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Development Of Leakage Detection System In Suction Catheter With Water Distribution As An Application

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ABSTRACT

In present scenario, the main challenge in water distribution system lies in sensing the leakages and minimizing the losses. This work aims to an on off controller mechanism for a selected pipelining structure to sense and minimize the leakages for a liquid process. LabVIEW software is used to monitor and control the leakage automatically using Arduino as an interfacing tool. A water flow sensor is used to sense the leakage and automates the flow of the water in a bypassed manner. A duplex pump system[9] is used for safety; each pump is capable of maintaining vacuum levels. It allows for periodic shut-down of each pump and provides a backup source for negative pressure, should one of the pump fails to operate effectively.

Keywords: leakage, suction catheter, water.

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INTRODUCTION

3,300,000,000 litres of water are lost every single day through leakage. Research says that water leakage is predominant even now despite 7.5 billion pounds invested in infrastructure in the last 10 years. Environmental analysis show that water levels could drop between 10 and 15 % over the next few years. Modern pipeline coatings and cathode protection helps prevent small corrosion leaks from occurring as long as the coating is as such. In most modern hospitals, vacuum is available from wall outlets located throughout the building. When the vacuum pressure fails to build up a pressure, a switch is disengaged and no further vacuum is created.

With the context of [1], the work process used here involves a water flow sensor that is installed to detect the leak, if there is a leak a message is sent to the user using GSM modem connected to thecircuit. But this method only involves detecting the leakage, for the user to take steps to control the leakage will result is time delay. And hence this work overcomes this disadvantage by detecting the leakage and bypassing it.

This is a closed loop system, consisting of a controller, actuator and process. This paper presents the implementation of on off mechanism to operate the valve during the leak and no leak condition. Labview is used to control the process, it receives input from the system via Arduino. Suctioning[9] is an important part of daily patient care and in many cases can be a potentially life-saving procedure. A thorough understanding of the physics involved in creating suction, the factors affecting flow rate will make the procedure effective.

SYSTEM

This is a closed loop system, the below block diagram depicts the working of the system.The input signal is the default force of the water in the system,this is given to the summer via arduino. The default force is the force of water in no leak condition. This input cannot be directly fed to the controller and hence arduino is used as an interface.

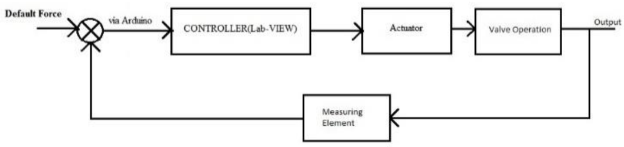

Figure 1: Block Diagram of the Process

Controller: It is a device that controls the process in a particular system, here which is leak detection. The controller operation is carried out by LabVIEW, which is a VI platform. The input force and the feedback force are subtracted to get the error signal which becomes the input to the controller. Through ARDUINO, the error signal is fed to the controller. LabVIEW is incorporated with the controller functions and hence governs the working of the valve.

Actuator: An actuator is a simple electromechanical switch made up of an electromagnet and a set of contacts. Relay of range 12V is used to convert the signal

Valve operation: Solenoidal valve operation depends on the input from the actuator. The on-off mechanism governs the operation of valve. Initially when there is a no leak condition the input signal received keeps the valve in OFF state while during the leak condition the error signal results in switching the valve to ON state and therefore it bypasses the water through another branch.

Measuring element: A measuring system exists to provide information about the physical value of some variable being measured. In simple cases, the system can consist of only a single unit that gives an output reading or signal according to the magnitude of the unknown variable applied to it. The water flow sensor senses the measure of the flow in both leak and no leak condition. When in leak condition the process variable changes and hence when fed back to the system produces an error signal to drive the controller.

SOFTWARE

The software uses an ARDUINO and LABVIEW to interpret data from the inline pipe measurements .The project aims at obtaining measurements through the measuring sensor, get the signal to LabVIEW using the ARDUINO board as an interface.

LabVIEW

Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is a system-design 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 operating systems (OSs), Execution is determined by the structure of a graphical block diagram (the LabVIEW-source code) on which the programmer connects different function-nodes by drawing wires. These wires propagate variables and any node can execute as soon as all its input data become available. Since this might be the case for multiple nodes simultaneously, G can execute inherently in parallel. LabVIEW integrates the creation of user interfaces (termed front panels) into the development cycle. LabVIEW programs-subroutines are termed virtual instruments (VIs). Each VI has three components: a block diagram, a front panel, and a connector panel. The last is used to represent the VI in the block diagrams of other, calling VI's the front panel is built using controls and indicators. The back panel, which is a block diagram, contains the graphical source code. All of the objects placed on the front panel will appear on the back panel as terminals. The back panel also contains structures and functions which perform operations on controls and supply data to indicators. LabVIEW includes extensive support for interfacing to devices, instruments, cameras, and other devices. Users interface to hardware by either writing direct bus commands (USB, GPIB, and Serial) or using high-level, device-specific, drivers that provide native LabVIEW function nodes for controlling the device.

The flow sensor used gives a pulsed signal, which varies according to the flow rate of water in the pipe. Flow rate is given as the volume of water passing per unit time. The pulse signal from the sensor is obtained in the LabVIEW virtual instrument through the Arduino Board. The Arduino is interfaced to LabVIEW by burning the LIFA Base (LabVIEW Interface for Arduino) file into ARDUINO ide. This allows us to access an ARDUINO palette in the Function palette which makes it possible to read data from the analog, PWM and digital pins or write data to the digital or PWM pins. The block diagram of the VIRTUAL INSTRUMENT is as follows:

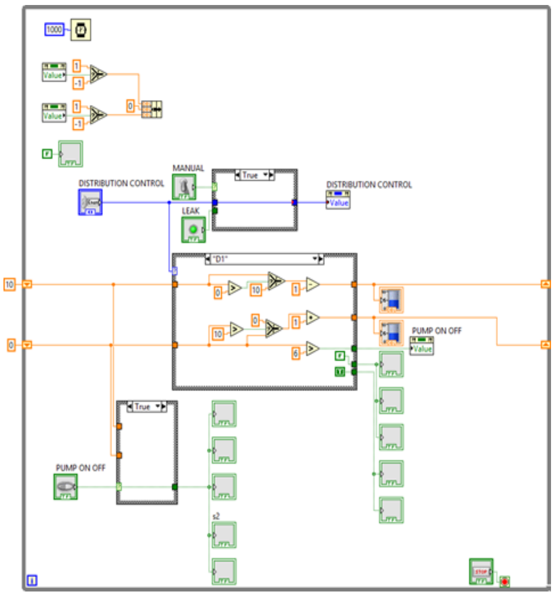

Figure 2: Block diagram of VI in LabVIEW

At the outset there is a While Loop which is used to switch the instrument off when the user desires to. The instrument has two modes of operation namely AUTO or MANUAL.

The Logic for the change in modes is obtained using a CASE STRUCTURE and AN ENUM for user input.

When the user selects the AUTO MODE the distribution to be used is dependent on the leak condition and if a leak is detected the distribution is changed automatically to the bypass distribution without user intervention In the MANUAL MODE, the user explicitly has a choice to select the distribution to be used in service or completely stop circulation as well.

There is a case structure used for the selection of distribution and switching circulation on or off .The ENUM to this structure comprises three option namely NO CIRCULATION,DI and D2(bypass distribution).

In MANUAL mode the user has access to this enum and select from the above three options. According to the selection of the user a logic high or low is sent to the digital pins on the ARDUINO preset for the switching on or off the solenoidal valves.

In the AUTO mode the VALUE PROPERTY node of this enum is used to automatically select between the distributions depending on leak checking.

The ON OFF mechanism is implemented through the leak checking and distribution selection which switches on or off the solenoidal valves for the respective distribution. A case structure for PUMP ON/OFF is used to for the switching on or off of the pump, the condition for which is selected from the aforementioned case structure. The ARDUINO is initialized outside the loop and the corresponding pulse from the pwm pins is read and the DIGITAL pins initialized as output for controlling the solenoidal valves. The PWM signal is converted to the corresponding flow rate using numeric calculations according to the datasheet of the sensor and checked for leak by comparing with the default no leak flow rate. The Boolean output for this comparison is used to glow a led which signifies a leak and as an input for the AUTO mode.

STRUCTURE

SETUP: The basic setup consists of an overhead tank discharging the water through a distribution line. To the tank nipple a T-shaped joint is connected which diverges the main supply line into two sub lines.Two solenoidal valves are connected at the discharge point of the T-section so that the sub line can be varied by actuating the valve of our choice and deactuate the other one. Each sub line is a 2 m long PVC pipe.At the end of the pipe is an ARDUINO flow sensor connected with a socket which gives us the volumetric flow rate of water through that pipe to detect a leak.The distribution ends in a reservoir from where water is pumped back to the overhead tank through a ¼ HP 12V DC pump to maintain close circulation and constant water level in the overhead tank.

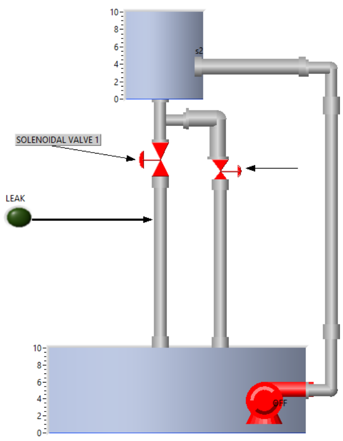

Figure 3: Structure in LabVIEW

Components:

OVERHEAD TANK: A conventional plastic container of 10 litres volume which is used as the supply tank.

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Figure 4: Overhead Tank

SOLENOIDAL VALVES- [7]The valves are programmatically used for the switch on or off a particular subline.

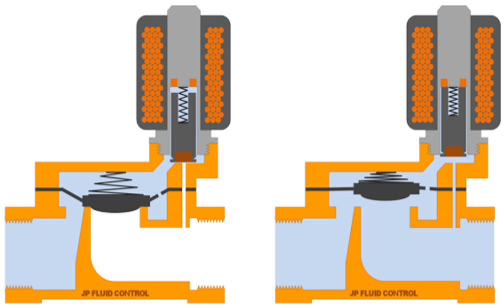

Figure 5: Schematical representation of semi-direct operated solenoid valves

A solenoid valve is an electromechanical controlled valve. The valve features a solenoid, which is an electric coil with a movable ferromagnetic core in its centre. This core is called the plunger. In rest position, the plunger closes off a small orifice. An electric current through the coil creates a magnetic field. The magnetic field exerts a force on the plunger. As a result, the plunger is pulled toward the centre of the coil so that the orifice opens. This is the basic principle that is used to open and close solenoid valves.

Solenoid valves can be categorized into different groups of operation.

Direct Operated:

Direct operated (direct acting) solenoid valves have the most simple working principle. The medium flows through a small orifice which can be closed off by a plunger with a rubber gasket on the bottom. A small spring holds the plunger down to close the valve. The plunger is made of a ferromagnetic material. An electric coil is positioned around the plunger. As soon as the coil is electrical energized, a magnetic field is created which pulls the plunger up towards the centre of the coil. This opens the orifice so that the medium can flow through.

Indirect Operated (Servo Or Pilot Operated)

Indirect operated solenoid valves (also called servo operated, or pilot operated) use the differential pressure of the medium over the valve ports to open and close. Usually these valves need a minimum pressure differential of around 0.5 bar. The inlet and outlet are separated by a rubber membrane, also called diaphragm. The membrane has a small hole so that the medium can flow to the upper compartment. The pressure and supporting spring above the membrane will ensure that the valve remains closed. The chamber above the membrane is connected by a small channel to the low pressure port. This connection is blocked in the closed position by a solenoid. The diameter of this "pilot" orifice is larger than the diameter of the hole in the membrane. When the solenoid is energized, the pilot orifice is opened, which causes the pressure above the membrane to drop. Because of the pressure difference on both sides of the membrane, the membrane will be lifted and the medium can flow from inlet port to outlet port. The extra pressure chamber above the membrane acts like an amplifier, so with a small solenoid still a large flow rate can be controlled. Indirect solenoid valves can be used only for one flow direction. Indirect operated solenoid valves are used in applications with a sufficient pressure differential and a high desired flow rate, such as for example irrigation systems, showers or car wash systems. Indirect valves are also known as servo controlled valves.

Figure 6: Solenoid Valve ST-DA 1/8'' Brass

This system uses the INDIRECT PILOT operated solenoidal valve to get a bigger orifice diameter and legitimate flow readings.

PIPE: 2 m long normal POLYVINYL CHLORIDE pipes

YF-S201 Hall Effect Water Flow Sensor[2]: This sensor sits in line with your water line and contains a pinwheel sensor to measure how much liquid has moved through it. There's an integrated magnetic hall effect sensor that outputs an electrical pulse with every revolution. The hall effect sensor is sealed from the water pipe and allows the sensor to stay safe and dry. The sensor comes with three wires: red (5-24VDC power), black (ground) and yellow (Hall effect pulse output).

By counting the pulses from the output of the sensor, you can easily calculate water flow. Each pulse is approximately 2.25 millilitersThe pulse signal is a simple square wave so its quite easy to log and convert into liters per minute using the following formula. Pulse frequency (Hz) / 7.5 is equal to flow rate in L/min.

Features:

Model: YF-S201
Sensor Type: Hall effect
Working Voltage: 5 to 18V DC (min tested working voltage 4.5V)
Max current draw: 15mA @ 5V
Output Type: 5V TTL
Working Flow Rate: 1 to 30 Liters/Minute
Working Temperature range: -25 to +80°C
Working Humidity Range: 35%-80% RH
Accuracy: ±10%
Maximum water pressure: 2.0 MPa
Output duty cycle: 50% +-10%
Output rise time: 0.04us
Output fall time: 0.18us
Flow rate pulse characteristics: Frequency (Hz) = 7.5 * Flow rate (L/min)
Pulses per Liter: 450Durability: minimum 300,000 cycles
Cable length: 15cm
1/2" nominal pipe connections, 0.78" outer diameter, 1/2" of thread
Size: 2.5" x 1.4" x 1.4"
Connection details:
Red wire : +5V
Black wire : GND
Yellow wire : PWM output.

Although a pressure transmitter may work directly for larger systems rather for a small system like this because it sits inline and gives a variable reading according to the volume of water flowing through it per unit time.It gives a pulse which needs to be converted to the required unit of flow i.e l unit /min through the programming.

Figure 7: YF-S201 Hall Effect Water Flow Sensor

RELAY

A 12V DC relay is used to achieve the shut on/off mechanisms of the distribution.Since Arduino can only supply a voltage of 5V maximum the relay is the switch which is turned on or off according to a logic high signal from the arduino.An AC supply is given to the Common pins of two channels and the NC pins are connected to the solenoidal valve terminals.

Figure 8: 4-Channel Relay

RESULT

The above work hence depicts the detection of the leakage using on off mechanism, the difference in the rate of flow of the water is fed to the controller (LabVIEW) through Arduino. The sensor which is operated by Arduino programming gives the change in flow rate that counters for the error signal. The controller output to the solenoid valve results in on or off of the valve. When the solenoid valve is opened the water is bypassed to other distribution path due to the leakage detected.

APPLICATION IN BIOMEDICAL INSTRUMENTATION

The work completed above can have vital application in biomedical instrumenation as well.

Suction is an important procedure used in the medicinal procedures.Suctioning is the drawing away or removal of unwanted bodily fluids by the force of suction. It helps in the cleaning of body cavities off fluid accumulation.In surgery, suction can be used to remove blood from the area being operated on to allow surgeons to view and work on the area. Suction may also be used to remove blood that has built up within the skull after an intracranial hemorrhage.[2]

Suction devices may be mechanical hand pumps or battery or electrically operated mechanisms. The plastic, rigid Yankauer suction tip is one type of tip attached to a suction unit. Another is the plastic, nonrigid French or whistle tip catheter. One such instrument used specifically in this respect is a suction catheter. Suction catheters are flexible, long tubes used to remove respiratory secretions from the airway. The purpose of suctioning is to keep the airway clear of secretions and to prevent plugging. One end of the suction catheter is connected to a collection container (suction canister) and a device that generates suction. The open end is advanced through the airway (endotracheal or tracheostomy tube) to remove secretions. The objective is to develop a prototype of a suction catheter with control such that it provides suctioning for an user defined time and monitors the flow rate of the fluid and changes the duty cycle of the suctioning mechanism accordingly.

SYSTEM

The system would consist of a catheter the open end of which is insterted through the endotracheal or tracheostomy tube.The catheter will terminate in a cannister ,through a solenoidal valve and the flow sensor. The flow rate of the fluid being suctioned is measured by the flow sensor and displayed in the virtual intrument.If the flow rate is not within a specified range ,the virtual instrument automatically terminate suctioning and wait till necessary adjustments have been made.The suctioning process will work for a time specified by the user after which it has to be restarted. The controlling mechanism for the above working will be the solenoidal valve. The instrument will work for a specific time(user defined) after which it automatically switches off by cutting off supply to the solenoidal valve.During service period if the flow rate fluctuates beyond specified range then it will alert the user by a led for necessary action to be taken.

HARDWARE MODIFICATIONS:

Instead of the regular piping used,non toxic pvc is used for the catheter.The same system diagram applies with the overhead tank being analogous to the patient body,D2 being the catheter section and with flow sensor attached to D2 itself The reservoir is replaced by the catheter cannister and the pump is replaced by a suction pump.

SOFTWARE MODIFICATIONS:

A property node for the stop button boolean for the while loop is used to control the automatic switch off of the virtual instrument.The value change of the stop button is linked to equality checkinga counter variable with the number of seconds the user wants the loop to work,given by a numeric control.

The switching off or on of the solenoidal valve follows the same leak conditon checking in the above system except leak conditon in this system is fluctuation beyond specified flow rate set by the user with another numeric control.

If fluctuation occurs a boolean led controlled by the same checking for the digital high of arduino in previous system glows on the front panel.

PROTYPE DIAGRAM:

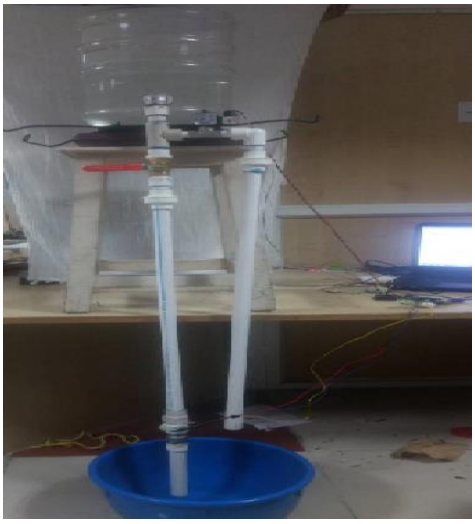

Figure 9: Structure

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