 3.0** is targeted to reach bandwidths up to 10 times the current bandwidth of USB 2.0 by using two additional high-speed signal pairs. This "superspeed" mode is expected to provide roughly 4.8 Gbit/s of bandwidth, enabling very high speed I/O streaming. The first commercial silicon for USB 3.0 is expected in 2009 or 2010.

Wireless is one of the most promising technologies for data acquisition. Wireless technologies have undergone a consolidation and standardization of technologies similar to what occurred for plug-in and cabled PC buses. For high-speed continuous transmission, IEEE 802.11 (Wi-Fi) has seen incredible adoption in mobile computing applications. Maybe even more importantly for data acquisition applications; vendors have improved the industrial ruggedness of Wi-Fi products. Additionally, IT requirements have significantly enhanced the security and reliability of Wi-Fi networks with technologies such as WPA2 data encryption. Today, Wi-Fi access points can be connected to Ethernet-based data acquisition systems such as NI Compact RIO and NI Compact Field Point. However, the economies of scale, reliability, and ease of use of Wi-Fi make the technology ripe for integration into future data acquisition devices [6].

Future data acquisition devices will continue to leverage and benefit from technology advancements in the broader computing and consumer electronics industries. Expect to see continued growth and adoption of USB, more integration of signal conditioning, and added flexibility with onboard FPGAs – programmable with Softwares – on data acquisition devices. Looking forward, further granularity and modularity, next-generation bus technologies, and integrated wireless capabilities will help define the data acquisition landscape of the future.

In the same line NASA launches his fully automatic Integrated DAS (The ADAS 5000 gives flight-test and safety engineer's reliable and accurate real-time data at greatly reduced maintenance costs. NASA studies put the savings at 20,000 worker-hours per year.) [27, 28].

CHAPTER-3
EXPERIMENTAL TEST SETUP

3.1 INTRODUCTION

In this section, we comprise the detail about Experiment test setup; which is situated in the Hydro Mechanical Laboratory of Alternate Hydro Energy Centre of IIT Roorkee. The test rig mainly consists of an induction motor coupled with 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; which actually in reverse mode works as Turbine and called Pump-As-Turbine (PAT). (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 control by motorised valve. 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 feeder panels. All the sensor/transducers are connected to the various parts of the test rig as mentioning ahead.

3.1.1 Experimental Test Setup Construction

The experimental test setup picture and schematic is shown in Fig.3.1 (a) and (b). It consisted an iron fabricated water tank with the capacity of 1.35x1.35x1.6 m.On the right hand side of the tank there is an induction motor coupled pump which is actually used to create the required head and discharge for the turbine, which situated on the left hand side as shown in above Figures. This pump works Pump as a Turbine when rotates in reverse mode. A 3-φ.415 volt, 50 Hz A.C. generator is coupled to the PAT with the shaft connected exciter.

3-φ bulb load is fed by the 3-φ supply of generator by means of two feeder panel. The resistive load of the generator consists of 5 rows of lamps with 3 lamps in each row and they are arranged such that all the 5 bulbs in each column which are connected to a phase, as the generator is of three phases all the lamps are accommodated by that system. Fig. 3.2 is an arrangement of load system which is connected through R, Y, B phases.

Fig.3.1 (a) Experimental Test Setup Photographs (at Hydro-Mechanical Lab AHEC IIT Roorkee)

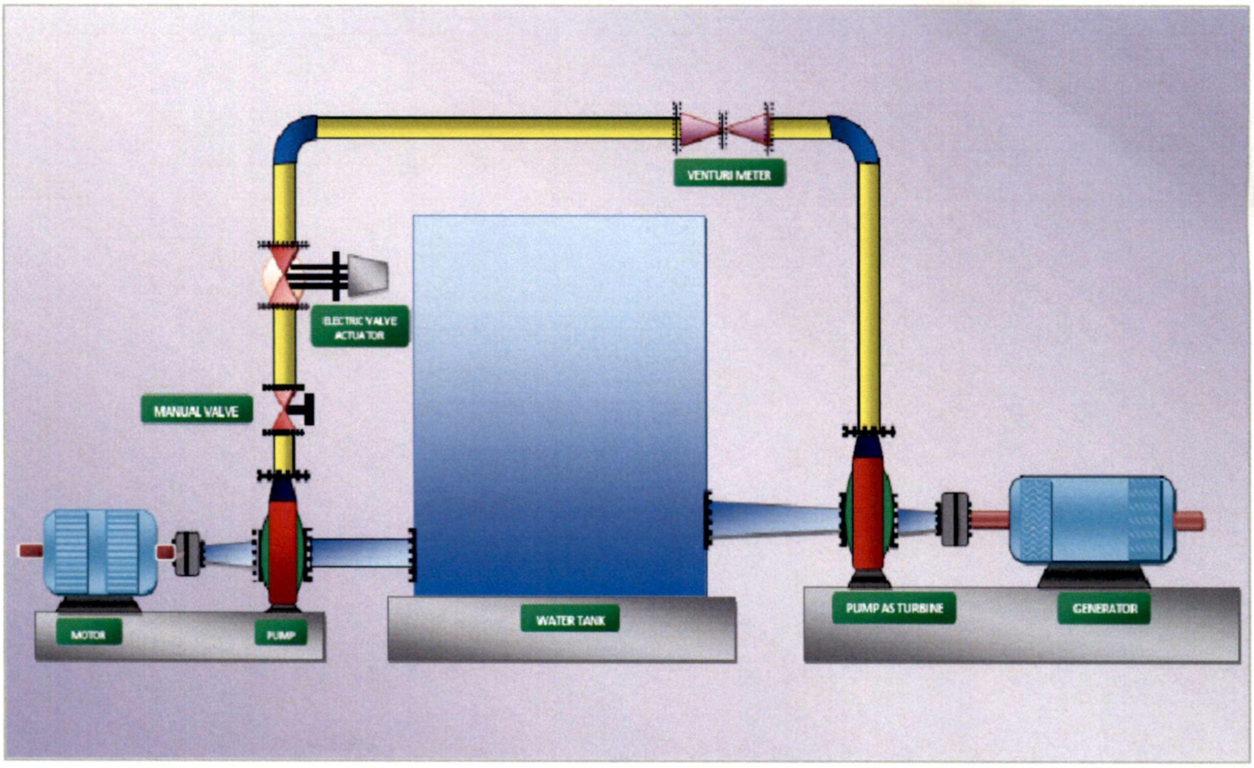


Fig.3.1 (b) Schematic of Experimental Test Setup

3.1.2 Technical Specification of Setup

The technical specifications mainly of Induction motor for water lifting pump, impeller pump, turbine-generator and load are:

a. Water Lifting Motor

Type: A.C.,3-ϕ,Induction

Terminal voltage: 415V

Active power: 22kW

H.P.:30

Frequency: 50 Hz

Speed: 1500 rpm

Made: Kirloskar

b. Turbine (PAT)

Total head: 32.8 meter

Flow rate: 14.5 liter/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 24.0 lps.

c. **Generator**

Type : Synchronous

Terminal voltage: 415V

Reactive power: 12.5 kVA

Active power: 10 kW

Power factor: 0.8

Frequency: 50 Hz

Speed: 1500 rpm

Excitation: 23.5V DC, 2.32 A

Made: Kirloskar

3.2 MEASUREMENT OF PARAMETERS

In this test setup we have to measure the following parameters:

(1) Electrical Parameters- Voltage (Phase Voltages V_1 V_2 V_3), Current (Phase Currents I_1 I_2 I_3), kW, kVAr, kVA, Power factor, Frequency.

(2) Non-Electrical Parameters- Speed, Temperature of bearing, Pressure (Head), Discharge, percentage (%) of gate valve opening and Efficiency of the unit.

For measurement purpose we used following instruments:

(a). Ultrasonic Transit Time Flow meter (UTTF)

(b). Power Analyzer

(c). Infrared Temperature Gun (IRTG)

(d). Pressure Transmitter

(e). Speed Sensor

(f). Motorised Control Valve (Electric Actuator)

(g). Data Acquisition Module (using NI USB 6212 DAC or DAQ card)

(h). PC/Laptop

(i). Variable DC Power Supply

(j). RS232 Connecting Cable (for flow meter output)

(k). NI 6212 USB Cable

(l). Miscellaneous

(The Details technical specifications, operation, working and application of each equipment are described in chapter 4, 5, and 6)

3.3 BLOCK DIAGRAM OF COMPLETE SETUP

All the instruments we are using give analog output to the module which further transmitted via USB port with PC/Laptop. The National Instruments (NI) **USB 6212** DAQ card or module is 16 analog inputs (16-bit, 400 kS/s) and 2 analog outputs (16-bit, 250 kS/s); 32 digital I/O; two 32-bit counters with Bus-powered USB for high mobility is used. In our experimental work we also are having the sixteen analog inputs of all sensors/transducers; which is further explained as:

- **(a) Analog Input from Power Analyzer:** It is having eight analog input of Voltage (Phase Voltages V_1 V_2 V_3), Current (Phase Currents I_1 I_2 I_3), kW & GND; which directly connected to DAQ card.
- **(b) Analog Input from UTTF:** It is having only single analog input after converting it into voltage signal; which is directly connected to DAQ card. Transducer gives output 0-10 V and 4-20 mA, for minimum to maximum discharge for each particular set.
- **(c) Analog Input from Pressure Transmitter:** It is having only single analog input after converting it into voltage signal. Two Absolute LD301model pressure transmitters are used to measure the inlet and outlet pressure of turbine in kg/cm^2 which give the necessary head. The output of the transmitter is in 0-20mA.
- **(d) Analog Input from IRTG:** It is having only single analog input after converting it into voltage signal; which is directly connected to DAQ card.
- **(e) Analog Input from Speed Sensor:** It is having only single analog input; which is directly connected to DAQ card.
- **(f) Analog Input from Electrical Actuator:** A electrically controlled gate valve is monitored. Output ranges 4-20 mA for closed to full open valve position. It is having only single analog input after converting it into voltage signal; which is directly connected to DAQ card.

Finally the DAQ card is connected to the PC/Laptop via USB cable which readable by means of LabVIEW software. The complete setup connection block diagram and position of all sensor/transducer is shown in Fig.3.2.

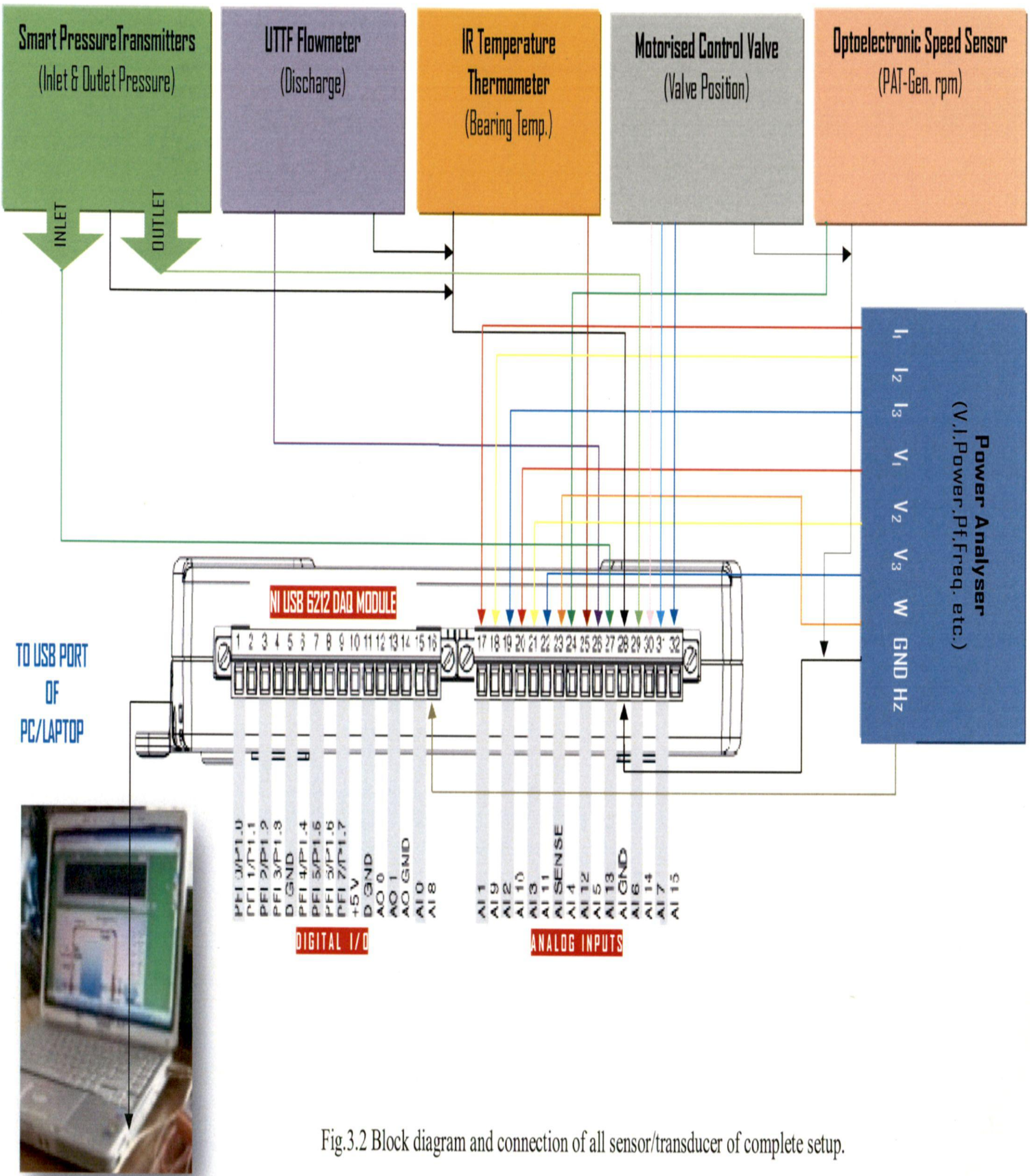


Fig.3.2 Block diagram and connection of all sensor/transducer of complete setup.

3.4 DATA REPRESENTATION

LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a platform and development environment for a visual programming language from National Instruments. LabVIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of platforms including Microsoft Windows, various flavors of UNIX, Linux, and Mac OS. LabVIEW is a graphical programming environment used by millions of engineers and scientists to develop sophisticated measurement, test, and control systems using intuitive graphical icons and wires that resemble a flowchart. LabVIEW programs are called virtual instruments, or **VIs**, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. LabVIEW contains a comprehensive set of tools for acquiring, analyzing, displaying, and storing data, as well as tools to help you troubleshoot code you write.

In LabVIEW, we build a user interface, or **front panel**, with controls and indicators. Controls are knobs, push buttons, dials, and other input mechanisms. Indicators are graphs, LEDs, and other output displays. After you build the user interface, you add code using VIs and structures to control the front panel objects. **The block diagram** contains this code. We can use LabVIEW to communicate with hardware such as data acquisition, vision, and motion control devices, as well as GPIB, PXI, VXI, RS232, and RS485 instruments. Demonstration of a few of the controls is illustarted in Fig. 3.3 with front and the block diagram objects respectively [6].

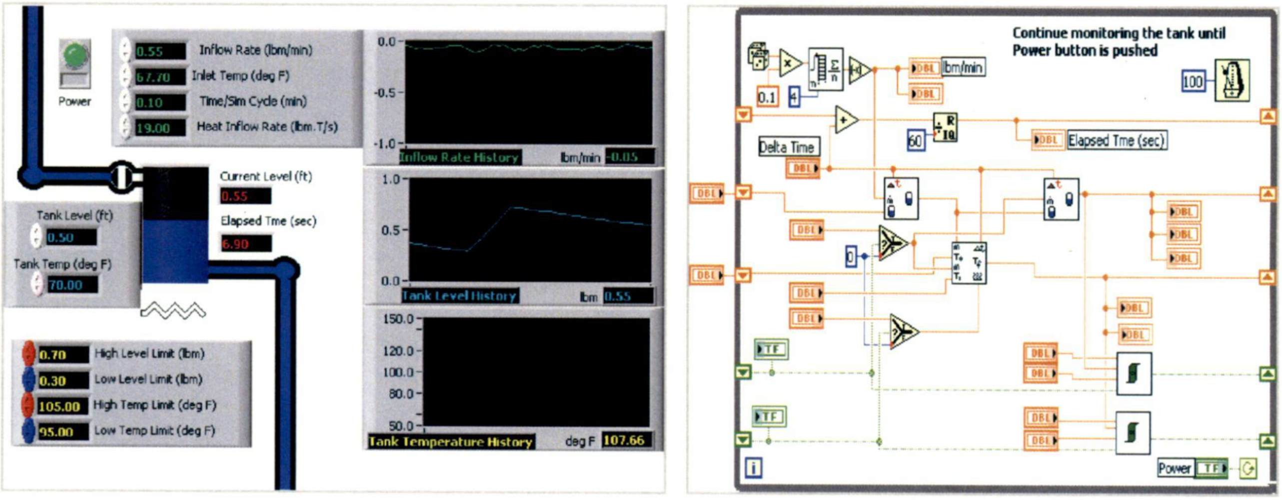


Fig. 3.3 A sample LabVIEW program of Tank Simulation, its Front Panel and block diagram

Benefit of LabVIEW over other development environments is the extensive support for accessing instrumentation hardware. Drivers and abstraction layers for many different types of instruments and buses are included or are available for inclusion. These present themselves as graphical nodes.

3.5 FINAL USER'S PC/LAPTOP DISPLAY OF HTGU IN LabVIEW

With the help of LabVIEW we designed the screen for monitoring of desired parameters of existing setup, which shown in Fig. 3.4.This screen shows the display for voltage & current in all three phases, kW, kVA, kVAr, power factor, frequency, discharge, temperature of bearings, pressure, % of electric valve opening, speed and Power Vs efficiency Curve and discharge Vs time curve.

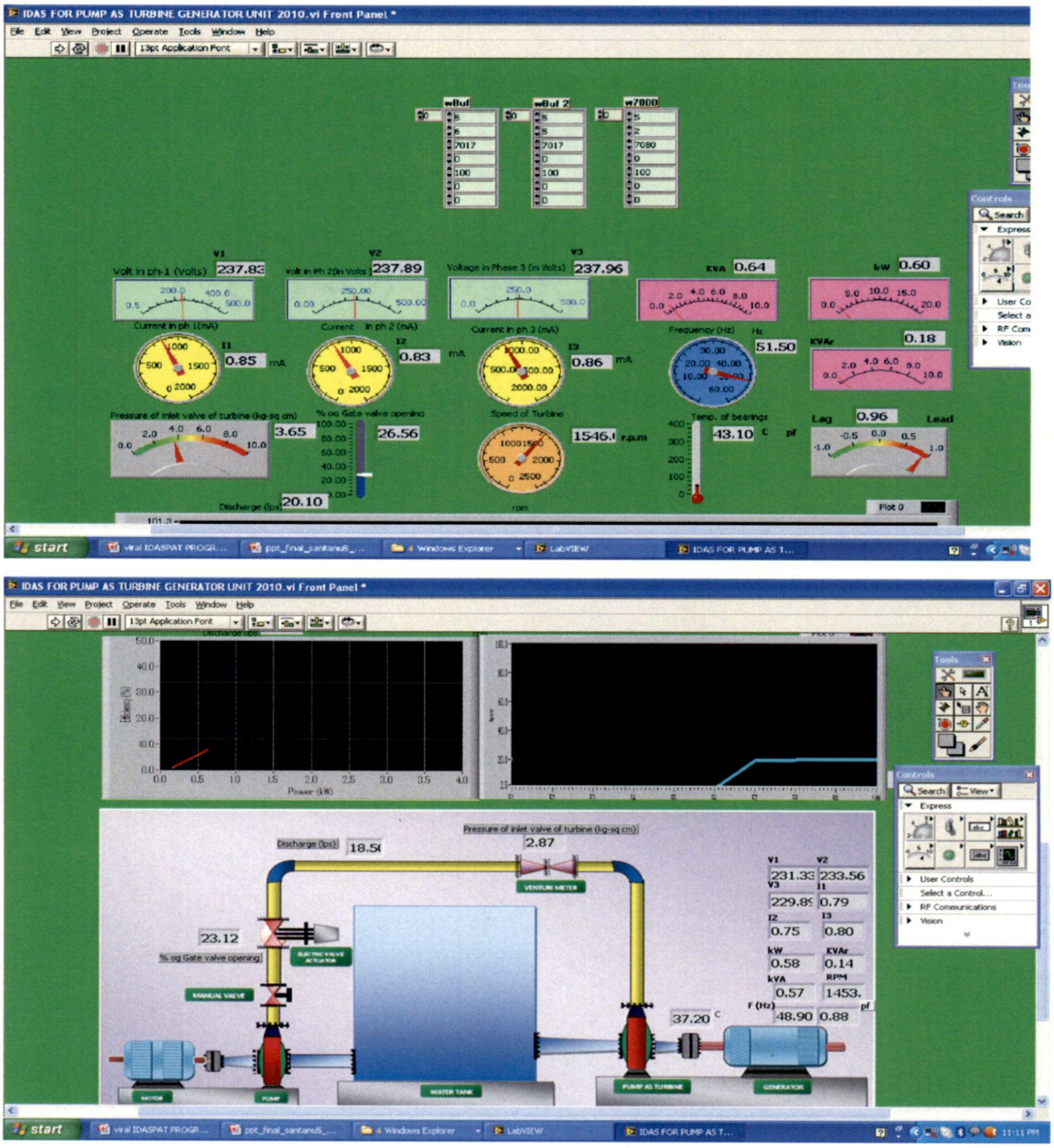


Fig. 3.4 Final User's display of HTGU in LabVIEW (Front Panel)

CHAPTER-4

INSTRUMENTATION & MEASUREMENT FOR TEST SETUP

4.1 INTRODUCTION

As we had discussed in last chapter about the demonstration setup of HTGU and its technical specification, followed to this in this section we describing the other instruments used for the required parameters measurement. The equipments included precision and sophisticated electronic, mechanical and electrical sensors/transducers. Before using them, it should be mandatory and compulsory to know about their, behavior, specifications, installation, operation & working and most importantly method of measurement for a particular application.

4.2 POWER ANALYZER

The Most important device is power analyzer, which can measure all electrical parameters. It also called clamp on hi tester. It is multiple purpose power testers that can be carrying anywhere. The 3165 clamp on Hi (made by HIOKI) tester is provided all measurement functions and data processing capabilities. Voltage and current measure is for low frequencies conventional power meter. Accurate power measurement can be performed over a wide frequency range from 10 Hz to 20 kHz. The Fig. 4.1 is a HIOKI made power analyzer model 3165. The complete array of data processing functions of this multipurpose power tester makes it suitable for wide variety of applications, from power line maintenance and supervision to development tests.

4.2.1 Special Features

It has following features [29]:

(a) Single unit capable of measuring single to multiphase power lines (upto 3ϕ/4 W system)

(b) Allows measurement over wide range of frequencies 10 Hz to 20 kHz.

(c) Wide span of measurement ranges, from 2A to 200A/200 W to 240 kW

(d) Calculates and displays or records apparent and reactive factor, and frequencies.

(e) User selectable scaling, comparator settings, and output(digital/analog or analog only)

(f) Allows real time control of watt hour meter and printer.

(g) Direct reading made possible by the CT and PT ratio multiplication function.

(h) Built in RS-232 interface.

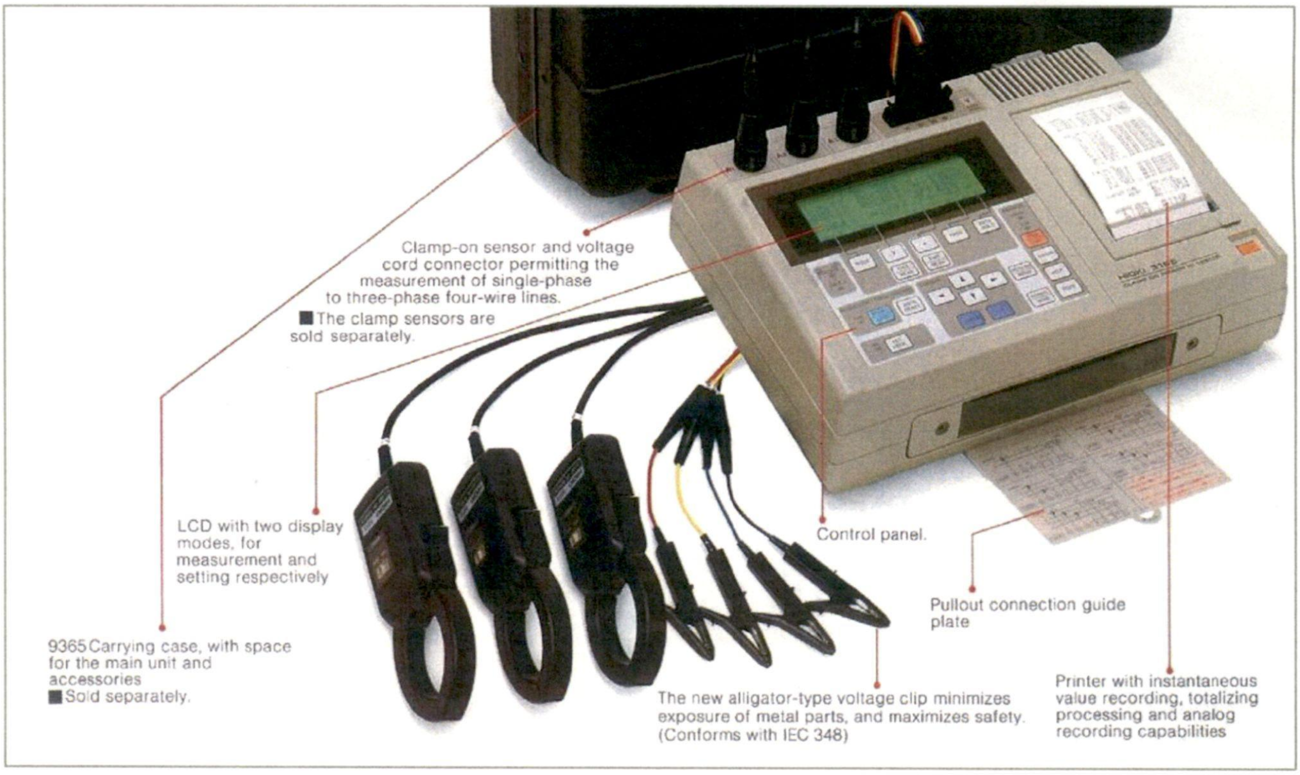


Fig. 4.1 Clamp on Hi Tester (HIOKI model 3165)

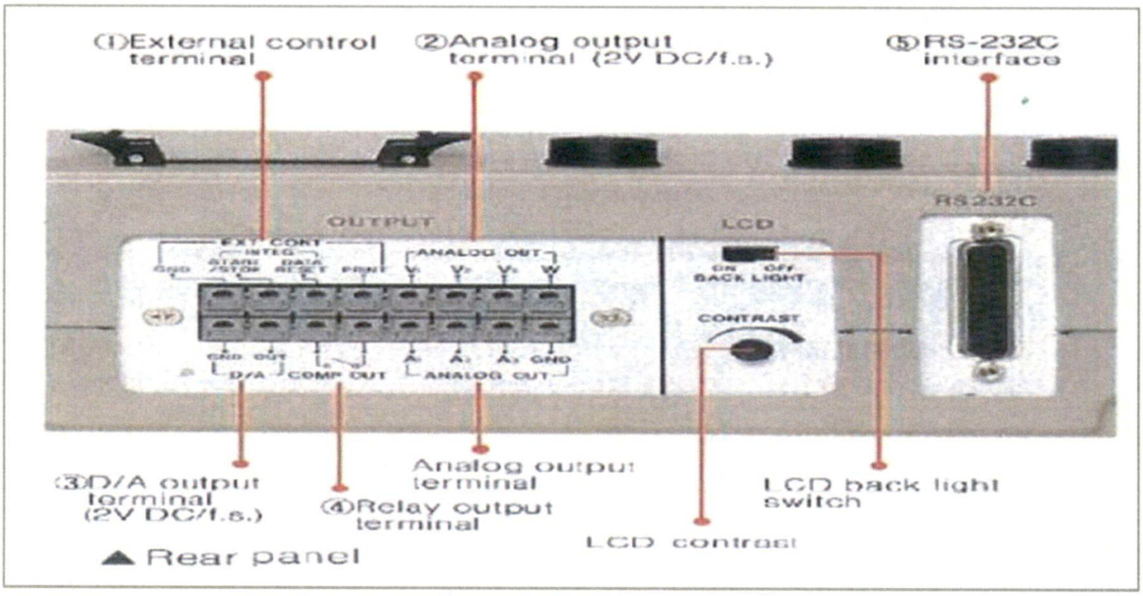


Fig. 4.2 Clamp on Hi Tester (HIOKI 3165) Rear panel

(a) Voltages, currents of three phases as well as Kilowatt total seven parameters output available on the back panel is Shown in the Fig. 4.2.

4.2.2 Analog Output

Voltage (V_1 to V_3), current (A_1 to A_3) and active power (W) can be obtained simultaneously as analog outputs.

(a) Output terminals are on the back panel.

(b) Output level is equal to DC 2V/f.s with regard to each range. (1-V output is obtained when measuring a 200-V line in the 400-V range and a 0.5-V output is obtained when measuring a 50-A line in the 200-A range.)

(c) The analog terminals are not affected at all by display processing (e.g. HOLD, AVERAGE, etc)

(d) Output impedance of these output terminals is 1Ω or less.

4.2.3 D/A Output

Similarly, it can give the following D/A outputs:

(a) This function supplies an analog output of data calculated by digital processing.

(b) One of the following data can be selected for output: average voltage (*V),

(c) Power factor (pf), apparent power (VA). Reactive power (VAR), and frequency (f).

(d) Output rate is DC 2 V/f.s. Negative output is not possible.

4.3 ULTRASONIC FLOW METER

4.3.1 Ultrasonic Transit-Time Flow Meter (UTTF) Principle

A typical transit-time flow measurement system utilizes two ultrasonic transducers that function as both ultrasonic transmitter and receiver. The flow meter operates by alternately transmitting and receiving a burst of sound energy between the two transducers and measuring the transit time that it takes for sound to travel between the two transducers. The difference in the transit time measured is directly and exactly related to the velocity of the liquid in the pipe.

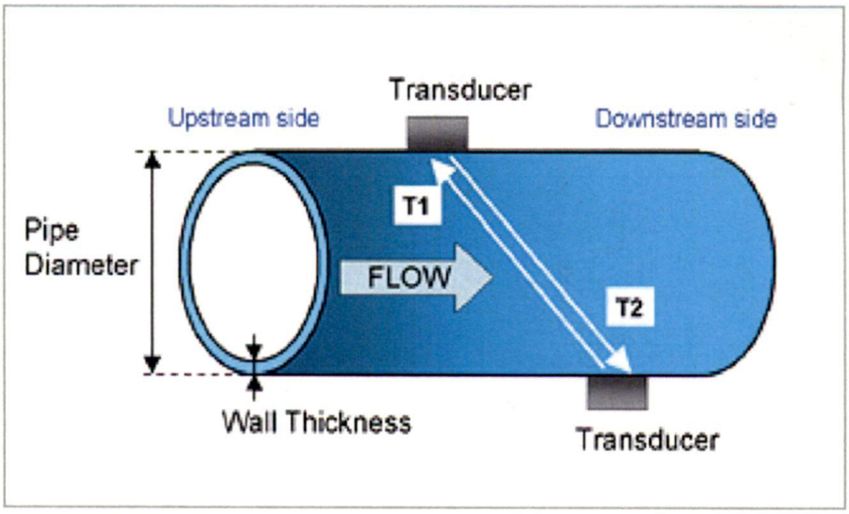


Fig. 4.3(a) Ultrasonic Flow measurement basic theory in a pipe

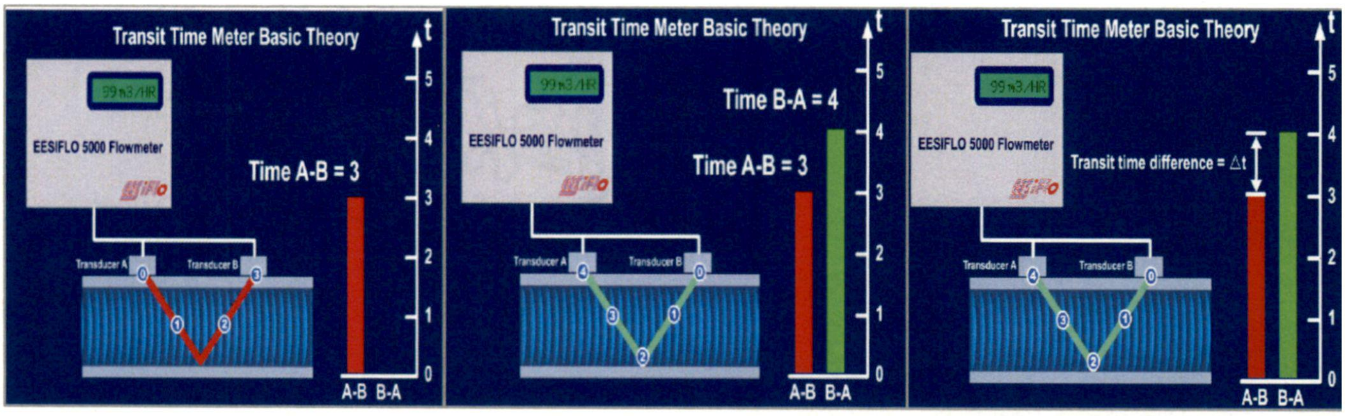


Fig. 4.3(b) Ultrasonic Flow measurement basic theory in a pipe [30]

Pair of transducers are placed on the pipe wall, each having its own transmitter and receiver, one for the upstream and the other for the downstream. The time for sound waves to travel from the upstream transducer to the downstream transducer is shorter than the time it requires for the same sound waves to travel from the downstream to the upstream. Acoustic waves travel time difference is directly proportional to the flow velocity.

Let's assume that T_1 is the transit-time (or time-of-flight) of a sound pulse traveling from the upstream transducer A to the downstream transducer B, and T_2 is the transit-time from the opposite direction, B to A as shown in Fig. 4.3(a) & (b). The following equations hold:

$$T_1 = (D / \sin q) / (c + V^* \cos q) \quad (4.1)$$
$$T_2 = (D / \sin q) / (c - V^* \cos q) \quad (4.2)$$

Where c is the sound speed in the liquid, D is the pipe diameter and V is the flow velocity averaged over the sound path. Solving the above equations leads to

$$V = (D / \sin 2q) * \Delta T / (T_1 * T_2), \quad (4.3)$$

Where $\Delta T = T_1 - T_2$. Therefore, by accurately measuring the upstream and downstream transit-time T_1 and T_2, we are able to obtain the flow velocity V. Subsequently, the flow rate is calculated as following,

$$Q = K * A * V, \quad (4.4)$$

Where A is the inner cross-section area of the pipe and K is the instrument coefficient. Usually, K is determined through calibration.

From equations (4.3) and (4.4), we see that the measurement results, V and Q, are independent of fluid properties, pressure, temperature, pipe materials, etc. The sound speed term does not appear in the final equations. These characteristics, plus large turn-down ratio, no pressure drop, no moving parts, no disturbance to the flow and many other features, make ultrasonic transit-time flow meter extremely attractive [31].

The transducers come with two types:

1. Clamp-on type
2. Wetted type
   (a) Insertion type and
   (b) Flow cell (or spool piece) type

4.3.2 Instruments Function

This measures the flow rate of acoustically conductive single-phase fluids. This includes most clean liquids, sewage, some slurries, some oil/water mixtures, and liquids with a small percentage of entrained gas bubbles. The flow meter provides one linear (0/4-20 mA) analog output of flow velocities or volumetric flow rate of these fluids, measuring velocities from ±0.03 to ±12 m/sec, along with one selectable frequency output or pulsed totalize output.

4.3.3 Electrical Connections

Before making measurements with the PT878, we must make all the necessary connections to the unit. This section describes how to connect the following:

(a) Power

(b) Transducers

(c) Input/Output

(d) Infrared Interface

Make all connections to the top of the PT878 unit as shown in Fig. 4.3 (c) below. We only need to make the proper power and transducer connections. The other connections are required for particular functions, but are not necessary for basic operation.

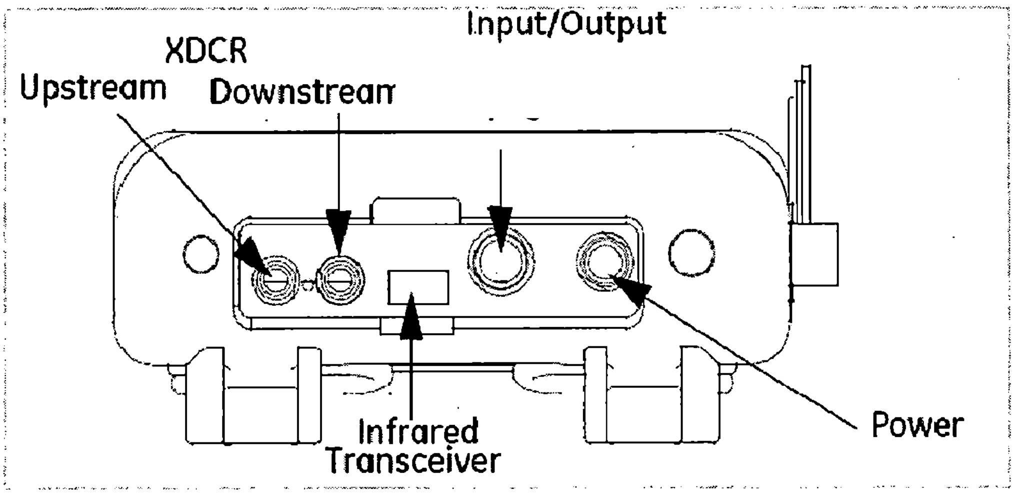


Fig.4.3(c) UTTF Rear Output Terminals

(a) Power Connections

The PT878 is powered by either a 100-120/200-260 V AC wall mount plug-in module, or by 5 internal Cs-size NiCad high energy rechargeable batteries or by a pack of 3.0 Ahr NiMH batteries. (An optional power supplement, part #703-1283, uses 6 AA alkaline batteries.) When we receive the PT878, the batteries are not charged; therefore, to make remote measurements using the batteries.

(b) Transducer Connections

The transducer cables connect to the PT878 with LEMO coaxial type connectors. Each color-coded cable should have a collar labeled UPSTREAM or DOWNSTREAM. Make transducer cable connections to the top of the flow meter as shown in Fig 4.3(c).

(c) Input/output Connections

The PT878 provides one 0/4-20 mA current output and two 4 to 20-mA analog inputs with switchable 16-V supply for loop powered temperature transmitters. It also supports digital, frequency, and totalize outputs. Connect the inputs/outputs using a LEMO® multi-pin connector as shown in Fig. 4.3(c), the pin numbers for the connector and the color code for the standard input/output cable are shown in Table 4.1.

Table 4.1 Connecting wires coding

Pin number	Wire color	Description
1	Black	Analog Out
2	Red	16 V (switched)
3	White	Supply or Return Temperature (Input A)
4	Yellow	Supply or Return Temperature(Input B)
5	Green	Analog Ground
6	Orange	Digital Output (frequency output, pulse totalizer, diagnostic output or calibration gate)
7	Blue	Digital Ground
8	Violet	Receive Monitor

4.3.4 Installation Using The Magnetic Clamping Fixture (MCF)

The magnetic clamping fixture is used to fasten transducer to the pipe at proper spacing without chains or straps. Different fixtures are used for a single and double traverse installation. Each type of MCF has magnets placed in the two blocks at either end of the fixtures. When the magnets are turned 'ON', the fixture magnetically "clamps" to the pipe wall.

4.3.4.1 Installation of Magnetic Clamp Fixture

The transducers can be mounted in three ways: Z-method, V-method and W-method. With Z-method as shown in Fig.4.3 (d).

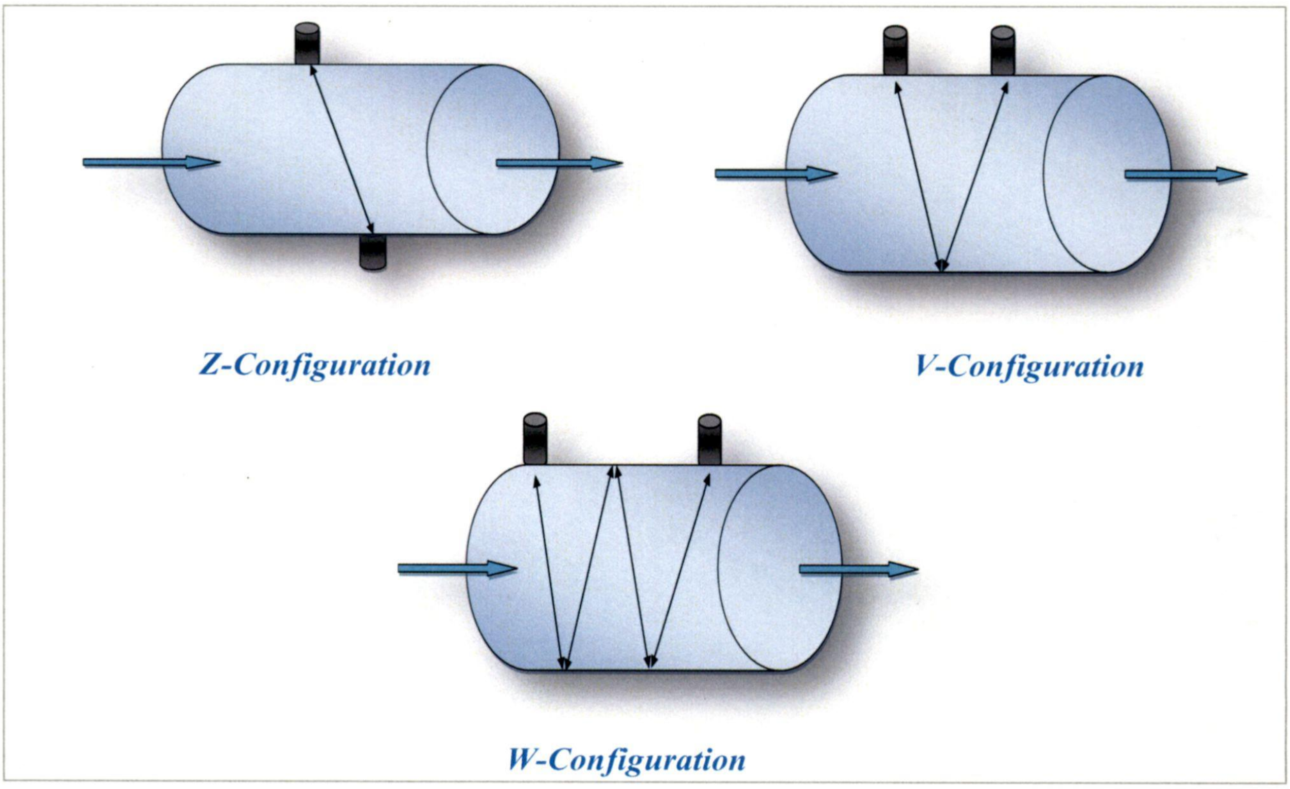


Fig.4.3 (d) Installation configuration of MCF Transducers

The double Traverse MCF consists of two blocks connected but two rods. One block is permanent while the other block may be adjusted. This type of fixture has two transducer blocks and like the magnetic blocks, one is fixed while other is adjustable.

The procedure for mounting the MCF involves setting the transducer spacing and then securing the fixture to the pipe. To set the spacing for the transducers, we need to obtain the spacing dimension S, which the flow meter automatically calculates from the user-entered pipe and fluid parameters. Following are the steps for mounting the MCF:

1. The location we has chosen for the installation should at least 10 pipe diameter of straight, undisturbed pipe upstream and 5 pipe diameters downstream of the measurement point.
2. The pipe where we intend to place the clamping fixture should clean and free of loose material.
3. Obtain the transducer spacing dimension S. Using the scale on the rod, move the adjustable block to the specified location. To move the block, loosen the red thumb screws, slides the block to the desired location and tighten the thumb screws. Use the pressure bolt or the edge of the block as the measuring point for the block.
4. Locate the magnetic block at least 4 inch away from the transducer blocks. This will ensure that there is enough clearance to mount the transducer in the blocks. Move the adjustable block in the same manner as the transducer block.
5. Position the clamping fixture along the horizontal plane of the pipe. If the pipe is horizontal, do not place the fixture on the top or bottom
6. Turn the switches on each magnet to the ON position

   Fig. 4.3 (e) shows the installation of Magnetic clamp fixture and transducer installation followed by all necessary steps [31].

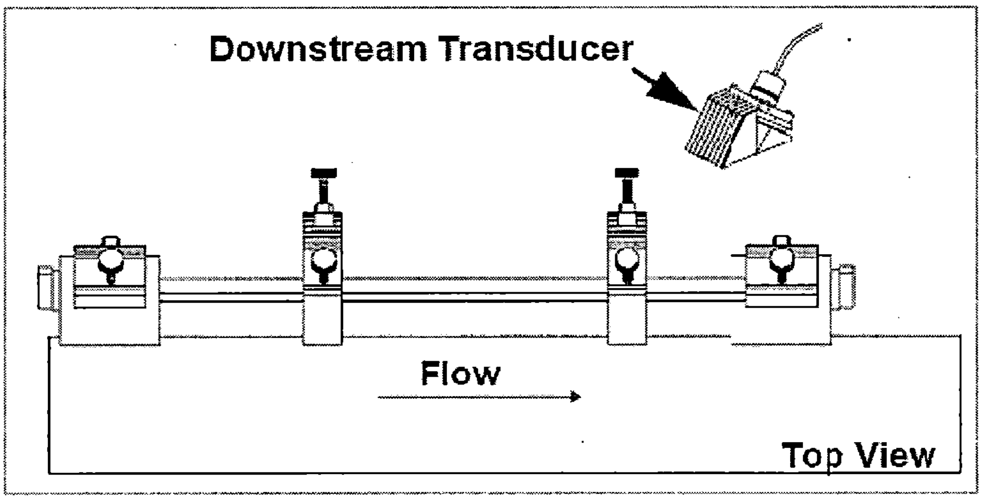


Figure 4.3 (e) Installation of Magnetic Clamp Fixture

4.3.4.2 Mounting Transducer into MCF

1. Before mounting, we may choose to connect the cables to the transducers
2. Take one of the transducer and apply a thin bead of couplant down the centre of its face approximately the size of a toothpaste bead.
3. Determine the upstream and downstream directions of the pipe and place one of the transducers into one of the blocks. Make sure the transducer cable connector faces away from the centre of the installation.
4. Use the pressure bolt to secure the transducer in place. The pressure bolt should fit into the dimple. Hand-tighten enough to hold the transducer in place. Do not over tighten so that the fixture lifts off the pipe
5. Repeat steps 1-4 to mount other transducer in the remaining block.
6. If not already done, connect the other end of the transducer cable to the appropriately marked connector on the flow meter unit.

Fig 4.3 (f) shows the single and double traverse installation of transducer.

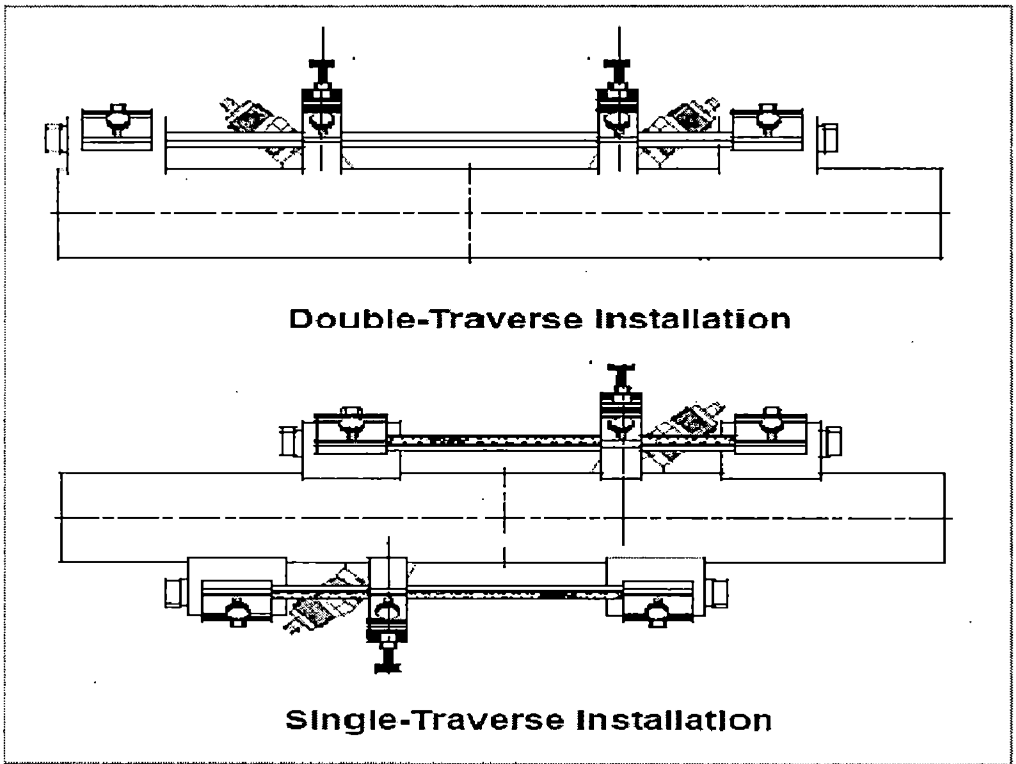


Fig.4.3(f) Mounting of transducer into MCF

4.3.5 Mounting Mode

In our experimental setup we mount the UTTF in Reflect mounting modes as shown in Fig. 4.3(i). 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 Fig.4.3 (g) and (h) below.

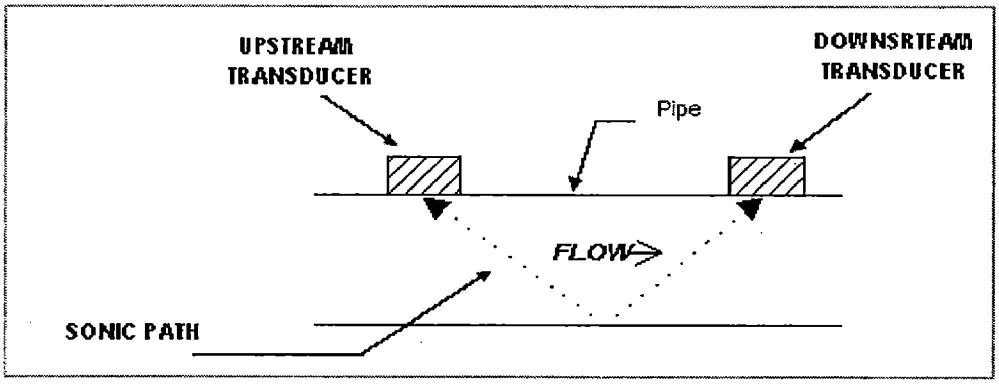


Fig. 4.3 (g) Reflect mount for Clamp-on transducer on same side of the pipe

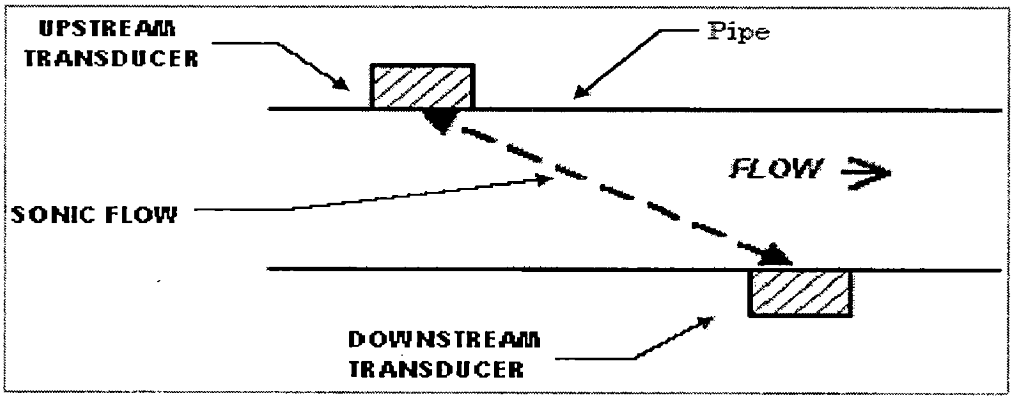


Fig.(h) Direct mount for Clamp-on transducer opposite side of the pipe

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.

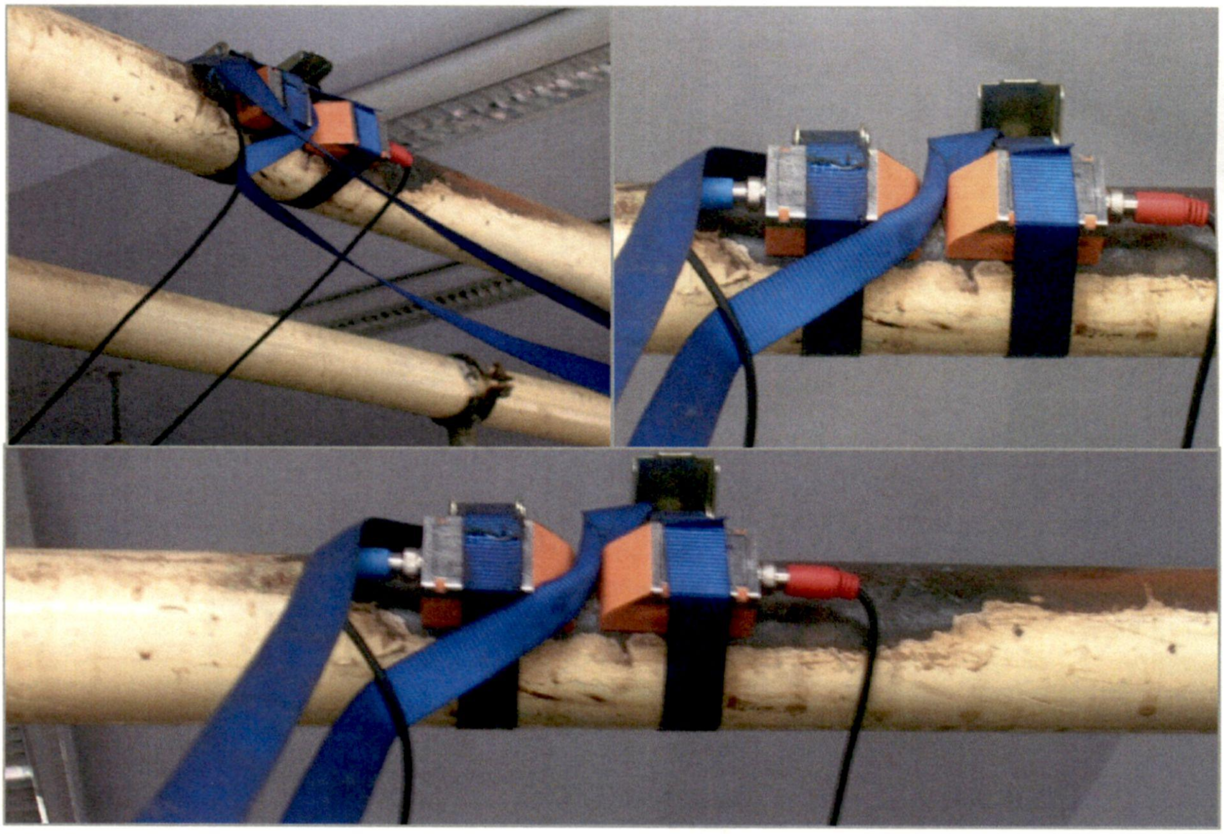


Fig.43.(i) Reflect mount on position for Clamp-on transducer for HTGU

4.3.6 Configuring the Flow Meter With Pipe Data

The following site data is to be entered into the flow meter 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 flow meter prompts the user if Install completed? If yes then it calculates the spacing between the transducers, it is 5.2 mm in this case.

4.4 INFRARED THERMOMETER

Infrared thermometer is a non contact thermometer. The OS530E/OS520E series is Handheld Infrared (IR) (made by OMEGA). Thermometers provide non-contact temperature measurements up to 4500°F. Fig. 4.4 (a) is an infrared non contact thermometer and in Fig. 4.4 (b) is the right side view of the thermometer as well as left side view of the thermometer. They offer effective solutions for many non-contact temperature applications, including the following:

(a) **Predictive Maintenance:** Tracking temperature shifts which indicate pending failure in solenoid valves.

(b) **Energy Auditing:** Locating wall insulation voids to reduce building heating costs.

(c) **Food Processing:** Taking accurate temperature readings without direct contact with the food or packaging material.

(d) The IR thermometer provides information at a glance the custom backlit dual digital LCD displays both current and minimum, maximum, average or differential temperatures.

(e) Also measures target distances from 5 inches to approximately 100 feet

(f) Emissivity adjustable from 0.1 to 1.00 in 0.01 steps provides ease of use when measuring a variety of surfaces.

(g) Built-in Laser sighting in Circle & Dot configurations.

(h) Thermocouple input available.

(i) Distance Measurement available, either field mountable or built in.

(j) Digital/Video Camera Option available

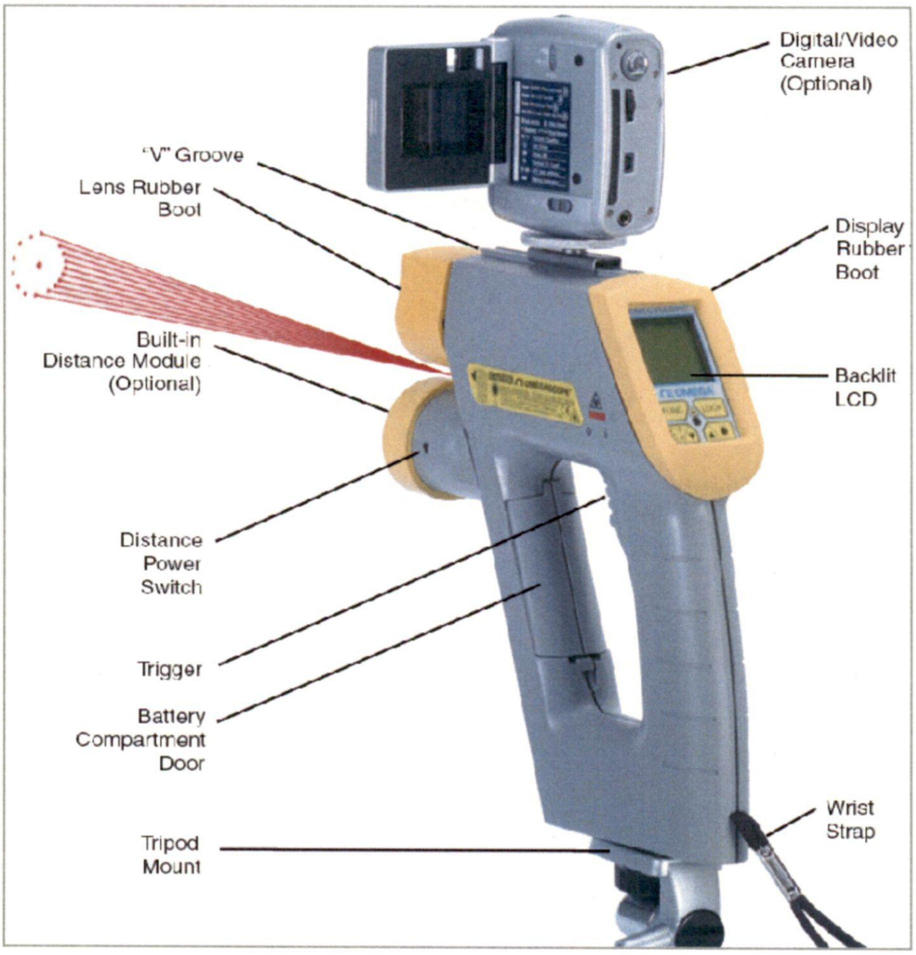


Fig. 4.4(a) Infrared thermometer non contact

(k) An electronic trigger lock feature set via the keypad allows continuous temperature measurement up to 10 times per second.

(l) Audible and visual alarms. The high and low alarm points are set via the keypad

(m) 1 mV per degree (°F or °C) analog output, which allows interfacing with data acquisition equipment (including chart recorders, data loggers and computers). OS524E (OMEGA) provides 0.5 mV/Deg.

(n) Last temperature recalls (Hold).

(o) Backlit display useful in low ambient light conditions.

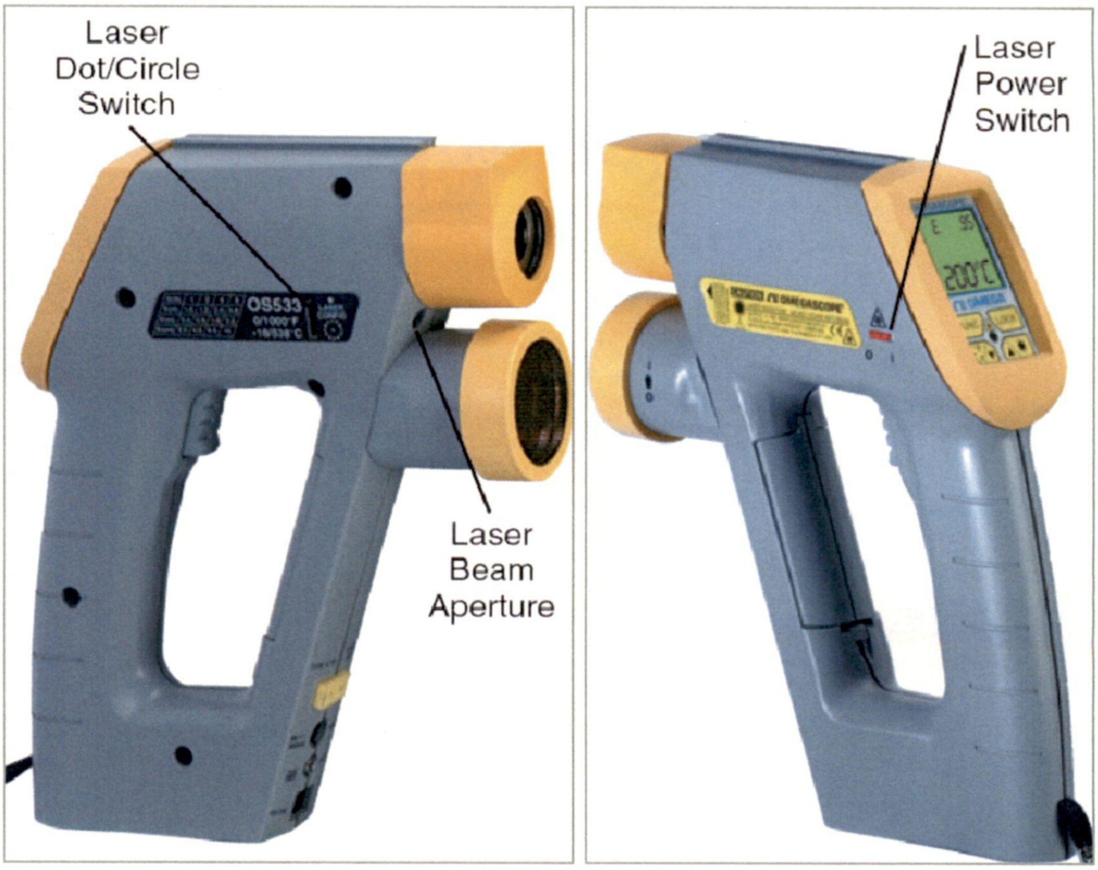


Fig.4.4 (b) Right Side View of the Thermometer Left Side View of the thermometer

(p) Powers from 4 AA size batteries or an ac adapter.

(q) RS232 serial communication to a PC or printer. This allows downloading data for further analysis.

(r) Ambient target temperature compensation. This provides more accuracy for measuring low emissivity targets.

(s) Record up to 800 temperature data points. Review the recorded data on the thermometer LCD, as well as downloading the data to a PC [32].

4.4.1 Working of Infrared Thermometer

Heat is transferred from all objects via radiation in the form of electromagnetic waves or by conduction or convection. All objects having a temperature greater than absolute zero (-273°C, -459°F, 0 K) radiate energy. The thermal energy radiated by an object increases as the object gets hotter. Measurement of this thermal energy allows an infrared thermometer to calculate the object's temperature if the emissivity (blackness) is known.

Generally, it is convenient to measure the amount of radiated energy in the infrared part of an object's radiation spectrum. Fig. 4.4 (c) shows a block diagram of an infrared radiation thermometer. Energy from the object is focused by the lens onto the detector. As the detector heats up, it sends out an electrical signal, which in turn is amplified and sent to the circuitry of the thermometer. The thermometer software then calculates the temperature of the object. Fig. 4.4 (c) is the block diagram of Infrared thermometer.

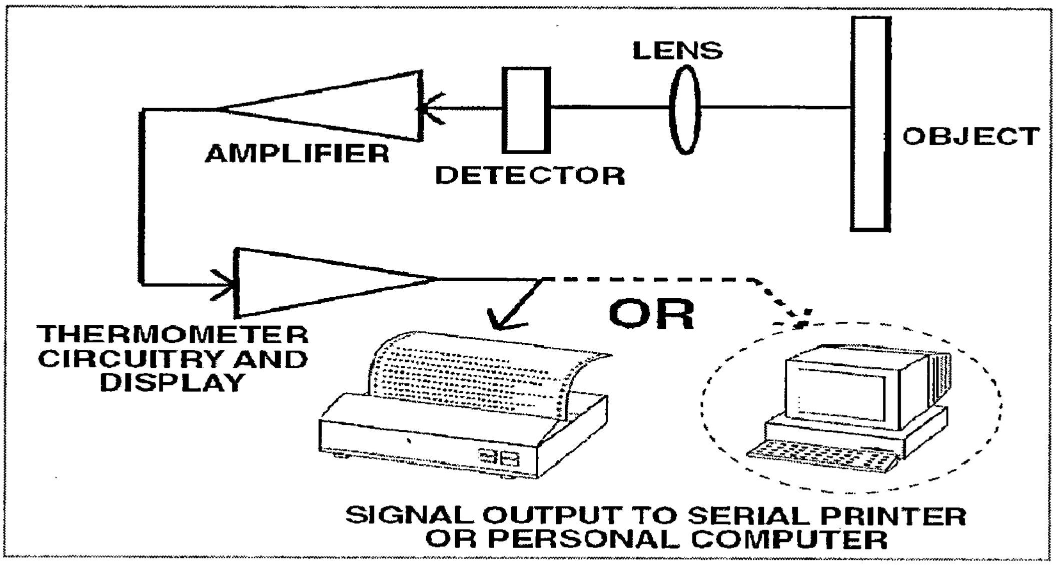


Fig. 4.4 (c) Infrared Thermometer Block Diagram

4.4.2 Calculation of Temperature

The net thermal power radiated by an object has been shown to depend on its emissivity, its temperature and that of the ambient temperature around the object. A very useful equation known today as the Stefan-Boltzmann Law has been shown both theoretically and empirically to describe the relationship.

$$I = \varepsilon\sigma(T^4 - T_a^4)$$

Where,

I = thermal power in watts/meter^2

ε = Emissivity

σ = 5.6703 x 10^{-8} watts/meter^2 x K^4 (Stefan's constant)

T = temperature of object in Kelvin

T_a = temperature of ambient surroundings in Kelvin

The infrared thermometer uses this equation directly in calculating the temperature of an object. The incident power is measured by the infrared detector. The emissivity of the object is determined by the user. The ambient temperature is measured by a sensor inside the thermometer. With all quantities known, the thermometer uses the Stefan-Boltzmann Law to calculate and output the temperature of the object [32].

4.5 SMART PRESSURE TRANSMITTER

The SMAR made Smart transmitter is used for the measurement of pressure inlet of the turbine. The SMAR made Absolute pressure Transmitter is used for the measurement of Inlet and Outlet head of the turbine as shown in Fig. 4.5 (a).

4.5.1 Principle of Operation

The SMAR transmitter model LD301 uses, as its measuring principle, the well known and field proven technique of capacitance sensing, enhanced by microprocessor based electronics [7]. 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 signals. Fig. 4.5 (b) is diaphragm of Smart Transmitter [33].

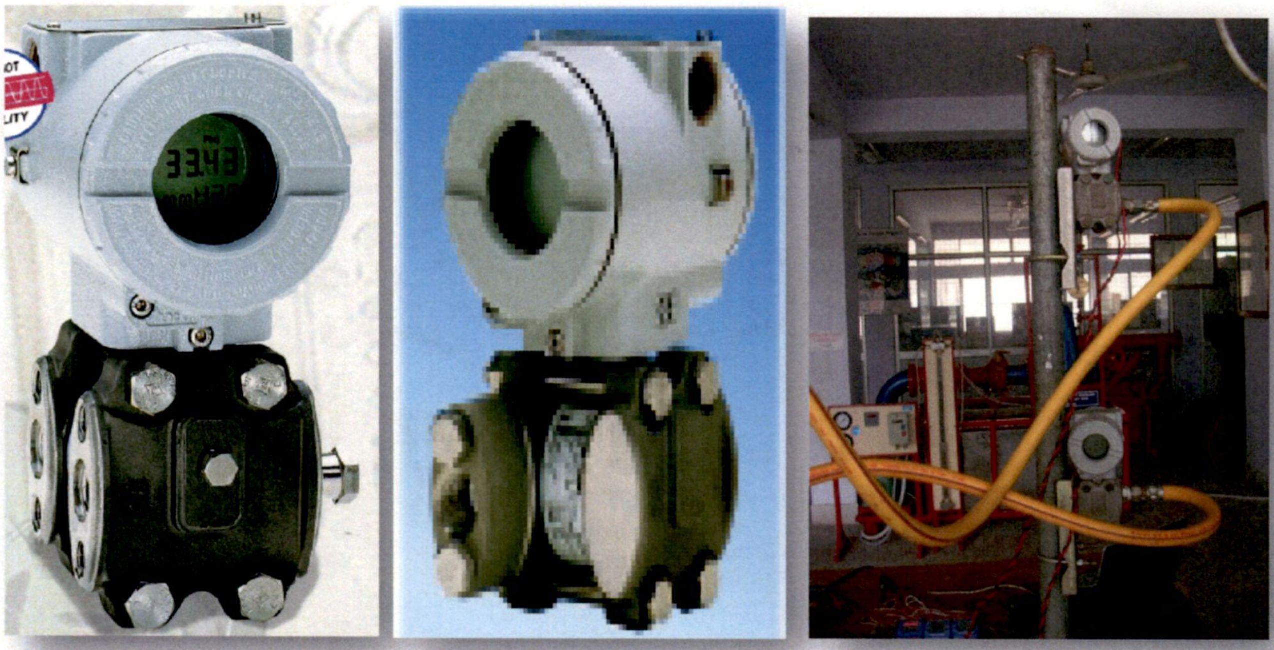


Fig. 4.5(a) SMAR made LD 301 absolute Pressure Transmitter with Turbine Inlet & Outlet

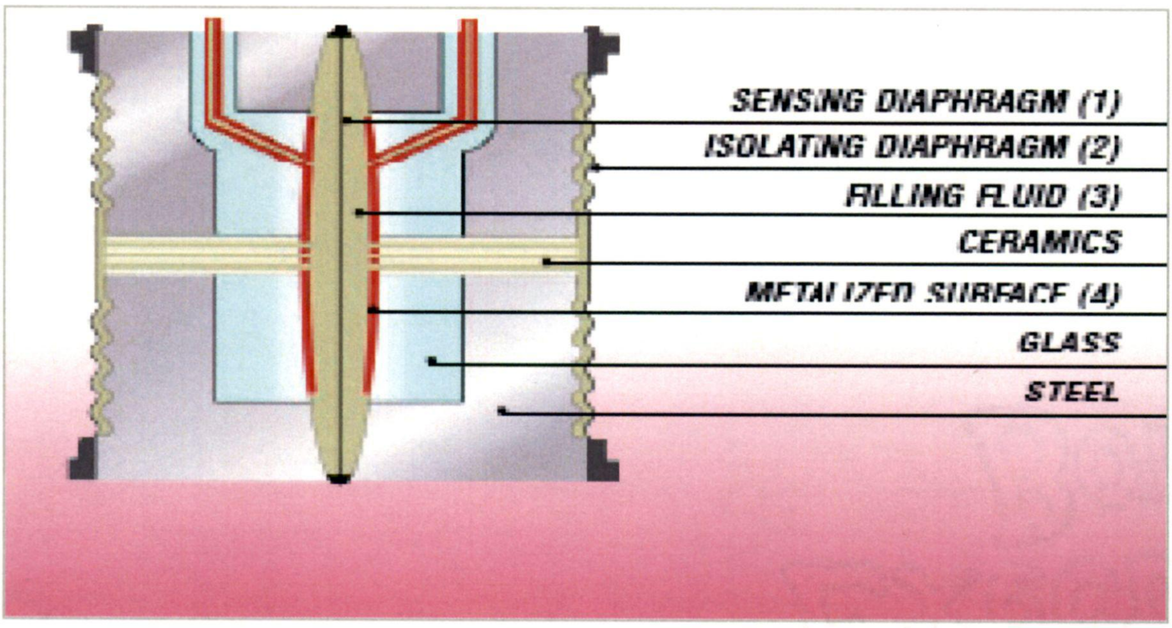


Fig. 4.5 (b) Diaphragm of Smart Transmitter [33]

4.5.2 Construction & 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 Fig. 4.5 (b) 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. The two metalized surfaces (4) are fixed plates. The sensing diaphragm deflection results in a variation on the capacitances between the moving and fixed plates. Fig 4.5 (c) sensor assembly as well as associated electronics.

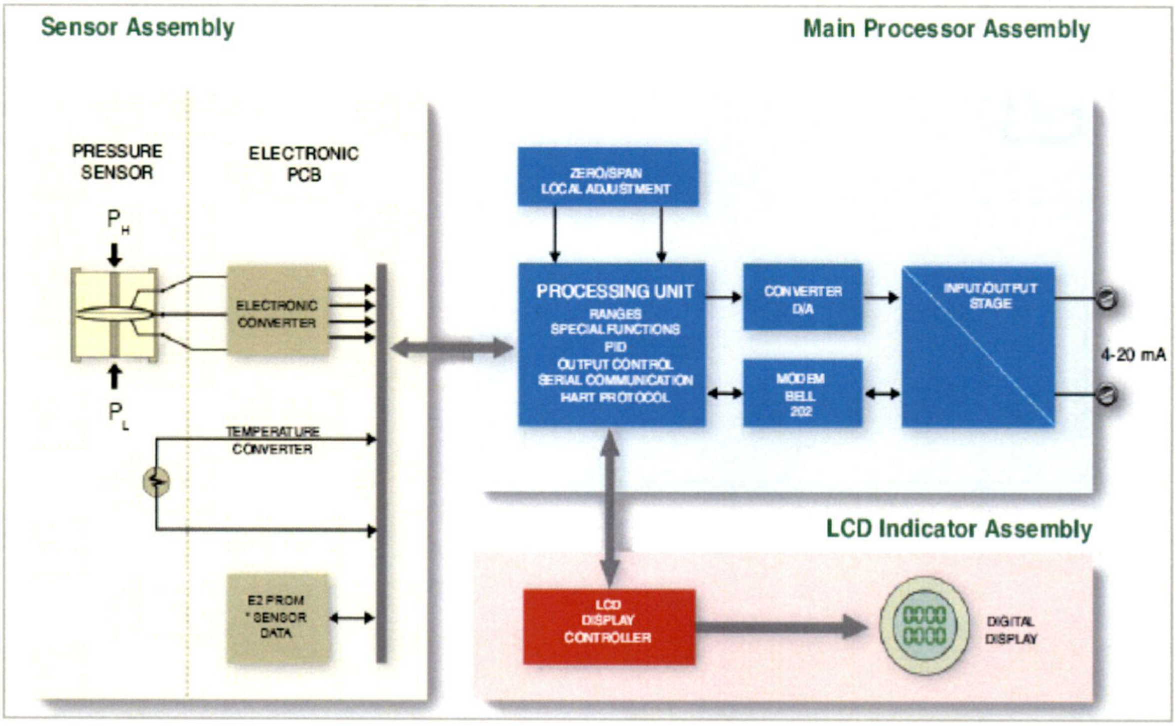


Fig.4.5 (c) Sensor assembly and associated Electronics[33]

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 signals 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.

4.5.3 Features

(a) 0.075% Accuracy

(b) 120:1 Rangeabilty

(c) Direct digital capacitance sensing (No A/D conversion)

(d) 4-20 mA output and direct digital communication (HART Protocol)

(e) Remote and Local calibration

(f) Online and offline programming

(g) Password protection

(h) Multi-drop operation mode

(i) Optional 4-1/2 digit numerical and 5 character alphanumerical LCD indicator

(j) Capable of handling most process fluids

(k) Explosion and weather proof housing

(l) Optional PID control function

(m) User selectable units

(n) Constant Signal generation for loop lest.

4.5.4 Electrical Connections

There are two different types of terminals i.e. the terminals and the communication terminals that allow respectively measuring 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 configuration in "COMM" and "-" terminals. Fig. 4.5 (d) & (e) shows how the connections are made.

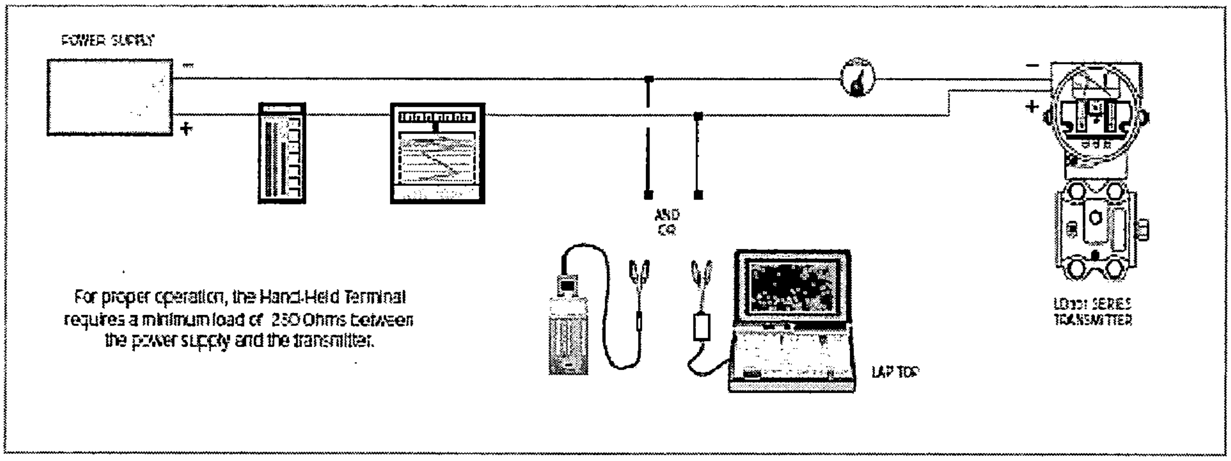


Fig. 4.5 (d) Transmitter Connection Diagram [33]

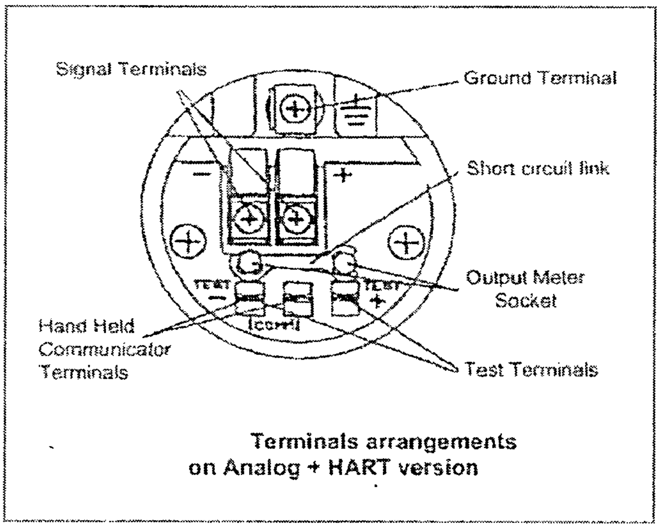


Fig. 4.5 (e) Rear Transmitter terminal

It is made sure that the transmitter is in the operating area.. 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.

4.5.5 Mounting and Calibration of Absolute Pressure Transmitter

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.

4.5.6 Calibration 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 wherein 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 mA is transmitted corresponding to 5 Kg/cm^2 is used.

4.6 MOTORISED CONTROL VALVES

The AVCON MV 5512A/B 2/2-Way Motorised Control Valves with Electric Actuator is used most commonly for either ON/OFF or control services [34]. Fig. 4.6 (a) various view of Electric valve actuator.

4.6.1 Principle and 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.

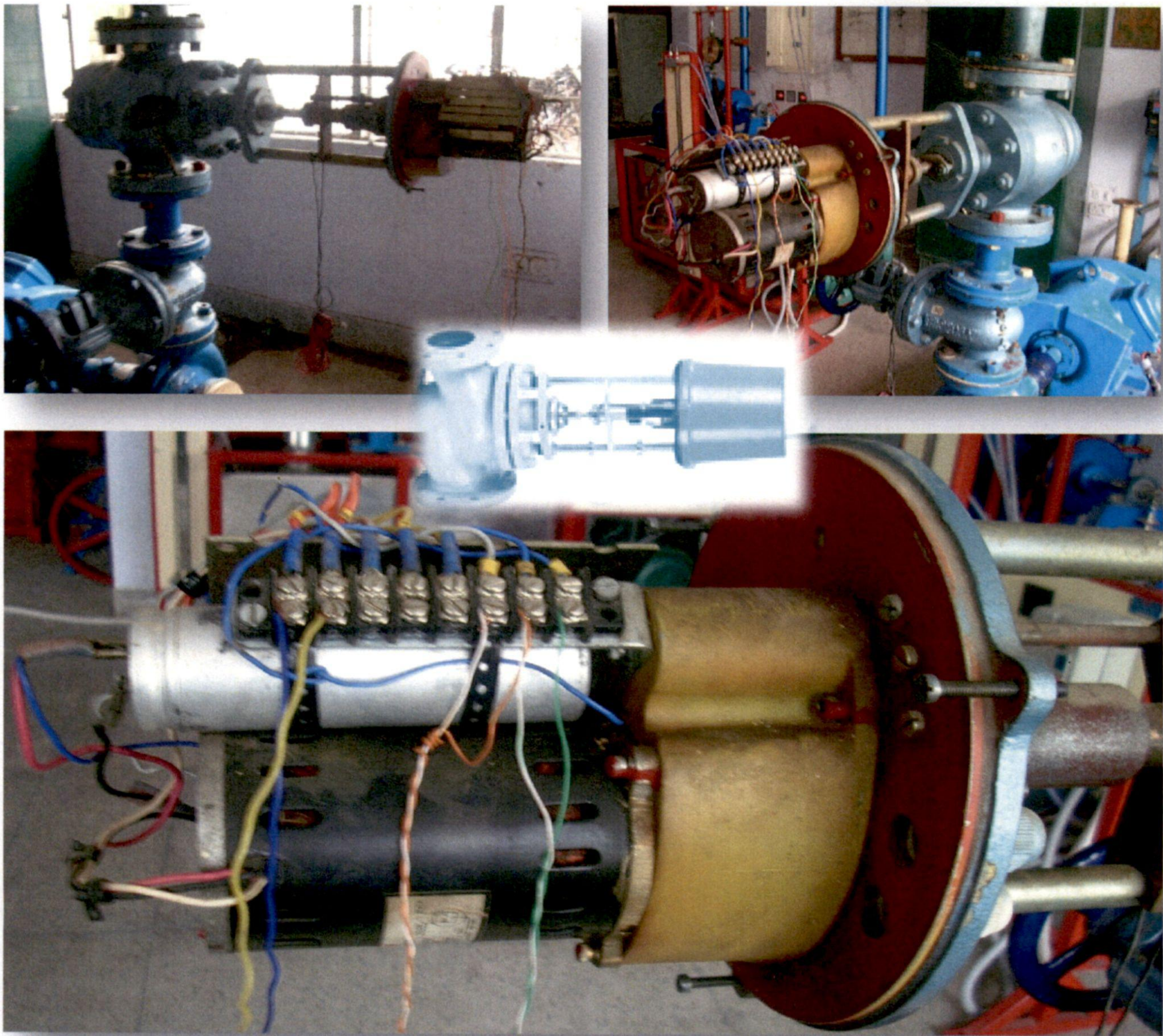


Fig. 4.6 (a) Motorised Control Valve with Electric Actuator various view

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 or 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.

4.6.2 Electrical Connections

The actual electrical connections of the manufacturer are as shown in Fig. 4.6 (b) below [34].This Electrical connection pertains to the 4-20 mA servo-controls 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 Fig 4.6 (c).

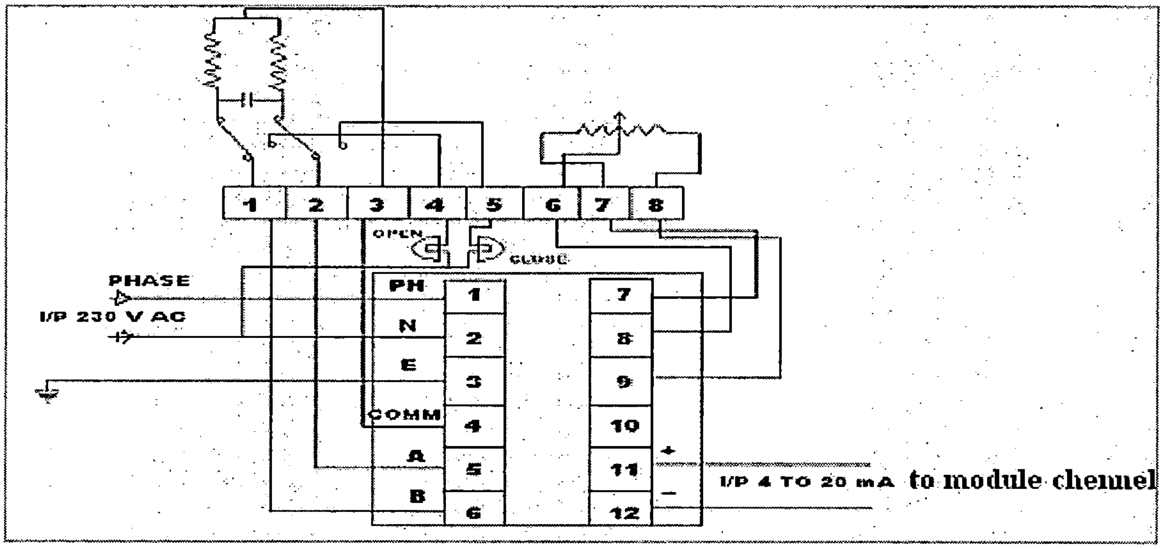


Fig. 4.6 (b) Actual Electrical connections

4.6.3 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:

(a) 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.

(b) 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.

(c) A 2V DC source is connected to the fixed POT terminals 7 and 8 and respective voltages at the two extreme voltages are measured, this voltage is further used for online indication of valve position using LabVIEW.

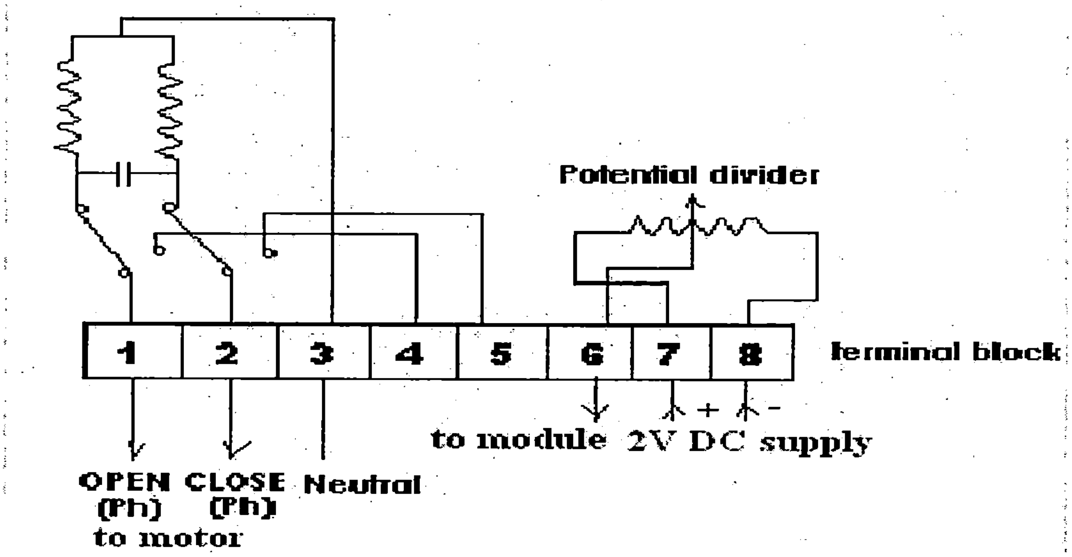


Fig. 4.6 (c) Modified electrical connections

(d) 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.

(e) 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.

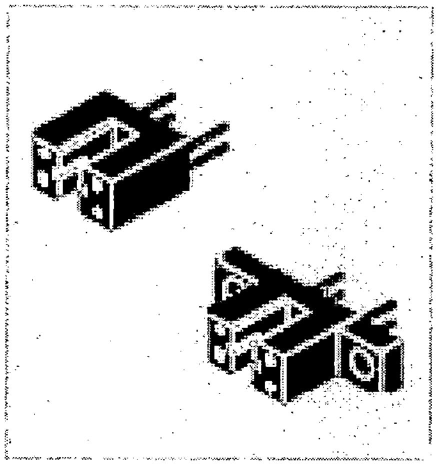
(f) The Limit switch positions on the actuator should not be disturbed otherwise the valve may be damaged or the actuator motor winding may burn out.

4.7 SPEED SENSOR

4.7.1 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 [35].

(b) **Optocoupler MOC7811/TCST2103:** The speed sensing is done using optocoupler MOC7811/TCST2103. 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. Fig 4.7 (a) shows the schematic of sensing speed [35].



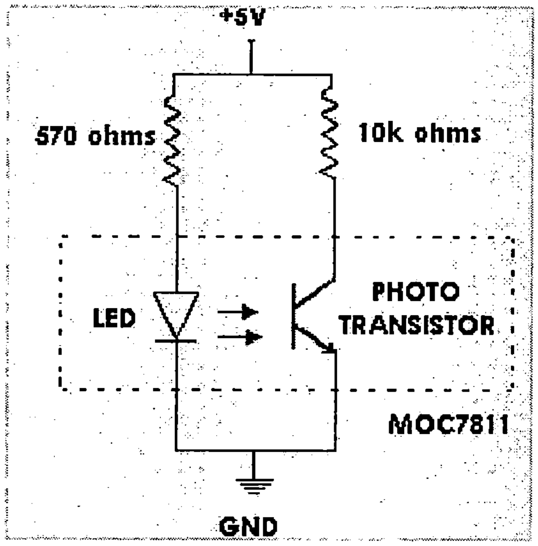


Fig. 4.7 (a) Optoelectronic Speed Sensor MOC7811/TCST 2103

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. Fig.4.7 (b) shows the picture of speed sensor assembly in experiment setup.

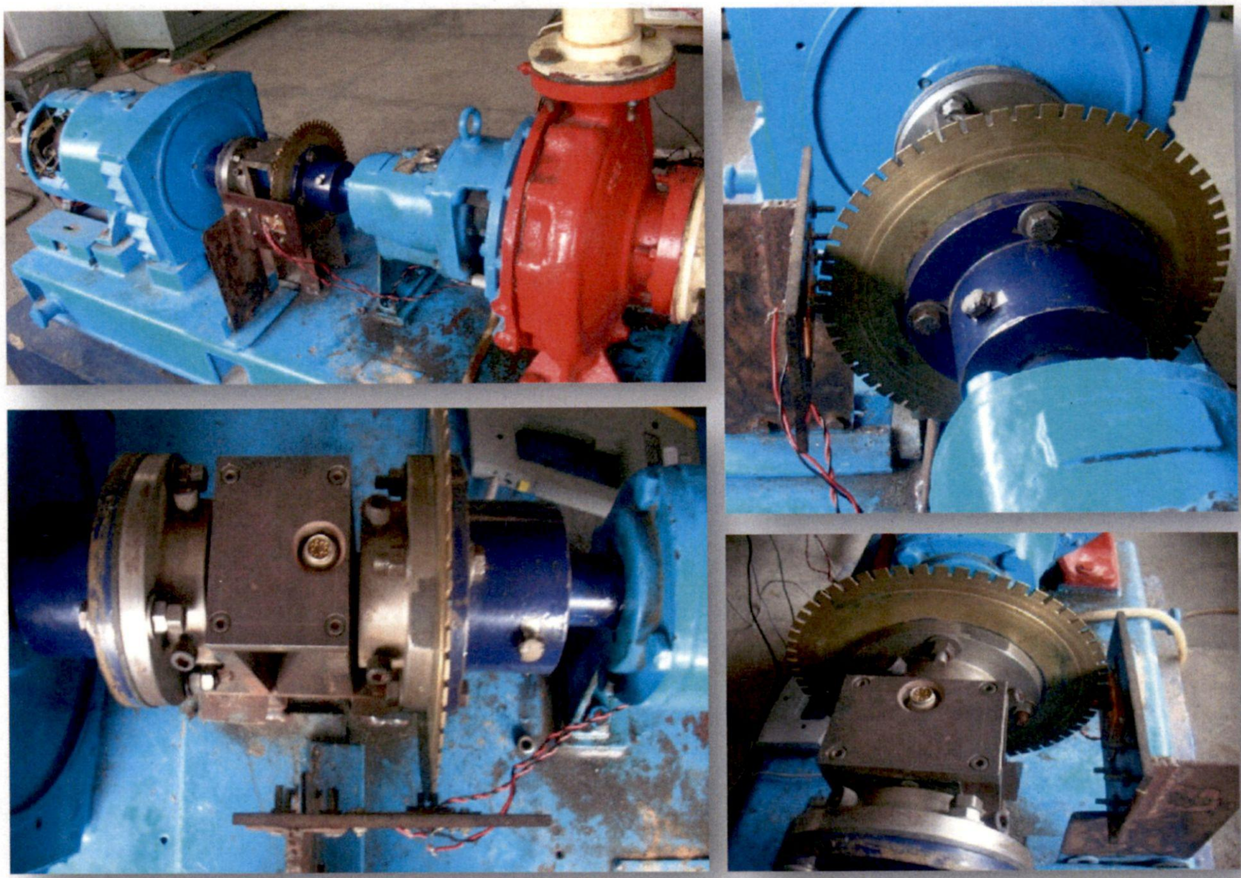


Fig. 4.7(b) Photograph of Speed Sensor and Disc

4.7.2 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. Fig. 4.7(c) is circuit for signal conditioning for speed sensor. The output of the LM339 is connected to an 741 op-amp in order to avoid loading by the frequency/counter module the o/p is then connected to 7080 frequency/counter module to measure the frequency of the square waves generated The frequency is nothing but the pulse count per sec or rpm of the generator.

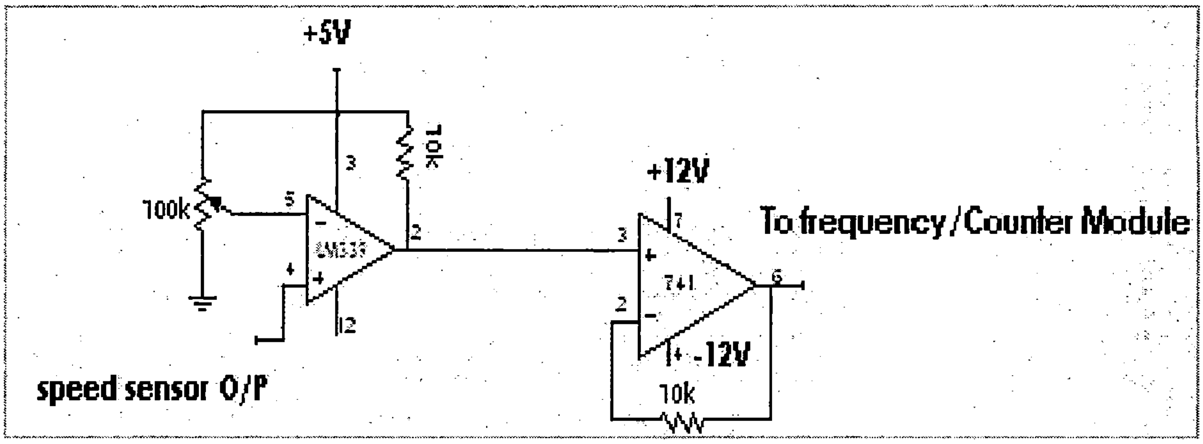


Fig.4.7 (c) Signal Conditioner for Speed Sensor

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.

CHAPTER-5

IDAS FOR HYDRO TURBINE GENERATOR UNIT (HTGU)

5.1 INTRODUCTION

To optimize the use of new technologies and to take high performance of all sensors/transducers and other instruments, with high precision and accuracy, easy-to-use and portable in size, we use a new innovations from National Instruments, USB based Data Acquisition module; which is USB NI 6212.USB has evolved into a core bus of choice for measurements and automation applications. This module enables sustained bi-directional high-speed data streams on USB. This is a multifunction DAQ device for USB are optimized for superior accuracy in a small form factor. In this section attempt is made to familiar with this DAQ device which is use in our experiment.

5.2 NI USB 6212 DATA ACQUISITION MODULE

The National Instruments USB-6212 is a bus-powered USB M Series multifunction data acquisition (DAQ) module optimized for superior accuracy at fast sampling rates. It offers 16 analog inputs; 400 kS/s sampling rate; two analog outputs; 32 digital I/O lines; four programmable input ranges (±0.2 to ±10 V) per channel; digital triggering; and two counter/timers [36].

The NI USB-6212 is designed specifically for mobile or space-constrained applications. Plug-and-play installation minimizes configuration and setup time, while direct screw-terminal connectivity keeps costs down and simplifies signal connections. This product does not require external power.

USB-6212 also features new NI signal streaming technology, which gives you DMA-like bidirectional high-speed streaming of data across the USB bus. NI-DAQmx driver and measurement services software provides easy-to-use configuration and programming interfaces with features such as DAQ Assistant to help reduce development time. The pictorial view of this DAQ is shown in Fig. 5.1 (a).

In addition to LabVIEW Signal Express, M Series data acquisition devices are compatible with the following versions (or later) of NI application software – LabVIEW 7.1, Lab Windows™/CVI 7.x, or Measurement Studio 7.x. M Series data acquisition devices are also compatible with Visual Studio .NET, C/C++, and Visual Basic 6.0 [37].

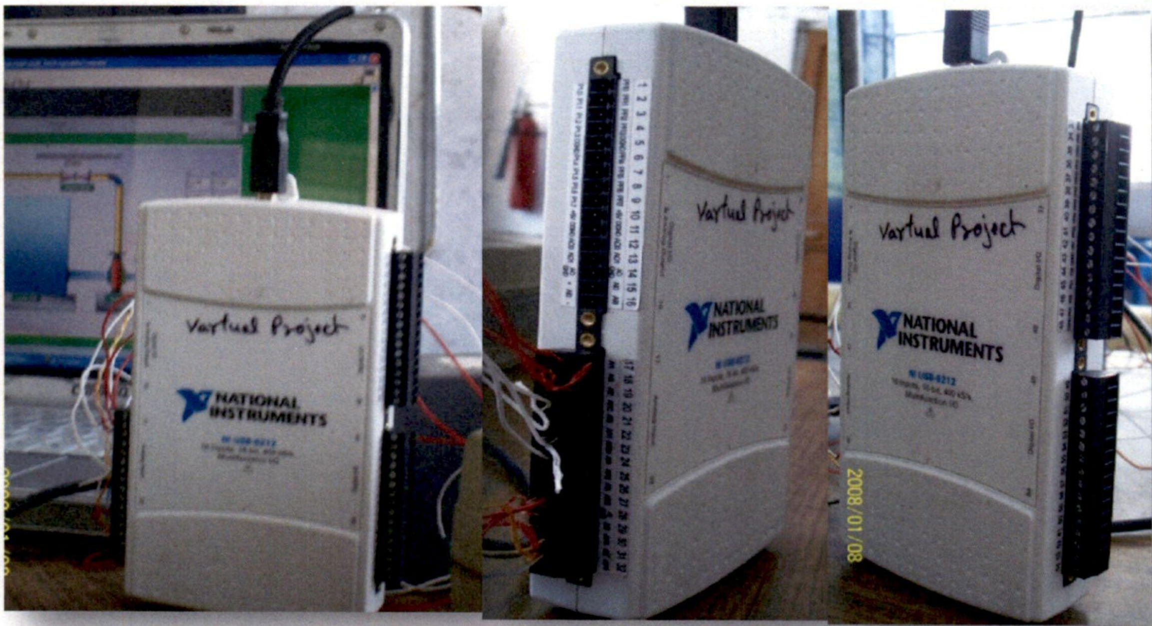


Fig. 5.1 (a) NI USB 6212 Data Acquisition Module

5.2.1 Specifications

NI M Series bus-powered multifunction data acquisition (DAQ) devices for USB are optimized for superior accuracy in a small form factor. They provide an onboard NI-PGIA 2 amplifier designed for fast settling times at high scanning rates, ensuring 16-bit accuracy even when measuring all available channels at maximum speed. All bus-powered devices have a minimum of 16 analog inputs, digital triggering, and two counter/timers. USB M Series devices are ideal for test, control, and design applications including [37]:

(a) Portable data logging – log environmental or voltage data quickly and easily
(b) Field-monitoring applications
(c) Embedded OEM applications
(d) In-vehicle data acquisition
(e) Academic lab use – academic discounts available

The important technical specification of this DAQ card is as follows:

A. GENERAL

Product Name	USB-6212
Product Family	Multifunction Data Acquisition
Form Factor	USB
Operating System/Target	Windows
DAQ Product Family	M Series
Measurement Type	Quadrature encoder , Voltage

B. ANALOG INPUT

Channels	16 , 8
Single-Ended Channels	16
Differential Channels	8
Resolution	16 bits
Sample Rate	400 kS/s
Max Voltage	10 V
Maximum Voltage Range	-10 V , 10 V
Maximum Voltage Range Accuracy	2.69 mV
Maximum Voltage Range Sensitivity	91.6 μV
Minimum Voltage Range	-200 mV , 200 mV
Minimum Voltage Range Accuracy	0.088 mV
Minimum Voltage Range Sensitivity	4.8 μV

C. ANALOG OUTPUT

Channels	2
Resolution	16 bits
Max Voltage	10 V
Maximum Voltage Range	-10 V , 10 V
Maximum Voltage Range Accuracy	3.512 mV
Minimum Voltage Range	-10 V , 10 V

Minimum Voltage Range Accuracy	3.512 mV
Update Rate	250 kS/s
Current Drive Single	2 mA
Current Drive All	4 mA

D. DIGITAL I/O

Bidirectional Channels	32
Input-Only Channels	0
Output-Only Channels	0
Number of Channels	32 , 0 , 0
Timing	Software
Logic Levels	TTL
Supports Handshaking I/O?	No
Supports Pattern I/O?	No
Maximum Input Range	0 V , 5.25 V
Maximum Output Range	0 V , 3.8 V

E. COUNTER/TIMERS

Counters	2
Buffered Operations	Yes
GPS Synchronization	No
Maximum Range	0 V , 5.25 V
Max Source Frequency	80 MHz
Pulse Generation	Yes
Resolution	32 bits
Logic Levels	TTL
Length	16.9 cm
Width	9.4 cm
Height	3.1 cm
I/O Connector	Screw terminals

F. ENVIRONMENTAL

Operating temperature	0 to 45 °C
Storage temperature	-20 to 70 °C
Humidity	10 to 90% RH, noncondensing
Maximum altitude	2,000 m

G. BUS INTERFACE

USB	Hi-Speed USB or full-speed USB
NI signal streaming	4 high-speed data streams; can be used for analog input, analog output, counter/timer 0, counter/timer 1

H. POWER REQUIREMENTS

USB Input voltage on USB-621x

USB port	4.5 to 5.25 V in configured state

Caution: Do not exceed 16 mA per DIO pin

5.2.2 I/O Channel Diagram of Module

Fig.5.1 (b) shows the connection pin out diagram of NI USB 6212 module, it has 15 to 32 analog input channels with one sense input (pin No.23) and one Ground pin (pin No.28) All the sensor analog inputs are connected to these pins with one channel is ground as common point,

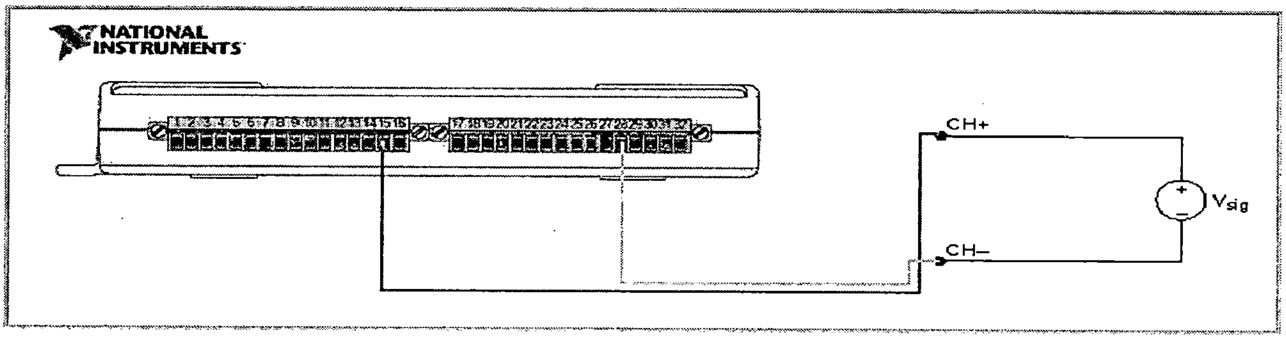


Fig. 5.1 (b) Sample Connection Diagram for Analog Inputs

Similarly the given below Fig.5.1 (c) shows the detail of all pin on Left side of the module. For a detailed description of each signal, refer to the I/O Connector Signal Descriptions in Appendix C.

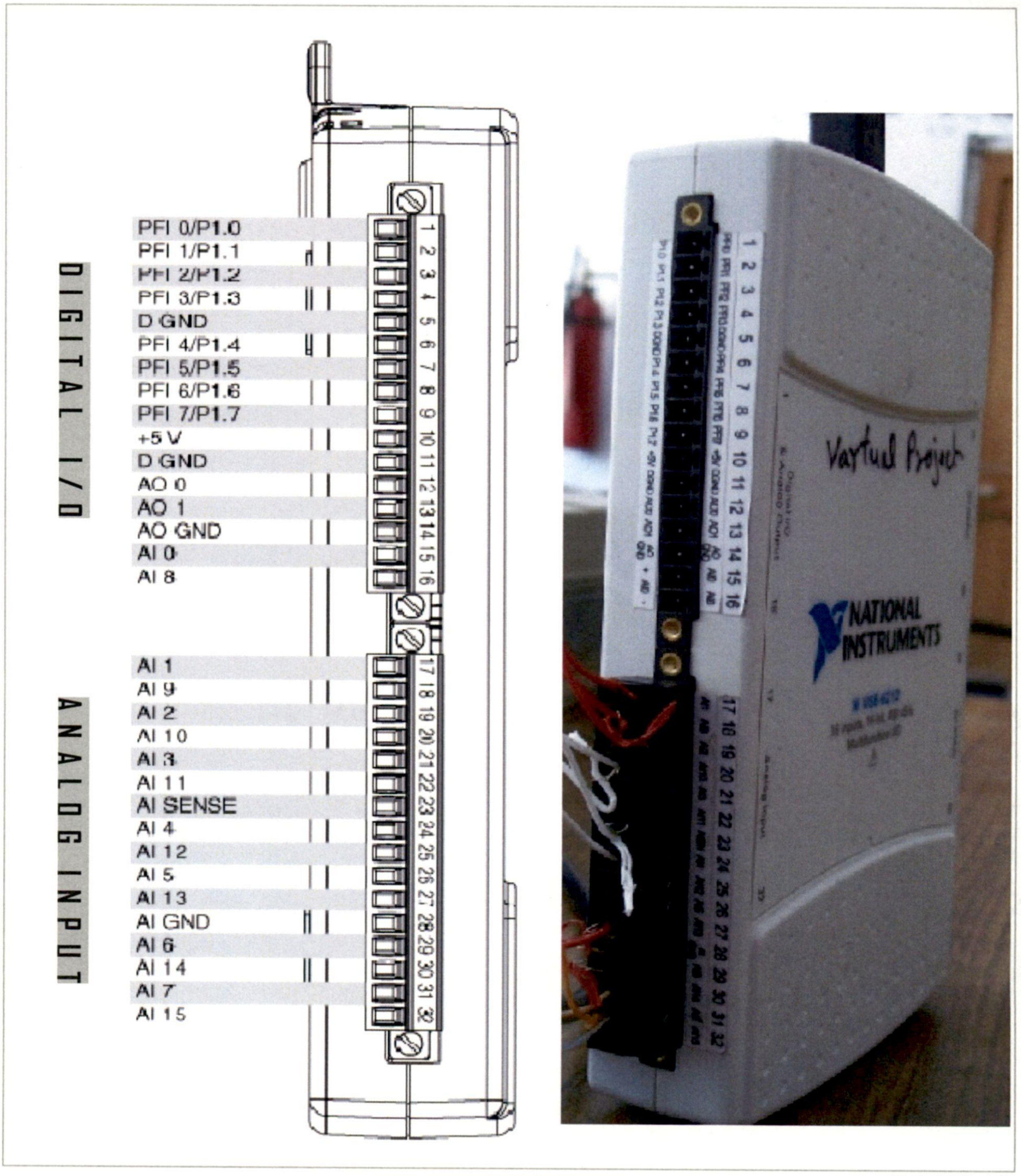


Fig.5.1 (c) Pin out diagram of NI USB 6212 module (with Digital I/O and Analog Inputs)

5.3 Connections of Module with HTGU's Sensors

The detail connection diagram has been discussed and shown in chapter 3 in Fig.3.2.In this section we are describing connection of sensors analog inputs to the module and its channel identification. Table 5.1 shows the detail of all sensor analog input to the module's channels used in our demonstration experimental setup for HTGU.

Table 5.1 Setting of the Sensors Analog Input to 6212 module's channels

S.NO.	SENSORS NAME & ANALOG INPUT	6212 MODULE PIN NO. / CHANNELNO.
1.	**Generator Output via Power Analyzer** Phase Voltages V_1, V_2, V_3 (3 Input) Phase Currents I_1, I_3, I_4 (3 Input) Power W (1 Input) Frequency Hz (1 Input) Ground GND	 20, 21, 22 17, 18, 19 23 16 28
2.	**Pressure Transmitter** Inlet Head Analog input (1 Input) Outlet Head Analog input (1 Input) Ground	 27 29 28
3.	**UTTF Flow Meter** 1 Analog Input Ground	 26 28
4.	**IR Temperature Thermometer** 1 Analog Input Ground	 25 28
5.	**Motorised Control Valve** 2 Analog Input Ground	 31,32 28
6.	**Optoelectronic Speed Sensor** 1 Analog Input Ground	 24 28
7.	**USB PORT Female on DAQ** (Port for Connector Cable)	USB Male Port to PC/Laptop via NI USB Connector Cable

CHAPTER-6

VIRTUAL INSTRUMENTATION USING LABVIEW

6.1 INTRODUCTION

LabVIEW is designed to simplify programming scientific computation, process control, and test and measurement applications. Unlike the traditional instrumentation modern instrumentation systems include computers, microcomputer, which provides more efficient control of instruments, automatic data acquisition, extensive data analysis capabilities. LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. LabVIEW contains a comprehensive set of tools for acquiring, analyzing, displaying, and storing data, as well as tools to help you troubleshoot code you write.

In LabVIEW, you build a user interface, or front panel, with controls and indicators. Controls are knobs, push buttons, dials, and other input mechanisms. Indicators are graphs, LEDs, and other output displays. After you build the user interface, you add code using VIs and structures to control the front panel objects. The block diagram contains this code. You can use LabVIEW to communicate with hardware such as data acquisition, vision, and motion control devices, as well as GPIB, PXI, VXI, RS232, and RS485 instruments [37, 38].

6.2 LABVIEW Vs 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:

(a) Graphical Programming
(b) Connectivity and Instrument Control
(c) Open Environment
(d) Reduces Cost and Preserves Investment
(e) Multiple Platforms

(f) Distributed Development

(g) Analysis Capabilities

(h) Visualization Capabilities

(i) Flexibility and Scalability - Key Advantages

6.3 BASIC CONCEPTS OF LABVIEW

LabVIEW Software is the most important component of virtual instruments. With the right software tool, engineers and scientists can efficiently create their own. Every VI uses functions that manipulate input from the user interface or other sources and display that information or move it to other files or other computers

As suggested above, there are two "faces" of any LabVIEW VI. They are the **block diagram** and the **front panel.** The front panel is the face that the user of the system sees. It contains **controls** and **indicators.** LabVIEW has a very rich selection of both (we can even design our own) and this permits a wide range of options to the designer. This is a demonstration of a few of the controls.

6.3.1 Front panel

We build the front panel with controls and indicators, which are the interactive input and output terminals of the VI, respectively. Controls are knobs, push buttons, 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 the front panel. The front panel is the user interface of the VI. The following Fig.6.1 (a) shows an example of a front panel of tank simulation.

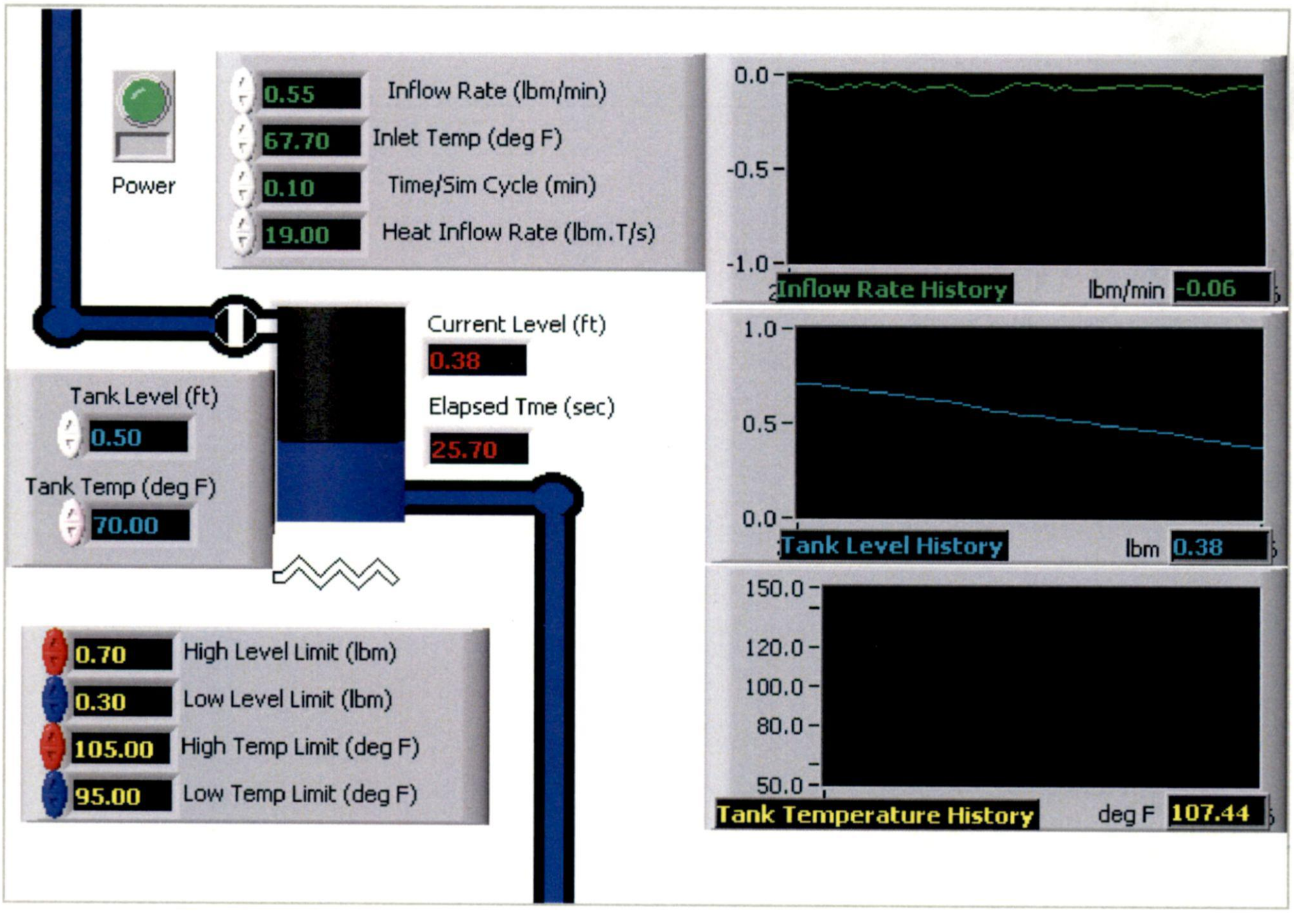


Fig. 6.1 (a) Front of Tank Simulation build in LabVIEW 8.6

6.3.2 Control and Indicators

Control can take many forms. Many of the forms are themselves "pictures" of real controls used on real instruments - rotary knobs for example. Others are strictly digital in concept. All controls have some form of visual feedback to show the user what state they are in. This helps enormously as you do not have to make explicit allowance to show the state of the controls in our design. A second extremely useful property of controls is that you can specify how they are to react if the input given is unsuitable. Fig. 6.1 (b) and 6.1 (c) shows the tools and control pallets in LabVIEW.

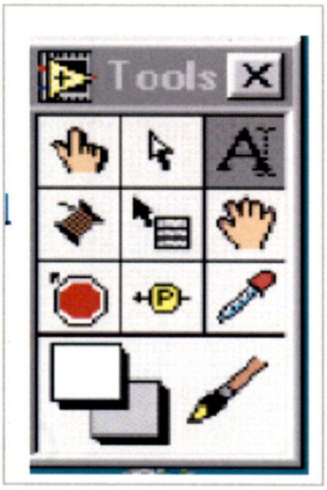


Fig. 6.1 (b) Tools pallets in LabVIEW

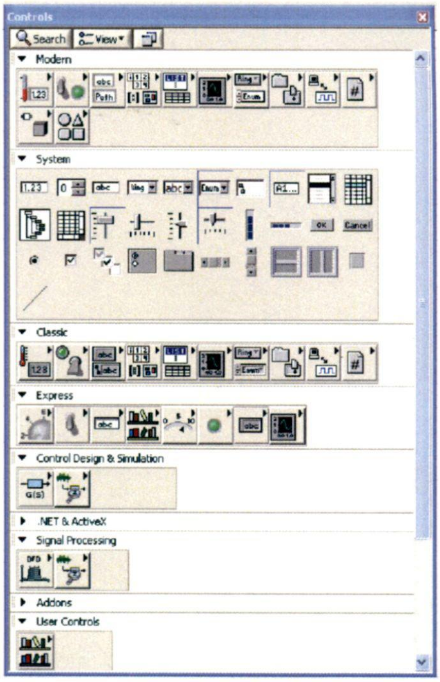


Fig. 6.1 (c) Control pallets in LabVIEW 8.6

Indicators take a large number of forms. Again some are "pictures" of real indicators -lights and meters. Some are more designed for the computer screen. The concept of indicator also includes graphs and charts which is a second major timesaver as we do not have to design any of these elements explicitly. Fig. 6.1 (d) shows different types of indicators available in LabVIEW. By intelligent design of the **front panel** of a VI it is fairly simple to produce a simple clean design for the user.

6.3.3 Block Diagram

The **Block diagram** of the VI is almost the "backside" of the **front panel**. It shows how all the controls and indicators fit together as well as the hidden modules where all the work gets done. Fig. 6.1 (e) shows a simple block diagram of front panel shown in Fig. 6.1 (a). It looks somewhat like an electronic schematic diagram and is at least conceptually wired up in the same way.

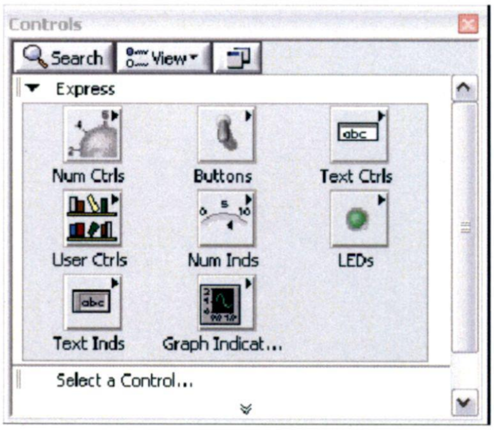


Fig. 6.1 (d) Different types of indicators used in LabVIEW

Like a real piece of instrumentation, it is easy for the wiring to look very complex and untidy. One of the major issues in LabVIEW programming is to allocate the timing and ordering of operations. LabVIEW works in exactly the same way, but the way in which you specify the ordering is more subtle. The concept in LabVIEW is "dataflow" - any item executes when all its inputs are available. The standard execution is left-to-right because inputs are generally on the left of an item and outputs on the right, but this is a convention, not a requirement. Table 6.1(a) & (b) show the important icons used in LabVIEW [38].

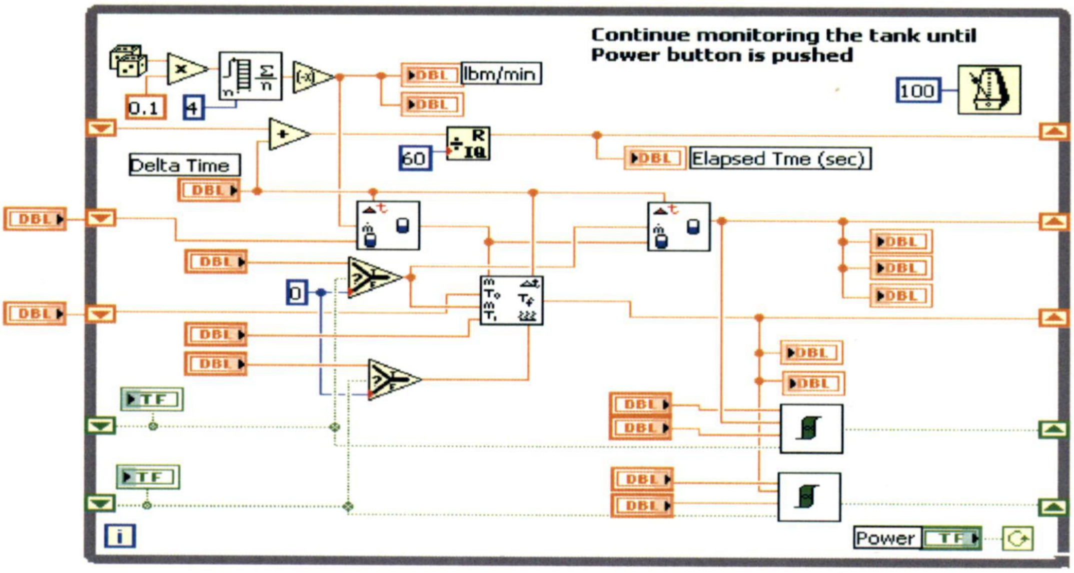


Fig. 6.1 (e) Block Diagram of Tank Simulation VI shown in Fig.6.1

Table 6.1 (a) Different icons and their functions used in LabVIEW

Icon	Meaning	Explanation
	FONTS	Controls the fonts (size and style of type) used for the front panel
	ALIGNMENT	Controls the alignment of groups of controls and indicators - useful for getting things in straight lines and columns
	DISTRIBUTION	Controls gaps between things - useful for getting things uniformly spaced.

Table 6.1 (b) Different icons for VI status

Icon	Meaning	Explanation
	RUN	Run the VI once. VIs, like conventional programs, do not repeatedly run unless you tell them to. The RUN button changes appearance when the VI is actually running.
	RUN REPEATEDLY	Run the VI over and over. Unless you are debugging a VI, this is not a recommended way of repeating any but the simplest of Vis. There are much better ways of doing this using LabVIEW constructs
	STOP	STOP (unceremoniously) the current VI
	PAUSE/ CONTINUE	Press once for pause, again to continue

6.4 CONFIGURING NI USB 6212 DAQ MODULE

This section describes how to confirm your NI data acquisition device is operating properly. Install our application and driver software first, then plug our device. Following steps should be complete [39]:

Step 1. NI USB 6212 device and plug it into a PC/Laptop on which **NI-DAQmx** has been installed as refer in Fig.6.2 (a).

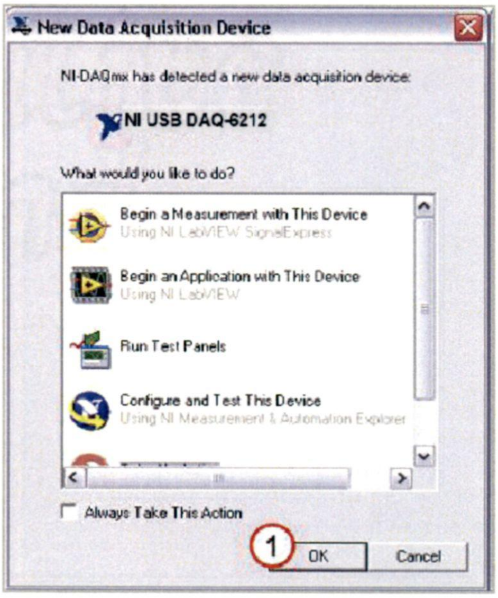


Fig. 6.2 (a) First Click from Device Detection Screen

Step 2. Once NI Compact DAQ is connected to the PC and powered on, the NI Device Monitor launches as in Fig. 6.2 (b), which gives a multiple options. Click **"OK"**

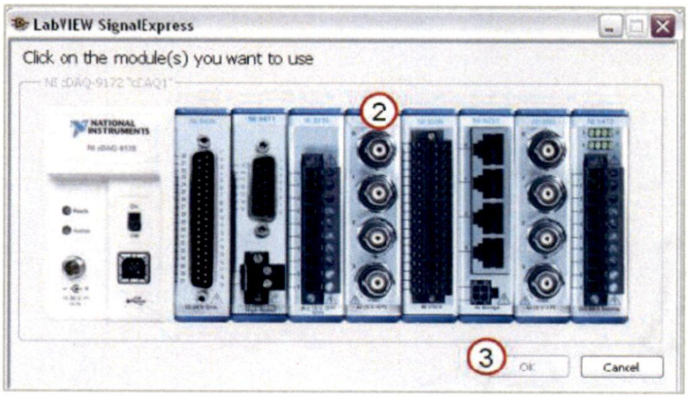


Fig. 6.2 (b) NI Compact DAQ User Interface to LabVIEW Signal Express with Clicks 2 and 3

Step 3. This user interface as in Fig. 6.2 (b) dynamically loads images of the specific modules you have installed in our NI Compact DAQ chassis. To begin taking a measurement, select one or more modules and click on **"OK"**

These three clicks we have to take the setup screen in LabVIEW Signal Express as shown in Fig. 6.2 (c) where, based on the module type you select, the software has already configured your measurement and are taking data. We can change this configuration while our data is running, which makes it easier to set up sensors such as thermocouples, strain gages, and other transducers that require multiple settings.

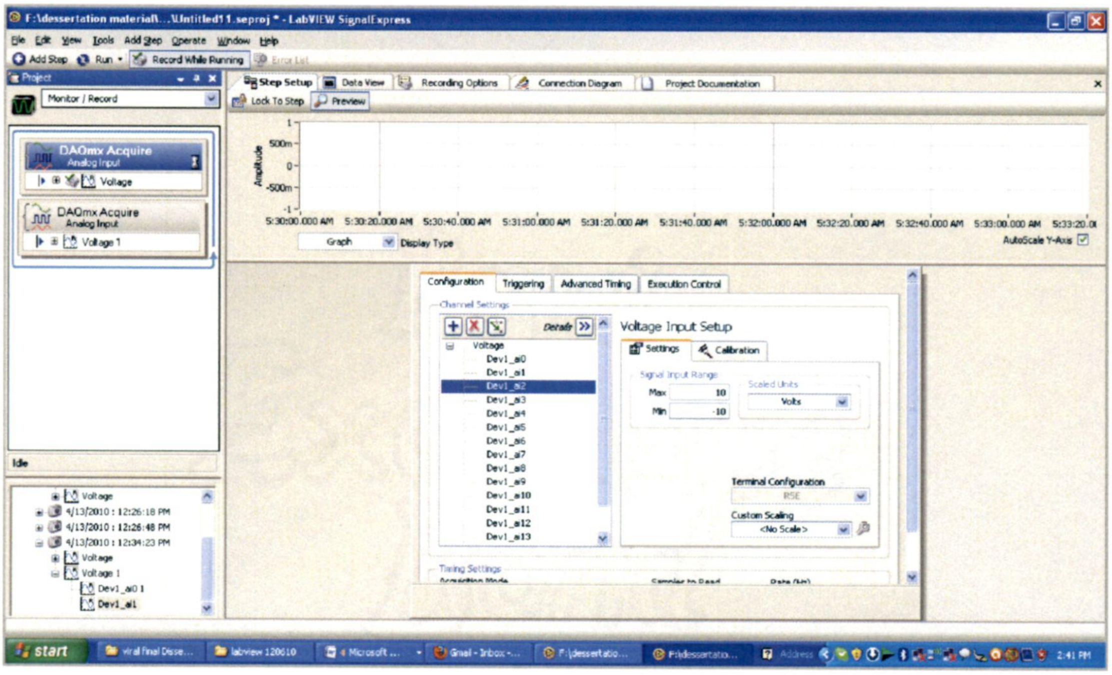


Fig. 6.2 (c) LabVIEW Signal Express Configuration Screen

Because the module selected in these screenshots is mainly for voltage signals (analog Inputs) (NI 6212), LabVIEW Signal Express has set up the measurement for a voltage and started taking measurements. We can see in the chart on the top of the window the vibration data from the module. Each color represents a different channel on the module. Fig. 6.2 (d) represent the all analog inputs waveform which is given on the different channel 6212 DAQ card as described earlier chapter 3 & 5.We can also add or remove channels, modify the settings for your accelerometer, or continue to log your data to disk.

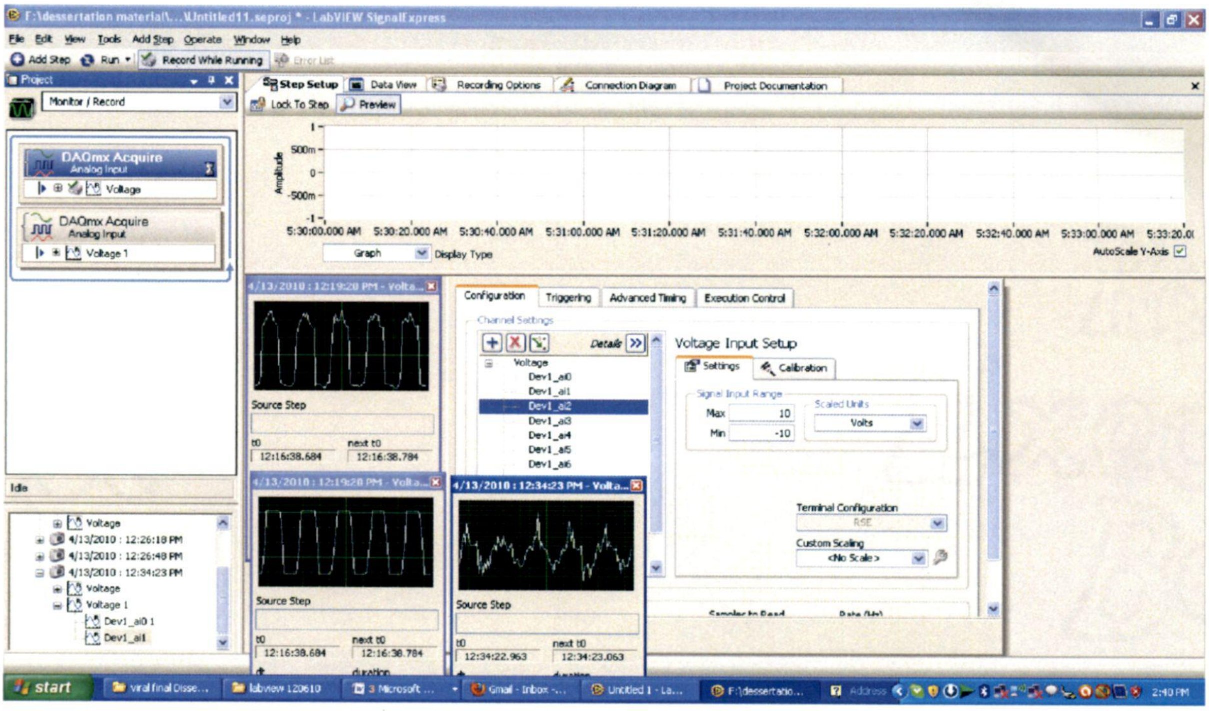


Fig. 6.2 (d) Configuration of all input analog signals and their waveforms when connected to NI 6212 to the sensor output.

Step 4. Now confirm NI data acquisition (DAQ) device is operating properly. **Double-click** the **Measurement & Automation** icon on the desktop to open **MAX**. Expand **Devices and Interfaces** to confirm your device is detected. Find and expand our target, and then expand Devices and Interfaces as shown in Fig. 6.2 (e).

Step 5. Right-click the device and select **Self-Test.** When the self-test finishes, a message indicates successful verification or if an error occurred.

Step 6. For **NI M** and **X Series** PCI Express devices**, right-click** the device and select **Self-Calibrate.** A window reports the status of the calibration. **Click Finish.**

Step 7. Now attach sensors and signal lines to the terminal block or accessory terminals for each installed device. The following Table 6.2 lists device terminal/pinout locations.

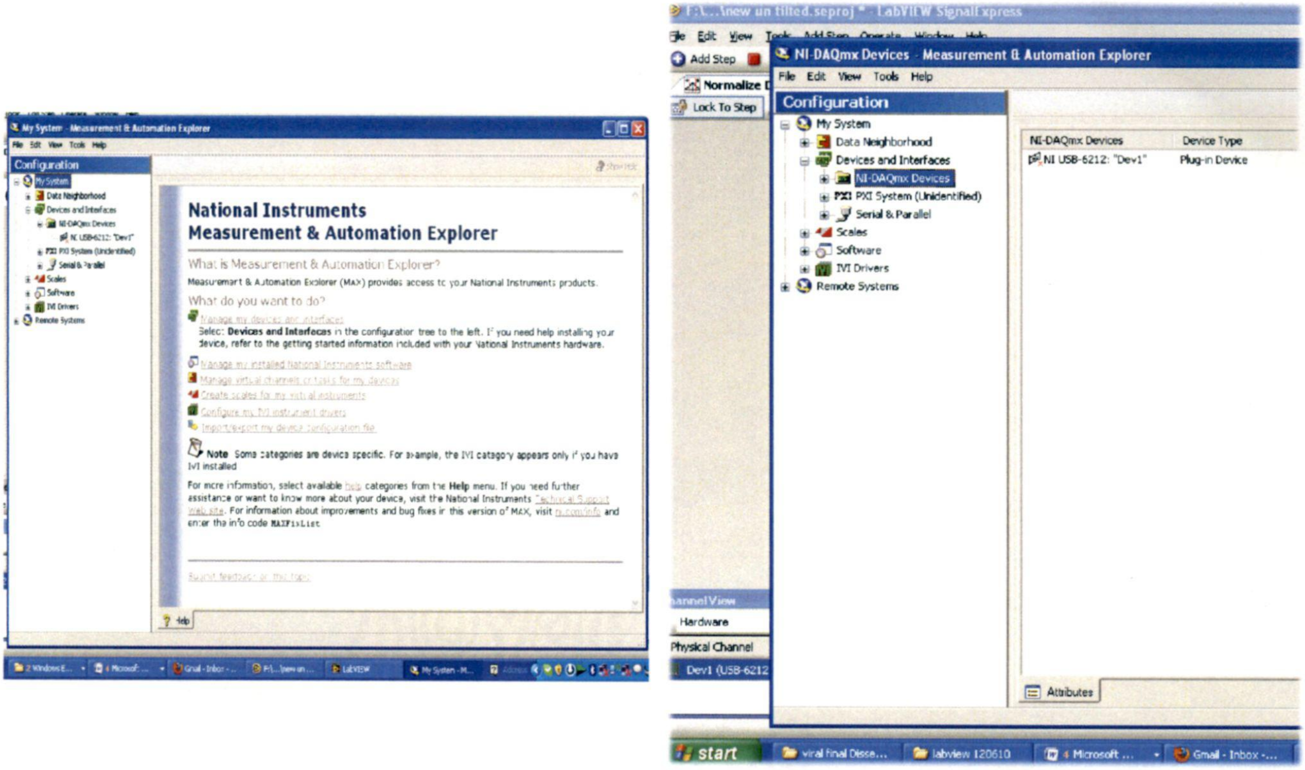


Fig. 6.2 (e) Device self Test and Calibrating in Measurement & Automation software

Table 6.2 lists of device terminal/pinout locations

Location	How to Access Pinout
MAX	Right-click the device name under NI-DAQmx Devices, and select **Device Pinouts**.
	Select **Help»Online Device Documentation**. A browser window opens to `ni.com/manuals` with the results of a search for relevant device documents.
DAQ Assistant	Select the task or virtual channel, and click the **Connection Diagram** tab. Select each virtual channel in the task.
NI-DAQmx	Refer to the *NI-DAQmx Help* that installs with NI-DAQmx.

Step 8. Now attach sensors and signal lines to the terminal block or accessory terminals for each installed device. The following Table 6.2 lists device terminal/pinout locations.

Step 9. Configure a Task Using the DAQ **Assistant** from **MAX** and, Complete the following steps to create a task using the **DAQ Assistant** in **MAX**:

(a) In MAX, right-click **Data Neighborhood** and select **Create New** to open the DAQ Assistant.

(b) In the Create New window, select **NI-DAQmx Task** and click **Next.**

(c) Select **Acquire Signals** or **Generate Signals.**

(d) Select the I/O type, such as analog input, and the measurement type, such as voltage.

(e) Select the physical channel(s) to use and click **Next.**

(f) Name the task and click **Finish.**

(g) Configure individual channel settings. Each physical channel you assign to a task receives a virtual

(h) Channel name, to modify the input range or other settings, select the channel. Click **Details** for physical channel information. Configure the timing and triggering for your task. Click **Run.**

Step 10. Now go to **Getting Started** with **LabVIEW»** Getting Started with DAQ»**Taking an NI-DAQmx Measurement in LabVIEW**; and run the front panel of required HTGU's VI as shown in Chapter 3, Fig 3.4 and RUN this VI and monitor the required parameters in real time.

6.5 LABVIEW BLOCK DIAGRAM FOR HTGU

In sequence the above discussed front panel, its respective block diagram is shown in Fig. 6.2 (f) & (g) which is communicate to the all the sensor/transducers.

Block diagram –I is for the measurement of Electrical parameters and II for Non electrical parameters. They communicate to the sensors/transducers when we start the HTGU unit and RUN the LabVIEW program. It instantly displays the values of all parameters as shown in next Chapter.

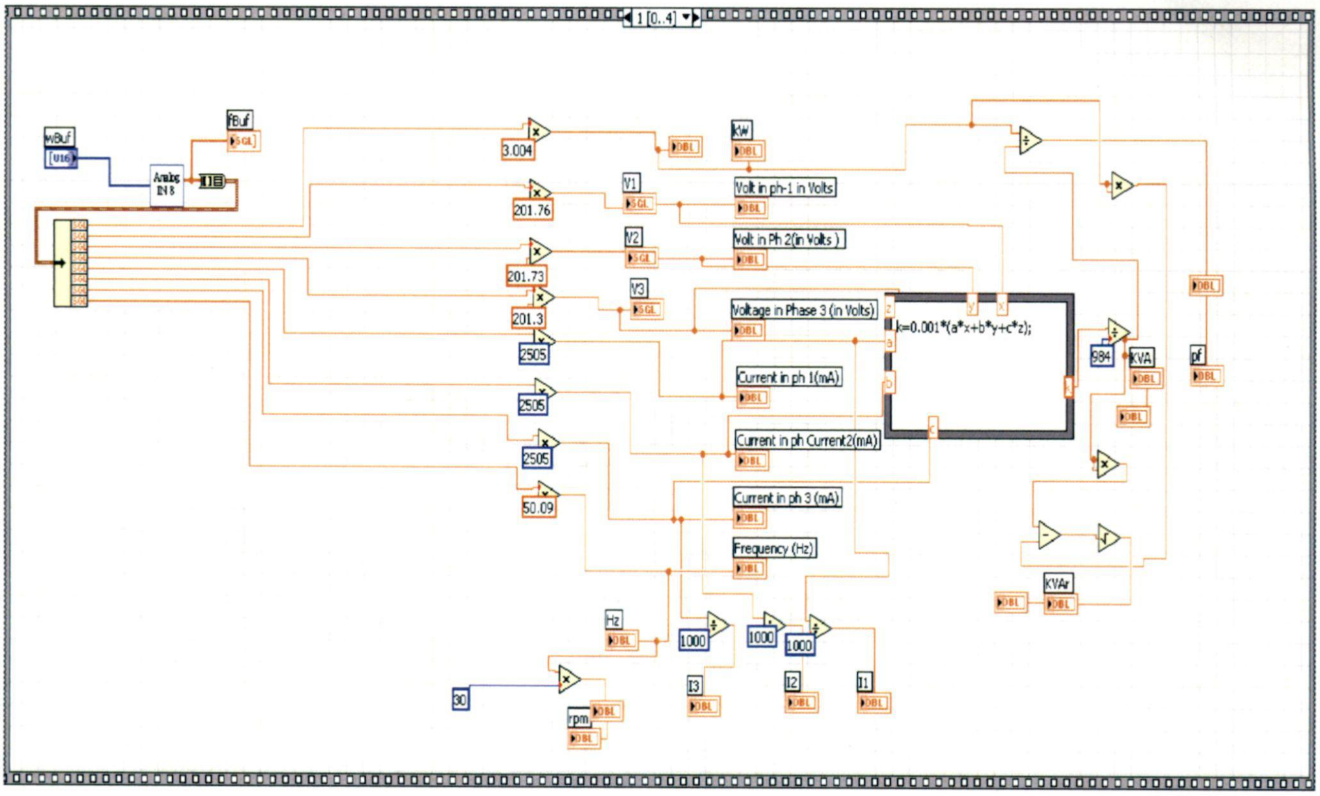


Fig. 6.2 (f) Block diagram-1 of HTGU's VI.

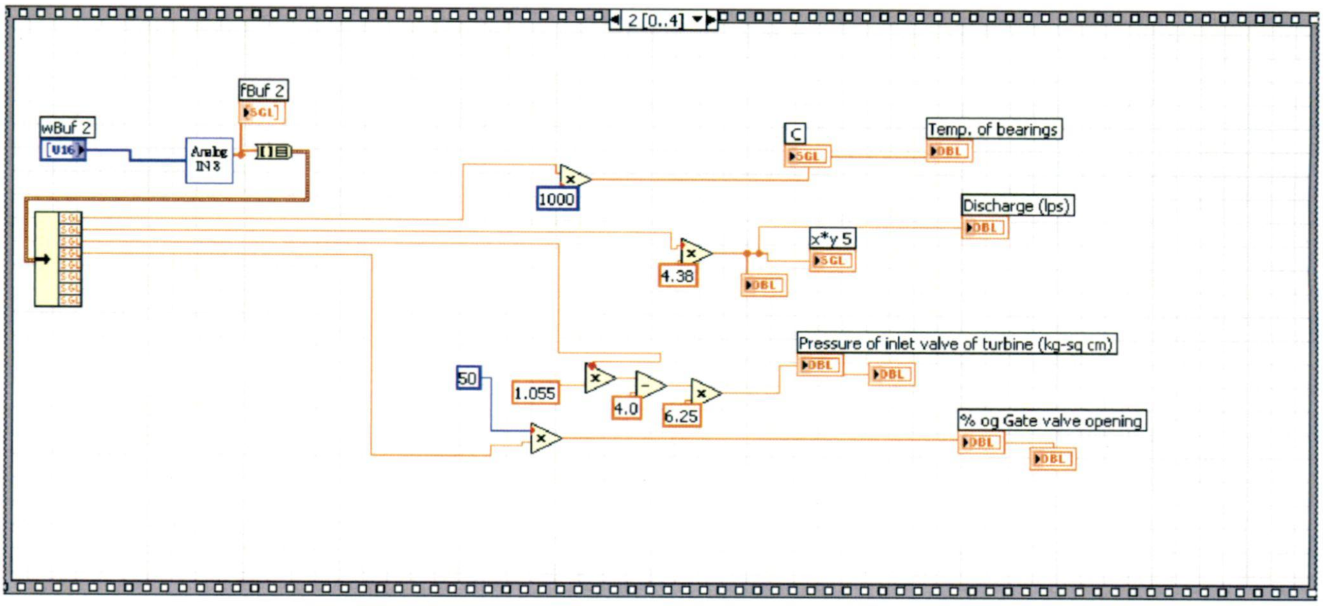


Fig. 6.2 (g) Block diagram-II of HTGU's VI

CHAPTER-7

EXPERIMENTAL DATA DISPLAY & RESULTS

7.1 INTRODUCTION

In this dissertation work experimental results are verified through meter readings by instruments or control panel readings. In this chapter, we will see how reading on PC/Laptop is nearer to meter readings, how much deviation between meter readings and the reading on computers. It is also necessary analyze experiment data. There should be displayed data matched with instruments readings or control panel readings so verification is needed. In this dissertation work there are almost all of the results are presided and also accurate besides little deviation. Here also an attempt is made to find out the errors and check the accuracy of used IDAS.

7.2 DATA DISPLAY IN LABVIEW

The experiment performed using IDAS shows all the seventeen parameters (electrical & non-electrical) on PC/laptop screen in LabVIEW's Front panel and its data flow by connecting leads and wires in Block diagram of LabVIEW 8.6 as discussed in earlier chapters. In this section we are displaying the data measured at the time of running the HTGU by LabVIEW Front panel in at various instant of the HTGU operation. Fig. 7.1 (a) shows the LabVIEW front panel of HTGU in steady state. It represent the data of all parameters in real time terms of knobs, dials graphs, palaetes etc. At the same time we had measured the meter reading by instruments for the deviation purpose and error calculation.

However raw parameters can be sized by actual showing display on instruments it selves and output voltage from the instrument. Take an example, for a particular device the scaling factor may be two hundred but, if it multiplying by two hundred it may be seen 2-3% error. It is basically device or wires attenuation as well as depends on maximum range of input module channels. Take an example, if we set input range of the module is 10V but given input less than 2 volts then percentage of error is more than set voltage of module is 2.5V. There are two ways to reduce error either voltage range of module channel should be matched near input value or we can change multiply factor in the program [40]. So with the help of this LabVIEW software

It is possible to change the multiplying factor easily. So errors can be minimized. Now the front panel VI's is shown in the Fig. 7.1 (a) below, before running program.

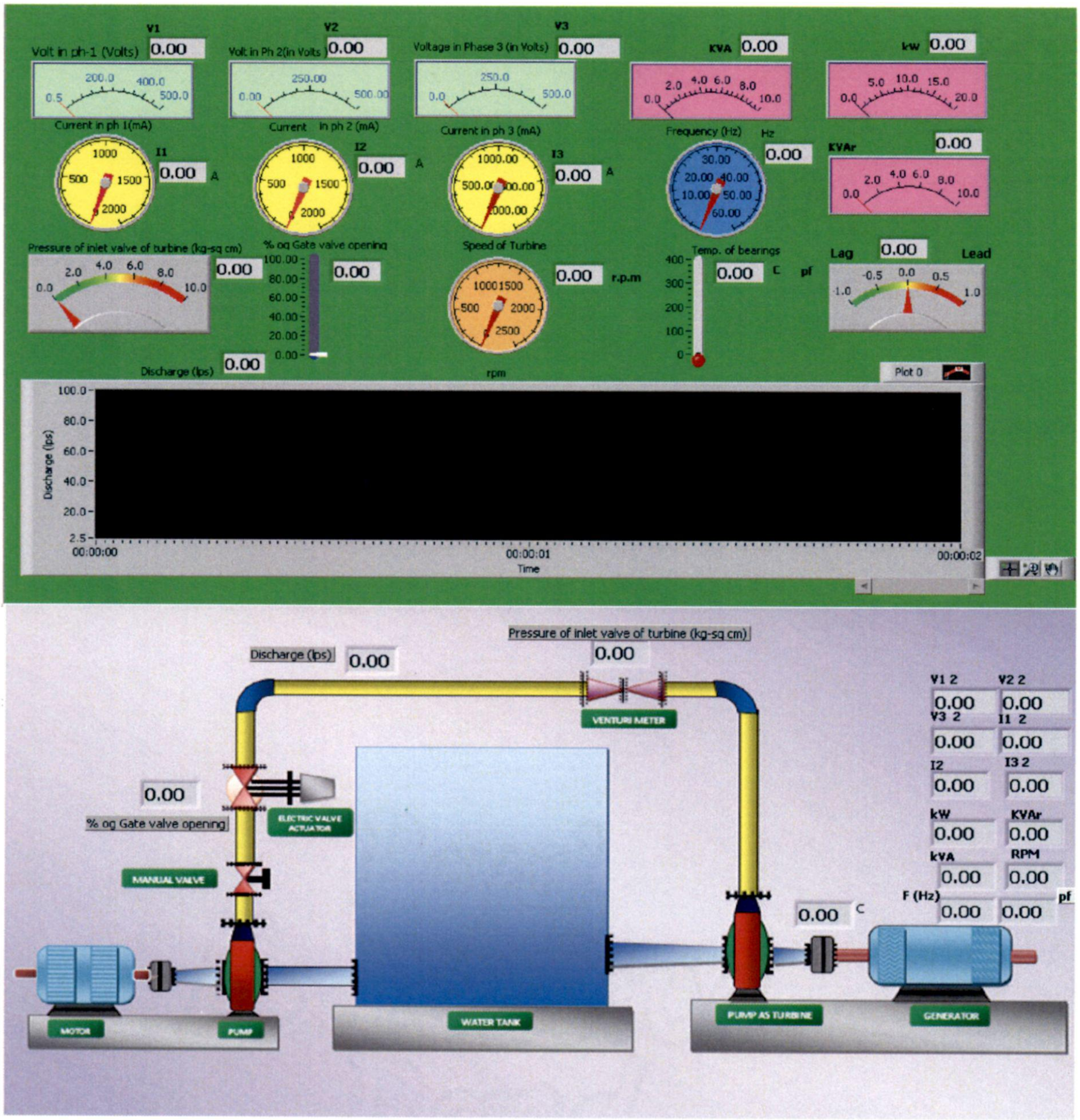


Fig. 7.1(a) Front panel before running the program & HTGU

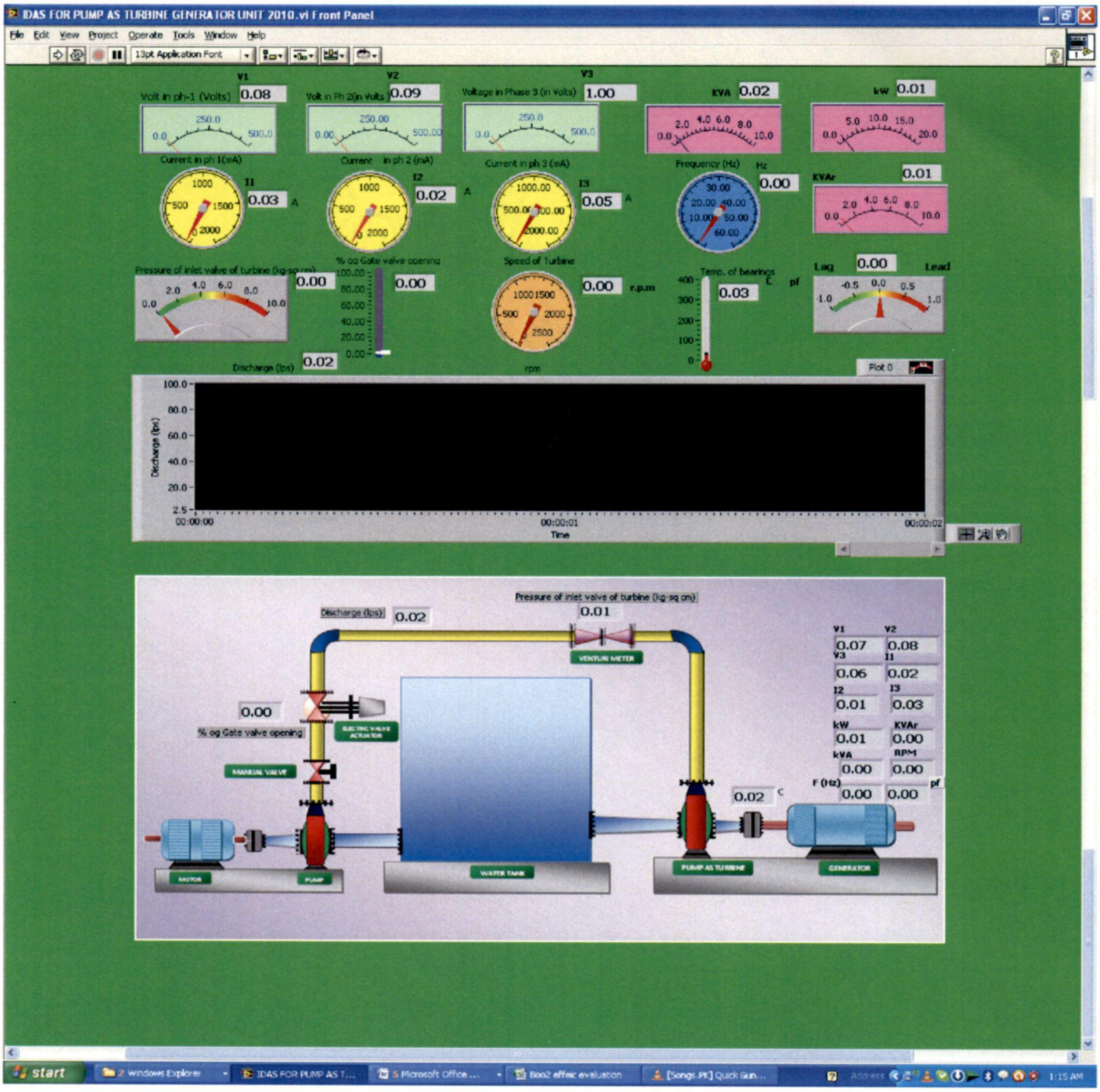


Fig. 7.1(b) Before starting the HTGU and after running software program

Above Fig. 7.1(b) shows defaults value before start the HTGU. Now after start up the display new changed values as in the Fig. 7.1(c) below. The above mentioned figures shows all real time values of all parameters.

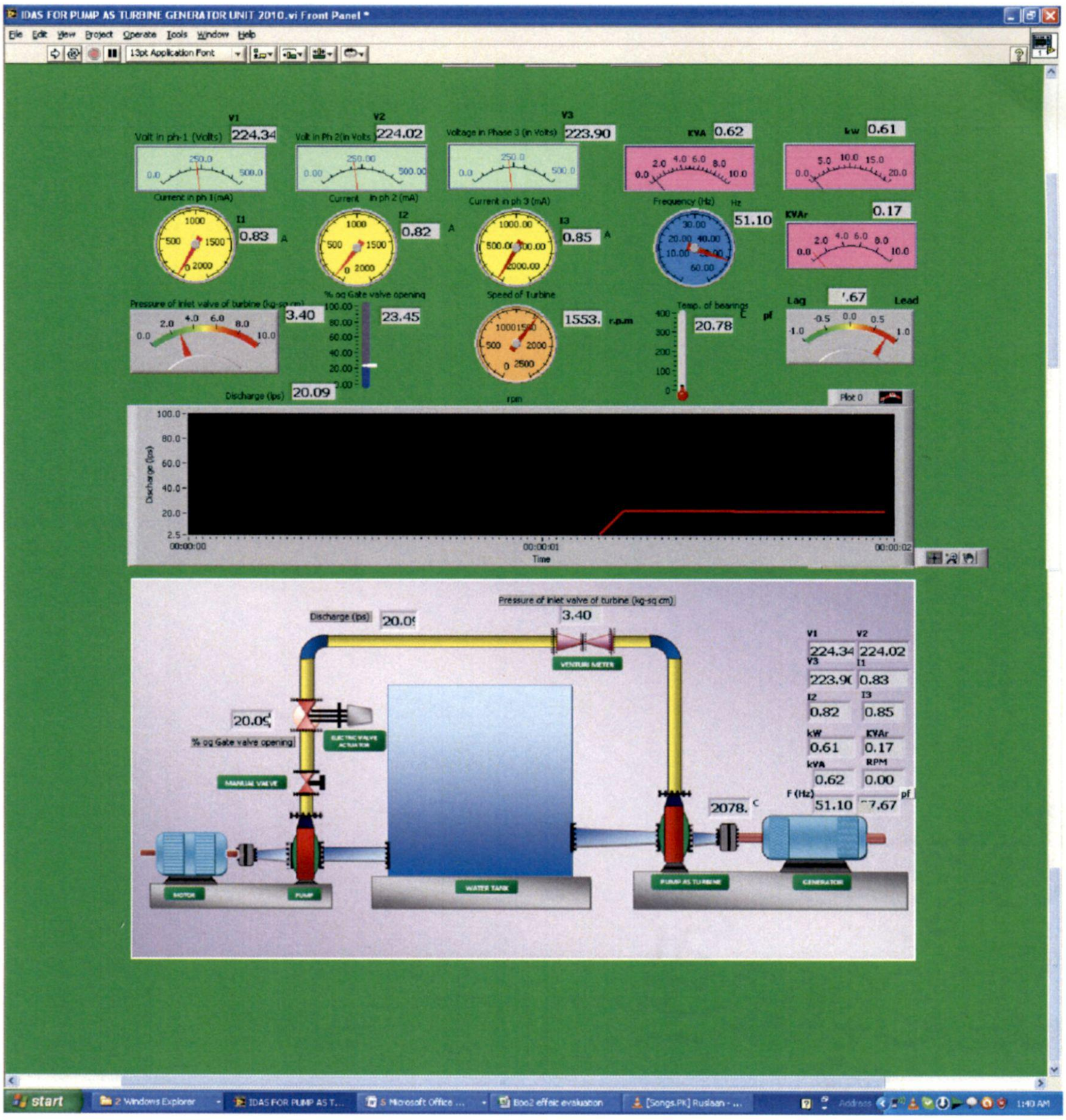


Fig. 7.1(c) After few minutes of the starting HGTU in continuous running mode

The Fig. 7.1 (d) it is seen that values are changed due to change the valve position, so Q or discharge is changed. It clearly depicted the variation of discharge Vs time graph in real time.

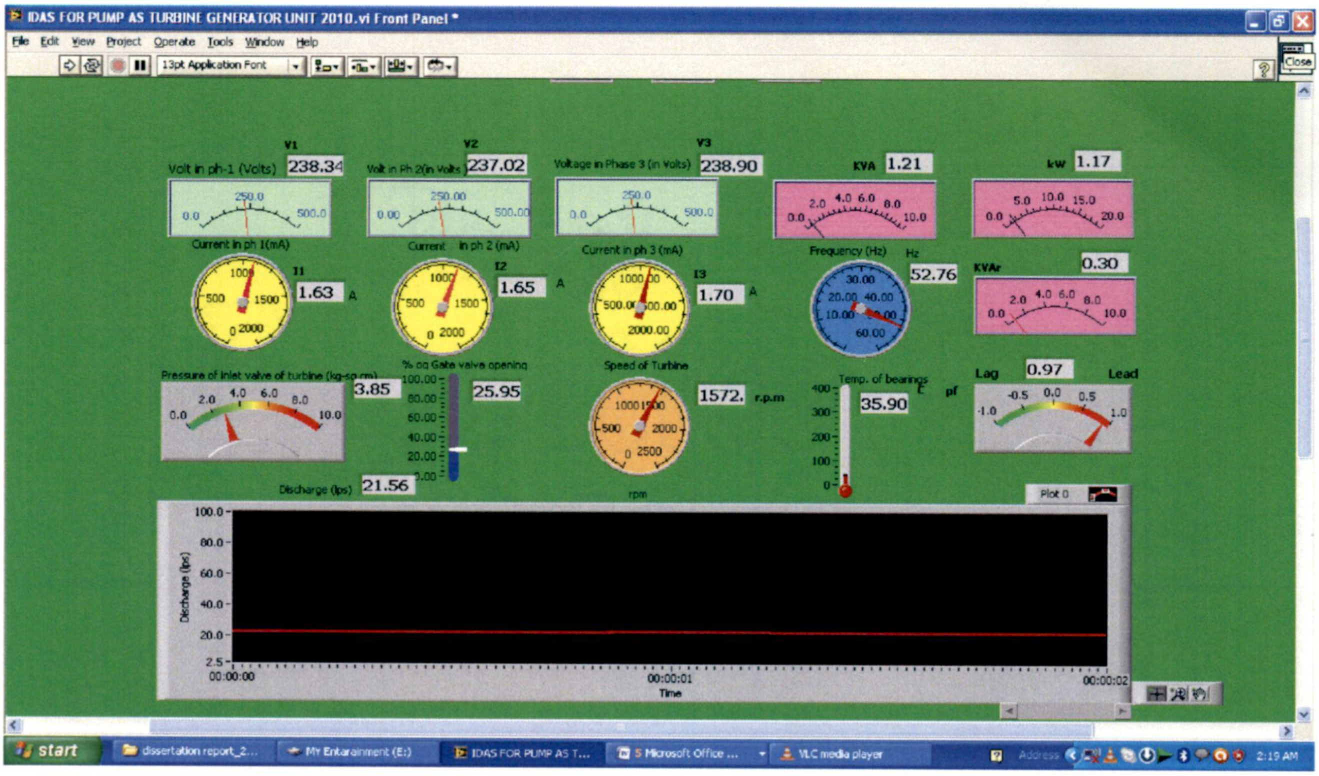


Fig. 7.1(d) After few minutes of the starting HGTU

The next Fig.7.1 (e) it is seen that values are changed due to load is increasing.

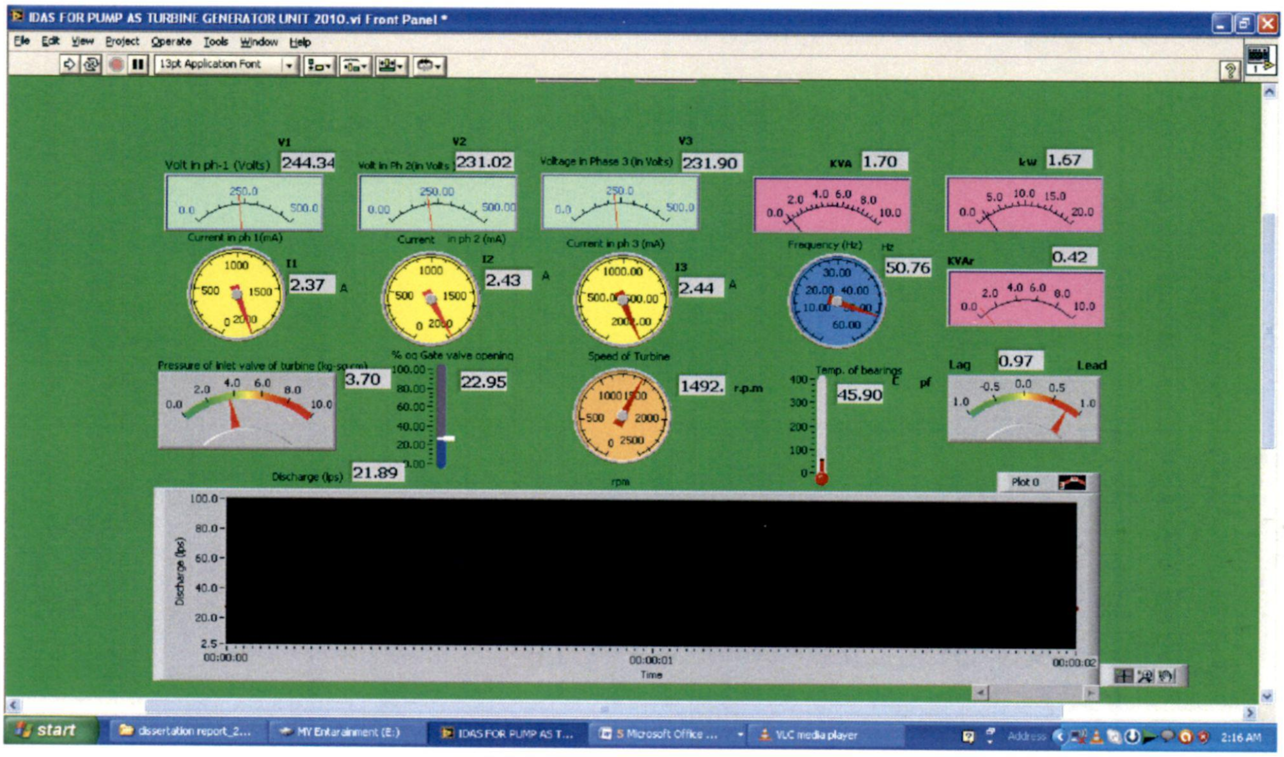


Fig. 7.1(e) After few minutes of the starting HGTU with load

So it is easily seen that change of readings in this monitoring screen is flexile in nature and display is according to parameter value change with time.

7.3 RESULTS AND DISCUSSIONS

In this section it is shown that readings of all parameters on the PC/Laptop are almost matched with control panel of this system as well as instrument readings. The secondary parameters that are desired from one or more primary parameters are almost equal and have very low % of error. The errors are produced due to transducers output raw voltage, current not being in pure ac forms or only root means square form.

Formula for measuring electrical parameters according to instruments software system is shown in the **Table C** specified in **Appendix-D**, supplied by the manual [29].

Other non electrical parameters such as discharge, percent of gate valve opening, temperature of bearings, pressure of inlet valve also have different desired transducer output. Outputs are volt, mV, and mA in ranges.

7. 3.1 Calibration of Parameters

The Table 7.1 indicates the meter readings and computer display readings are shown in the next page these are basically electrical parameters at various input of turbine and load variations.

The Table represents the two reading of each quantity one is Meter Reading (M.R.) or Instrument Reading (IR) and Personal Computer (PC) readings. All the electrical parameters reading and non-electrical parameter readings are shown in Table 7.2 (a) and & 7.2 (b) respectively.

Table 7.2 (a) Reading of Electrical parameters by *PC and **MR

SL NO.	V_1 Ph-1 (Volts)		V_2 Ph-2 (Volts)		V_3 Ph-3 (Volts)		I_1 Ph-1 mA		I_2 Ph-2 mA		I_3 Ph-3 mA		kW		kVA		kVAr		Pf		F (Hz)	
	M.R	P C	M.R	P C	M.R	P C	M.R	PC	M.R	PC	M.R	PC	M.R	PC	M.R	PC	M.R	PC	M.R	PC	M.R	PC
1	250.5	250.9	249.9	250.1	251.0	250.7	967	969	978	977	989	990	0.180	0.179	0.733	0.734	0.743	0.745	0.223	0.230	50.10	50.08
2	237.4	237.0	238.0	238.1	239.0	238.9	1969	1968	1980	1977	1969	1970	0.787	0.789	1.456	1.478	1.211	1.200	0.578	0.580	49.56	49.76
3	223.3	223.1	223.1	222.9	223.2	223.3	2565	2568	2670	2672	2670	2571	1.182	1.190	1.790	1.789	1.245	1.250	0.680	0.679	51.03	52.0
4	234.1	234.2	233.0	233.1	232.8	232.9	3655	3654	3629	3633	3632	3630	2.352	2.450	2.799	2.810	1.998	1.201	0.900	0.902	49.90	49.91
5	243.1	243.1	243.2	243.0	242.7	243.0	779	778	790	781	784	783	0.498	0.486	0.546	0.544	0.345	0.359	0.745	0.749	50.53	51.0
6	244.0	243.9	242.9	243.1	249.0	250.0	964	965	968	971	987	989	0.190	0.890	0.745	0.744	0.746	0.745	0.233	0.230	51.10	50.19
7	237.4	237.0	238.1	238.4	240.0	239.9	1958	1957	1984	1987	1971	1970	0.907	0.909	1.489	1.488	1.207	1.206	0.687	0.680	49.89	49.56
8	222.3	223.1	224.1	223.9	222.2	223.1	2570	2568	2678	2676	2576	2571	1.797	1.180	1.790	1.789	1.255	1.250	0.650	0.669	50.03	50.0
9	233.1	232.2	232.0	232.1	233.8	233.0	3667	3665	3665	3664	3644	3640	2.342	2.340	2.989	2.986	1.998	1.100	0.780	0.756	48.90	48.91
10	244.1	245.0	244.2	243.8	242.7	243.2	799	797	796	793	789	789	0.499	0.476	0.746	0.744	0.365	0.360	0.775	0.769	50.80	50.50

*Note: *M.R means Meter Readings,*
***PC means Reading by LabVIEW/PC*

Table 7.2 (b) Reading of Non-Electrical parameters by *PC and **MR

SL NO.	Percentage of gate valve opening (%)		Pressure of inlet valve(kg/cm^2)		Discharge(Q) m^3/sec		R.P.M. of turbine		Temperature of the bearings (°C)	
	Scale Reading of Actuator	PC	M.R	PC	M.R	PC	M.R	PC	M.R	PC
1	22	19.76	4.04	3.99	0.0200	0.0201	1480	1478	40	41.40
2	45	34.43	4.05	4.15	0.0213	0.0212	1499	1496	41	39.90
3	76	63.46	3.97	3.88	0.0234	0.0232	1560	1561	40	41.30
4	80	74.06	3.84	3.81	0.0227	0.0227	1499	1499	51	52.00
5	90	85.90	3.69	3.68	0.0220	0.0221	1550	1552	56	55.90
6	100	94.10	4.20	4.19	0.0239	0.0229	1691	1689	59	57.90
7	60	46.47	4.54	4.49	0.0206	0.0203	1523	1520	46	42.90
8	40	32.01	3.85	3.80	0.0207	0.0201	1487	1484	38	37.01
9	20	15.06	3.09	3.00	0.0200	0.0200	1456	1454	36	35.60
10	15	9.76	3.01	3.00	0.0201	0.0200	1301	1297	33	32.00

*Note: *M.R means Meter Readings,*
***PC means Reading by LabVIEW/PC*

Here it is seen that primary output parameters i.e. which provide directly 0 to full scale output from instruments output, it has not much different. But some other secondary parameters i.e. it is not direct output, can be made from two or more primary parameters has difference. The basic reason it is not calculated by vector multiplication system.

7.3.2 Calibration all parameters (M.R and R.C)

Figures from 7.3 to 7.8 show that, the deviation between M.R Vs. PC. In the same sequence Fig. 7.3 is the deviation between readings of all three phases of voltage V1, V2 & V3 of MR and PC respectively. It is clearly seen that deviation between all two readings is almost negligible.

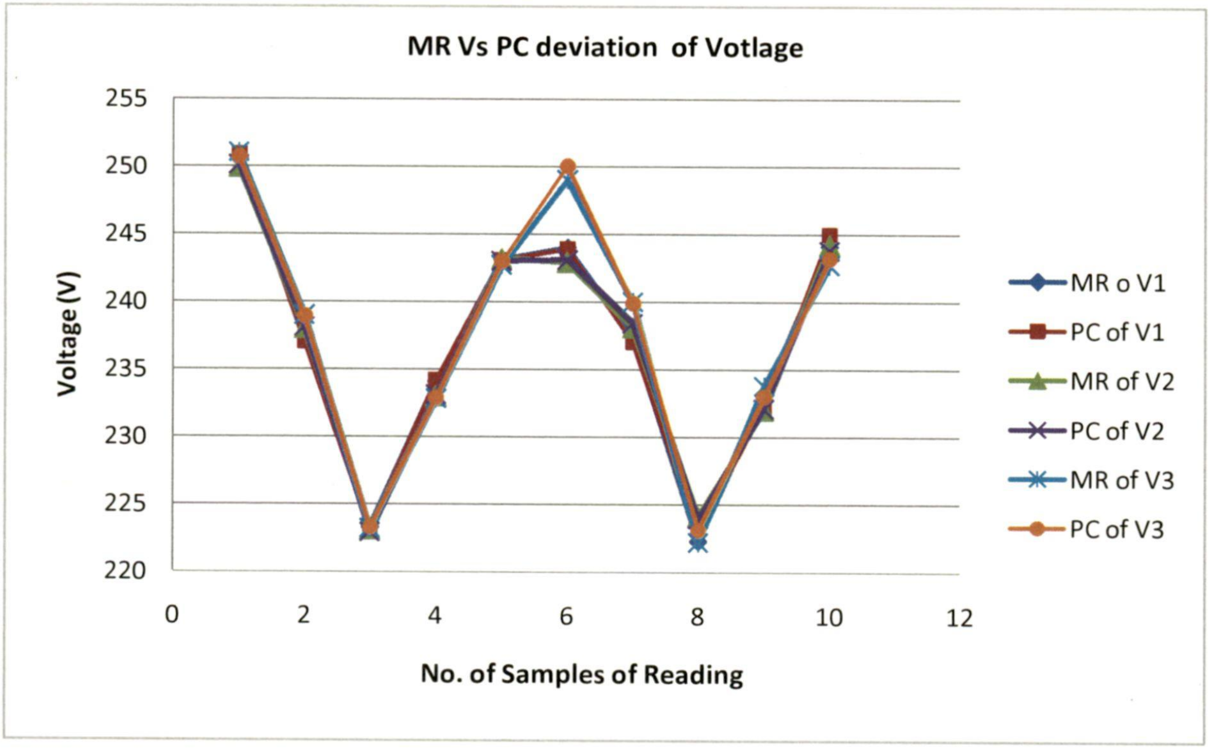


Fig. 7.3 Deviation of Voltage phases reading between MR & PC

Similarly, Fig.7.4 is the deviation between readings of Current phase I1, I2 & I3 of M.R and PC has hardly deviation among six lines.

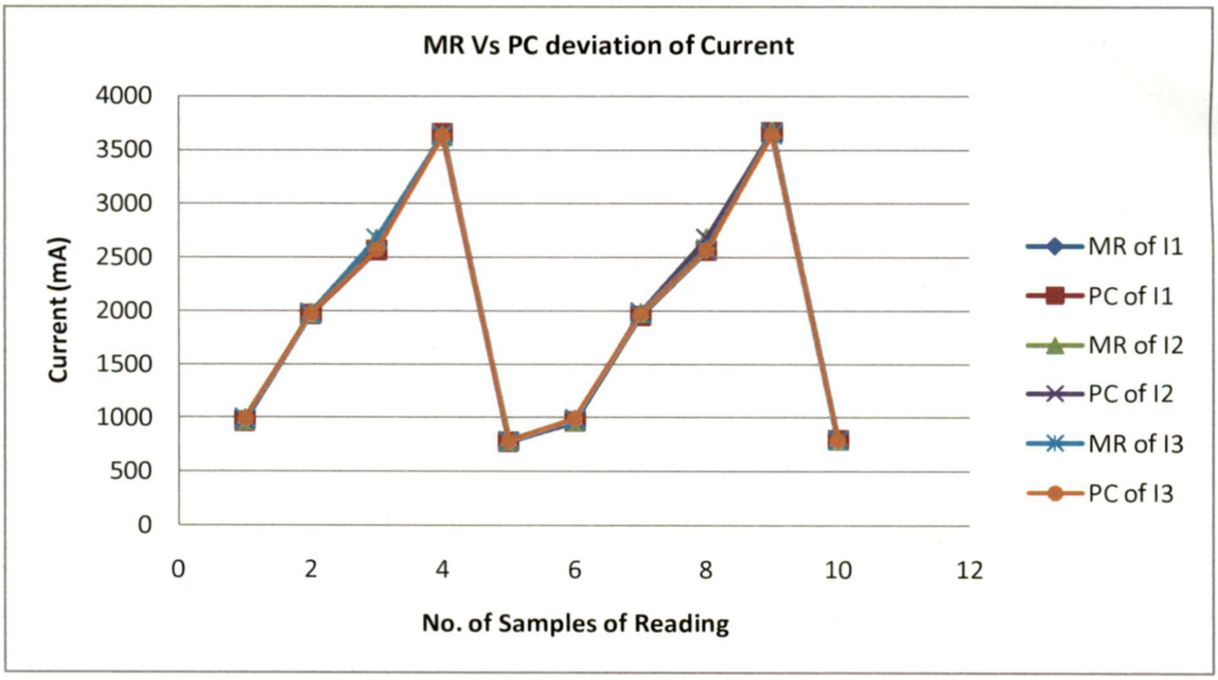


Fig. 7.4 Deviation of Current phases reading between MR & PC

In the same line, Fig.7.5 is the deviation between readings of kW,kVA & kVAr of M.R and PC has hardly find deviation among six lines.

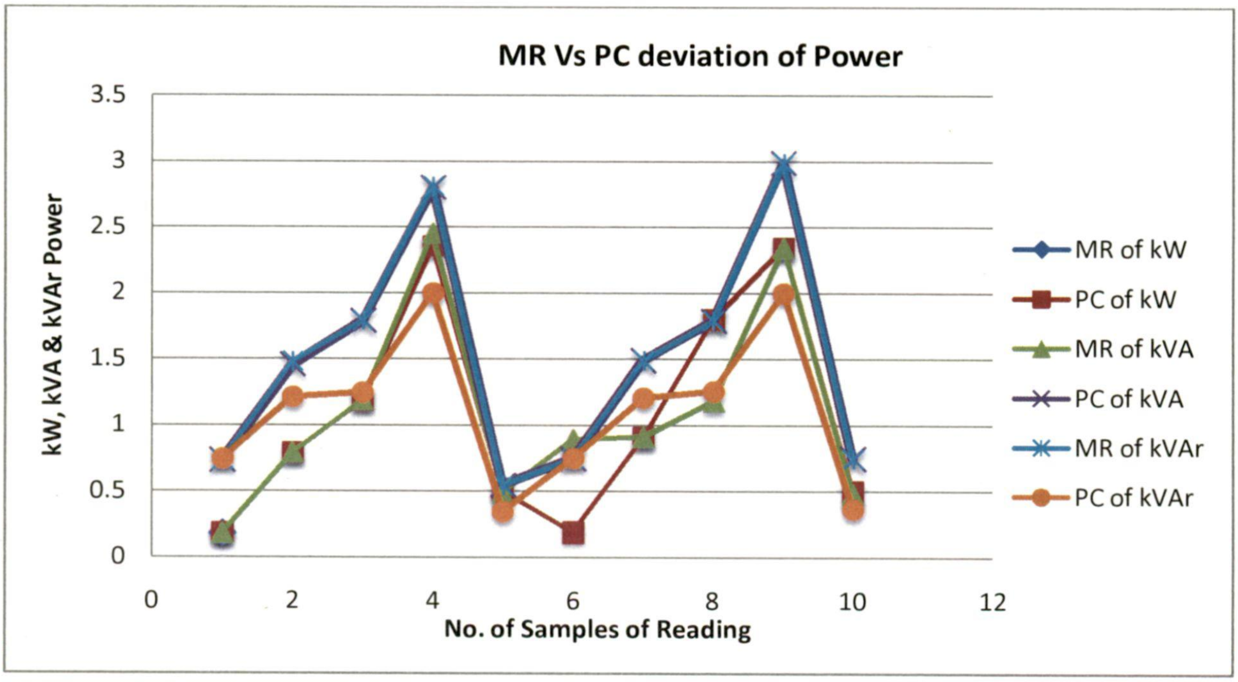


Fig. 7.5 Deviation of Power (kW. kVA &kVAr) reading between MR & PC

Similarly, Fig.7.6 is the deviation between readings of pf & Frequency of M.R and PC has hardly deviated from true values..

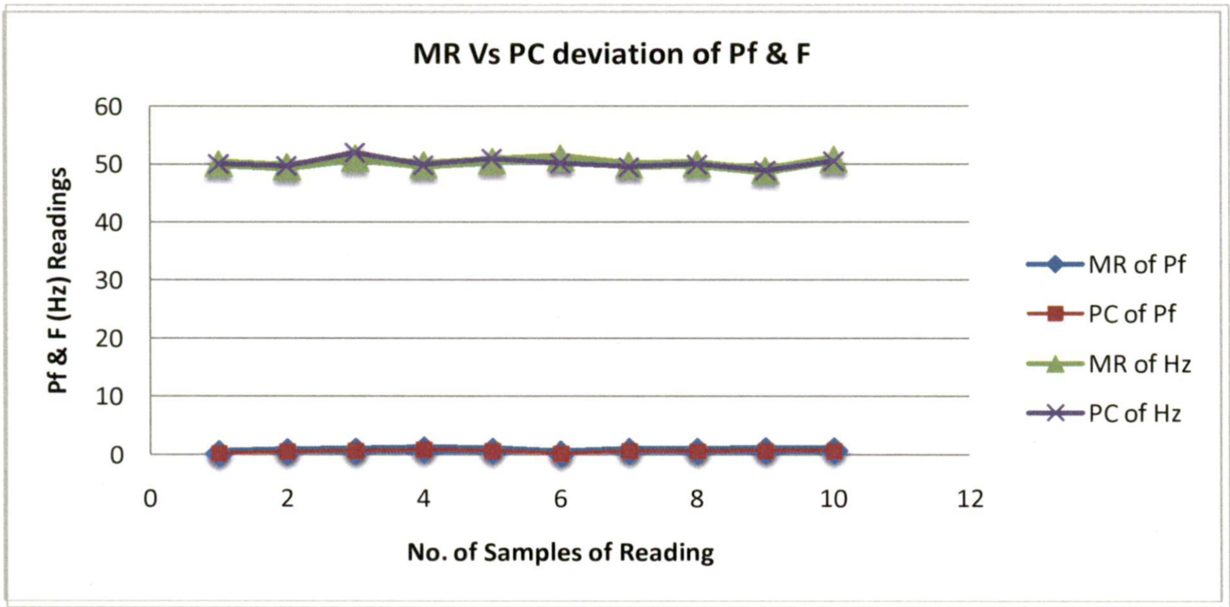


Fig. 7.6 Deviation of Power Factor & Frequency reading between MR & PC

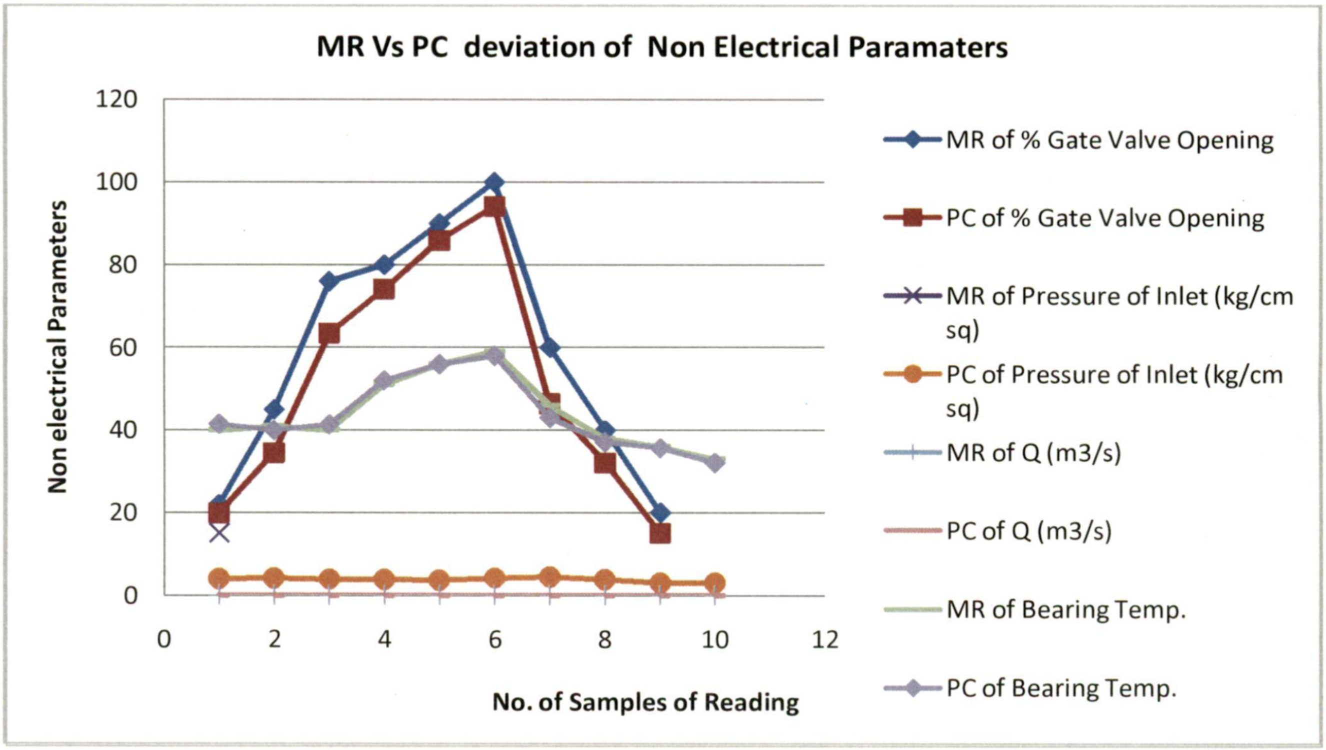


Fig. 7.7 Deviation of Non electrical Parameters (Q, Pressure, % Gate Valve Opening & Bearing Temp.) reading between MR & PC

Similarly, the deviation in Non-electrical parameters such as Discharge, Pressure of inlet valve,% of Gate valve opening, Bearing Temperature and Speed are shown in Fig. 7.7 and 7.8 respectively.

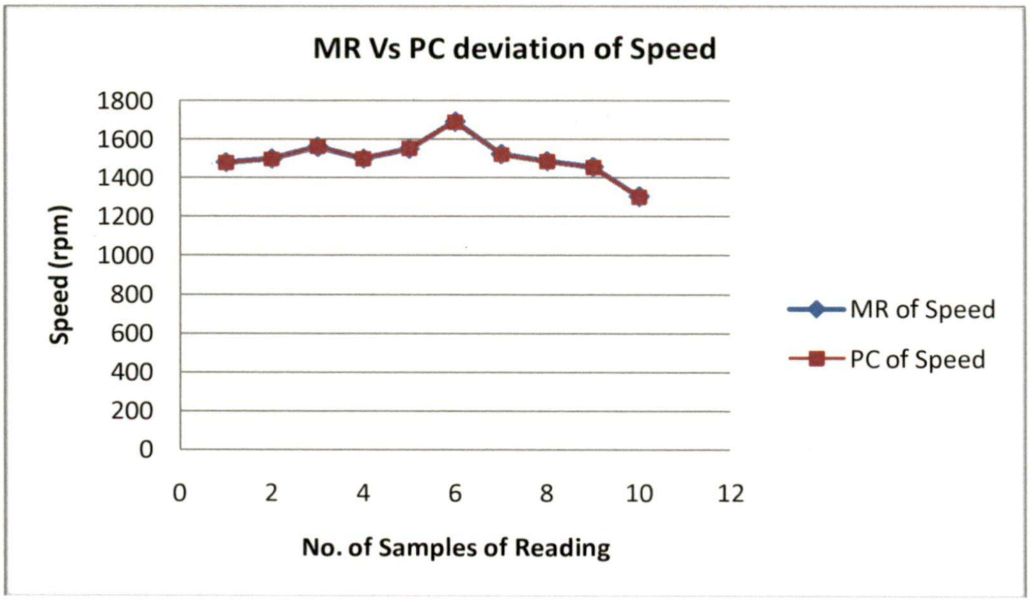


Fig. 7.8 Deviation of Non electrical Parameters (Speed) reading between MR & PC

7.3.3 Analyzing Parameters

All parameters are double verified by instrument it selves and panel readings. Computer program gives certain difference in secondary parameters only, or the instrument which is not working properly. As far as efficiency is concerned, firstly kilowatt output should be noted as well as actual power generated by the formula equation (1), and efficiency of that Hydropower demonstration unit is given by equation (2).

$$P=9.81QH \quad (1)$$

$$\text{Efficiency } (\eta) = \text{kilowatt} / (9.81QH) \quad (2)$$

Where

Q = Discharge (m^3/sec)

H = (10000/density of water = appx. 10)*pressure

Reading of this program HTGU's VI shown in the Table7.3.

Table 7.3 Table for Efficiency Evaluation of HTGU Demonstration unit

S.No	Discharge Q (m3/sec)	Pressure (kg/cm^2)	Head H (m)	$P_{i/p}$=9.81QH (kW) turbine	$P_{o/p}$ (kW)	η (%)
1	0.0195	3.40	34	6.504	0.200	3.075
2	0.0198	3.51	35	6.817	0.393	5.764
3	0.020	3.59	36	7.043	0.610	8.660
4	0.0215	3.66	37	7.723	0.801	10.370
5	0.0219	3.71	37	7.970	0.980	12.295
6	0.0220	3.74	37	8.071	1.200	14.866
7	0.0224	3.80	38	8.350	1.400	16.765
8	0.0229	3.92	39	8.821	1.556	17.638
9	0.0230	3.97	40	8.957	1.602	17.884
10	0.0232	4.14	41	9.422	1.690	17.936

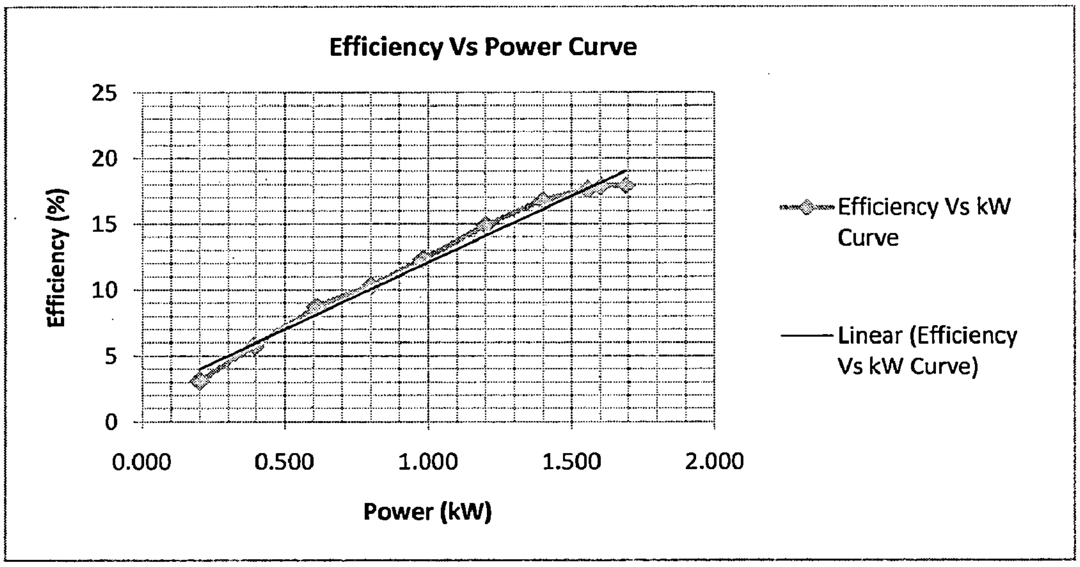


Fig. 7.9 Efficiency vs. power plot

The graph plot of Power Vs Efficiency is shown Fig. 7.9. Here efficiency is very low for this hydro turbine demonstration unit, because it is an impeller pump acts as pump as turbine.

Discharge of the pump is very less compared to full capacity of discharge. Also there is problem of servicing as well as oiling regularly. The calculated maximum efficiency is 17.93%.

7.3.4 Percentage Error in Measurement of MR and PC Values

Here we are measured total of sixteen parameters i.e. V_1,V_2,V_3,I_1,I_2,I_3, kW, kVA, kVAr, pf, f,% of gate valve opening, Pressure, Discharge, RPM, Temperature of bearing.

The percentage of error is shown in the Table 7.4 and in the Fig.7.10. Basically deviation between real values means deference between MR and PC readings, so;

Deviation form real value $= (MR \sim PC)$

% of error $= \dfrac{(MR \sim PC)}{MR} x100\ \%$

Table 7.4 Percentage of error of all parameters

SL No.	Parameters Name	Deviation form real value	% of error
1	V_1	0.16	0.042
2	V_2	0.31	0.052
3	V_3	1.06	0.13
4	I_1	32	0.53
5	I_2	87	1.27
6	I_3	28	0.406
7	kW	0.080	1.6
8	kVA	0.001	0.02
9	kVAr	0.108	10.8
10	pf	0.0101	0.86
11	f	0.01	0.01
12	% of gate valve	50.21	10.1
13	Pressure	0.01	0.042
14	Discharge	0.0002	0.18
15	rpm	8	0.01
16	Bearing Temp.	2.1	0.84

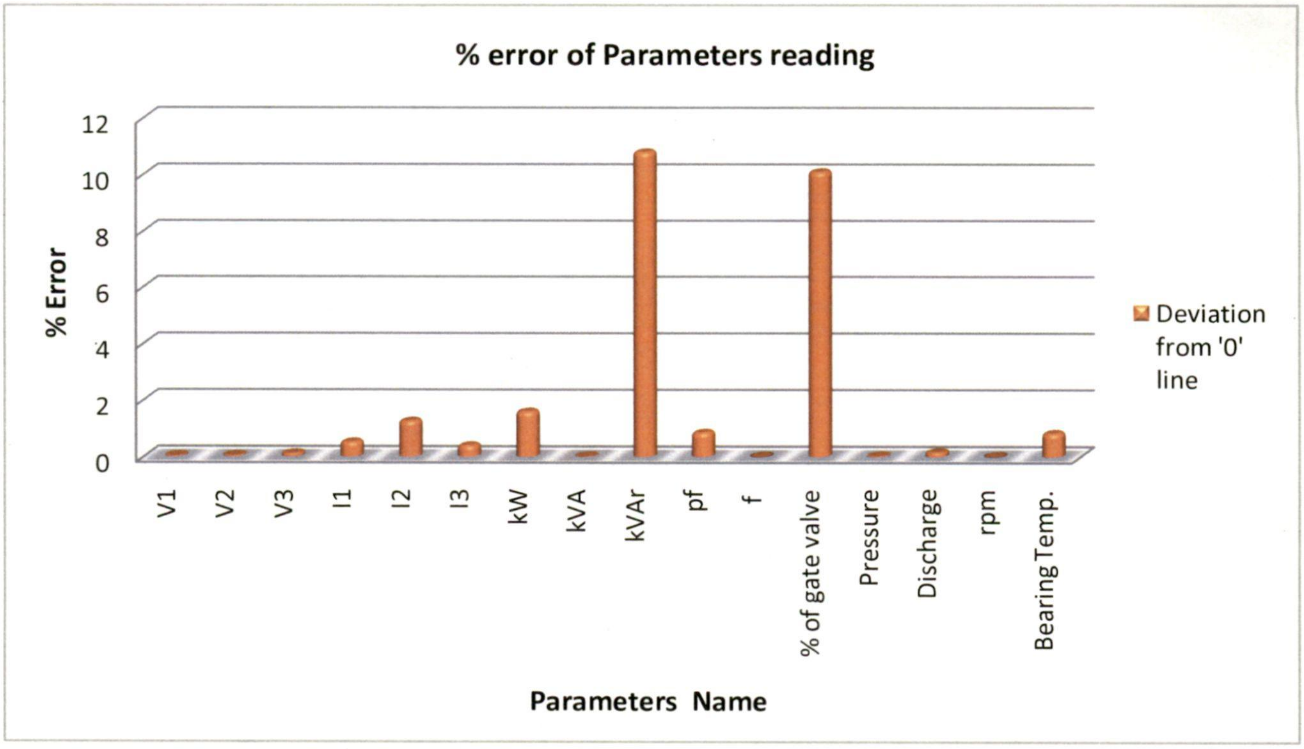


Fig. 7.10 Percentage of error deviation from zero line of all parameters

Above Fig.7.10 shows that kVAr point on horizontal axis has maximum deviation because of it is secondary parameter, made from one or more primary parameters as well as not calculated by vector multiplications. Then % of Gate valve opening point i.e. potentiometer output was not correct, only close or shut down position it is working, other gives always default value.

CHAPTER-8

CONCLUSION, LIMITATIONS AND FUTURE WORK

8.1 CONCLUSION

An Integrated Data Acquisition System is developed using latest Data Acquisition modules NI USB 6212 and LabVIEW 8.6 real time professional software, which integrate all the sensor/transducers and measuring instruments. The experimentation performed on the HTGU comprises the measurement of sixteen Electrical & Non-electrical parameters in real time with a very small deviation and error from true value of them.

The IDAS provide the direct monitoring of all parameters PC/Laptop with easy-to-use graphical user interface front in LabVIEW and also show the real time characteristics. The parameters are:

(a). Non electrical parameters such as of Speed of HTGU, Discharge, Inlet head, Temperature of bearings and % Gate valve opening.

(b). Electrical parameters such as Voltages, Current of all the three phases as well as all other parameters such as Power in kW, kVA, kVAr, frequency, and power factor.

Calibration of all the above parameters and analyzing the parameters for performance of HTGU has also done in the dissertation work.

This IDAS also helps to monitor all parameters of Small Hydropower Station which are generally remotely located, in a single window on PC. The proposed architecture permits the rapid system development and has the advantage of flexibility in the case of changes, while it can be easily extended as per the requirement.

8.2 LIMITATIONS

As mentioned above the IDAS is useful for SHPs monitoring but it has some own limitations. Only basis of this IDAS is that it tested on HTGU in Hydro mechanical Lab. AHEC IIT Roorkee. In this regard this IDAS has certain limitations:

(a). To apply outside SHP stations multiplying factor should be changed of respective variables o instruments. So knowledge of LabVIEW is required.

(b). The voltage range of module channel should be matched near input value or we can change multiply factor in the program; otherwise the LabVIEW program so error in results.

(c). The IDAS is tested only for SHPs for Large hydro and other application it need to require the change of sensor/transducer's range and input voltage range of instruments input.

(d). The IDAS use the USB DAQ device which have their own input and output channel limitations.

(e). For more no. of input the DAQ device must have to change which also require the changes in software block diagram.

(f). Keep try to minimize the wires and leads attenuation.

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

8.3 FUTURE WORKS

The work can be further extended by:

(a). This may be also led to help in monitoring the SHPs remotely/wirelessly by using Web Publishing Tool of LabVIEW with no hardware modification and can also be access anywhere, where the internet facility is avail.

(b). The IDAS can also be use to evaluation the efficiency directly from the LabVIEW software by making some Block diagram modifications.

(c). Making a provision for torque measurement so that the efficiency of the turbine alone can also be calculated direct.

(d). It is also possible we can controlled this from a remote PC embedded mode of LabVIEW with LabVIEW Run-time Engine is required on client PC.

(e). Remote online or Wireless automation is also possible by the help of this LabVIEW few more programming blocks, with LabVIEW Run-Time Engine. This will help to monitor the SHP from a remote location using PC/ PDA/ mobile phone etc.

(f). This IDAS can also be extended in future for the I/O control of SHPs by some necessary modification in hardware.

(g). The IDAS can be made more reliable, faster and error free by using future Automatic IDAS.

(h). Wireless is one of the most promising technologies for data acquisition. For high-speed continuous transmission, IEEE 802.11 (Wi-Fi) has seen incredible adoption in mobile computing applications. The IDAS can be extended using these technologies.

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PUBLICATIONS

1. Full length paper has been presented in International Conference on ADVANCES IN RENEWABLE ENERGY, ICARE-2010 held in MANIT Bhopal organized by Mechanical Engineering Department on June 24-26, 2010 entitled ***"Development of an Integrated Data Acquisition system for Pump As Turbine generator unit".***
2. Full length paper has been sent and accepted in International Conference on ***Electrical Power and Energy Systems*** going to be held in MANIT Bhopal organized by Electrical Engineering Department on Sep. 2010,entitled ***"Remote Data Acquisition System for Hydro Turbine Generator Unit for SHP".***
3. Extended Abstract has been sent and accepted in 8^{th} International Conference on Hydraulic Efficiency Measurement, IGHEM-2010, going to be held in IIT Roorkee organized by Alternate Hydro Energy Centre on Oct.2010,entitled ***"Development of LabVIEW Based Integrated Data Acquisition System for Pump As Turbine Generator Unit Performance Evaluation".***

A. ACRONYMS USED

Table A. Represent the acronyms used in dissertation

ACRONYMS AT A GLANCE

A
A/D Analog-to-digital.
ADC Analog-to-digital converter.
ADC Resolution The resolution of the ADC,
AI Analog input.
AIGND The analog input ground pin on a DAQ device.
AO Analog output.

B
b Bit
B Byte
bps Bits per second

C
CMRR Common-mode rejection ratio
CPU Central processing unit

D
D/A Digital-to-analog.
DAC Digital-to-analog converter.
DIFF Differential
DIO Devices Refers to all devices with the letters DIO in their name, unless otherwise noted.
DLL Dynamic Link Library.
DMA Direct Memory Access.
DSP Digital Signal Processing
DAQ Data acquisition
DAS Data acquisition system
dB Decibel
DCE Data communications equipment
DCOM Distributed Component Object Model
DCS Distributed control system
DDE Dynamic Data Exchange
DIO Digital input/output
DLL Dynamic Link Library
DMA Direct memory access

F
FIFO A first-in-first-out memory buffer.

G
GPIB General Purpose Interface Bus
GUI Graphical user interface

H
hex Hexadecimal.
Hz Hertz
HMI Human-machine interface

I
IEEE Institute of Electrical and Electronic Engineers.
I/O Input/output.
ISA Industry Standard Architecture.

K
Kwords 1,024 words of memory.

L
L Inductance
LED Light emitting diode
LabVIEW Laboratory Virtual Instrument Engineering Workbench.
LSB Least Significant Bit.

M
MB Megabytes of memory. 1 MB is equal to 1,024 KB.
MAC Media access control
MUX Multiplexer

DSP Digital signal processing
DTE Data terminal equipment

E
EEPROM Electrically erased programmable read-only
EPROM Erasable programmable ROM memory

R
RMS Root Mean Square.
RSE Referenced Single-Ended.
RTD Resistance Temperature Detector.
RTSI Real-Time System Integration bus.
RFI radio frequency interference
ROM read-only memory

S
SCADA supervisory control and data acquisition
SE single-ended
S/H sample-and-hold
SNR signal-to-noise ratio
SPC statistical process control
SQL Structured Query Language
SS simultaneous sampling
STP shielded twisted pair
SCXI Signal Conditioning eXtensions for Instrumentation
STC System Timing Controller.

N
NB NuBus.
NI-DAQ The NI-DAQ configuration utility on the Macintosh.
NRSE Non-referenced single-ended

P
PGIA Programmable Gain Instrumentation Amplifier
PC Personal computer
PCI Peripheral Component Interconnect
PCMCIA Personal Computer Memory Card International
PID Proportional-integral-derivative
PLC Programmable logic controller

T
TCP/IP Transmission Control Protocol/Internet Protocol
TTL Transistor-to-transistor logic
TC Terminal count

U
UTP unshielded twisted pair

V
V Volts.
VDC Volts, Direct Current.
VI Virtual Instrument.
Vref Voltage reference.

B. NI USB-6212 DAQ CARD SCREW TERMINAL PINOUT DIAGRAMS

Fig. A. represents the screw pinout diagram of NI USB 6212 of both sides.

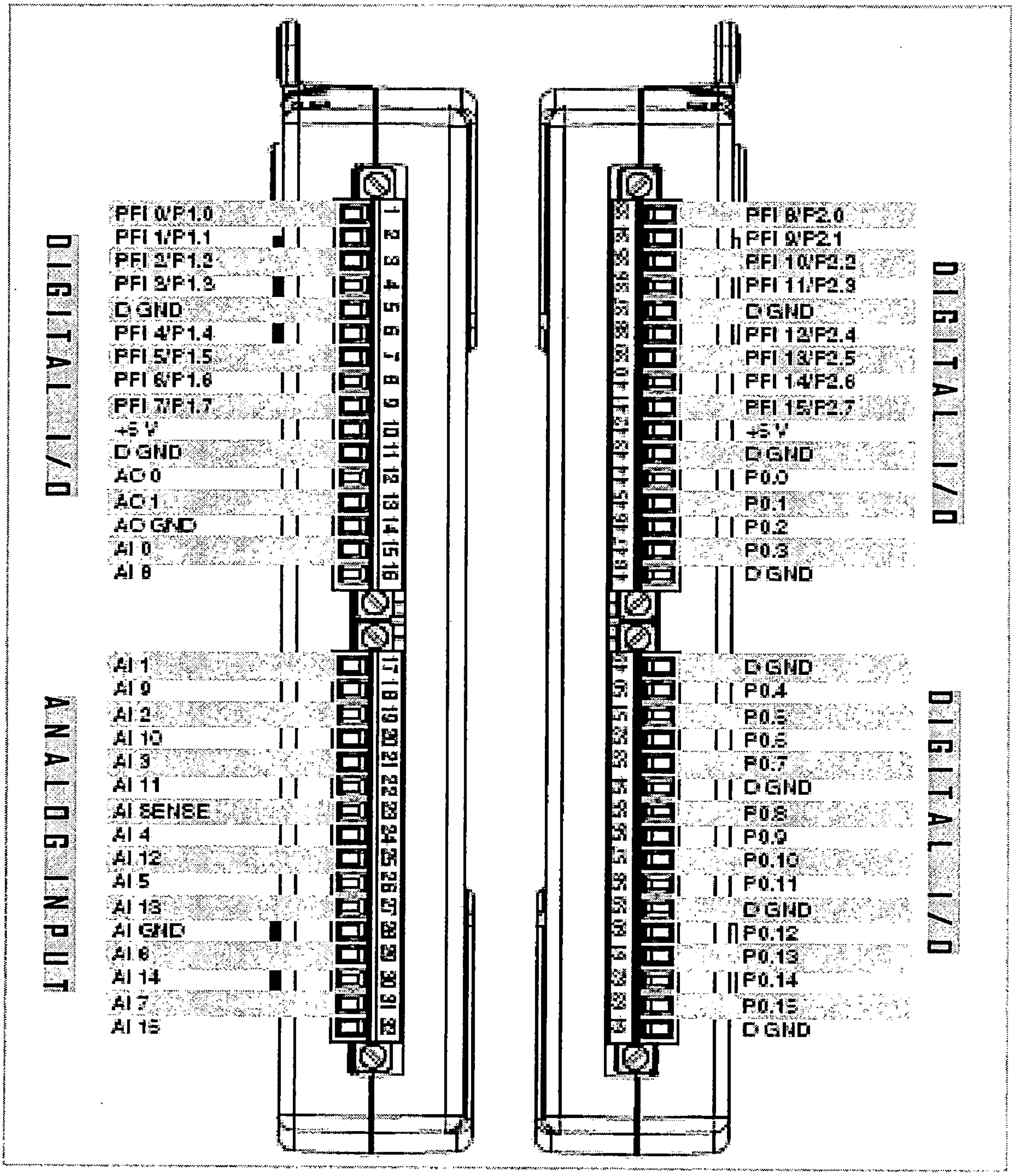

Fig. A The Screw Terminal Pinout Diagram Of NI USB 6212 of Both Sides

C. NI USB 6212 I/O CONNECTOR SIGNAL DESCRIPTIONS

The Table B given below describes the signals found on the I/O connectors. Not all signals are available on all devices.

Table B The I/O connectors of NI USB 6212

Signal Name	Reference	Direction	Description
AI GND	—	—	**Analog Input Ground**—These terminals are the reference point for single-ended AI measurements in RSE mode and the bias current return point for differential measurements. All three ground references—AI GND, AO GND, and D GND—are connected on the device.
AI <0..31>	Varies	Input	**Analog Input Channels 0 to 31**—For single-ended measurements, each signal is an analog input voltage channel. In RSE mode, AI GND is the reference for these signals. In NRSE mode, the reference for each AI <0..31> signal is AI SENSE. For differential measurements, AI 0 and AI 8 are the positive and negative inputs of differential analog input channel 0. Similarly, the following signal pairs also form differential input channels: <AI 1, AI 9>, <AI 2, AI 10>, <AI 3, AI 11>, <AI 4, AI 12>, <AI 5, AI 13>, <AI 6, AI 14>, <AI 7, AI 15>, <AI 16, AI 24>, <AI 17, AI 25>, <AI 18, AI 26>, <AI 19, AI 27>, <AI 20, AI 28>, <AI 21, AI 29>, <AI 22, AI 30>, <AI 23, AI 31>
AI SENSE	—	Input	**Analog Input Sense**—In NRSE mode, the reference for each AI <0..31> signal is AI SENSE.
AO <0..1>	AO GND	Output	**Analog Output Channels 0 to 1**—These terminals supply the voltage output of AO channels 0 to 1.
AO GND	—	—	**Analog Output Ground**—AO GND is the reference for AO <0..1>. All three ground references—AI GND, AO GND, and D GND—are connected on the device.
D GND	—	—	**Digital Ground**—D GND supplies the reference for PFI <0..15>/P0/P1 and +5 V. All three ground references—AI GND, AO GND, and D GND—are connected on the device.
+5 V	D GND	Input or Output	**+5 V Power**—These terminals provide a +5 V power source or can be used to externally power the digital outputs.
PFI <0..3>, PFI <8..11>/P0.<0..7>	D GND	Input	**(USB-6210/6211/6215/6218 Devices) Programmable Function Interface or Static Digital Input Channels 0 to 7**—Each PFI terminal can be used to supply an external source for AI, AO, or counter/timer inputs. You also can use these terminals as static digital input lines.
PFI <4..7>, PFI <12..15>/P1.<0..7>	D GND	Output	**(USB-6210/6211/6215/6218 Devices) Programmable Function Interface or Static Digital Output Channels 0 to 7**—You can route many different internal AI, AO, or counter/timer outputs to each PFI terminal. You also can use these terminals as static digital output lines.
P0.<0..15>*	D GND	Input or Output	**(USB-6212/6216 Devices) Port 0 Digital I/O Channels 0 to 15**—You can individually configure each signal as an input or output.

PFI <0..7>/P1.<0..7>, PFI <8..15>/P2.<0..7>	D GND	Input or Output	**(USB-6212/6216 Devices) Programmable Function Interface or Digital I/O Channels 0 to 15**—Each of these terminals can be individually configured as a PFI terminal or a digital I/O terminal. As a PFI input, each terminal can be used to supply an external source for AI, AO, DI, and DO timing signals or counter/timer inputs. As a PFI output, you can route many different internal AI, AO, DI, or DO timing signals to each PFI terminal. You also can route the counter/timer outputs to each PFI terminal. As a Port 1 or Port 2 digital I/O signal, you can individually configure each signal as an input or output.
USER	—	—	**(USB-621x BNC Devices) User-Defined Channel**—The USER BNC connector allows you to use a BNC connector for a digital or timing I/O signal of your choice. The USER BNC connector is internally routed to the USER screw terminal. Refer to the appropriate *USER* section for your USB-621x BNC device in Appendix A, *Device-Specific Information*, for more information about the USER signal.
NC	—	—	No connect—Do not connect signals to these terminals.

* USB-6212/6216 BNC/Mass Termination devices have eight digital I/O lines, P0.<0..7>.

D. FORMULAE MANUAL SUPPLIED BY THE MANUFACTURERS

Table C is supplied by the manufacturer to calculate the power. Other non electrical parameters such as discharge, percent of gate valve opening, temperature of bearings, pressure of inlet valve also have different desired transducer output. Outputs are volt, mV, and mA in ranges.

Table C Formulae supplied by the instrument manufacturer for Power Calculation

Mode	1Φ2W	1Φ3W	3Φ3W-2	3Φ3W-3	3Φ4W
Voltage	V1	V1 V2	V1 V2	V1 V2 V3 $*V[\frac{V1+V2+V3}{3}]$	v1 v2 v3 $*v[\frac{v1+v2+v3}{3}]$
Current	A1	A1 A2	A1 A2	A1 A2 A3 $*A[\frac{A1+A2+A3}{3}]$	a1 a2 a3 $*a[\frac{a1+a2+a3}{3}]$
Effective Power	**V1.A1**	**V1.A1 +V2.A 2**	**V1.A1+ V2.A2**	**v1.A1+v2.A2+v3.A3**	**v1.A1+v2.a2+v3.a3**
Apparent Power	V1.A1	V1.A1 +V2.A 2	$\frac{\sqrt{3}}{2}$ (V1.A1+ V2.A2)	$\frac{\sqrt{3}}{3}$ (V1.A1+V2.A2+V3. A3)	v1.a1+v2.a2+v3.a3
Reactive Power	$\sqrt{(VA^2 - W^2)}$				
Power Factor	$\frac{W}{VA}$				

NOTE: *Bold letters i.e.* ***V1.A1+V2.A2+V3.A3*** *are used to indicate vector notations i.e. "V; Line voltage, v; phase voltage, A; line current,* ***V, A, v, a****; vector values, *V,*v, *A; average values"*