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PROGRAMMABLE LOGIC CONTROLLER (PLC) - BASED RADIATION AREA ACCESS CONTROL AND WARNING SYSTEM

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ABSTRACT

Radiation from radioactive particles causes intensive harm to lives, depending on the intensity and type of the radiation. Various types of cancer leukemia can occur due to radiation. So nuclear power plants or the laboratories for nuclear research works need well apprehensible

Introduction

We are constantly exposed to radiation, whether from natural or man-made sources. Radiation consists of energy and particles that are given off by unstable atoms as part of a natural process to become stable or generate during the operation of high energy devices (e.g., accelerators) (Podonsky, 2012). When we are exposed to radiation from the work we do, care is taken to protect against biological damage to the cells and DNA (genetic material) of our body, as well as risk of illness using engineered controls and by establishing regulatory controls. Fortunately, such risks are minimal at normal background radiation levels, at typical levels of medical exposure, and at

system that has the ability to deal with an emergency evacuation arrangement. This paper present the design and simulation as well as hardware configuration of a PLC-based access control system with emergency evacuation warning such that if the radiation level exceeds a critical threshold, the warning message will alert occupant to take their exit through one of the available doors.

Keywords: *Radiation, access control, Logo soft, Logo PLC*

occupational exposure levels allowed by regulations (Podonsky, 2012).

One of the main concerns regarding the quality of the environment, and consequently, the life quality, is related to the environment pollution and the level of radiation, especially, in urban regions, in areas with nuclear power plants, and in other contaminated locations. Due to security reasons, several modern radiation monitoring systems were developed in the last decades, most of them for nuclear plants (Storch, et al., 2008). In the recent years a new technology was proposed for the development of intelligent environmental monitoring systems, the wireless sensor networks

Stationary radiation monitoring and warning systems are used in the environmental protection field for a defined perimeter, for identifying, isolating and later containing of contaminated sources. For example, radiation monitoring is used in industry for high speed grinding machine cutting heads, which incorporate a radioactive element, and the cutting head wear is signaled by an increase in normal background noise (Oliveira and Goncalve, 2010). The systems reported in the literature are specific to laboratory environments and consist in a microcontroller-based monitoring unit and a desktop-computer-based data acquisition unit (Kim, et al., 2008), (Lewis, 2004).

To control machines in industries, one of the conventional systems was the combination of sequential relay circuits (Kevin, 1998), (Steven, 1997). Programmable Logic Controller (PLC), superseded the place of sequential relay circuit's for the urgency of automation. This microprocessor-based device with programmability enabled changes to be effected considerably faster. The PLC works by taking logic from its inputs and depending upon their states, turning on-off its outputs.

Programmable logic controllers (PLCs) found applications in control, monitoring and protection of nuclear reactors in nuclear power plants (Vasile and Oprea, 2012). Several characteristics set PLCs apart from other programmable electronic systems (PESs) or computer systems: they use a deterministic operating system, their primary interfaces are digital and analog sensors and actuating devices (Kossiloy, 1995), and they typically allow programming to be done with ladder logic diagrams. These diagrams allow the design of the logic of the system to proceed using the traditional ladder logic method of expressing the logic of the system.

However, as these systems have evolved, they have begun to include other programing methods. PLC systems are beginning to resemble other general purpose industrial digital control systems as the distinctions between them have begun to blur (Vasile and Oprea, 2012).

PLC equipment is designed to withstand severe environmental conditions (dust, moisture, high temperature limits, heat, and cold) and has a high degree of immunity to electrical noise and high resistance to vibration and impact (Paloma and Wyman, 1993).

The Digital Radiation Monitoring System is designed to measure the absorbed dose rate as well as to monitor gamma field levels in different places within a nuclear site (Glenn and Podonsky, 2012).

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Such a digital measurement system contains a number of four detection assemblies located in the monitored areas, primary processing blocks, threshold comparators, a given acquisition block, a sound and visual alarm block, and a central station with a PC (Stana, et al., 2019).

DESIGN

a. Design requirement

- LOGO Soft Comfort V8.0
- The Siemens LOGO PLC [Type - 6ED1 052-1MD00-0BA5, RS 488-6498]

This LOGO PLC has the following features:
1. Four relay outputs
2. Eight digital inputs, two of which can be configured as analogue inputs.

So, the design was considered to have:
1) 3 relay outputs
2) 1 analogue input, 4 digital inputs
3) 4 timers, 7 counters, 2 display systems

b. Design Assumptions:

The design was carried out based on the following assumptions

It was assumed that, there were four research rooms in the laboratory and three evacuation doors. Among the four research rooms, one didn't have the ADC, and considered as analogue input alongside the radiation level detection sensor and this room is nearer to the gate no: 1, that's why at the evacuation moment, display would prescribe to use the gate no:1 for the room no 1. The other three rooms had the ADC and the display would prescribe to use the gate no: 2 Or 3. Gate no: 3 will be used in access control as well.

c. Design of the Access Control:

For access control, digital input I4 was considered dedicatedly. It was assumed that, every person working in the LAB had an access card. This card would be used to get access to the LAB. After swapping the card, the gate would stay opened for five seconds. After this time, the gate would close automatically. Gate-3 will be used for this purpose considering it as the main entrance. The gate normally stay closed, until a valid card is swapped to open it. One second delay is allowed before gate open. Table 1 shows the states of the access for corresponding input and output.

State	Input -I4	Output - Gate3	Time Delay
1	1	1	1 sec.
2	0	0	5 sec.

Table 1: States of access module

Input section of this system was designed with one digital input (i.e I4), one counter, one AND gate and a timer. The output section of this module shared Gate 3 with the other module with an OR gate. The output Q3 goes to high after one second, the following figure depicts the access control system as designed using logo soft.

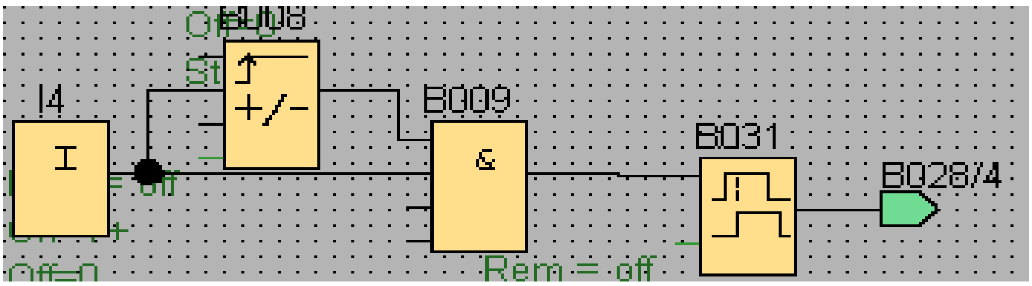

Fig 1: Access control system.

After swapping a valid card (I4 on), Q3 comes on after a delay of one second (indicating gate opening). The output (Q3) goes OFF after five seconds (indicating automatic gate closure after a delay of 5s). The same process applied when going out. The configuration of a time that accomplishes this task is as shown in figure 3.

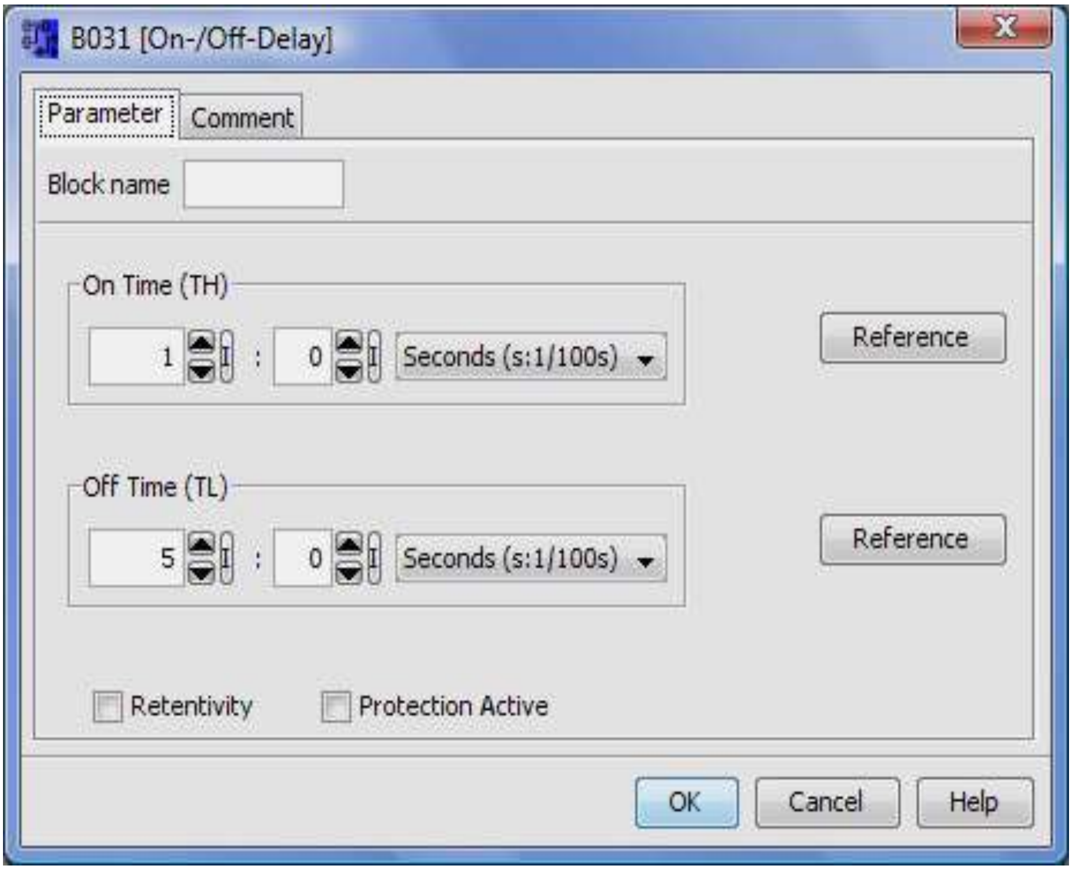

Fig 2: Access control timer (BO31) configuration

d. Evacuation System Design:

This part was designed using one analogue input (AI), three digital inputs (I1, I2, and I3), two displays (Display 1 and Display 2), and three gates (Gate1, Gate2 and Gate3). Table 2 shows the logic behind the evacuation system.

The evacuation system comprises of three gates (or doors). Each gate was designed with one timer and one counter module. All the three gates used the same combination. The counter would notify the number of times a gate was opened. Figure 4 shows the counter record that gate 1 was opened 2 times.

Radiation Alert !!! Go to Door No: 1

Radiation Alert !!! Go to Door No: 2 Or 3

Input				Output				
Analogue Input	Digital Input							
AI	I1	I2	I3	Display 1	Dispaly2	Gate1	Gate2	Gate3
<10(0)	0	0	0	0	0	0	0	0
>=10(1)	1	0	0	1	0	1	1	1
<10(0)	0	1	0	0	1	1	1	1
<10(0)	0	0	1	0	1	1	1	1
<10(0)	0	0	0	0	1	1	1	1
>=10(1)	1	1	1	1	1	1	1	1

Table 2: Truth Table of the system Inputs and Outputs (**Evacuation**)

Here it was considered that, if any of the four radiation sensors would go over the minimum levels, all the three gates would be opened in serial, with a delay of 1 second after each other along with the displays, though they have their different display systems.

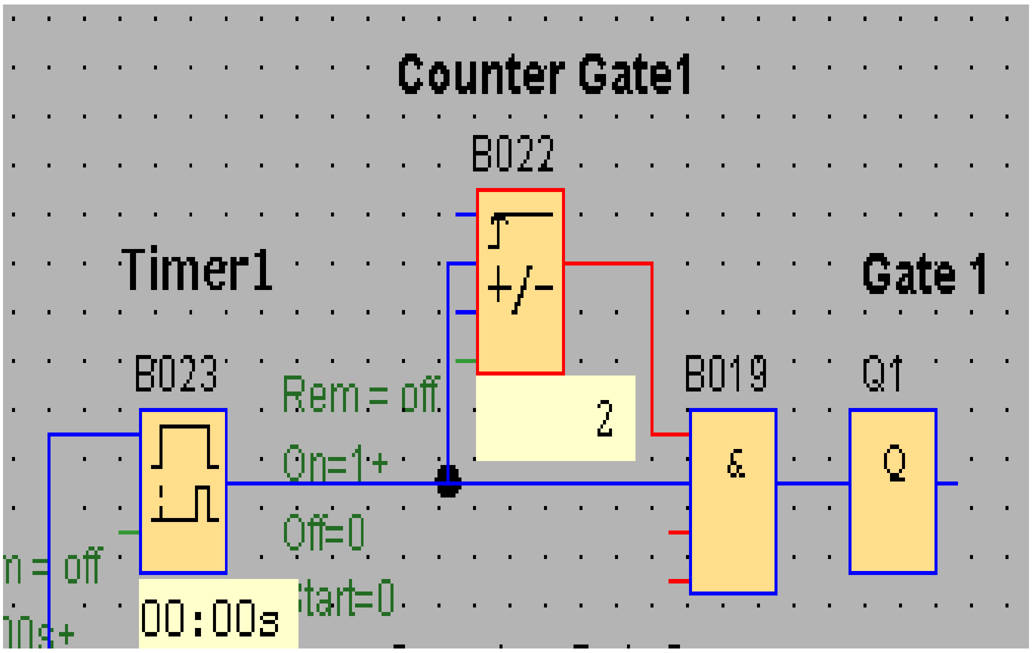

Fig. 3. Evacuation circuit diagram

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Evacuation flow chart:

The figure below depicts a flow chart describing the safe evacuation procedure.

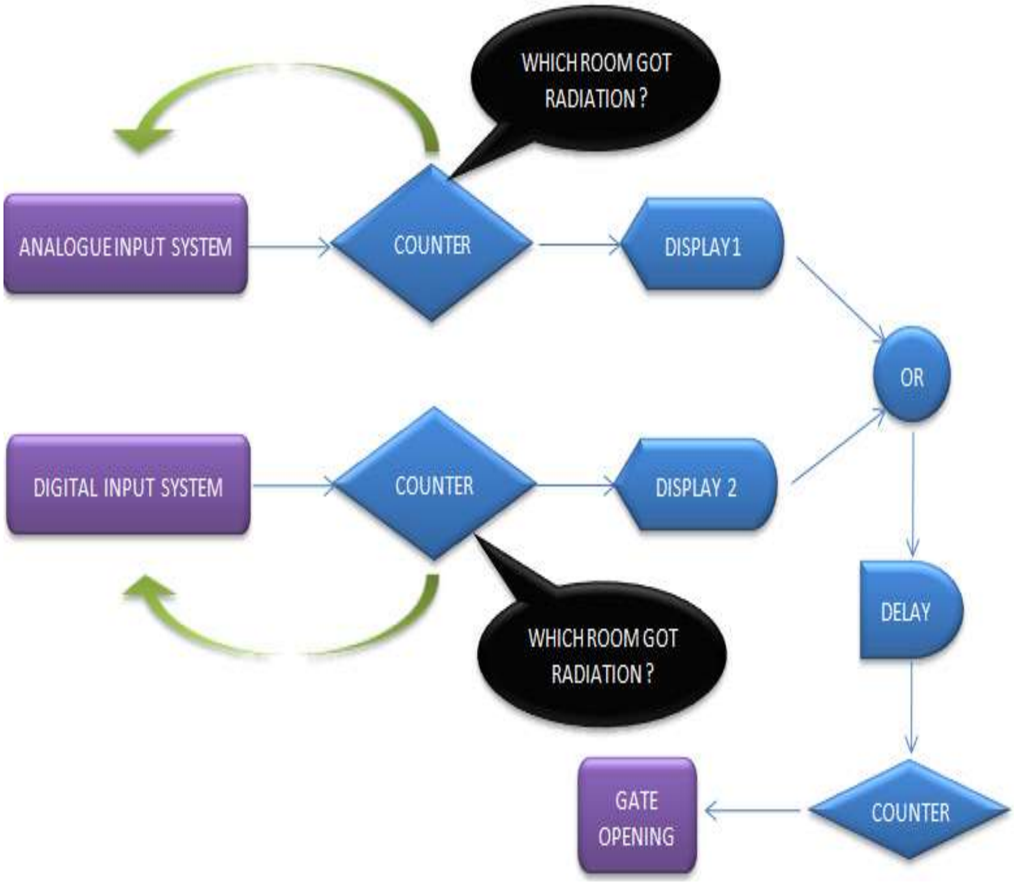

Fig 4: Flow chart for emergency evacuation system.

The complete system design using logo soft functional block diagram (FBD) is as shown in figure 5 below.

The entire system could be divided into some sub-system or module as listed below:

1) Analogue input
2) Digital input
3) Counter
4) Display
5) Timer
6) Evacuation

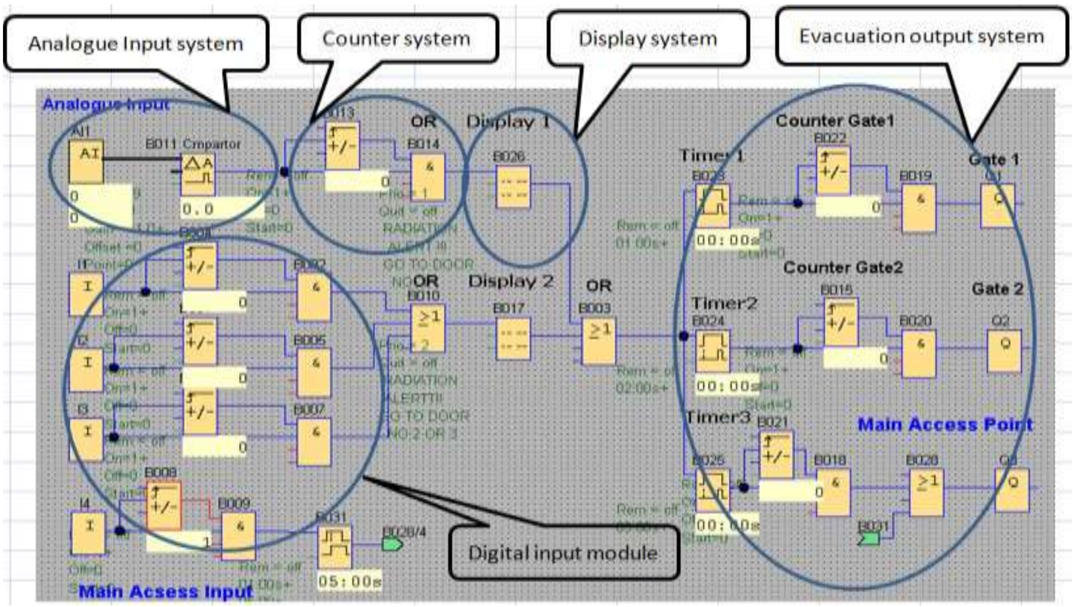

Fig 5: System Circuit Diagram (Modules of the design)

e. Details of other sub-sections

Analogue Input:

The analogue input was connected to the output function through OR gate, and has a comparator attached to it. The analogue input was set to a threshold value of 10 but could take value up to 1000. The comparator compares radiation level with the threshold value and trigger display if radiation exceeded threshold value. Figures below shows active and inactive modes of the analog module.

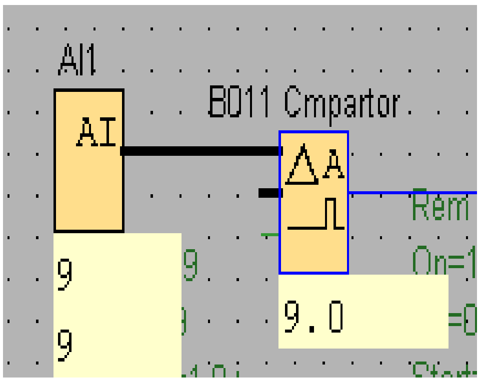

Fig 6: Analogue Input system (Off mode)

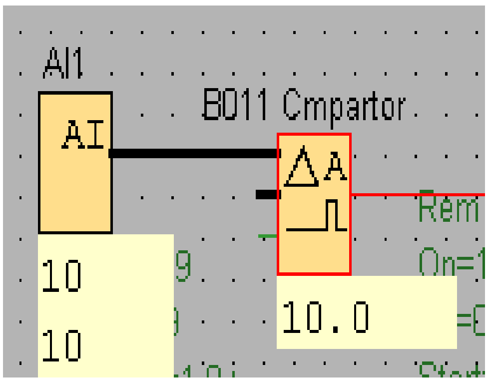

Fig 7: Analogue Input system (On mode)

Display module:
Display system was used to notify the residents of the rooms about radiation and through which gate they should take their exit. Residents of the room that has analog sensor would be asked to use the door no. 1. Other room's residents would go to the door no 2 or 3. The following figures reflect the resemblance. Here it could be said that the priority was set high (1) for the door no 1 and low for the door no 2 or 3.

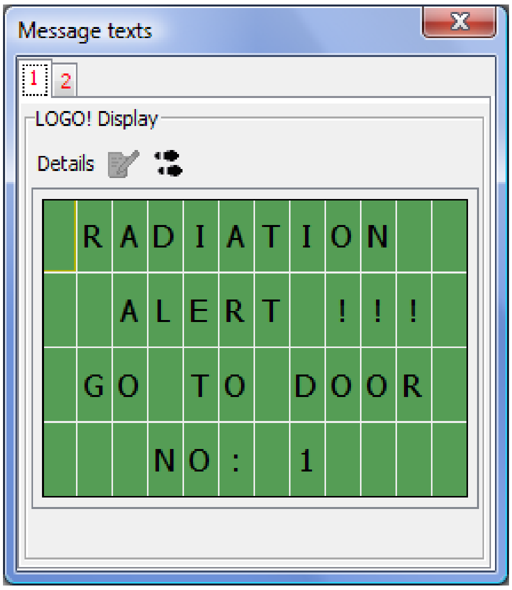

Fig 8: Display 1, For Room 1

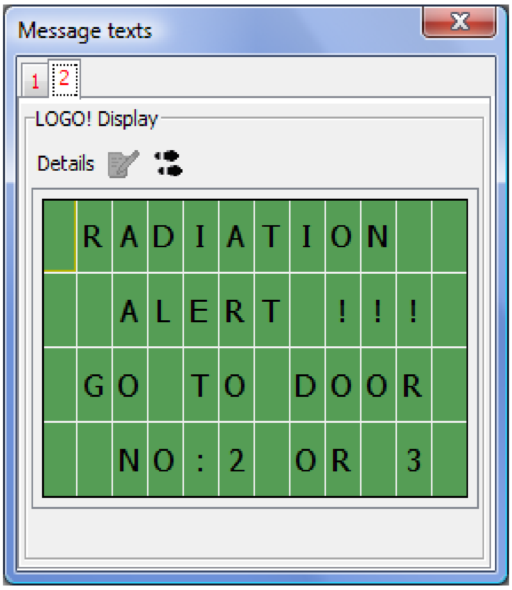

Fig 9: Display 2, For Room 2 or 3

TESTS AND RESULTS
The following are a number of tests carried out to confirm expected outcomes. These tests include simulations and practical.
Tests were divided as follows:
1. Access Control Test (With LOGO Soft) [development work]
2. Analogue input Test (With LOGO Soft)
3. Analogue input Test (With LOGO PLC)
4. Digital input Test (With LOGO Soft)

5. Digital input Test (With LOGO PLC)
6. Simultaneous Analogue and Digital Input Test (With LOGO Soft)
7. Analogue and Digital Input Test (With LOGO PLC)

Access Control Test (With Logo Soft)**:**
Output (Q3) turned on after putting input (I4) high, after one second (fig 10 & 11).

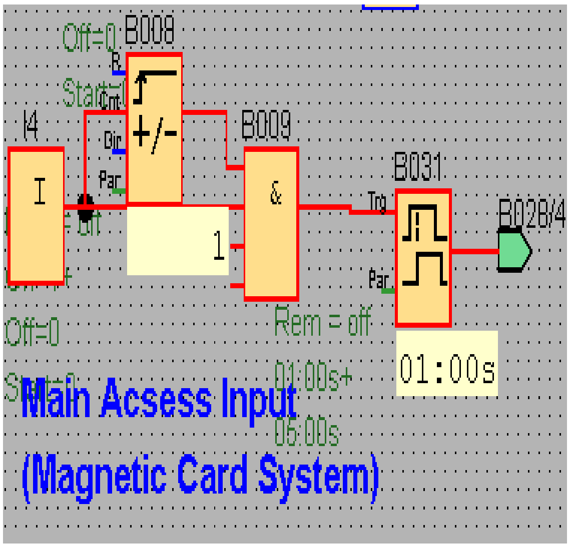

Fig 10: Input I4 = 1

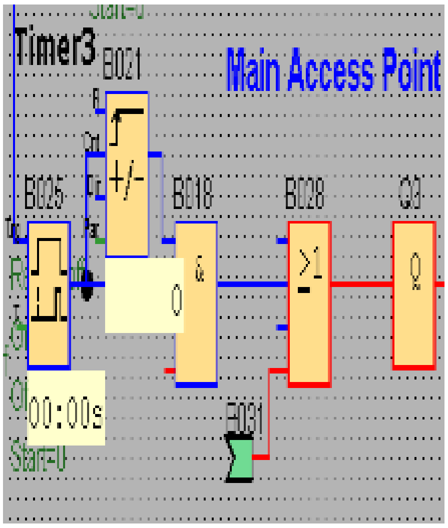

Fig 11: Output.

The output turned off after five seconds (as shown in fig. 13) when the input was turned off. Here it should be noted that the counter in fig. 12 was not incremented because I4 as input functioning only as the access controlling system, not the evacuation system.

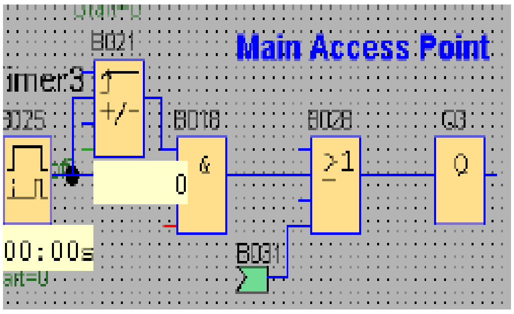

Fig 12: Input I4 = 0.

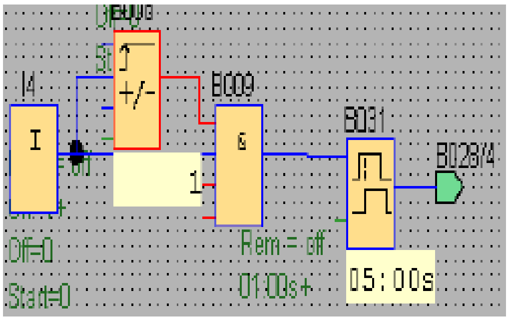

Fig 13: Output.

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Analogue Input Test (With Logo Soft)

At threshold level of 10 (max), radiation alert appears and at the same time the gates opened having 1 second time delay each, figure 14 shows the radiation alert at threshold.

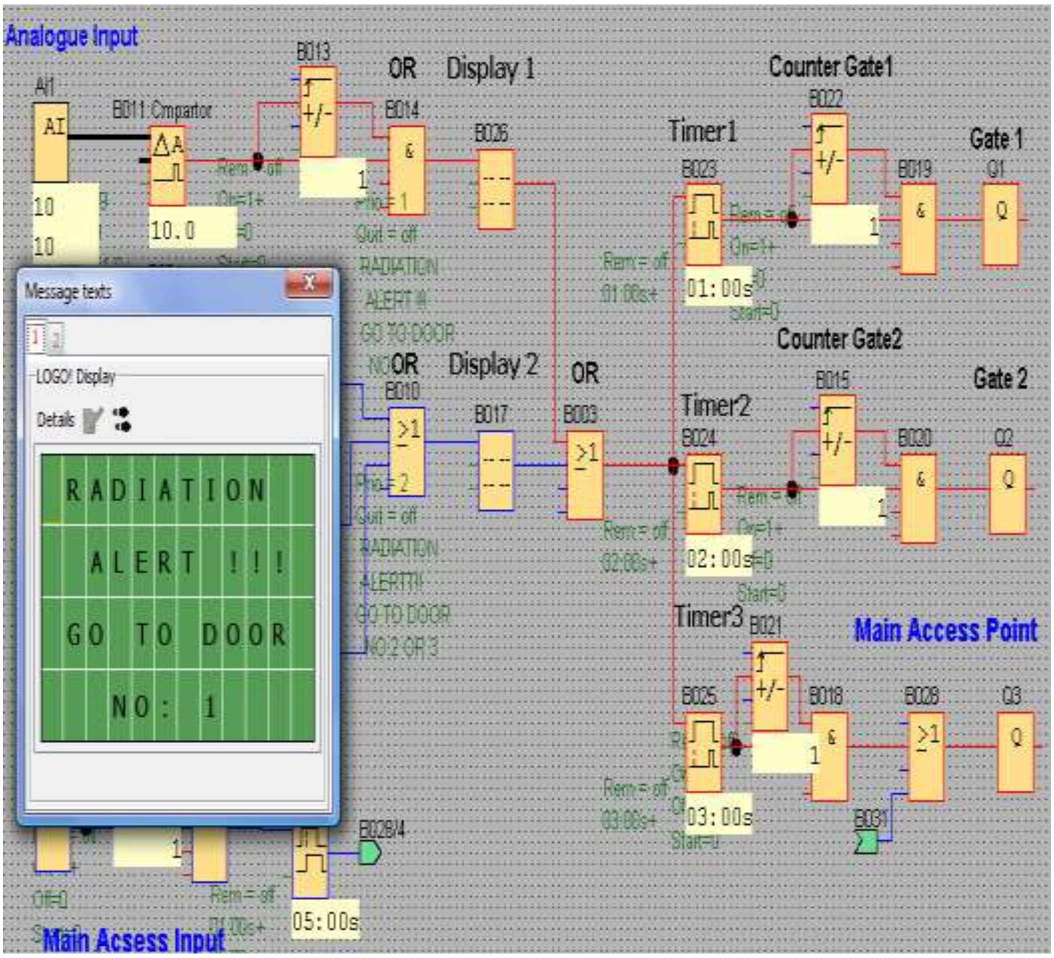

Fig 14: Analogue input test

Analogue input test - (With LOGO PLC)

This test was carried out with Siemens LOGO PLC. The blue analogue input button was tuned to the highest value (max.) (the threshold), as a result the warning message appears as depicted in plate 1. The three LEDs were lit which indicates that three of the evacuation doors would be opened. Figure below shows the results of the test as explained.

Plate 1: Analogue input Test (AI=10)

Digital Sensor Test (With Logo Soft**)**
When the digital input system like I1, turned high, it was found that the three gates (3 lamps) were opened one after another at a delay interval of one second each.

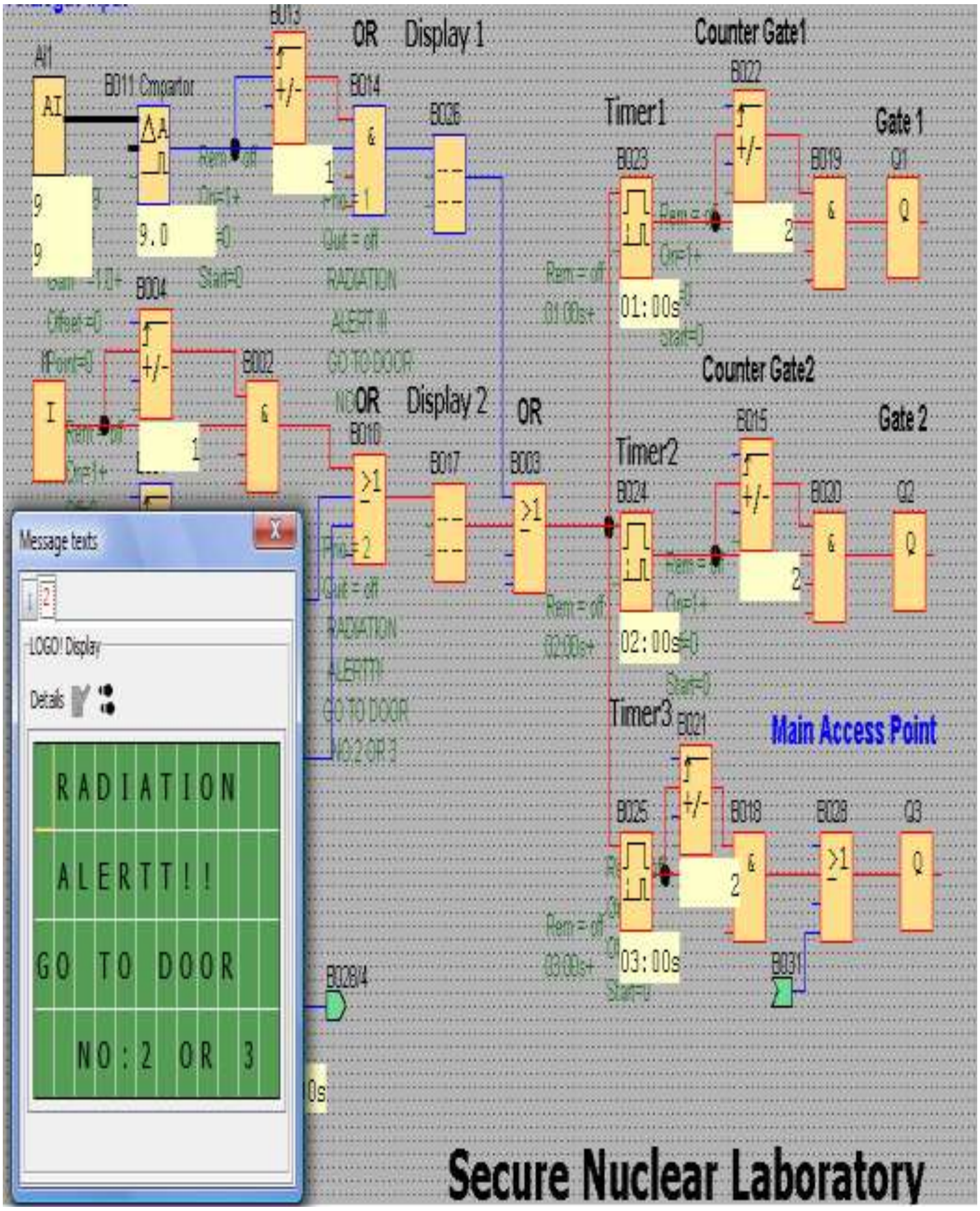

Fig 15: Digital Sensor Test

Digital Sensor Test (With LOGO PLC)

This test was done with the digital input I4 (At the time when Access control was not made). Though I4 now is being used as access control input system, previously I4 was used as digital sensor and to test with LOGO PLC, plate 2 shows the PLC under test.

Plate 2: Digital Sensor Test (I4 = 1)

Simultaneous Analogue and Digital Input Test (With Logo Soft)

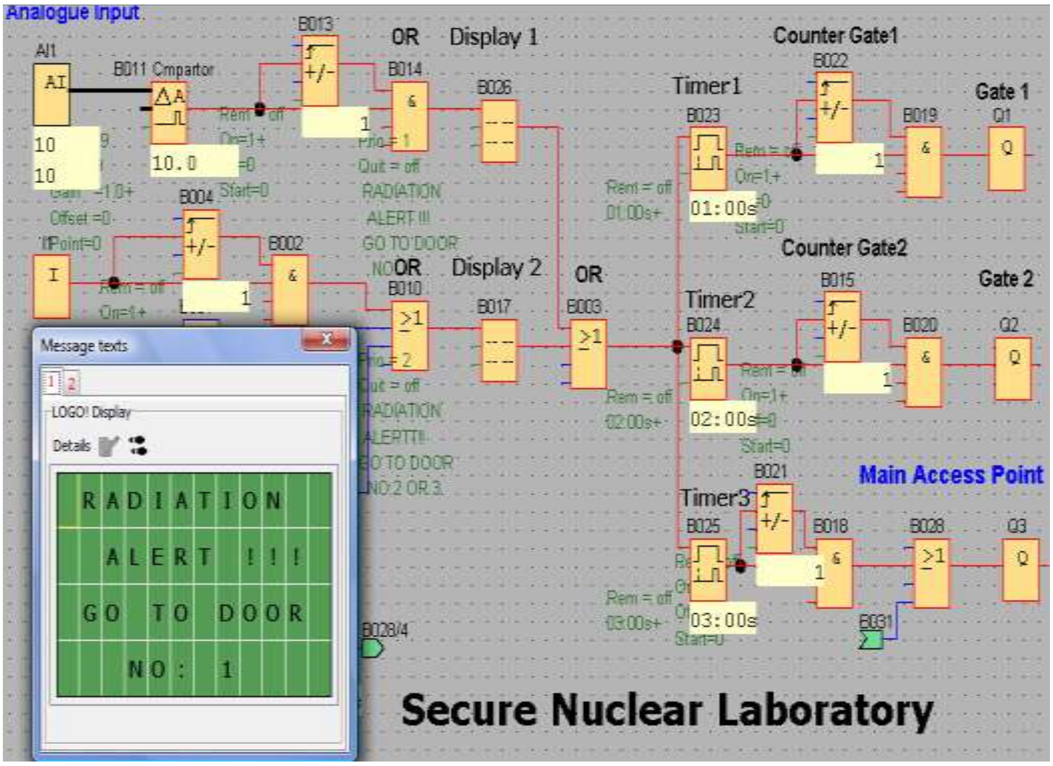

Fig 16: Simultaneous Analogue and Digital Input Test (With Logo Soft)

Initially the analogue input was turned on, the three gates were opened, counter for gates were displaying the number of opening, in this case 1 (the first time), the display 1 was enabled. After some time, I1 (one of the digital inputs), was turned on. In that case the counter for gates were not counting again, as because they (gates) were opened before but the display system 2 was enabled, shown in figure 21. So the analogue and digital system are enabled to control the evacuation system mutually having no difficulty.

Summary of Results

The following table summarises the results of all important tests carried out. Tests that were not very much important were labeled ND (not done). Some areas in the table were labeled NR (not

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related) indicating that the particular test is not related to the particular part of the system were NR was placed.

	Test Title	Input System		Output System					
				Gates				Display System	
		Counter	Timer	Gate1	Gate2	Gate3	Timer	Display 1	Display 2
1	Access Control Test (In PC)	✓	✓	NR	NR	✓	NR	NR	NR
2	Access Control Test (In LOGO PLC)	ND	ND	ND	ND	ND	ND	ND	ND
3	Analogue System Test (In PC)	✓	✓	✓	✓	✓	✓	✓	NR
4	Analogue System Test (In LOGO PLC)	✓	✓	✓	✓	✓	✓	✓	NR
5	Digital System Test (In PC)	✓	✓	✓	✓	✓	✓	NR	✓
6	Digital System Test (In LOGO PLC)	✓	✓	✓	✓	✓	✓	NR	✓
7	Simultaneous Analogue and Digital Input SystemTest (In PC)	✓	✓	✓	✓	✓	✓	✓	✓
8	Simultaneous Analogue and Digital Input SystemTest (In LOGO PLC)	ND	ND	ND	ND	ND	ND	ND	ND
	Acronyms	**ND:** Not Done; **NR:** Not related; ✓ Expected output ✗ Unexpected Output							

Table 3: Summary of results

Conclusion

Having completed the task, it was conceded that all of the variables (type of inputs/ outputs and the functionalities) were the key criterion to a complete success in developing an access control system with emergency evacuation. Knowledge of properties of these key variables has help in making decisions as well as maximizing functionality to plummet down long-term costs. Simulation provision before implementation of a huge system has made the design process more flexible and cost effective. The most transcendent phenomenon was the 'Automatic PROGRAM', build by the 'LOGO Soft' which made the whole work really straightforward and time saving. Results obtained from simulations and hardware test revealed the reliability of the design. Hence the system can be employed in a nuclear power plant for radiation area access control and evacuation alert.

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