

## **DEVELOPMENT OF LABVIEW BASED INTEGRATED DATA ACQUISITION SYSTEM FOR PUMP AS TURBINE GENERATOR UNIT PERFORMANCE EVALUATION**

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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 paper, the development of a computer based data acquisition system for monitoring parameters and performance of Pump As Turbine (PAT) generator unit is presented. The proposed system consists of a set of transducers for measuring both non-electrical (e.g. turbine head, discharge, power, speed, efficiency 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 pump as turbine is an attractive and significant alternative in the range of small hydro. Pumps are relatively simple machines with no special designing and are readily available in most developing countries. Besides, their installation, commissioning & maintenance are easy and cheap.

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 PAT 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.

**Keywords:** PAT; Renewable Energy System; Data- acquisition system; Transducers; Internet; LabVIEW.

### **1. INTRODUCTION**

Small hydro power stations is one of the renewable energy source, which grown from the past rapidly and used to electrify isolated and remotely distributed rural communities like in India. To electrify these areas, mini/micro/pico hydro is one of the best conventional RESs; but the installation cost and development of such kind of plants using conventional turbine-generator units seems not quite logical. In context to above, application of PAT is a feasible option. Pumps are readily available in various sizes. Past studies found many applications of PAT in mini/micro/pico hydro in most developing countries. The overall cost of such plants is very low as compared to other plants [1, 2 &3].

With the rapid developments of internet and computer technologies, accessing and operating of real time applications is becoming reality. 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 [4&5].

This paper is set out as follows; the second section of paper is emphasis on the PAT background. The third section acquaints the readers with the PAT generator unit experimental setup. Fourth section

familiar with data collection and interfacing process. Section five focuses on data representation in LabVIEW. Sixth section shows the experimental results and discussion. The last section summarizes the conclusion of the paper.

## 2. PUMP AS TURBINE

In many developing countries, the micro hydropower stations are in demand, specially in remote locations. In the range of micro hydro standard size of turbine are not easily and economically available. So we need same machine for each site but pumps are available in no. of size, covering different range of head, discharge and capacity. Clearly, says pump is a suitable option for meeting the demand in micro hydro if running in reverse mode. Except the micro hydro nowadays, applications of PAT have been developed in villages, farms, irrigation systems, as pressure dropping valves and as small pump storage power stations [6&7].

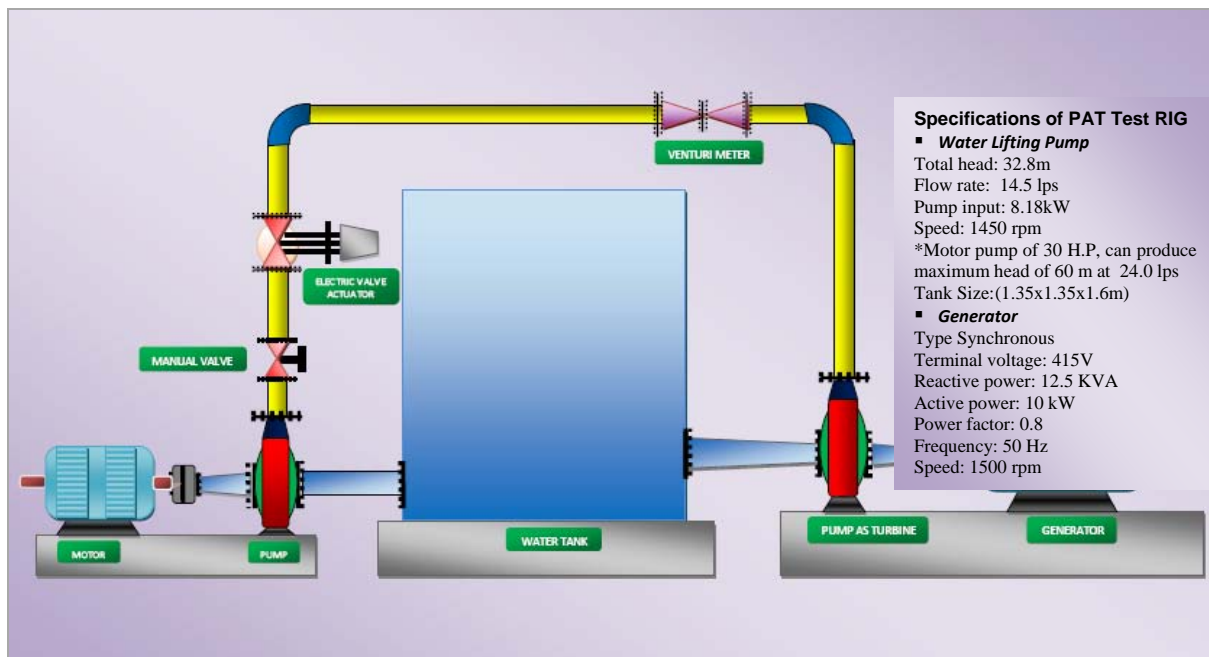


Fig. 3(a) Schematic of Test Rig (Hydro mechanical laboratory at AHEC IIT Roorkee)

Small centrifugal pumps are suitable for use as hydraulic turbines and have the advantage of being mass produced in many countries throughout the world. When used with an integral induction motor, they can be installed as a combined turbine and generator unit. Pumps are mass-produced, and as a result, have the following advantages for micro-hydro power compared with purpose-made turbines.

- i. Integral pump and motor can be used as a turbine and generator set
- ii. Available for a wide range of heads and flows
- iii. Available in a large number of standard sizes
- iv. Short delivery time
- v. Spare parts such as seals and bearings are easily available
- vi. Easy installation - uses standard pipe fittings

The main disadvantage of using a pump as turbine is the difficulty of finding the turbine characteristics that are needed to select the correct pump for a particular site [8]. It is also possible to plot the performance curve for PAT which assists in PAT operation and selection.

## 3. PAT GENERATOR TEST SETUP

A complete test rig of a PAT generator (directly coupled) is installed in Alternate Hydro Energy Centre (AHEC),

Indian Institute of Technology, Roorkee as shown in Fig. 3 (a). It consists of a metallic open tank, a constant speed pump motor set, a flow meter, two flow regulating valves (one motorsied control valve) and a turbine (pump) generator set. The pump draws water from the open tank and supplies to the turbine.

The turbine discharges into the same tank through draft tube. The generator is coupled to the turbine by means of shaft arrangement. The generator output terminal connected to the load, and it also connected to the control panel.

### 3.1 Parameter Measuring

The proposed data acquisition system under consideration used to measure the following two types of parameters namely:

- (i) **Non-electrical Parameters**
  - Discharge
  - Speed of pump and Generators
  - Temperature of bearings
  - Pressure measurement inlet and outlet of pump
  - Percentage of gate valve opening
  - Efficiency of the PAT
- (ii) **Electrical Parameters**
  - Voltage output of generator of three phases in r.m.s.
  - Current of generator in three phases
  - kW, kVA, kVAR power of generator
  - Power factor and frequency of generator

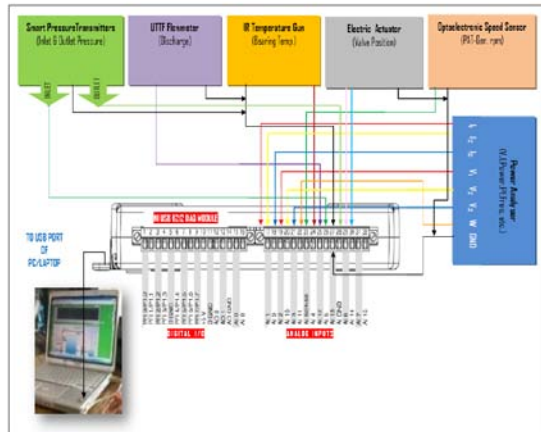
### 3.2 The Transducers/sensors and

#### Interface Circuits

Above mentioned parameter required the various type of transducers/sensors which convert the primary non electrical quantities into electrical which can be use for further processing to interface circuit. The transducers/sensors are:

- (i) **Ultrasonic Transit Time Flow (UTTf) meter (Model PT878)**  
Transducer gives output 0-10 V and 4-20 mA, for minimum to maximum discharge for each particular set [9 &10].
- (ii) **Temperature measurement (Omega Made, Model OS530E/OS520E)**  
Using non contact infrared temperature thermometer are used for bearing temperature measurement [11].
- (iii) **Speed measurement**  
(TIMIC Made, MOC 7811/TCST2103)  
A slotted disc of sixty teeth with 21 cm diameter and MOC7811 optical sensor are used. Give analog output of 0-5/20mA [12].
- (iv) **Power Analyser (HIOKI Made, Model 3165)**  
One power analyzer sensor having eight analog outputs all of them have 2 V/ full scale [13].
- (v) **Motorised Control Valve (AVCON Made, Model MV5512A/B)**  
A electrically controlled gate valve is monitored. Output ranges 4-20 mA for closed to full open valve position [14].
- (vi) **Pressure Transmitter (SMAR made, Model LD301)**  
Two Absolute LD301model pressure transmitters are used to measure the inlet and outlet pressure of turbine in kg/cm<sup>2</sup>. Which give the necessary head. The output of the transmitter is in 0-20mA [15].

The interfacing circuit and position of all transducers/sensors shown in Fig. 3(b). All these modules are connected to the PC by means of National Instruments (NI) USB 6212 data acquisition module.



**Fig. 3(b) Block diagram of interfacing circuit and position of various transducer/sensors**

Fig.3(c) show the actual pictures of the of Experimental test setup comprising various above mentioned equipments.



**Fig. 3(c) Experimental setup**



**Fig. 3(d) Actual experimental test setup**

#### 4. DATA COLLECTION AND PROCESSING INTERFACE

As in Fig. 3(b) the data received by instruments (sensors) is to be transferred to NI USB-6212. The NI USB-6212, M Series is a low-cost multifunction DAQ board optimized for cost-sensitive applications, all the data is communicated to this specific DAQ module through 16 analog input channels as shown in Fig. 3(b) & 4. The NI USB-6212 series is a family of network data acquisition providing analog I/O, digital I/O (input/output), timer/counter and other functions. Also consider the high-speed M Series devices for 5X faster sampling rates or the high-accuracy M Series devices for 4X resolution and superior measurement accuracy [16 & 17].



**Fig.4 NI USB 6212 module**

#### 4.1 Specification of NI USB 6212 [18]

Analog Input Channels	16
Sample Rate	400 kS/s
Max Voltage Range	-10V, 10V
Minimum Voltage Rang	-200mV, 200mV
Analog Output Channels	2
Max O/P Voltage	10 V
Digital I/O Bidirectional Channels	32
Counter/Timers	2
Resolution	16bit
Power Requirement	4.5-5.25V

(No external Power, in configured state via USB Port)

All transducers output connected to the analog input of NI 6212 card between A0-A15 (as shown in Fig.3(b)).The output of this card transferred to the PC by USB port. This can be read further by LabVIEW software.

#### 5. DATA REPRESENTATION

The data-acquisition card is controlled by a properly developed interface, using the LabVIEW software, running on the PC. It consists of two parts first is a graphical environment with components such as displays, buttons and charts in order to provide a convenient-to-use environment for the system operator called front panel, and second is the program code, which is in block-diagram format and consists of built-in virtual instruments (VIs) performing functions such as analog channel sampling, mathematical operations, file management etc.

The LabVIEW 8.6 software runs under the Windows 95/98/NT/2000 operating system or earlier than [19, & 20]. It contains Dials, Graphs etc. to display the parameters.

LabVIEW is programmed to sense change in parameters every second and according to that display on the screen. The screen contains block diagram for each parameter measurement, which can be seen, after stop the program, it shows the virtual form of cable connection and the values of data at each stage of transfer. The greater reliability of LabVIEW program is that it can be access through internet using its web publishing tool in tool menu. This tool allows modifying the look of the document in the web browser. Title, Header, and Footer text and the previewing the document in web browser, then click save to disk. This is saved to the .html file to the www directory. Name and save the file then click ok. This will bring up another window giving the URL name of the document for putting in the web browser. The sample code block diagram and the final user's monitoring screen developed in LabVIEW program is illustrated in Fig.5 (a&b), (c) respectively. The front panel in Fig.5(d) also show the real time discharge Vs time and Efficiency Vs Power output Characteristic.

#### 6. EXPERIMENTAL RESULTS & DISCUSSION

The PAT generator unit set monitored through LabVIEW software and manually. The numerical values of various parameters are given in the table 6 (a), (b) & (c). Table 6 (a & b) shows the Electrical parameter reading measured manually and using software on PC/laptop. Similarly, table 6(c & d) represent the Non-electrical parameters. The front panel also show the real time discharge Vs time and Efficiency Vs Power output Characteristic , which could easily help to evaluation of performance of PAT generator unit set.

The results clearly shows that the IDAS are give accurate and correct results. It is also show deviation in LabVIEW reading (PC Reading) and Meter Readings (M.R).

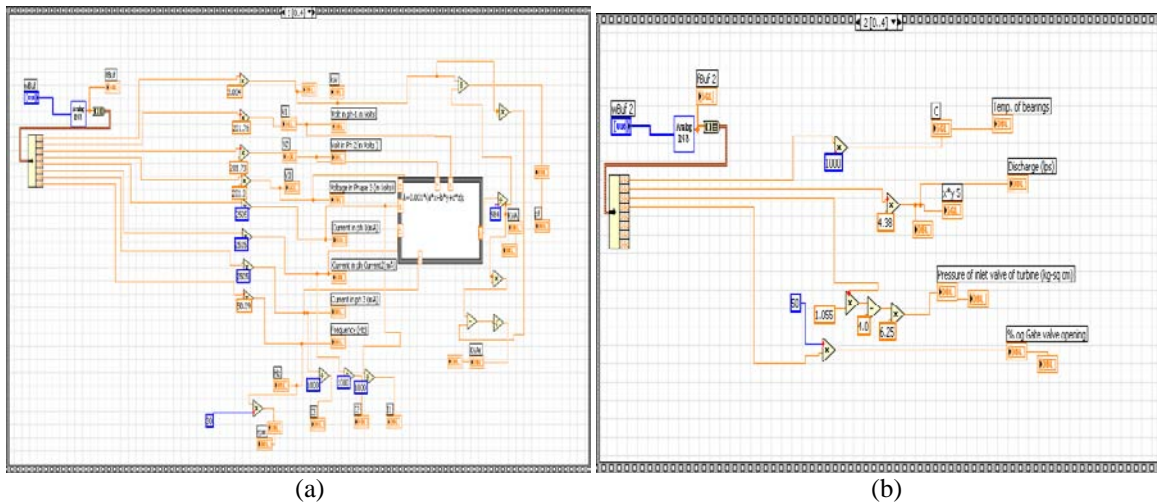


Fig. 5 Block diagram of LabVIEW program for monitoring Electrical & Non-electrical parameters of PAT generator unit respectively

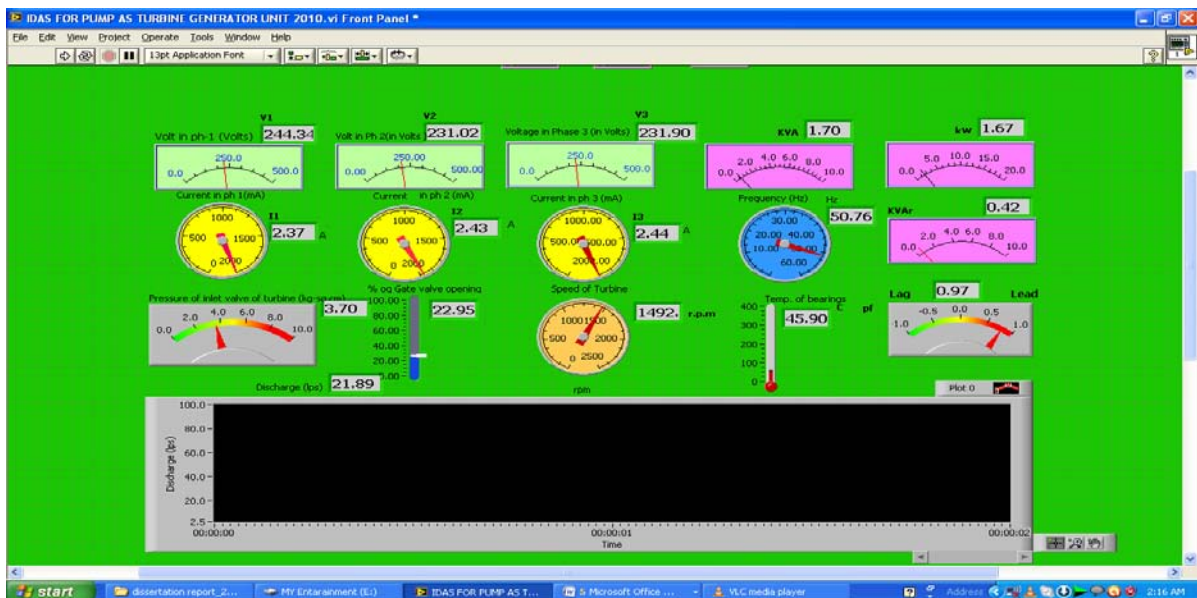


Fig. 5 (c) LabVIEW Front panel-I for monitoring of PAT generator unit parameters after running the unit with Discharge vs Time curve

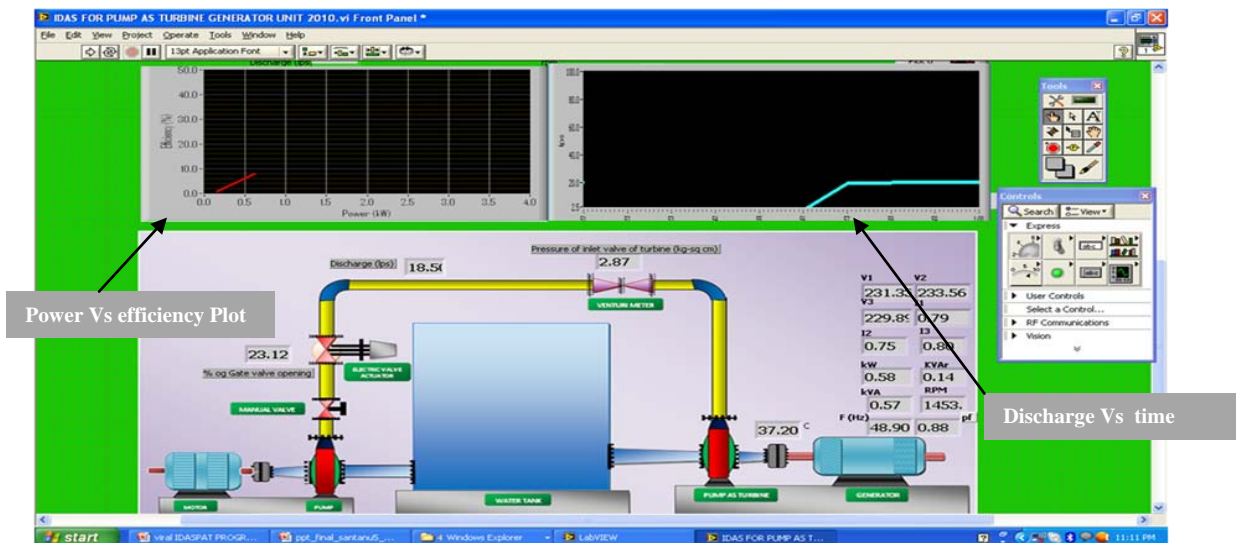


Fig. 5 (d) LabVIEW Front panel-II after few minute of starting the of PAT generator unit with Power vs Efficiency curve

**Table 6 (a) Electrical parameters monitored**

S. No.	V <sub>1</sub> Ph-1 (V)		V <sub>2</sub> Ph-2 (V)		V <sub>3</sub> Ph-3 (V)		I <sub>1</sub> Ph-1 (mA)		I <sub>2</sub> Ph-2 (mA)		I <sub>3</sub> Ph-3 (mA)	
	M.R*	P C *	M . R	P C	M . R	P C	M . R	P C	M.R	P C	M.R	P C
1	256.2	255.35	256.3	255.67	257.00	256.8	106	100	97	90	70	60
2	247.7	247.62	247.8	247.46	248.20	248.55	882	870	887	870	918	910
3	229.3	230.17	230.2	230.23	230.50	231.25	2379	2370	2412	240	2445	2440
4	225.2	225.53	225.2	225.51	224.34	225.34	2345	2340	3150	3100	3175	3170
5	237.0	237.83	238	237.92	238 .00	238.96	860	850	857	850	900	890

(M.R\*.-Meter Reading, P.C.-LabVIEW Reading)

**Table 6 (b) Electrical parameters monitored**

P <sub>output</sub> kW		kVA		kVAr		Pf		Hz	
M.R	PC	M.R	PC	M.R	PC	M.R	PC	M.R	PC
0.200	0.201	0.069	0.07	0.063	0.06	0.421	0.370	56.2	56.13
0.610	0.698	0.663	0.67	0.160	0.18	0.987	0.960	54.4	54.40
0.980	0.980	1.665	1.69	0.450	0.41	0.993	0.980	50.6	50.64
1.400	1.401	1.940	1.92	1.195	1.98	0.222	0.280	49.6	49.41
1.690	1.690	0.614	0.60	0.624	0.63	0.103	0.107	48.4	48.56

**Table 6 (c) Non-Electrical parameters monitored**

S.No.	Percent of gate valve opening (%)		Pressure of inlet valve (kg/cm <sup>2</sup> )		Discharge (Q, m <sup>3</sup> /sec)		*P <sub>Input</sub> = 9.81QH (kW)	Efficiency η (%)	R.P.M of turbine		Temperature of the bearings (°C)	
	Scale Reading	PC	M.R	PC	M.R	PC		PC	M.R	PC	M.R	PC
1	100	80.15	3.40	3.43	0.0195	0.0193	6.504	3.075	1683	1682	39	40.10
2	90	80.15	3.59	3.57	0.020	0.020	7.043	8.660	1634	1633	44	43.00
3	90	80.15	3.71	3.67	0.0219	0.0217	7.970	12.295	1523	1519	52	51.10
4	85	80.15	3.80	3.78	0.0224	0.0221	8.350	16.765	1491	1485	56	55.20
5	95	80.15	4.14	4.12	0.0232	0.0230	9.422	17.936	1567	1563	58	57.50

 (\*P<sub>Input</sub> & H is calculated by software for Efficiency evaluation which can be directly observe and represent in Power vs Efficiency curve on the Front panel of LabVIEW)

## 7. CONCLUSION

The development of a computer based IDAS for PAT generator set is analyzed in this paper. The proposed method is based on precision electronic circuits and an easy-to-use graphical environment, based on the LabVIEW program, for processing, displaying and storing the collected data. The system operator can easily process of the measured parameters and evaluate the performance (efficiency) of the system directly from the user front panel of LabVIEW in very short time. The system can be monitor remotely by using internet and web publishing tool of LabVIEW. It is helpful in monitor the PAT based small hydro power plants (mini/micro/pico); which is generally located at remote and isolate places. The IDAS can be extended in future for control the I/O remotely of PAT generator by some hardware modification.

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