DESIGN AND DEVELOPMENT OF AUTOMATIC WATER FLOW METER

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ABSTRACT

Effective irrigation water management begins with timing and regulating irrigation water application in a way that will satisfy the need of the crop without wasting water, soil and crop nutrients. This involves supplying water according to the crop requirement, quantity that can be held by the soil and is available to the crop at rates tolerated according to the soil characteristics. So measuring water in fields is very essential step in irrigation management systems. There are many water flow measurement techniques as well as different types of water flow meters used in irrigation to measure the volume of water flow in pipelines but these all are too costly. This paper describes design and development of low cost automatic water flow meter which supplies only required amount of water to the crops saving water as well as energy. G1/2 Hall Effect water flow sensor is used as a sensing unit with a turbine rotor inside it whose speed of rotation changes with the different rate of flow of water. The Hall Effect sensor outputs the corresponding pulse train for frequency input to the microcontroller. The whole system comprises of AT89S52 microcontroller, G1/2 Hall Effect water flow sensor, relay, optocoupler, a water pump, 5V supply, LCD, keypad and some passive components. The AT89S52 microcontroller is programmed in Keil development Tool.

KEYWORDS

Low cost sensor, Hall Effect sensor, rotation of rotor, flow rate of water, AT89S52 microcontroller, Keil software, Ultrasonic flow meter.

1. INTRODUCTION

Flow meters have proven excellent devices for measuring flow in the irrigation fields as it is required for measuring the water needed in irrigation fields in order to avoid damage of crops with excess water and even to save the water as it is most precious resource. Flow meter also serves the purpose of judging the irrigation pipelines as for example lower than normal flow rates may indicate the need for pump repair or leakage of pipelines. Flow can be measured with contact type or non contact type of sensor.

Accurate flow measurement is an essential step both in the terms of qualitative and economic points of view. Previously a technique known as ultrasonic flow measurement a non invasive type of measurement is widely used to calculate flow, because of its capability to avoid noise

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interferences in its output. Now a day due to its non linear characteristics its use is restricted. Various types of flow meters are available in the market. Table 1 lists different type of flow meters based on various principles.

Table 1. Categorization of flow meters based on various principles

Principle	Types
Differential pressure	Orifice Plate type of meter, Rota Meter, Flow Nozzle, Pitot type Tube, Elbow Tap, Venturi Tube
Positive Displacement	Oval Gear type, Nutating Disc type, Rotary Vane type, Reciprocating Piston
Velocity	Turbine type, Vortex Shedding Electro-magnetic, Ultrasonic Doppler type, Ultrasonic Transit Time type.
Mass	Coriolis , Thermal
Open channel	Weir, Flume

Some of the meters like velocity meters use a sensor which calculates the flow rate based on the speed of water, ultrasonic sensors which works on two different principles that is transit time measurement principle and other is based on Doppler Effect but these are having high cost of maintenance.

The aim of this paper is to develop a prototype of a low cost turbine type water flow meter which measures to water flow rate/totalization of water passed through the irrigation pipelines. This type of flow meter not only conserves the water by only providing the required amount of water to the fields but also saves the energy by having the pump automatically off. Pump gets off after the amount of time set by the user. The system is fully user friendly.

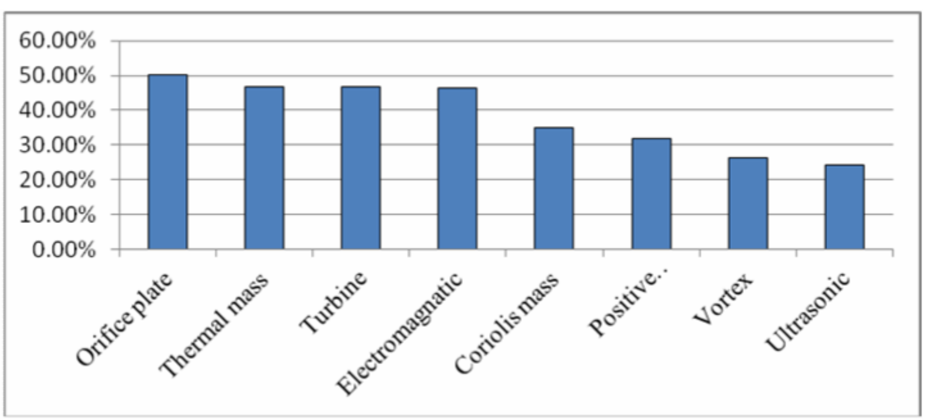

Figure 1. Industrial flow meter usage [1]

Figure 1 shows the usage of various flow-meters in industries. It clearly shows the flow meter with turbine or rotor is the third highest to be used because of its measurement accuracy

2. PREVIOUS WORKS

Lot of research work has been carried out for evolving different water flow measurement techniques. Luis Castalier et. al (1997) describes design and fabrication of a low cost water flow meter which can measure up to 9 litre/minute, avoiding direct contact of flow with silicon sensors in [2]. Techniques of measuring water flow rates with the help of neural networks had also been proposed. Shiqian Cai and Haluk Toral(1993) proposed a technique of measuring flow rate in Air-Water Horizontal Pipeline with the help of Neural Networks. In this paper the Kohonen self-organising feature map (KSOFM) and the multi-layer back propagation network (MBPN) were applied in a hybrid network model to measure the flow rate of individual phases in horizontal air-water flow [3]. Santhosh KV and BK Roy(2012) proposed an intelligent flow measurement technique using Ultrasonic Flow Meter with optimized neural network. The objective of this work includes: to extend the linearity range of measurement to 100% of the input range, to make the measurement system adaptive to variations in pipe diameter, liquid density, and liquid temperature, and to achieve the above two objectives by an optimal Artificial Neural Network[4]. Young-Woo Lee et. al(2008) had developed a wireless Digital Water Meter with Low Power Consumption for Automatic Meter Reading in which they used magnetic hole sensors to calculate the amount of water consumption and they had used ZigBee wireless protocol to transfer amount of water consumption to the gateway[5]. Javad Rezanejad Gatabi et. al (2010) developed an auxiliary fluid flow meter in which the flow of an auxiliary fluid is measured, instead of direct measurement of the main fluid flow. The auxiliary fluids injected into the main fluid and with measuring its travel time between two different positions, its velocity could be calculated [6]. Zhang Wenzhao et. al (2010) had developed a liquid differential pressure flow sensor for Straight Pipe. In this system a pressure difference between the upstream branch pipe and the downstream pipe is detected and converted into a voltage signal by the DP sensor. This voltage signal is transmitted to a microprocessor to determine liquid flow rate [7]. Thwe Mu Han, Ohn Mar Myaing(2011) developes Microcontroller-Based Water Flow Control System. In this system,as sensing unit, photo interrupter and slotted disk are used to produce pulse train for frequency input of the microcontroller. This signal is converted into flow rate by software program in PIC[8].

3. SELECTION OF SENSOR

Flow sensors, the devices that detect and measure water flowing through pipes, are becoming necessary components of efficient irrigation systems and mainly acts as a sensory organ for the brain in the irrigation controller, giving it information to make operating decisions. Flow meter basically works with the output of the flow sensor. In this system in order to calculate the flow the rotor surrounded by a magnet along with the Hall Effect sensor is used. This is known as G1/2 water flow sensor. As the water flows through the rotor, it's blades rotates. As the turbine rotates magnetic field is produced and accordingly an Ac pulse is generated which is then converted into the digital output with the help of Hall Effect sensor placed just after the turbine. The number of pulses generated per litre can be counted by the software programming. Thus pulses produce an output frequency which is directly proportional to the volumetric flow rate/total flow rate through the meter. Also measuring flow rate through rotating rotor provides high accuracy, excellent repeatability, simple structure and low pressure loss [9]. Table 2 lists the specifications of water flow sensor

Table 2. Specifications of G1/2 water flow sensor

Parameters of Sensor	**Value / Range**
Working Voltage (Volts)	5 - 24
Maximum Current (mA)	15
Flow rate range (L/min)	1 - 30
Operating temperature (ºC)	0 – 80
Liquid temperature (ºC)	<120
Operating humidity (RH)	35%-90%
Operating pressure (Mpa)	Under 1.2
Store temperature (ºC)	-25 to +80

3.1 Working theory of Hall Effect Sensor

Hall Effect sensor attached to G1/2 water flow sensor is a transducer which examines the rotations of rotor and passes the pulse train which is in the form of electrical signal as a frequency input to the microcontroller that is programmed to convert it to flow rate. They are temperature resistant and stress resistant sensor especially suited for electronic computation.

Sensor consists of multiple bladed, free spinning, and permeable metal rotor as shown in figure 2.

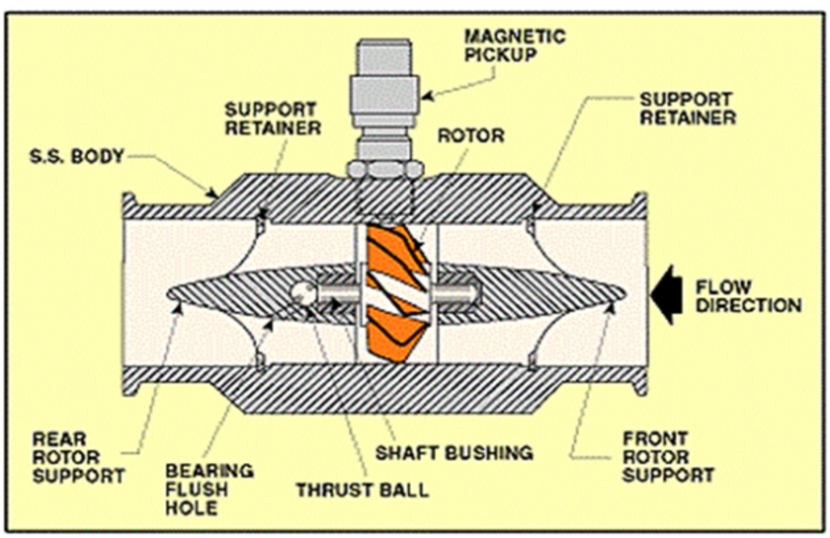

Figure 2. Internal structure of G1/2 water flow sensor [10]

The main benefit of using water flow sensor with Hall Effect sensor is that it is highly durable due to non-contact detection, works with high speed operation over 100 kHz, operates with stationary input, no moving parts, highly repeatable operation, highly resistant to contamination such as dust, dirt & oil, small in size and easy subsequent signal processing due to digital output [10]. Hall Effect sensor working flow is shown in figure 3.

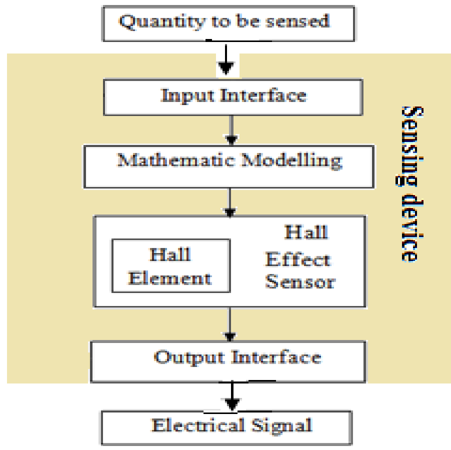

Figure 3. Working flow of water flow sensor

In order to measure the quantity of water being passed in particular time through the sensor it is first passed through the rotor present inside the sensor with magnet attached to it which is taken as input interface in the flow. Formulas are applied in order to measure the number of rotations in a minute of rotor.

Hall Effect sensor has a Hall element which is a magneto-electric transducer and is made of a thin semiconductor layer as shown in figure 4 with two input voltage terminals and two output voltage terminals. The magnetic flux perpendicular to the semiconductor layer generates a voltage by the Lorentz force.

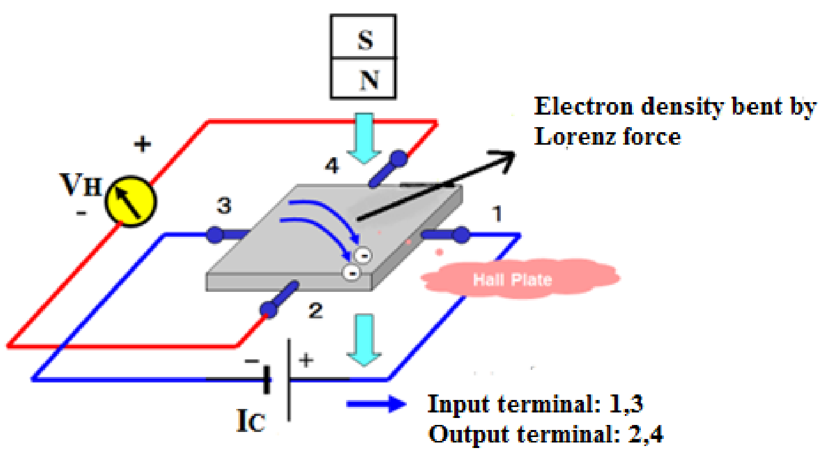

Figure 4. Behaviour of hall element in presence of magnetic field [11]

The Hall voltage produced in the Hall element is directly proportional to the current produced (*I*) and the magnetic flux density (*B*) as shown in equation 1.

$$V_H = R_H\,(\boldsymbol{I/T * B}) \qquad (1)$$

Where, V_H is Hall voltage, R_H is Hall Effect coefficient, I is current flowing through sensor in amperes, T is thickness of sensor in mm and B is magnetic flux density in Tesla, I_c is drive current. Hall voltage is of the order of 7 μV/Vs/gauss in silicon and thus requires signal conditioning for practical applications. Signal conditioning circuit consists of a voltage regulator, a signal amplifier that is differential amplifier and a Schmitt trigger in order to convert the analog output to digital output on a single silicon chip as shown in figure 5. A voltage regulator is used to automatically maintain a constant voltage level with the amplifier to amplify the Hall voltage according to the application.

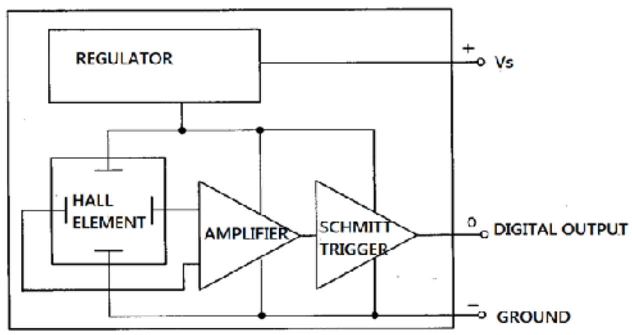

Figure 5. Digital output Hall Effect sensor

The comparison of the output from the differential amplifier is done with the preset reference and if amplifier's output exceeds the reference, the Schmitt trigger turns on and when it falls below the reference point, the Schmitt trigger turns off.

3.1.1 Transfer Function of Hall Effect Sensor

The transfer function for a digital output Hall Effect sensor incorporates hysteresis as shown in Figure 6.

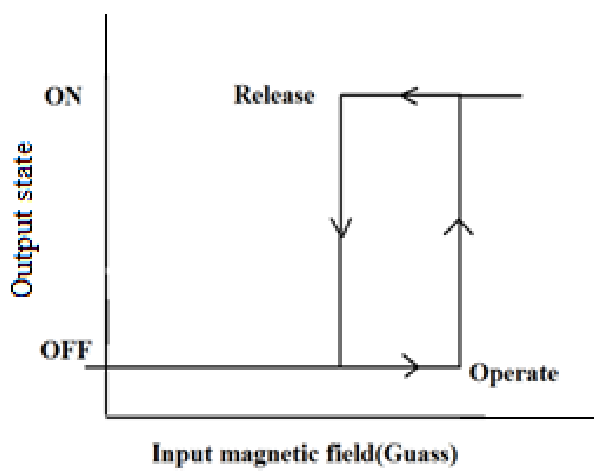

Figure 6. Transfer function of Hall sensor

The principal input/output characteristics are the operate point, release point and the difference between the two. As the magnetic field is increased, the output of sensor remains the same until the operate point is reached. Once the operate point is reached, the state of the sensor will change. There will be no effect of further increased magnetic field input. Now if magnetic field comes below the operate point, the output will remain the same until the release point is reached. Now at this point the sensor returns to its original OFF sate. This hysteresis eliminates the false triggering that can be caused by minor variations in input.

4. SYSTEM DESIGN AND DEVELOPMENT

The selection of a microcontroller plays very important role in any embedded system. According to the need of the system a microcontroller is chosen. Here in this system in order to design a low cost automatic water flow meter Atmel AT89S52 microcontroller is used. We have designed and developed a low cost water flow meter mainly for irrigation purposes to deliver only the correct amount of water as per requirement to the irrigation fields. It can also be useful in detecting catastrophic problem due to plugging/hose break so that this can be corrected before crop loss and flooding occurs. Keeping records of flow meter readings regularly can indicate when the pumping system is deteriorating. AT89S52 microcontroller is used to monitor the sensor with which LCD is interfaced to display the flow rate of water. Flow rate can be determined inferentially by different techniques like change in velocity or kinetic energy. Here we have determined flow rate by change in velocity of water. Velocity depends on the pressure that forces the through pipelines. As the pipe's cross-sectional area is known and remains constant, the average velocity is an indication of the flow rate. The basis relationship for determining the liquid's flow rate in such cases is shown in equation 2[12].

$$\boldsymbol{Q = V * A} \tag{2}$$

Where, $\boldsymbol{Q}$ is flow rate/total flow of water through the pipe, $\boldsymbol{V}$ is average velocity of the flow and $\boldsymbol{A}$ is the cross-sectional area of the pipe. Viscosity, density and the friction of the liquid in contact with the pipe also influence the flow rate of water.

AT89S52 microcontroller based system is shown in figure 7. A pump is used to supply water through the sensor to the required field. Inlet of water to the sensor is through the pump and outlet of water is from another side of sensor which is fed directly to the field. When no water flows through the pipelines as if the supply of water stops at any moment the pump gets automatically off hence saving the electricity too. Optocoupler is used to prevent high voltages from affecting the system receiving the signal. This prototype works on the basis of time which means that it works for the particular amount of time that is set by the user through the keypad according to the need of particular crop. According to the need if the time set is for example 1 hour, the system gets automatically off after 1 hour. The system is programmed according to the requirement in the fields. So this reduces the man’s effort of keeping eye everytime on field for avoiding damaging of crops and also helps in conservation of water.

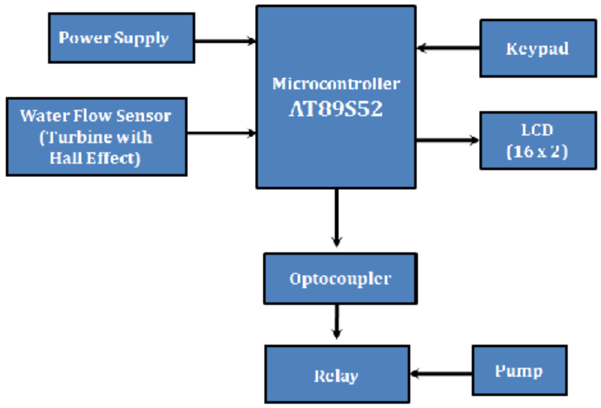

Figure 7. Block diagram of the system

4.1 Flow diagram of the system

The system working flow is described in figure 8. Water when passes through the rotor cause the rotor to rotate at the speed equivalent to velocity of water. Rotor's speed changes with different rate of flow of water. As each blade passes through the magnet magnetic field is created at the base of the Hall sensor and thus pulses are generated. These pulses produce an output frequency proportional to the volumetric flow/ total flow through the sensor. This frequency is converted to the flow rate by using software program for microcontroller AT89S52.

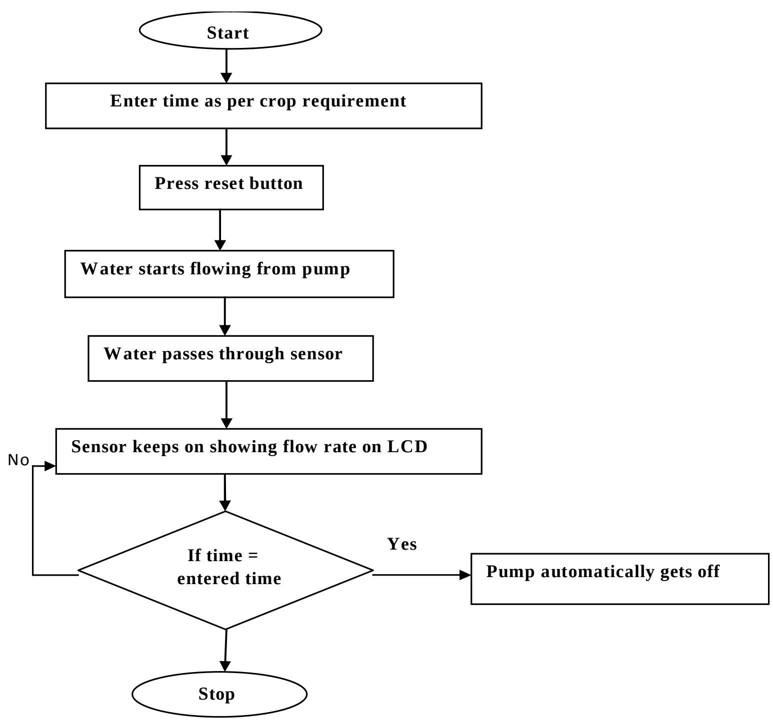

Figure 8. Flow chart of the system

5. RESULTS AND PERFORMANCE ANALYSIS

The table 3 lists reading of water flow rate with different multiplication factors with and without sensor.

Table 3. Calibration of sensor and observed readings

Multiplication factor	Observed reading with sensor (Litre per minute)	Actual reading (Litre per minute)
1.5	19	20
1.6	18	20
1.7	20	20
1.8	23	20
1.9	24	20
2.0	25	20

As in table 3 with the increase in multiplication factor the readings shown by the sensor degrade as compared to actual readings and a point comes where it becomes close to the actual value that is the rate at which the water actually flows as measured without the sensor.

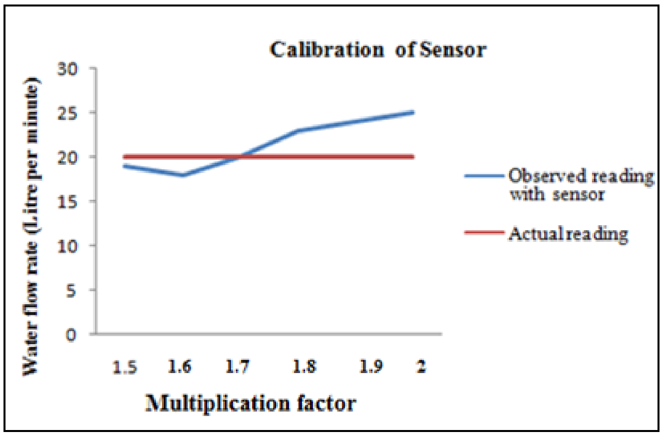

Figure 9. Calibration of water flow rate with Sensor

Figure 9 shows the graph of calibration of sensor which indicates that the actual reading we have observed with our sensor is a little bit deviates from original due to air present.

Table 4.Comparison between standard and experimental analysis

Water Flow Rate (litre per minute)	Water Flow Rate with Sensor (litre per minute)	Error (litre per minute)
12.52	11	1.52
10.50	10	0.50
15.28	15	0.28
41.40	41	0.41

Readings are taken with different volume of water. It is observed that the readings taken with our system is approximately equal to the actual readings.

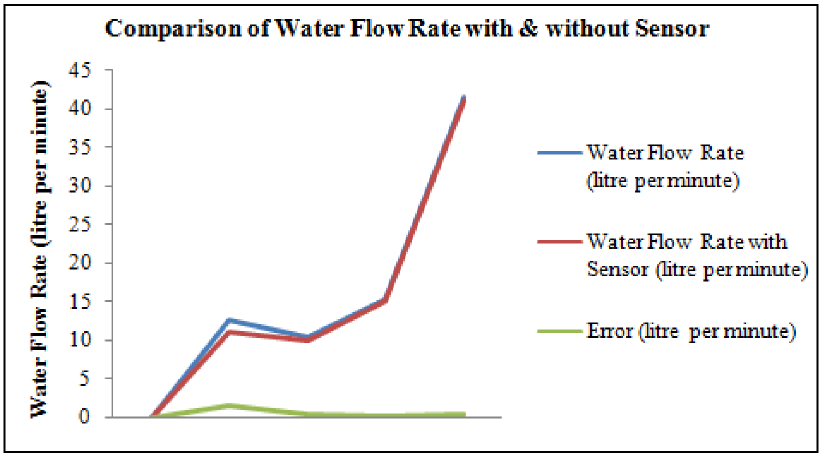

Figure 10.Comparison of water flow rate with and without Sensor

6. CONCLUSION

In summary, a technique to measure flow rate of water in irrigation pipelines is introduced. Though the use of Hall Effect sensor has been in studied in many areas but here we have seen the benefit of using Hall Effect sensor in measuring the flow rate of water within the irrigation pipelines. Application of hall sensor in this field proves to be a good system that can detect the leakage in the pipelines if we observe the flow rate of water regularly, saves water as excess water would not be delivered to the crops which may also damage it and at last but most important that is in the terms of cost the system proves to be a low cost with many of the benefits as compared to the other products available in the market. So development of low cost water flow meter can replace the other high cost water flow measuring meters available in the market. This system eliminates the manual mistakes in flow rate measurement. Also it is more accurate in comparison to other types of meters. This system is more attractive, as it provides automatic operation with great accuracy and the most too cheap method to measure flow rate of water in agriculture.

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