DESIGN AND CONSTRUCTION OF A PIPELINE PROTECTION CIRCUIT

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Abstract: This paper presents the design and construction of an electronic circuit that will protect petroleum-product carrying pipelines from being vandalized. It involves the mounting of vibration sensors on the pipelines carrying petroleum products, and transmitting the output of the sensors to a microcontroller based circuit. This circuit activates a GSM phone and sends a text message to the user or security personnel stating that the protected pipeline is being vandalized. The system also has a switch that triggers the phone to send an SMS to the user when the main electronic circuit itself is being vandalized. The system is therefore a proactive design which also has a two-way protection that enables both the pipelines and the protecting circuit to be protected.

Keywords: Oil, petroleum, pipelines, protection, technology, vandalisation

Introduction

Oil pipelines vandalism is an illegal breaking of the pipes that convey crude oil from one point to another, with the intention of redirecting the content of the pipelines to a different destination for personal or collective gain which is regarded as theft or illegal oil bunkering.

Nigeria has since independence relied on crude oil as the major means of funding it's economy as well as revenue generation (Olugboji, 2011). Any threat to the production and eventual distribution of the petroleum products to the required destination is a threat to the nation's economy (Okoli and Orinya, 2013; Njoku, 2016). Nigeria as a country, the companies and different ministries in charge of this crude oil have not been quiet to cubing this menace (Odalonu, 2015; Mboho and Udousoro, 2014). Several approaches have been adapted to solving this problem (Udofia and Joel, 2012), each of which has different technologies to alert the security agents when the vandalism is taking place on the pipelines. However each previous approach had its own flaws, loop holes and short comings. A solution has been proffered as an improvement to other previous solutions by using the latest, fastest and most reliable technology available. This is a technology that combines GSM, Microcontroller and Sensors altogether to achieve the desired result. The design and construction of a pipeline protection circuit addresses the issue of oil pipelines vandalism in Niger-Delta area of Nigeria, this is done by alerting the appropriate security personnel by SMS over a mobile telecommunication network.

Ononiwu *et al.* (2014) designed a real-time oil pipeline anti-intrusion system using acoustic sensors. This approach involves the transmission of audio tones through wires laid along the pipeline. The system consists of a master controller module and three or possibly more slave modules. The master module regularly polls the slave modules for acoustic signals that are transmitted to a computer. This is quite complex and cannot be used without internet.Ezeh *et al.* (2014) implemented an automated crack and vandalism detection alert for pipeline with remote monitoring and location specification. The design circuit consists of transceiver (GSM module), microcontroller, power supply and alarm units. A continuous electrical path was provided by resistant sensor and any break in the signal path causes cessation of signal and provides detectable change in the state of the system. The continuous electrical path is susceptible to failure which can trigger false alarm; the usage of alarm also has a distance limitation as compared with SMS.

Abraham and Nwako, (2015) designed and implemented an Intelligent microcontroller based pipeline monitoring system with alarm sensor. The system is designed in such a way that whenever a leakage is detected in the pipeline, it triggers an alarm and sends SMS to the control unit. The control unit will then use the system interface to ascertain the exact point of the leakage detected for possible action. This design detects leakage as against protection against damage, it is also complex and internet dependent. Obodoeze *et al.* (2014) implemented an automated electronic pipeline vandalism detection and surveillance system with the capacity to detect intrusion into pipeline system before vandalization takes place and send SMS and email alerts to plant operators. It also incorporates video footage by means of a surveillance camera. The intrusion detection using surveillance camera in this design is limited to the range covered by the camera.

This paper presents a design that protects the oil pipelines as well as the protecting circuit itself by sending a message to the authorized personnel. This helps to prevent non detection of vandalism as a result of tampering with the protecting circuit. The design presented here is economical, simple and not internet dependent, it is a proactive circuit design which protects and prevents the oil pipelines against vandalism rather than just detect vandalism which is a reactive measure.

Design and implementation

The Design and Construction of a Pipeline Protection Circuit was actualized using discreet components such as resistors capacitors, transistors etc. It also includes the use of some integrated circuits like a bilateral switch (4066), an operational amplifier (LM324) and an AND logic gate (4081). Finally, the system includes a programmable integrated circuit, a microcontroller. The presence of the programmable integrated circuit makes the system an embedded system. Fig. 1 shows the block diagram.

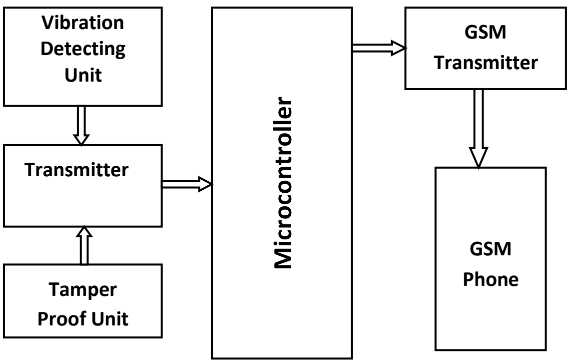

Fig. 1: Block diagram

Power supply unit

This is the circuit that supplies power to the full system. The system has a dual power supply system in the sense that it obtains its power source from two sources. The first is from a 220 volts ac power supply source and then a back up from a 6 volts battery power source, to deliver a 5 volts dc output as shown in Fig. 2. The power source from 220 volts ac is first stepped down into 12 volts ac by the step down transformer. This stepped down ac power fed into rectifier diodes to convert the ac power output into pulsating dc. These ripples would be filtered off by the filtering capacitor and finally, the voltage regulator would keep the output voltage constant.

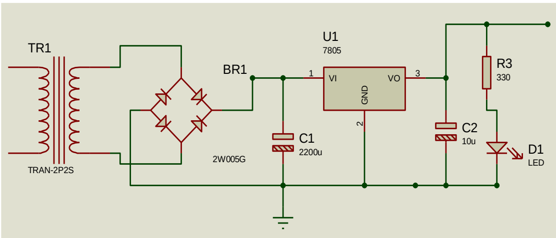

Fig 2: The power supply unit

Vibration detecting unit

This is the circuit that enables the system detect when the pipeline is being vandalized. This system is equipped with vibration sensors that outputs up to 24 volts dc power supply output depending on how it is vibrated. The output of this sensor is coupled to the inputs of operational amplifiers whose outputs are likewise coupled to the inputs of a 2 input AND gate. The final output is fed into the appropriate input of the microcontroller. This is shown below in Fig. 3.

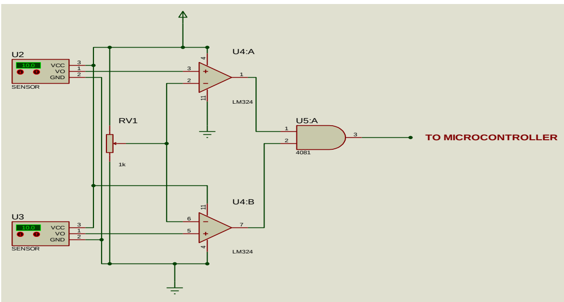

Fig. 3: Vibration detecting circuit

U2 & U3: these are the vibration sensors used. From the datasheet configuration, the output voltage is 24 volts dc @3khz. The output voltage depends on the extent of vibration and is fed into the input terminals of operational amplifiers.

U4a & U4b: these are the operational amplifiers that the sensors inputs are connected into. The operational amplifier used is the LM324 and it is connected in comparator mode. The output of this operational amplifiers were fed into the inputs of an AND gate.

U5a: this is the two-input AND gate that the output of the operational amplifiers fed into.

Tamper proof circuit

Since it is a security based device, a special security feature was placed on the circuit itself in such a way as to detect when the circuit itself is being manipulated. This involves the use of a lone push button switch whose state is known by the program embedded into the ROM of the microcontroller. The circuit diagram is as shown in Fig. 4.

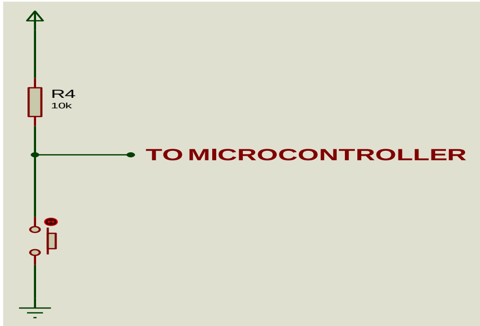

Fig. 4: The tamper proof switch

R4: this is the pull up resistor that the switch uses to send a signal into the microcontroller. Pull up resistors are given a range of values between 1 k to 22 k, a value mid way between the two was chosen, R4 = 10k

Transmitter indicator

This circuit indicates to the user that a message is being transmitted. It is basically an LED that would be blinking in synchronism with the transmission signal as shown in Fig. 5.

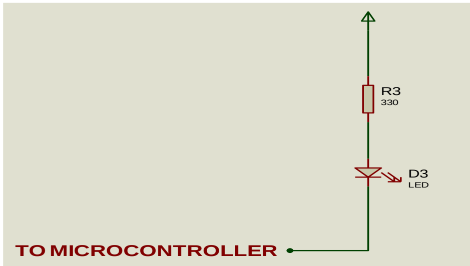

Fig 5: Transmitter indicator circuit

R3: this is the current limiting resistor for the light emitting diode. Its value is obtained as shown

Forward current of…..10×10^{-3}A to 20×10^{-3}A

Voltage drop of…….2V

$R_3 = (Vs\text{-}Vd)/ Id = (5\text{-}2)/10\times10^{-3} = 300\Omega$

GSM transmitter

This is the circuit that the system uses to send the text message to the user's phone. It comprises of bi-lateral electronic switches that are used to push down the necessary buttons to send an SMS to a user as shown in Fig. 6.

U6a TO U6c: these are the bi-lateral switches that are used for the SMS actions. The one used is called CD4066.

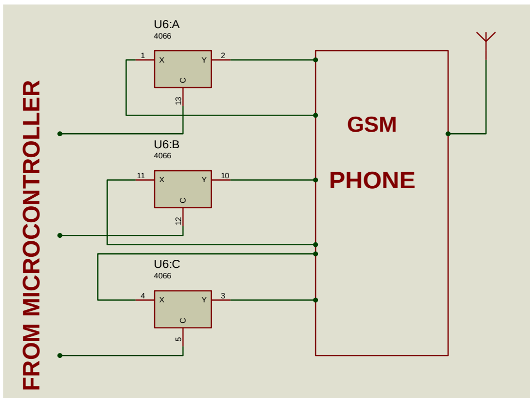

Fig. 6: The GSM transmitter circuit

Mircrocontroller unit

The microcontroller unit is the heart of the system. This is where the program for the control part of the system is written and burned using assembly language and a universal programmer, respectively. The microcontroller circuit diagram is as shown in Fig. 7 while the complete circuit diagram is shown in Fig. 8.

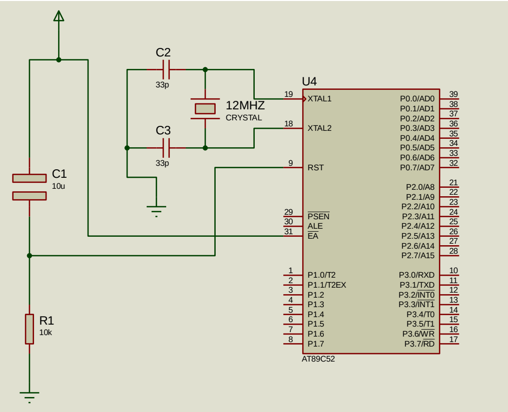

Fig. 7: Microcontroller unit circuit

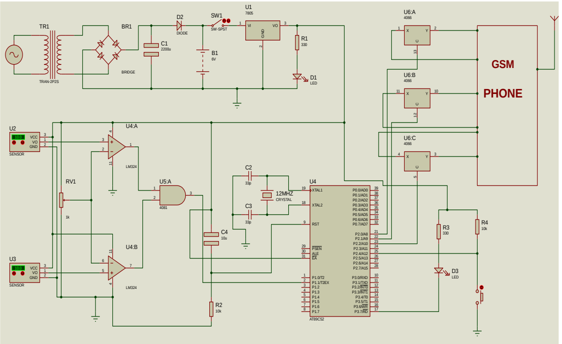

Fig. 8: Complete circuit diagram

Monitoring and testing

The microcontroller based pipeline protection circuit has vibration sensors which are placed on the pipeline to be protected so that the sensor would be triggered when there is an attempt to vandalize the pipeline. The output voltage from the vibration sensors would be too small to be of any appreciable or useful value and to this effect, the differential rise in voltage was used rather than the actual output voltage itself. In other to achieve this, an operational amplifier is connected in a comparator mode. The output of the comparators goes into the input of an AND gate while the output of the AND gate itself goes into the appropriate input terminal of the microcontroller.

The output of the comparators would both be high (5 volts) when the pipeline is not being vandalized and as such, the output of the AND gate would be high and so would the input terminal of the microcontroller. This high signal is regarded by the program, as a normal mode where the pipeline is safe. On the other hand when the pipeline is being vandalized, one or both of the sensors output would go low (lower than the reference of the operational amplifier), then the output of the op-amp would go low, consequently making one or both of the input terminals of the AND gate to go low, this in turn makes the input to the microcontroller to change from high (normal state) to low (abnormal state). This triggers the microcontroller to send SMS via the GSM phone attached whose keypad has been connected to the right combination of switches and in the right sequence.

The whole system is powered using a dual power source, a 220 volts ac power supply as the main power supply source, but the system has an inbuilt back up battery power source. When power comes, the battery is charged; however, when power goes off, the retained charge in the battery powers the circuit.

Results and Discussion

A multimeter was set to ac and used to test the output from the mains. It was then set to dc and used to measure the output from the voltage regulator. The output from the mains registered 216 volts ac on the multimeter screen while the multimeter screen displayed 4.82 volts dc when used to measure the voltage regulator's output. This shows that the required power for the circuit is therefore correct and adequate to power the system. The dc voltage as well as the ac voltage that the rest of the circuit need for their operation is available for use.

The sensor was powered and a multimeter was used to measure the output voltage of the module. It was observed that before the sensor was struck, the output voltage was about 0.31volts. Each time the sensor was struck, the voltage drops to 0.23 volts. This indicates that the vibration sensor responded perfectly to vibration.

When the sensor was struck, it was also observed that the transmitter LED started blinking and after a while, it stopped. Soon after, a text message was received on the user's phone informing of the vandalization in progress and calls for immediate attention as shown in Fig 9. This confirms that the SMS alerting system feature is up and running perfectly to protect the pipeline.

Fig. 9: Pipeline protection alert

Fig. 10: Circuit protection alert

An attempt was made to open the cover of the circuit while the system was in operation. This bridged the tamper proof switch which in turn triggered the transmit LED to start blinking and after a while, a text message was received on the user's phone, informing them of the circuit tampering in progress as shown in Fig. 10. This means that the circuit effectively protects itself.

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