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(FPGA) based design for minimizing petrol spill from the pipe lines during sabotage

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Abstract: Sabotage operations on petrol pipe lines happen all over the world. The saboteurs aim from such operations is to hinder the petrol exportation process. The sabotage operations on petrol pipe lines causes a spilling of a large amount of petrol from the pipe lines. Sabotage of the petrol pipe lines also causes fires and pollution to the environments . Such operations causes a lot of loss in economy to the country concerned where the sabotage took place. This paper sheds the light on this challenging issue to steady and propose an intelligent electronic circuit design solutions to this problem. An electronic circuit design based on using a Field Programmable Gate Array (FPGA) is proposed to reduce to minimum the amount of petrol spilling when a sabotage on the petrol pipe lines happens. A real time sensing and response electronic circuit is implemented to fulfill this task .The system design is programmable (i.e intelligent) and hence the electronic actions established in the design can be modified easily. An electronic interface circuit is deigned to be connected to the (FPGA).The task of the electronic interface circuit is to acquire data from the sensors installed on the petrol pipe line and to give commands to the electronic and electrical devices to stop the pumping operation and to close the petrol pipe line immediately. Many electrically controlled pipe closing valves are to be installed along the pipe line. These electronic closing valves are remotely controlled by the embedded system based on the (FPGA).

Keywords : FPGA , VHDL , ASIC , PLD , embedded system , petrol pumping , petrol pipe line , interface circuit , smart sensors.

I. INTRODUCTION

The field programmable gate array (FPGA) is an integrated circuit designed to be configured after manufacturing. The FPGA configuration is generally specified using a verilog hardware description language (VHDL), similar to that used for an application-specific integrated circuit (ASIC). FPGAs can be used to implement any logical function that an ASIC could perform.

FPGAs contain programmable logic components called "logic blocks", and a hierarchy of reconfigurable interconnects that allows the blocks to be "wired together"—somewhat like many (changeable) logic gates that can be inter-wired in (many) different configurations . Logic blocks can be configured to perform complex combinational functions, or merely simple logic gates . In most FPGAs, the logic blocks also include memory elements, which may be simple flip-flops or more complete blocks of memory.

There are numerous options for designers in selecting a hardware platform for custom electronics design, ranging from embedded processors, application specific integrated circuits (ASICs), programmable microprocessor, FPGAs to programmable logic devices (PLDs). The decision to choose a specific technology such as an FPGA should depend primarily on the design requirements. Therefore, if the hardware requirements require a higher level of performance, then the FPGA offers a suitable level of performance. [4]

The definition of the behavior of the FPGA is performed by programming it by a very high speed integrated circuit hardware description language (VHDL).[1]

This paper deals with using the embedded system based on the FPGA as a means for minimizing the crude oil spilling when a sabotage operation occurs. The FPGA is programmed to offer real time sensing and control of petrol pumping in addition to closing the nearest electronic valve on the petrol pipe when sabotage occurs .In the normal petrol pumping operation , the FPGA senses the conditions of the petrol pumping pipe in order to offer secure pumping .Wireless smart sensors are mounted on the petrol pumping pipe. The aim of the design is to mainly avoid pipes damage or explosion due to mal functions of pumping in addition to the immediate closure of the pipe when sabotage occurs .

II. PROBLEM STATEMENT

Minimization of petrol spilling from the pipe is a challenging issue .A proposed solution is based on using multi-sensing control system based on FPGA . The embedded system gives a real time response based on the data acquisition from the wireless smart sensors mounted on the pipe . The high speed of processing of the FPGA offers an instantaneous response for any data coming from the smart sensors.

III. METHODOLOGY

This paper explains the approach for the design based on the FPGA platform .The aim of the complete design is to offer maximum safety for the petrol pumping process plus minimizing the petrol spilling when sabotage occurs. A closed loop control system design is adapted . A number of smart sensors are installed on the petrol pumping pipe . The smart sensors provide the FPGA with an instantaneous data showing the status and condition of the pipe .The sensors are connected to the FPGA through a data acquisition interface circuit designed to provide the data . According to this design the FPGA will be able to monitor and control the petrol pumping process instantaneously. Hence the embedded system offers a real time monitoring and control for the secure petrol pumping and sabotage operations. The following block diagram figure (1) shows the basic parts of this design.

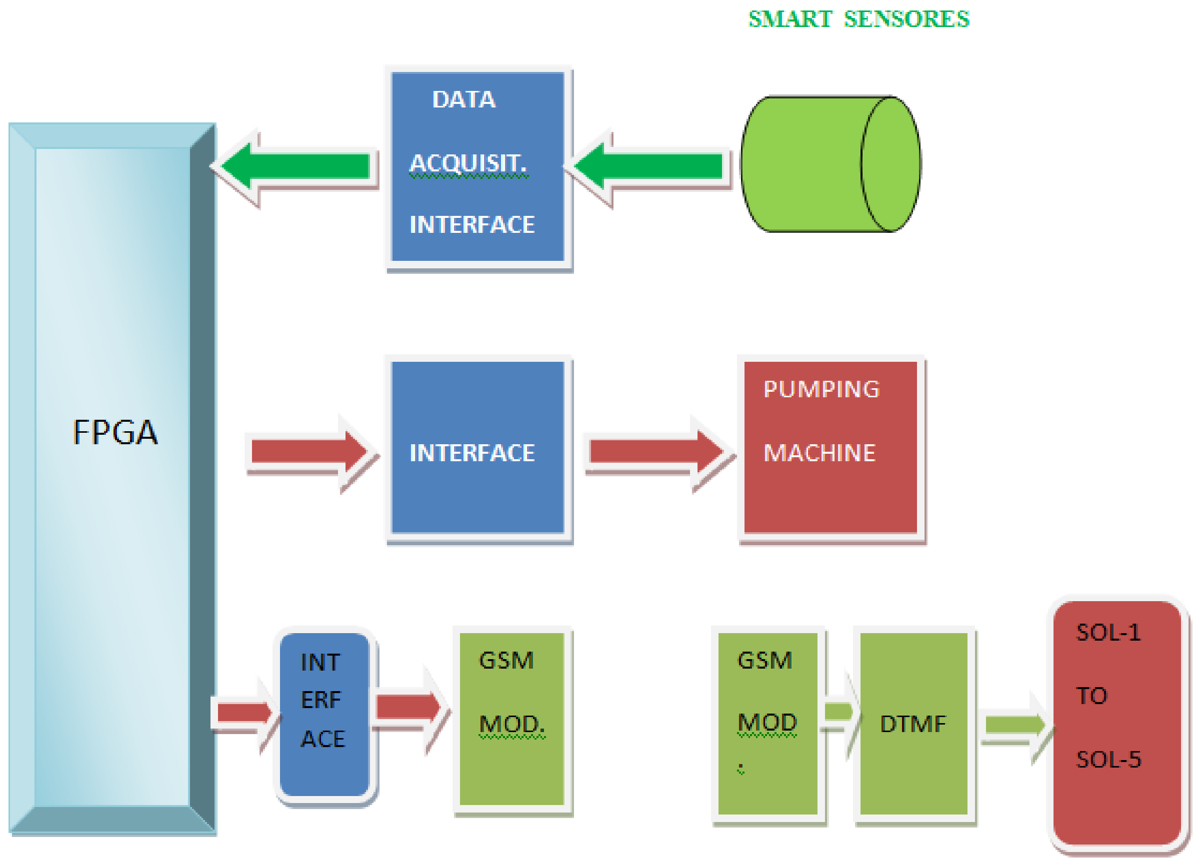

Figure (1) Block diagram for monitoring and control of the petrol pipe.

The proposed model assumes the installation of five solenoid vales (SOL-1 to SOL-5) and five rate of flow sensors (R1 to R5) are to be installed on the petrol pumping pipe are shown on figure (2) below. The spacing between a pair of solenoid valve plus rate of flow sensor and the other pair on the pipe is assumed to be equal to one meter. The solenoid valves are controlled remotely by the embedded system. The rate of flow sensors are wireless sensors. A (DTMF) electronic circuit is used to control remotely the operation of the solenoid valves. Once saboteurs attack the petrol pipe line , the system responds immediately by stopping the pumping and closing the nearest solenoid valve to the leakage of petrol .The same thing happens when an accidental leakage in pipe happens.

Figure (2) A pipe line model mounted with five pairs of solenoid valves plus rate of flow sensors.

The electronic circuit components of the design are :

- Field Programmable Gate Array (FPGA) .
- Smart temperature sensor.
- Smart pressure sensor.
- Smart rate of flow sensor.
- Data acquisition interface circuit (Buffer SN74373).
- Interface circuit to control the pumping machine (Buffer + Darlington amplifiers ULN2003).
- Interface circuit to control the electronic valves on the pipe line (Buffer + Darlington amplifiers).
- Dual Tone Multiple Frequency decoder (DTMF 8870).
- GSM modem.
- Solenoid valves.
- Pumping machine.

IV. OBJECTIVES

The objectives of the design are :
1.Development of a computer program in VHDL language. **2.**
Downloading the program into the FPGA. **3.**
The task of the program is to perform a real time multi-sensing monitoring and control for secure pumping of petrol in the pipes.
4. The embedded system senses the sabotage operations and the program immediately stops the pumping operation and closes the nearest valve on the pipe.

SOFTAWE PROGRAM & ALGORITHM:

To achieve the objective of the real time monitoring and control of petrol pumping operation and closing of the valves on the pipe , we need to go through five steps as follows:

1. Step one is developing a VHDL program in the computer by using Spartan-3 software .
2. Step two includes VHDL synthesis in the design, which converts the design in the behavioral description file into gates. The synthesis tools figure out what gates to be used based on the VHDL program file.
3. Step three includes downloading of the program into the FPGA as shown in figure (3).
4. Step four includes integration of the embedded platform with the smart sensors , data acquisition , interface circuit , solenoid valves and the pumping machine as shown in figure (1).
5. Step five includes testing and debugging the operation of the whole system .

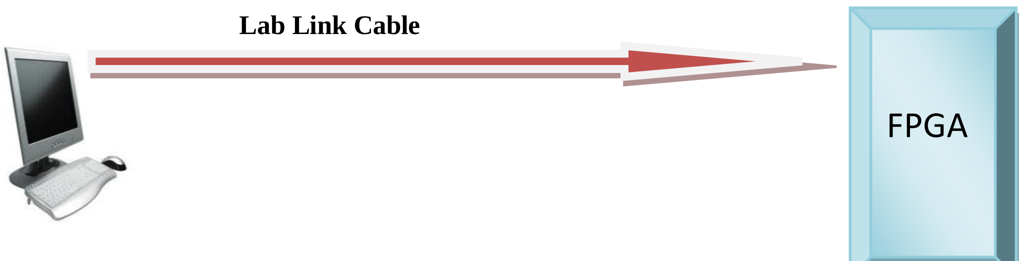

Figure (3) Connection for programming the FPGA

The algorithm for performing a real time monitoring and control of petrol pipe contains four subroutines . The condition for calling the subroutine depends on the values acquired from the smart sensors .If the values are normal ,standard subroutine will be called . If the rate of flow sensor readings are abnormal due to petrol leakage , a sabotage subroutine will be called. The algorithm is :

Start
Initialization :
--- Clear all output control signals.
Check incoming data:
--- Check the incoming data from data acquisition interface circuit-1.
--- Analyze the incoming data.
--- If the [(Rate of flow is NORMAL), then call standard pumping subroutine.
--- If the [(Rate of flow is ABNORMAL), then call sabotage subroutine.
--- Go to check incoming data .

End.
Standard pumping subroutine :
Start:
--- Set the petrol pumping machine to the standard RPM based on the specifications of the pipe (1000 RPM).
Return.

Sabotage subroutine :
Start:
--- Shut down the petrol pumping machine (0 RPM).

Analyze leakage location:
-- If the [(R1 > R2) & (R1 > R3) & (R1 > R4) & (R1 > R5)], then close solenoid valves (SOL-1,2).
-- If the [(R2 > R3) & (R2 > R4) & (R2 > R5)], then close solenoid valves (SOL-2,3).
-- If the [(R3 > R4) & (R3 > R5)], then close solenoid valves (SOL-3,4).
-- If the [(R4 > R5)], then close solenoid valves (SOL-4,5).
-- If the [(R5 > R4)], then close solenoid valve five (SOL-5).
--- Operate the emergency alarm siren for one minute.
Return..

FPGA connector A1 is programmed for data acquisition from the smart sensors on the pipe.
FPGA connector A2 is programmed for data output to control the RPM of the petrol pumping machine.
FPGA connector B1 is programmed for data output to control the five solenoid valves on the petrol pumping pipe.

V. RESULTS

The FPGA is the right choice for the operation of petrol pumping process despite its high cost relative to other processors .The FPGA has huge facilities to control systems according to its ability to execute the commands in a parallel way. This criteria widens the range of controlled elements with less delay time. The same thing in VHDL language, in spite of its complicated language, but it is the right choice to program complicated control systems. It is suitable for a system that needs fast execution of commands.
.The designed monitoring and control system is a real time system. It operates and responds according to the data values acquired from the smart sensors.
Table (1) below shows the results of operating the system.
Equation (1) to (6) show the conditions for the activation of the five solenoid valves and pumping shut down operations.

(SOL-1,2)closed = [(R1 > R2) & (R1 > R3) & (R1 > R4) & (R1 > R5)]….. (1)
(SOL-2,3)closed = [(R2 > R3) & (R2 > R4) & (R2 > R5)] ……………… (2)
(SOL-3,4)closed = [(R3 > R4) & (R3 > R5)] ………………………………..(3)
(SOL-4,5)closed = [(R4 > R5)] …………… ………………………… …. (4)
(SOL-5)closed = [(R5 > R4)] …………………….. …………………….. (5)
SHUT DOWN (RPM = 0) = (R >> HIGH) ………. ………………… ……..(6)
Where;
R1 – R5 = Rate of flow sensors..
RPM = Revolution per minute .

Table (1) Results of operating the system under all possible conditions.

R	D	SOL-1	SOL-2	SOL-3	SOL-4	SOL-5	PUMP
NORMAL							ON
ABNORM.	(D >1 m.) AND (D <2 m.)	CLOSED	CLOSED				OFF
ABNORM.	(D >2 m.) AND (D <3 m.)		CLOSED	CLOSED			OFF
ABNORM.	(D >3 m.) AND (D <4 m.)			CLOSED	CLOSED		OFF
ABNORM.	(D >4 m.) AND (D <5 m.)				CLOSED	CLOSED	OFF
ABNORM.	(D >5 m.)					CLOSED	OFF

Note: R = Rate of flow , D = distance to leakage , SOL-1 = solenoid valve one , SOL-2 = solenoid valve two , SOL-3 = solenoid valve three , SOL-4 = solenoid valve four , SOL-5 = solenoid valve five

VI. CONCLUSION

A problem usually has multiple solutions, and a process can usually be controlled using different controllers based on different methods. Almost every control method has its merits and weaknesses. What is important is to use the right controller to fit the application at a minimum cost.

In the recent years, there has been a technical revolution in the semiconductor industry and in the electronics industry, which has significantly developed the existing technologies in industrial control.

This technical development in both the semiconductor and the electronics industries have evolved industrial control into both real-time control and distributed control. Real-time control requires controllers to capture all the significant target activities and to deliver their responses as swiftly as possible so that system performance is never degraded.

The (FPGA) have now approached intelligence similar to that of microprocessors, so that they are performing more important functional role in various control systems. This paper dealt with the implementation of an embedded system design for minimizing the petrol leakage when sabotage occurs . .

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