IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 8, Issue 2, February 2020

IoT Based Coriolis Mass Flowmeter using LabVIEW

Kishore. S[1], Milan Patel. R[2], Mohamed Ashik. A[3], Venubalan. T[4] and M. Shanmugavalli[5]

Student, Department of Instrumentation and Control Engineering, Saranathan College of Engineering, Trichy, India[1-4]

Professor, Department of Instrumentation and Control Engineering, Saranathan College of Engineering, Trichy, India[5]

Abstract: Coriolis mass flowmeter measures the mass flow of the fluid, such as water, acid, chemicals and gas/vapor. This paper covers an experimental analysis on establishing Internet of Things (IoT) interface to the Coriolis Mass Flowmeter (CMF). National Instruments LabVIEW and Data Acquisition Hardware (myRIO-1900) have been used to provide sensing as well as a medium to connect with IoT platform.

Keywords: NI LabVIEW, PZT, myRIO-1900, IoT, IBM Watson Bluemix

I. INTRODUCTION

The Coriolis mass flowmeter works on the principle of Coriolis effect. an effect whereby a mass moving in a rotating system experiences a force (the *Coriolis force*) acting perpendicular to the direction of motion and to the axis of rotation. Over the past two decades, flowmeters based on the Coriolis principle have become one of the most important areas of development of flow measurement.

Table 1: Capital investment in maintaining CMF.

		Coriolis	DP/Orifice	Turbine
Capital Costs, $	Meter	5,000–8,000	1,200	2,500
	Straight pipe runs	0	1,000	1,000
	Filter/strainer	0	0	500
	Pressure sensor	0	500	400
	Temperature sensor	0	250	250
	Flow computer	0	1,000	1,000
	Wiring	500	2,300	200
Engineering Costs, $	Flowmeter	500	1,000	1,000
	Flow computer	0	200	200
	Wiring, etc.	200	200	200
Installation Costs, $	Meter	500	1,000	1,000
	Straight pipe runs	0	500	500
	Filter/strainer	0	500	500
	Pressure sensor	0	100	100
	Temperature sensor	0	100	100
	Flow computer	0	200	200
	Wiring	200	400	400
Maintenance Costs (over a 10-yr life), $	Meter repair*	1,000	2,000	5,000
	Meter flow calibration	0	2,000	5,000
	Pressure	0	1,000	1,000
	Temperature	0	500	500
	Flow computer	0	500	500
Total		$7,900–10,900	$14,350	$26,850

The significant development of Coriolis flow measurement technology has covered several technical aspects and is due to advances in the critical modelling, signal processing, computing power, and testing facilities, and most importantly due to the acceptance by various industries. CMF using Lead Zirconate Titanate (PZT) piezoelectric ceramic materials as a sensor and actuator is discussed in [1]. Unsatisfactory performance due to precision of flow signal because of presence of large damping and hysteresis is one notable constrain in CMF and the delay it causes in response time is given in [2]. The latest trends in CMF technology and the latest research using Modbus and Profibus alongside various tube design can be studied in [3] and how it has improved when compared to the previous records are seen in [4]. [5] and [6] tells about the signal conditioning aspect that is required to obtain error free signal from sensors. Whereas [7] tells about sensor interfacing using LabVIEW. The simulation of Coriolis mass flowmeter using ANSYS is done in [8]. The advancement in PZT is covered in [9]. [10] gives the idea about how use of piezoelectric material is evolved in MEMS field. Internet of things is much talked topic in recent times hence [11] and [12] tells about the water management involving embedded microprocessor-based water sensors in a pipe. [13] is about how the idea of IoT can be taken up in LabVIEW environment. [14] and [15] is about the measurement and detection system involved in flow measurement in IoT domain using a microcontroller as a standalone system. A case study as shown in Table: 1 was done by Emerson a reputed flow meter manufacturer to show the cost factor involved in maintaining a Coriolis mass flowmeter. Application of CMF is in food processing industry, Oil refinery, Petrochemical industry and Natural Gas industry.

This paper is aimed to provide a methodology which will make use of myRIO-1900 of National Instruments to be acting as stand alone system as well as to provide actuation for a pair of Piezoelectric Sensors (PZT) instead of using an external function generator to provide actuation. It also acts as a Data Acquisition (DAQ) device for sensing another pair of PZT for determining the phase shift in LabVIEW. To maintain the flow inside the experimental tubes (PVC pipes) Hydraulic workbench is considered which allows accurate measurements for various process conditions and changing fluid densities. Single tube design of the Coriolis mass flowmeter is discussed in Section 2. U-tube design approach which is followed for the experimentation is explained in Section 3. The section 4 briefs about the methodology involved in the interfacing of CMF using LabVIEW. IoT interfacing of the CMF is given in Section 5.

II. SINGLE TUBE DESIGN

Generally, there are two different designs of single tube flowmeters. In the first design ((a) in figure: 2), the tubes are bent to form a double loop. This design is similar to the dual tube flowmeter with the difference that the tubes are in series and not in parallel. Such single tube flowmeters offer the same advantages as dual tube meters, and they do not have the disadvantage of flow splitters. However, with this design the tube length increases dramatically, which results in an increased pressure loss. Furthermore, an easy drainage of the instrument is not possible with this design. The second design ((b) in figure: 2) of single tube flowmeters consist of a straight or fairly straight single tube. Slightly bent tubes have the further advantage, that they offer a wider temperature range than straight tubes. From a user point of view single tube designs are often preferred since they offer the best cleanability and the most careful fluid handling. However, it is challenging to find a balancing mechanism for such flowmeters. Figure: 1 shows the basic arrangement of a single tube flowmeter with most generally preferred sensor locations. Nevertheless, there are single straight or fairly straight tube Coriolis mass flowmeters, which offer a similar performance to dual tube flowmeters.

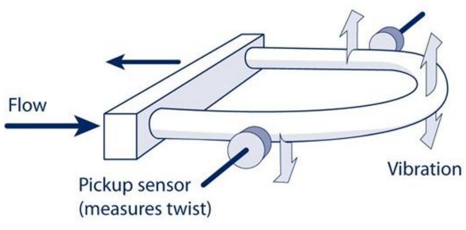

Figure 1: Tube assembly of a typical Coriolis mass flowmeter

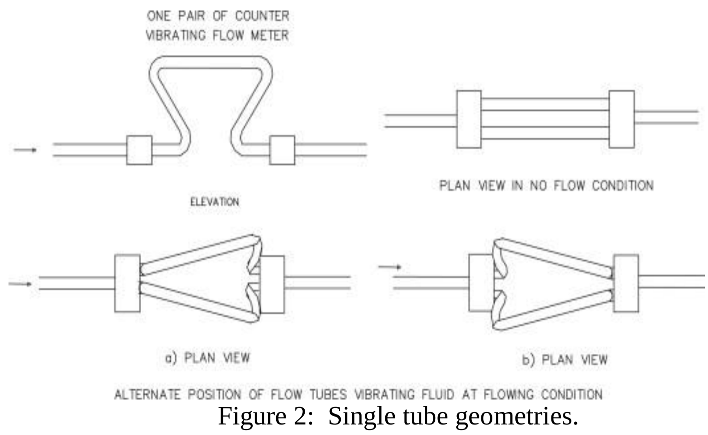

Figure 2: Single tube geometries.

III. U-TUBE DESIGN OF CORIOLIS MASS FLOWMETER

The material of construction is PVC pipe of dimensions as shown in Figure: 3 is used for the experiment. The setup is mounted on the table and sensors are fixed at 32.5 cm from the inlet and outlet port. The PZT patches which is going to be used as an actuator is fitted at the top. While other patches which will measure the flow are fixed at the bottom. The U-Tube setup is mounted on a wooden table 28 cm out of the entire length and rest is suspended freely. Figure: 4 shows the actual U-tube arrangement of CMF used in for experimentation.

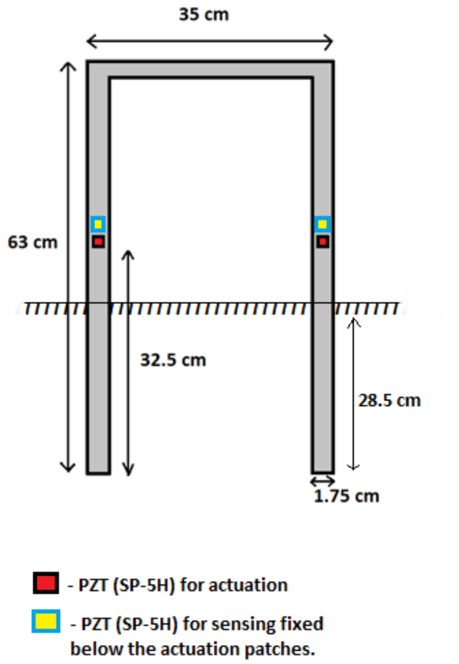

Figure: 3 The U-Tube model used in experimentation.

Figure: 4 U-Tube CMF experimental setup.

IV. CORIOLIS MASS FLOWMETER USING LABVIEW

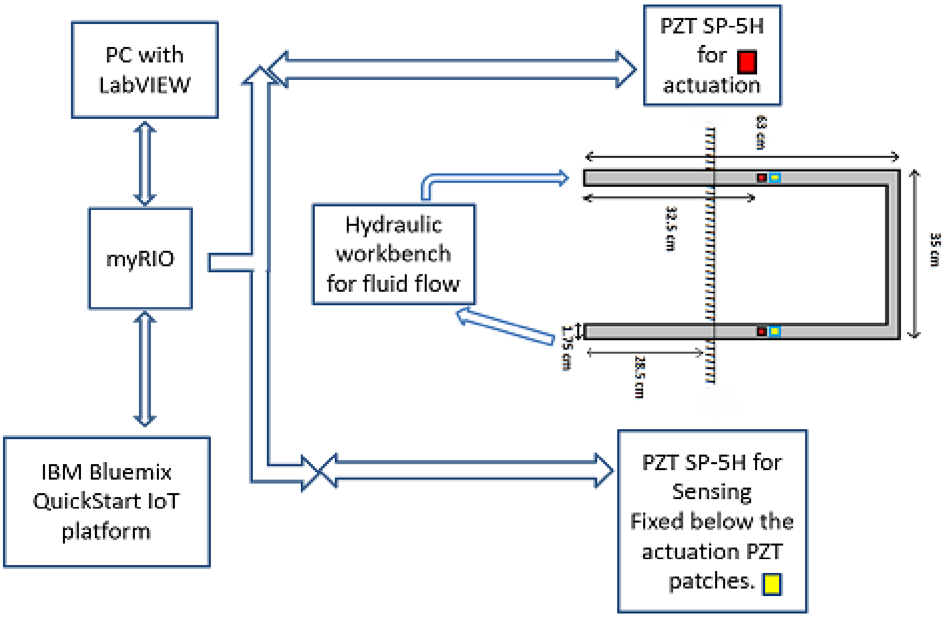

Figure 5: Schematic of the Coriolis mass flowmeter experimentation.

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 8, Issue 2, February 2020

Figure: 5 shows the schematic of the CMF experimentation. The hardware components like myRIO - 1900 and Hydraulic workbench is used to impart the flow in the range of (0-55) LPH. Figure: 6 shows the actual experimentation setup for the CMF interfaced with LabVIEW using myRIO Wi-Fi module.

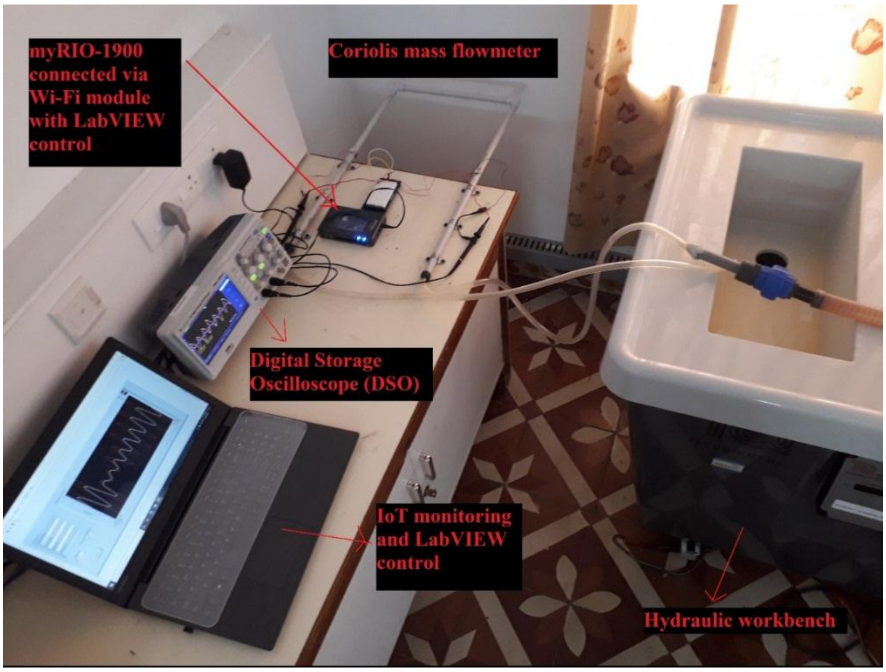

Figure: 6 LabVIEW based Coriolis mass flowmeter experimentation setup.

PZT is used for both actuation and sensing. First, LabVIEW is used where coding for the actuation to be provided for the sensor is done and also it is used as a Data Acquisition module with help of myRIO. Once the code is ready it is installed in the myRIO hardware which is connected via Wireless Fidelity (Wi-Fi) module in order to eliminate wire clutter and also to deploy myRIO as nearer as possible to the sensor so as to increase the response time. myRIO can act as a function generator providing the necessary sinusoidal input to the set of PZT acting as a actuator with adjustable frequency. When reading the signal from sensors, myRIO act as DAQ device to measure the phase shift simultaneously. The resonant frequency of the U-Tube PVC Pipe is measured using LabVIEW programming through myRIO. This can also be done by varying the frequency and visualizing the phase shift in Digital Storage Oscilloscope (DSO). Figure: 7 shows the first mode of resonance for the U-Tube vibrated using PZT as an actuator and another sensor which was used to sense the phase shift.

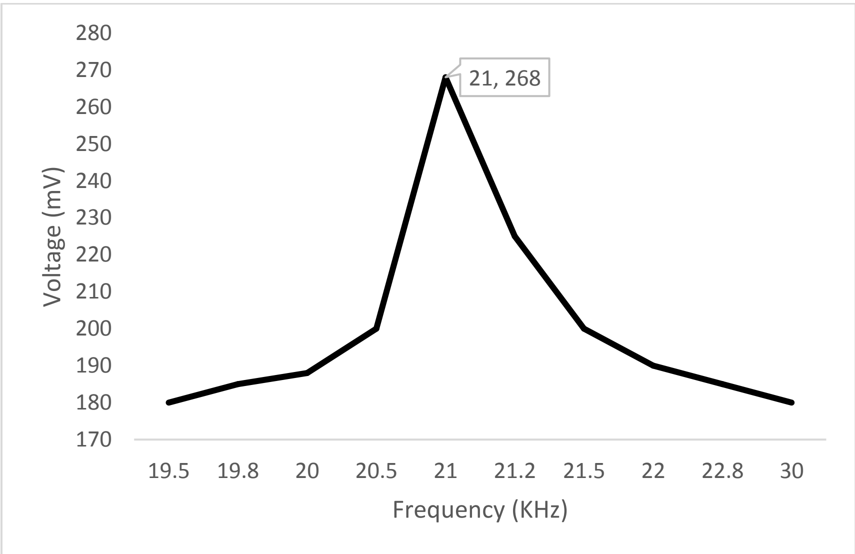

Figure: 7 First mode of resonance values of the PZT.

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 8, Issue 2, February 2020

After determining the resonant frequency, the pipe is made to oscillate at the first mode of resonance from myRIO (21 KHz from AO channel). Fluid is passed from Hydraulic workbench of TQ solutions which is used to maintain the flow of the fluid. When the fluid flows through the oscillating pipe a phase shift is visualized using DSO. Figure: 8 shows the phase shift which is observed in DSO.

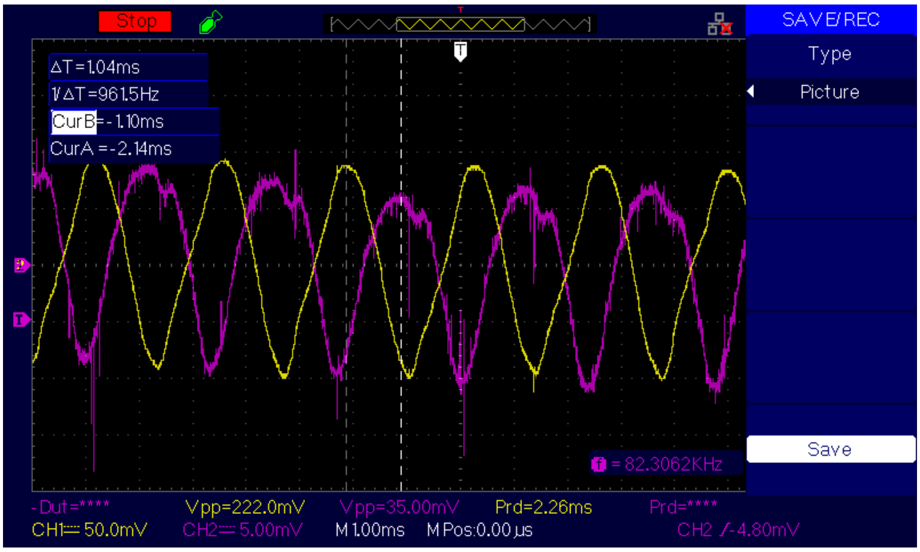

Figure : 8 Phase shift measurement in Digital Storage Oscilloscope (DSO).

The proper signal conditioning either using filter circuits or filter devices which can be done in LabVIEW. Signal conditioning function palette is available in LabVIEW which enables us to program it and modify based on needs. There are various range of filters and algorithms which can be used for effective reconstruction of PZT signal which are often affected by noise and Electro Magnetic Interference (EMI).

V. IoT INTERFACE OF CORIOLIS MASS FLOWMETER

The Internet of things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with Unique Identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. LabVIEW is used as a medium to connect the Coriolis mass flowmeter with the cloud. The Analog Input (1 Sample) will sense the signal from PZT and amplification is done in order to merge two signals to be displayed in the same line in LabVIEW (Figure: 9). The obtained signal contains noise hence it is not a perfect Sine wave. To rectify that Basic Function Generator Express VI is used to produce a perfect Sine wave from PZT sensed values. The difference between two signals is measured and it is fed into IBM QuickStart IoT using IoT foundation toolkit which can be downloaded from VI Package manager. From that toolkit three basic IoT Express VIs are used for establishing the connection (Connect.VI), publishing the data using Build Text Function and Publish.Vi and Disconnect.Vi will disconnect the connected device (myRIO) if there is any error in the code manually.

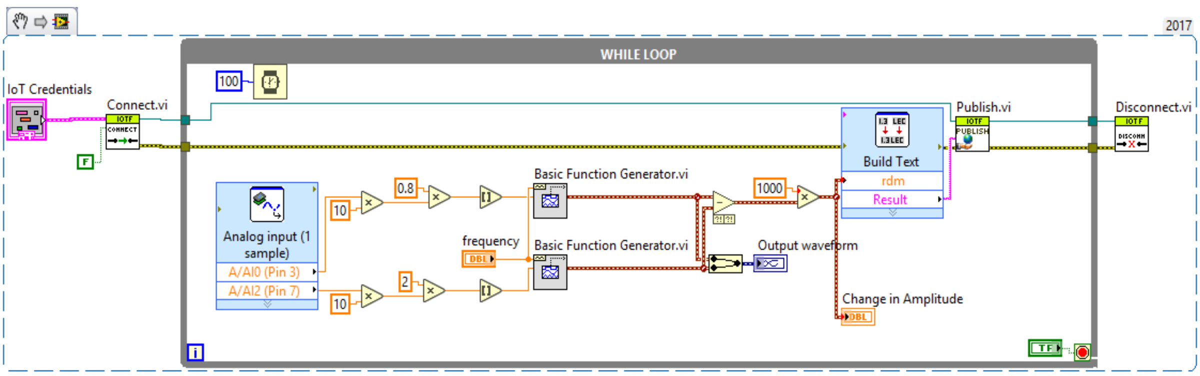

Figure: 9 LabVIEW code for Data Acquisition and IoT interfacing.

IJIREEICE

ISSN (Online) 2321-2004
ISSN (Print) 2321-5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

Vol. 8, Issue 2, February 2020

VI. RESULT AND DISCUSSION

The phase shift is measured using LabVIEW. Figure: 10 shows the phase shift in LabVIEW. It is found that Phase shift varies as the change in flowrate. As soon as the fluid starts to flowing through the measuring tube, additional twisting is imposed on this oscillation due to the fluid's inertia. Two PZT detect the change of tube oscillation in time and space as the "phase difference." The biggest advantage of the Coriolis mass flowmeter is that its measuring principle independent of the physical fluid properties and the flow profile. The sensor's characteristics is experimentally determined and the graph Figure:11 shows the linear characteristics. From the graph sensitivity was found to be around 0.13 ms/gs^{-1}. The range for which the experiment conducted is between (0-5) g/s. Figure: 12 shows the data monitoring in IBM QuickStart IoT platform which shows the mass flow rate values in terms of grams per seconds (g/s).

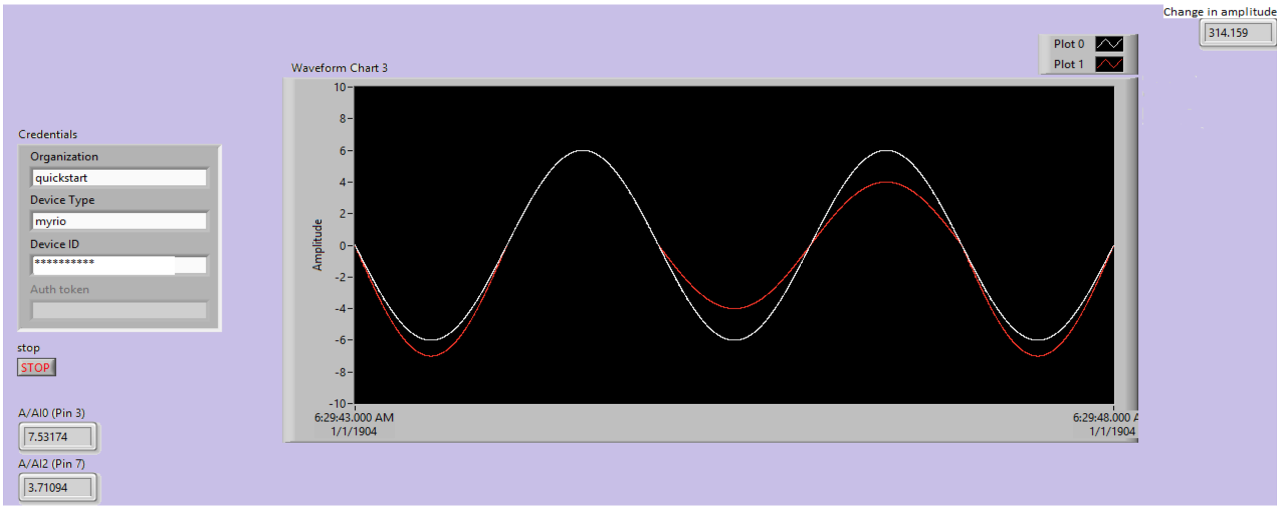

Figure : 10 LabVIEW Front Panel for Phase shift measurement

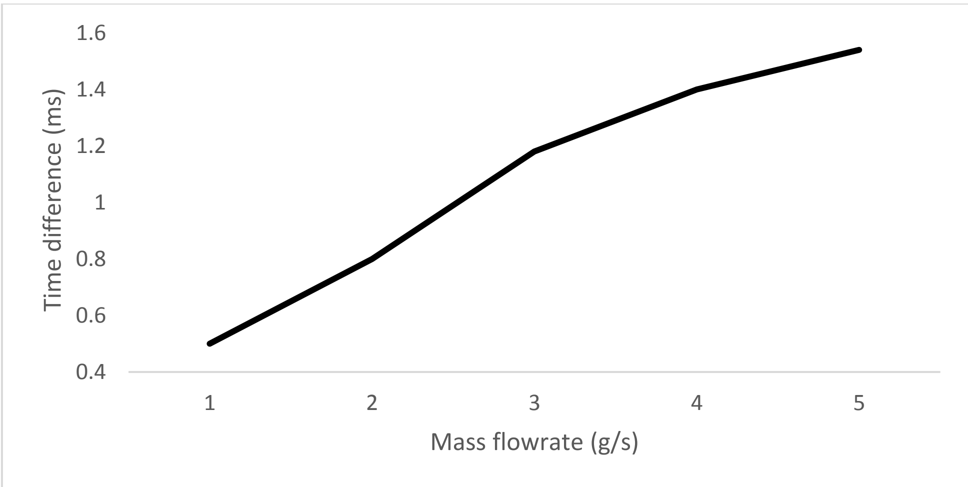

Figure : 11 I/O Characteristics graph for the SP-5H sensor.

DOI 10.17148/IJIREEICE.2020.8208

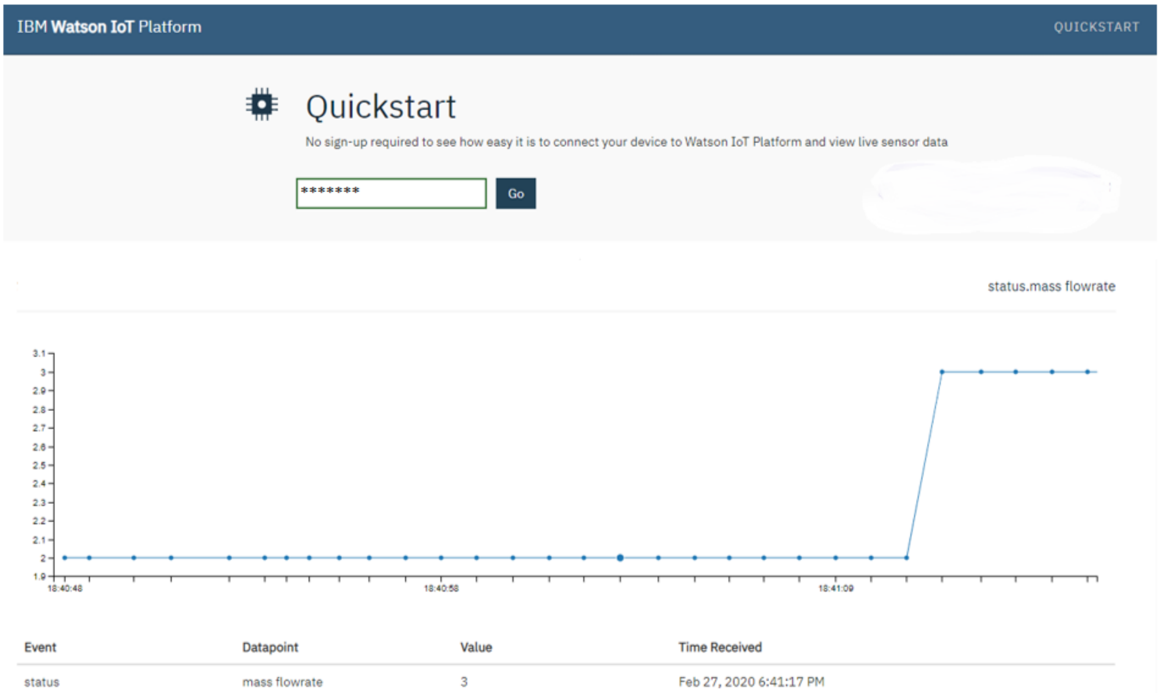

Figure:12 IBM QuickStart IoT platform to monitor mass flowrate in g/s.

ACKNOWLEDGEMENT

The authors would like to acknowledge the financial support provided by the Department of Science and Technology (SEED division), Ministry of Science and Technology, Government of India, New Delhi, India to carry out research work under the project No. SP/YO/040/2017 dated 13.03.2018.

REFERENCES

[1]. M.Shanmugavalli.,Umapathy,G.Uma " Smart Coriolis mass flowmeter" Measurement Volume 43, pp549-555, 2010.
[2]. Dezhi Zheng, Qiong Nan, Jiying Shi & Shangchun Fan "Experimental study on dynamic performance of Coriolis mass flow meter and compensation technology "ISSN 00204412, Instruments and Experimental Techniques, 2012, Vol. 55, pp. 503–507,2012.
[3]. Martin Anklina, Wolfgang Drahmb, Alfred Riederb"Coriolis mass flowmeters: Overview of the current state of the art and latest research" V.17 pp 317–323 (2006).
[4]. TaoWang, Roger Baker "Coriolis flowmeters: are view of developments over the past 20 years, and an assessment of the state of the art and likely future directions" V 40, pp 99–123,2014.
[5]. Chen, N., Fan, S., & Zheng, D. X "A phase difference measurement method based on strong tracking filter for Coriolis mass flowmeter". V 90(7), PP 075003, 2014.
[6]. Ming Li, Manus Henry "Complex Bandpass Filtering for Coriolis Mass Flow Meter Signal Processing" V 42, PP 4592-4597, 2016.
[7]. Junguo Wang , 9999Yang, Rui Sun, Minqiang Ren and Yongxiangn Zhao "Fault simulation platform of gear transmission system based on LabVIEW" V 242(3), PP 032052 , 2019.
[8]. Zhao, J., Li, Z., Zheng, D., & Fan, S. "Modal simulation and experiment analysis of coriolis mass flowmeter" V 2019.
[9]. Richard Smith, Douglas R. Sparks, Diane Riley, and Nader Najaf "A MEMS-Based Coriolis Mass Flow Sensor for Industrial Applications" VOL. 56, NO. 4, 2009.
[10]. Shu, L., Yu, Y., Yong, Z., Rao, Z., Ke, S., Fei, L.Wang, Y. "Negative Coriolis effect in piezoelectric metamaterials". V 2019 , PP 9013 – 9016, 12 2019.
[11]. D.Anandhavalli, K.S. Sangeetha, V. Priya Dharshini, B. Lukshana Fathima "Smart Meter for Water Utilization using IoT" International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 04, PP 2395, 2018.
[12]. Adam Drenoyanis , Raad , Ivan Wady and Carmel Krogh "Implementation of an IoT Based Radar SensorNetwork for Waste water Management" V 19(2) , PP 254 , 2019.
[13]. Arun Mozhi Devan Panneer Selvam & Midhun Kumar "IoT based water usage monitoring system using LABVIEW" V 2019 PP:205-212, 2019
[14]. Audrius Urbonaviciusa, Nagham Saeeda "IoT leak detection system for building hydronic pipes" I.J.Engg & Manufacturing, V:5, PP:1-21,2019
[15]. Gyusun Hwang, Jeongcheol Lee, Jinwoo Park & Tai-Woo Chang "Developing performance measurement system for Internet of Things and smart factory environment" V 55(9), PP 2590-2602, 2016.