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A Simple Experimental Programmable Logic Controller Based Belt Conveyor for Technicians Training, Industrial Applications and Economic Advantages

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ABSTRACT

Logic controller based belt conveyor provides a means of controlling a conveyor belt using programmable logic controller (PLC). This paper presents an experimental view on how an industrial conveyor can be controlled and monitored by sensor. The developed system allows the user to control the conveyor automatically by sensing the objects when the conveyor is filled up to a particular level and self-unloading bulk freighters and in live bottom trucks. It is considered a labour saving system that allows large volumes to move rapidly through a process. Also by using optical sensor this helps to regularize the filled up level and the decongestion of the conveyor automatically. Thus from the design and implementation of a programmable Logic controller based belt conveyor, users can save the power of motor operating the conveyor by regulating the conveyor automatically. The paper concluded with a discussion on industrial applications, economic advantages and recommended that the training of technicians should include modern technology in PLC control; this will reduce human labour and boost industrial production and the nation economy.

Key Words: Application, Conveyor, PLC, Technicians

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1. Introduction

In the past, humans were the main Method for controlling a system. More recently electricity has been used for control. Early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical Control decisions. The development of low cost computer has brought the most recent revolution. The Programmable Logic Controlled Conveyor is emphatically used where conveyor jamming and decongestion can be monitored or controlled. This project will save the power of motor operating the conveyor by regulating the conveyor automatically i.e. the conveyor actuates only when a tag is sensed.

1.1 Logic Control and Sequencing

A logic control system is a switching system whose output at any moment is determined exclusively by the value of inputs. A logic control system has no memory and does not consider any previous values of the input signals in determining the output signal. Neither does it have any operating characteristics that perform as a function of time, [11]. A sequencing system is one that uses internal timing devices to determine when to initiate changes in output variables. There are three basic elements of Logic Control, which are also called Logic Gates: AND, OR and NOT [4]. There are other elements which are derived from these three basic elements above like NOR, and NAND, etc. A motor has one start and one stop button. Being power to motor the output, construct the logic flow diagram and, the truth table, Figure 1 and Figure 2.

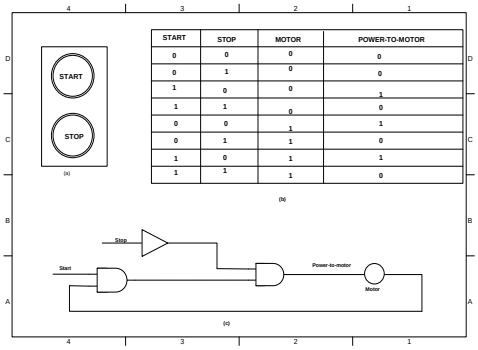

Figure 1 (a) Pushbutton switch; (b) Its truth table; (c) Its logic network diagram

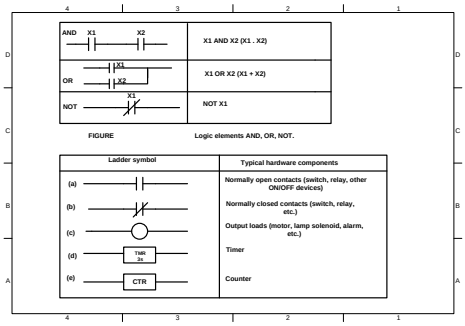

Figure 2 Symbols for common logic and sequence components in a ladder logic diagram

By selecting ladder logic as the main programming method, the amount of retraining needed for engineers and trades people was greatly reduced. Modern control systems still include relays, but these are rarely used for logic. A Relay is a simple device that uses a magnetic field to control a switch, when a voltage is applied to the input coil; the resulting current creates a magnetic Field. The magnetic field pulls a metal switch (or reed) towards it and the contacts touch, closing the switch. The contact that closes when the coil is energized is called normally open. The normally closed contacts touch when the input coil is not energized. Relays are normally drawn in schematic form using a circle to represent the input coil. The output contacts are shown with two parallel lines. Normally open contacts are shown as two lines, and

will be open (non-conducting) when the input is not energized. Normally closed contacts are shown with two lines with a diagonal line through them [12].

Conveyor belts and roller systems are part of everyday life. Supermarket tills have them, warehouse delivery systems rely on them and airports couldn't function without them. In heavy industry they are used in mining and other extractive industries to move spoil and overburden from the original site to a place where it can be treated or retained for reuse once the mining possibilities are exhausted. These days, conveyor systems are manufactured to have a combination of strength and durability; they can withstand both outdoor and indoor use and can run for great distances and in all weather conditions [6].

The PLC components are housed in a suitable cabinet designed for the industrial environment. A commercially available PLC is shown in Figure 8 [13]. The input module and output module are the connections to the industrial process that is to be controlled. The inputs to the controller are signals from limit switches, pushbuttons, sensors, and other on off devices. In addition, as we will describe later, larger PLCs are capable of accepting signals from analog devices of the type modeled. The outputs from the controller are on/off signals to operate motors, valves, and other devices required to actuate the process. The processor is the central processing unit (CPU) of the programmable controller [9]. It executes the various logic and sequencing functions by operating on the PLC inputs to determine the appropriate output signals. The processor is microprocessor very similar in its construction to those used in personal computers and other data-processing equipment. Tied to the CPU is the PLC memory, which contains the program of logic, sequencing, and other input/output operations. The memory for a programmable logic controller is specified in the same way as for a computer, and may range from 1k to over 48 k of storage capacity [7]. A power supply of 115V or 120V

ac is specially used to drive the PLC even though the components of the industrial process that are regulated may have a higher voltage and power rating than the controller itself.

1.2 Programming the PLC

The PLC is programmed by means of a programming device. The programming device (sometimes referred to as a programmer) is usually detachable from the PLC cabinet so that it can be shared between different controllers. Different PLC manufactures provide different devices, ranging from simple teach pendant-type devices, similar to those used in robotics, to special PLC programming keyboards and CRT displays.

Most of the programming methods in use today for PLCs are based on the ladder logic diagram. This diagram has been found to be very convenient for shop personnel who are familiar with circuit diagrams because it does not require them to learn an entirely new programming language [5]. What is required is a means of inputting the program into the PLC memory. There are various approaches for entering and interconnecting the individual logic elements. These include:

I. Entry of the ladder logic diagram

II. Low-level computer-type languages

III. High-level computer-type languages

IV. Functional blocks

V. Sequential function chart

2.2 Objectives of the study

In view of developing countries, this project is needful in training of technicians on PLC automation. The key objective of developing this module is to develop suitable experimental

conveyor belt using PLC for technicians training and demonstration. The study further briefly discussed on industrial applications, economic advantages of Programmable Logic Controller (PLC) Based Belt Conveyor.

2. Proposed System

Control engineering has evolved over time. The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls. PLCs have been gaining popularity on the factory floor and will probably remain Predominant for some time to come. Most of this is because of the advantages they offer [3].

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.
- Trouble shooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.

A programmable logic controller (PLC) is a special form of microprocessor- Based controller that uses a programmable memory to store Instructions and to implement functions such as logic, sequencing, timing; Counting and arithmetic in order to control machines and processes are designed to be operated by engineers with perhaps a Limited knowledge of computers and computing languages. They are not designed so that only computer programmers can set up or change the Programs. Thus, the designers of the PLC have pre-programmed it so that the control program can be entered using a simple, rather intuitive, form Of language. The term logic is used because programming Is primarily concerned with implementing logic and switching operations, e.g. if A or B occurs switch on C, if A and B

occurs switch on D. Input Devices, e.g. sensors such as switches, and output devices in the system Being controlled, e.g. motors, valves, etc., are connected to the PLC. The Operator then enters a sequence of instructions, i.e. a program, into the Memory of the PLC. The controller then monitors the inputs and outputs According to this program and carries out the control rules for which it has been programmed, [15]. The proposed system consists of sensing section, input section, controller, programmer and output Section as show in block diagram, Figure 3.

i. The Sensing Section

This section consists of limit switches, photoelectric sensors, push buttons etc. These incoming hardware devices provides input signal to the PLC. These devices are also called as field input devices. The term “field input" is used because this device provides incoming signals that are tangible items that you physically connect to PLC.

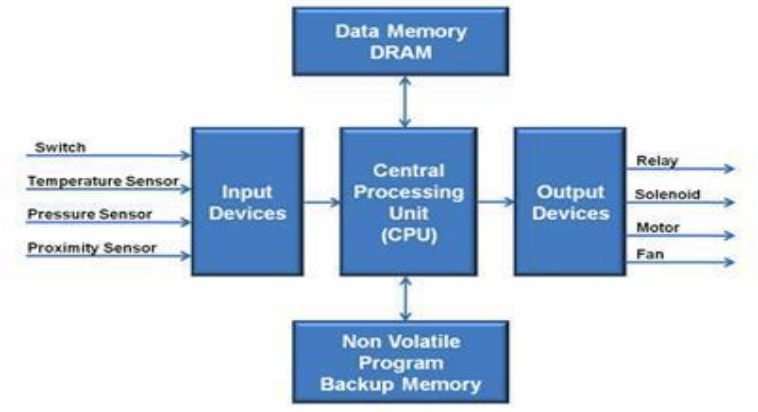

Figure 3 General block diagram of the proposed PLC system

ii. Input Section

This section is majorly divided into two parts:

First, the physical screw terminals, where incoming signal (input), from the field input devices (limit switch) are connected to the PLC. The second portion of the input section is the PLC's internal conversion electronics. This section converts and isolates the high-voltage input level

from field input devices. High-voltage signals from field input devices are converted to +5 volts direct current (VDC) for a valid ON input signal, and a 0 VDC for a valid OFF input signal. Incoming signal conversion and isolation is necessary because microprocessor components operate on +5 VDC, whereas an input signal may be of 24 VDC, 120 volts alternating current (VAC), or 220 VDC. If 120 VAC signal is inputted, for example, into 5 VDC, circuit will quickly destroy your PLC.

iii. Controller

The controller is also known as central processing unit (CPU), or simply as the processor. Central processing unit controls or supervises the entire process. The central processing unit solves the user program and apparently updates the status of the outputs.

iv. Programmer

The programmer is a device used by the programmer or operator to enter or edit program instructions or data. The programmer can be hand-held unit, a personal computer, or an industrial computer programming terminal.

v. Output Section

The ON or OFF status of the inputs are read and the information is used to solve the user ladder program and the updated signals is sent to the output section. The output section is simply a series of switches, one for each output point, that are controlled by CPU and are used to turn output field devices ON or OFF.

vi. Conveyor Belt

There are two main industrial classes of belt conveyors; those in general material handling such as those moving boxes along inside a factory and those in bulk material handling such as those used to transport industrial and agricultural materials, such as grain, coal, ores, fines, and

lumps material. The belt consists of one or more layers of material. They can be made out of rubber. Many belts in general material handling have two layers. Programmable logic controller (PLC) has the great advantage that the same basic controller can be used with a wide range of control systems. There is no need to rewire. The result is a flexible, cost effective, system which can be used with control systems which vary quite widely in their nature and complexity? PLCs are similar to computers but whereas computers are optimized for Calculation and display tasks, PLCs are optimized for control tasks and the Industrial environment. Thus PLCs are: rugged and designed to withstand vibrations, temperature, humidity and noise.

3. Experimental PLC Controlled Conveyor Belt Integrated Component

In an attempt to implement the proposed system, it was divided into two parts which are hardware and software. The constructed system hardware, Figure 12, components comprise of Electric motor, the infrared sensor and reflector, the conveyor belt with roller, contactor and PLC.

i. Electric motor

Electric motor is used to drive the conveyor pulley sequel to electric signal from the contactor as relayed by the PLC. Three-phase (Squirrel Cage) Induction Motor, Figure 4, is used because of its simplicity and

Figure 4 Electric motor drive

trouble free features, it is the type of motor most commonly employed for industrial use, with three essential parts, namely the stator frame, the stator windings and the squirrel cage rotor.

ii. The Infrared sensor and reflector: two infrared sensors, Figure 5a and b, with reflector glass were placed sideward along the motion belt to mainly sense level of load at the carriage source and destination. When the load is loaded to the extent that the transmitted infrared can no longer be received by the receiving infrared sensor; this triggers a move forward motion to carry the load to the destination. At the receiving end the infrared sensor send stop-drive signal to the motor via the embedded logic sequence in the PLC. When both sensors notice load presence, the PLC will direct the motor to stop until when either the sensors is free of load before next move decision can be taken.

(a) (b)

Figure 5 Infrared sensor (a) and reflector (b)

iii. The conveyor belt and the roller: The conveyor belt, Figure 6, carries the load through a constructed metal frame from the source to the destination. It is a wide belt supported by two rollers along motion path. The pulley moves forward and backward in response to motor drive direction.

Figure 6 Conveyor belt with roller

iv. Contactor: This, Figure 7, typically has multiple contacts, and those contacts are usually normally-open, so that power to the electric motor is shut off when the coil is de-energized.

It is used to control the three-phase electric motor. The main function of a contactor was to make or break the circuit on receiving a command from the PLC.

Figure 7 Contactor

iv. The PLC

Figure 8 Picture of a programmable logic controller

3.2 PLC Software Design

3.2 1. PLC Logic Control

Ladder logic is the main programming method used for the PLC programming. Ladder logic has been developed to mimic relay logic. The PLC follows the instructions stored in memory. Each instruction given by the programmer is placed in PLC memory in ascending order. A list of instruction is called as the user ladder program. Instructions are registered into the PLC's memory; the desired instructions for the PLC to carry out were transferred to the controller memory using a personal computer. The first step was to develop the user ladder program, Figure 3. Once the user ladder program is verified for correctness, the next step is to download the program into the processor's memory. The process of transferring the user defined PLC program from personal computer's memory into PLC memory is called as downloading the program. But before downloading the user program, the processor must be in program mode. If all the inputs and outputs signals are wired to the correct screw terminals, the processor can be put in run mode. In run mode, the program will continuously run and solve the programmed instructions. The process of solving the programmed instruction is sometime called as solving the logic. This constant running of the program in a PLC is called as scanning. When the PLC is switched into the program mode, all outputs from the PLC are forced OFF regardless of their rung logic status, and the ladder I/O scan sequence is halted. Run mode is used to execute the user program. Input devices are monitored and output devices are energized accordingly. Test mode is used to operate or monitor the user program without energizing any outputs. Remote mode allows the PLC to be remotely changed between program and run mode by a personal computer connected to the PLC processor.

3.2.2 Entry of the Ladder Logic Diagram

The first method involves direct entry of the ladder logic diagram into the PLC memory. This method requires the use of a keyboard and CRT with limited graphics capability to

display symbols representing the components and their interrelationships in the ladder logic diagram. The PLC keyboard device is often designed with keys for each of the individual symbols. Programming is accomplished by inserting the appropriate components into the rungs in the ladder diagram. The components are of two basic types: Contacts and coils. Contacts are used to represent loads such as motors, Solenoids, relays, timers and counters in effect; the programmer inputs the ladder logic circuit diagram rung by rung into the PLC memory with the CRT displaying the results for verification.

Ladder Logic

The ladder logic programming window, Figure 9, was used to program the PLC. Ladder logic is the main programming method used for PLCs. Ladder logic has been developed to mimic relay logic. The decision to use the relay has objectives: knowing the general PLC issues, writing simple ladder logic programs, understand the operation of a PLC and the PLC history.

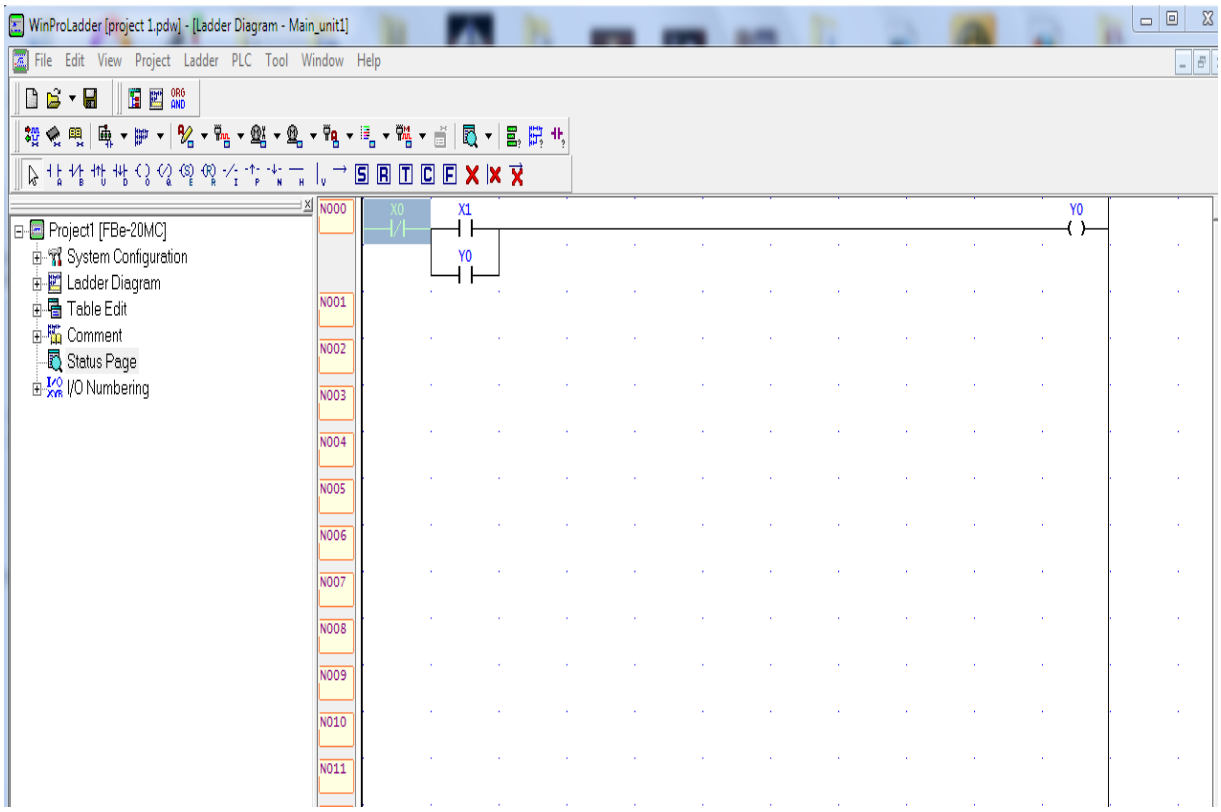

Figure 9 Ladder Logic Program Window

3.2.3 The System Operation Flow Chart

The system operation, Figure 10, was in sequential order.

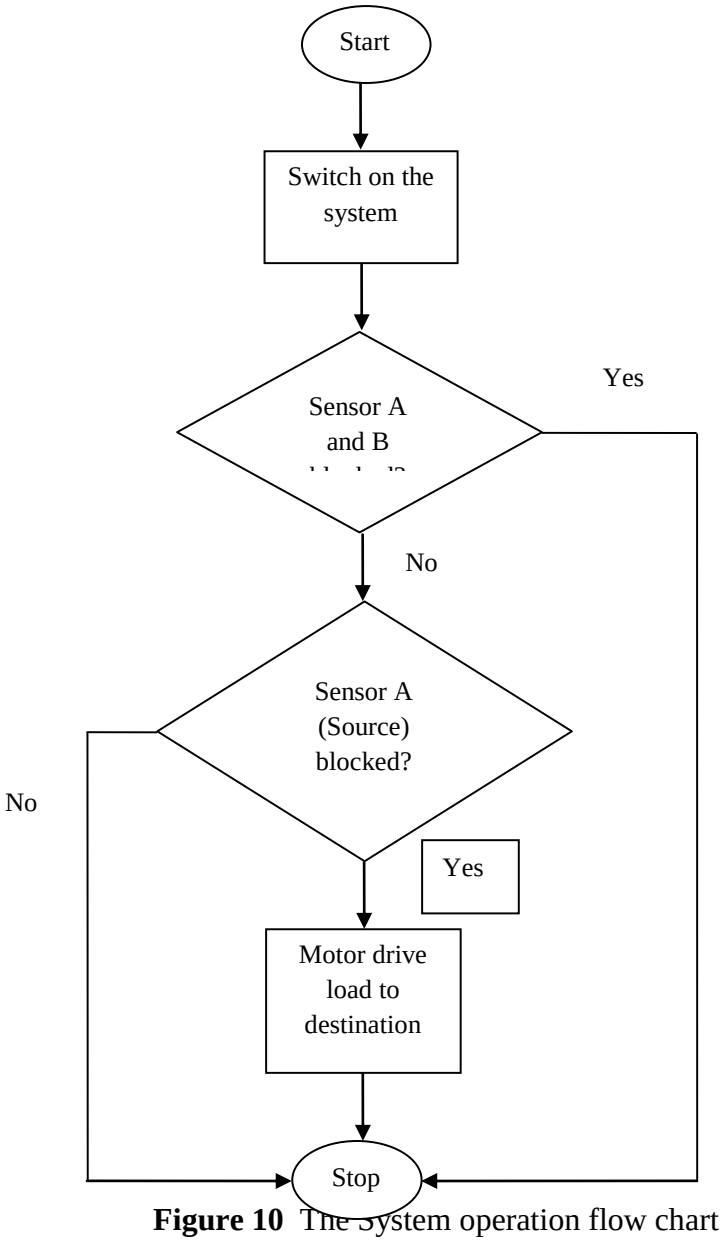

Figure 10 The System operation flow chart

4.0 Experimental Testing

The stages involved in the construction of the proposed systems are: design validation, welding implementations and testing.

4.1 Design Validation

The Ladder Logic development was taking into consideration with some parameters such as signal levels between components, compatibility of signals and components, cost and availability of components. A very important advantage of design validation is the use of Ladder logic software to simulate the operation before implementation.

4.2 Welding implementations

The major factors considered for the selection of materials include operating environment, quality and availability of materials. The principal material used for the construction is less weight square steel pipe. The welding and fabrication of PFBR equipment are carried out by combination of gas tungsten arc welding and shielded metal arc welding process. The welding is carried out using 16-8-2 filler wires and E 316-15 electrodes with controlled heat input to minimize the distortion and dimensional deviations. The welding procedure is qualified with stringent destructive and non-destructive examinations & testing before executing welding on the actual design.

4.3 Testing and Result

Testing without and with object were conducted**.** The test instrument used for examining logic signal, testing and troubleshooting applications in the course of the project were: digital multimeter, logic probe, and oscilloscope. Testing involve

troubleshooting the hardware to detect, isolate and correct internal or external fault such as malfunction in the internal circuitry, input or output shorted to ground.

The testing was carried out in stages.

I. The electric motor and contactor were first tested using the multimeter in order to check for their state of performance.

II. The sensor unit circuitry was tested to ascertain the degree of sensitivity. An object was used to interrupt the infrared sensor light rays. The voltage levels at the output were observed with the aid to a digital multimeter.

III. Also, the PLC control circuit was tested by applying logic '1' or '0' to point A and B of the circuit. When logic '1' is applied, the motor rotate in a clockwise direction. Logic '0' will never activate the motor.

IV. After the proper testing of the components and found to be working perfectly, the entire system was tested. Series of programs {ladder logic} were written and tested before the working program was fully achieved. The circuit worked perfectly as designed. The load carriage capacity was also observed during the testing.

Load carriage Response Curve, Figure 11, for 5 Kg load to move from starting point 'A' to destination point 'B' on the pulley was in average of 3.5 seconds. The delay time was mainly due to the pulley-roller friction, load weight and the driving motor torque strength. This is acceptable for demonstration purpose.

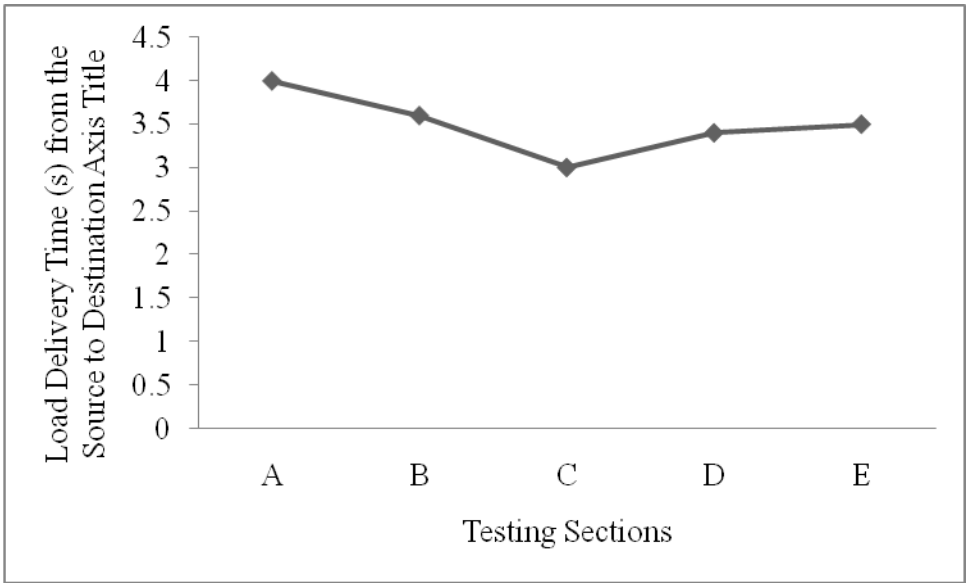

Figure 11 Load carriage response curve

4.4 Packaging

After proper testing was conducted, the packaging of the design into a model and casing was considered. The connecting wires were properly connected and well insulated, also the wires were well packed, Figure 12, and bounded together.

Figure 12 Constructed System

5.0 Applications of Programmable Logic Controller Based Belt Conveyor

It can be used for different applications and, via the program installed in its memory, provides the user with a simple means of changing, extending and optimizing control processes [2]. The biggest benefit in using a PLC is the ability to change and replicate the operation or process while collecting and communicating vital information.

Industrial Applications

Belt Conveyors are used in self-unloading bulk freighters and in live bottom trucks. Conveyor technology is also used in conveyor transport such as moving sidewalks or escalators as well as on many manufacturing assembly lines. Stores often have conveyor belts at the check-out counter to move shopping items. Ski areas also use conveyor belts to transport skiers up the hill. A wide variety of related conveying machines are available, different as regards principle of operation, means and direction of conveyance, including screw conveyors , vibrating conveyors, pneumatic conveyors, the moving floor system, which uses reciprocating slats to move cargo, and roller conveyor system, which uses a series of powered rollers to convey boxes or pallets . Long belt conveyors Belt conveyor systems are durable are and reliable components used in automated distribution and warehousing. In combination with computer controlled pallet handling equipment this allows for more efficient retail, wholesale, and manufacturing distribution. It is considered a labor saving system that allows large volumes to move rapidly through a process, allowing companies to ship or receive higher volumes with smaller storage space and with less labor expense. Rubber conveyor belts are commonly used

to convey items with irregular bottom surfaces, small items that would fall in between rollers (e.g. a sushi conveyor bar), or bags of product that would sag between rollers. Belt conveyors are generally fairly similar in construction consisting of a metal frame with rollers at either end of a flat metal bed. The belt is looped around each of the rollers and when one of the rollers is powered (by an electrical motor) the belting slides across the solid metal frame bed, moving the product. In heavy use applications the beds which the belting is pulled over are replaced with rollers. The rollers allow weight to be conveyed as they reduce the amount of friction generated from the heavier loading on the belting. Belt conveyors can now be manufactured with curved sections which use tapered rollers and curved belting to convey products around a corner. These conveyor systems are commonly used in postal sorting offices and airport baggage handling systems. A sandwich belt conveyor uses two conveyor belts, face-to-face, to firmly contain the item being carried, making steep incline and even vertical-lift runs achievable. Belt conveyors are the most commonly used powered conveyors because they are the most versatile and the least expensive. Product is conveyed directly on the belt so both regular and irregular shaped objects, large or small, light and heavy, can be transported successfully. These conveyors should use only the highest quality premium belting products, which reduces belt stretch and results in less maintenance for tension adjustments. Belt conveyors can be used to transport product in a straight line or through changes in elevation or direction. In certain applications they can also be used for static accumulation or cartons. Belt Conveyor systems at a Packing Depot Baggage Handling Belt Conveyor systems Accumulation conveyor for cartons and totes in a fashion distribution centre Long belt conveyors [12].

Every modern industrial system or machine has a controller. Depending on the type of technology used, controllers can be divided into pneumatic, hydraulic, electrical and electronic controllers. Frequently, a combination of different technologies is used. Furthermore, differentiation is made between hard-wired programmable (e.g. wiring of electro-mechanical or electronic components) and programmable logic controllers. The first is used primarily in cases, where any reprogramming by the user is out of the question and the job size warrants the development of a special controller. Typical applications for such controllers can be found in automatic washing machines, video cameras, and cars [14]. However, if the job size does not warrant the development of a special controller or if the user is to have the facility of making simple or independent program changes, or of setting timers and counters, then the use of a universal controller, when the program is written to an electronic memory, is the preferred option. The PLC represents such a universal controller.

Economic Advantages of Programmable Logic Controller Based Conveyor Belt

Manufacturing in industries forms a significant part of Nigeria's economic [7]. PLCs have been gaining popularity on the factory floor and will probably remain Predominant for some time to come. Most of this is because of the advantages they offer. An advantage of a PLC system is that it can be modular. That is, you can mix and match the types of Input and Output devices to best suit your application [1]. This creates flexibility in the control system that has positive growth implication on production and nation economy.

The economy of Nigeria historically was based on agriculture (with cocoa, rubber, and palm products being historically major export), and about 70% of the workforce is still engaged in farming (largely of a subsistence type), [10] The chief crops: cocoa, peanuts, palm oil, corn, rice, sorghum, millet, soybeans, cassava, yams, and rubber necessitate finishing

processes to preserve and prepare them for export. Industry in Nigeria includes the processing of agricultural products and minerals, and the manufacture of textiles, construction materials, footwear, chemicals, fertilizer, and steel. Fishing and forestry are also important to national development [12].

Incorporating PLC technology enhances production with reduction in labour cost hence, tremendous boost on national economy. Besides, Petroleum is the leading mineral produced in Nigeria and provides about 95% of foreign exchange earnings and the majority of government revenues. It is largely found in the risky region of Niger delta and in the bights of Benin and Biafra, [10]. The growth and steady production with less human life loss in oil industry have been major challenges to the government. The life risk in the upstream crude extraction is huge; however, usage of automation process control system in every stage of production will be of obvious and measurable reward.

6.0 Conclusion and Recommendation

The key objective of developing this module is to develop suitable experimental conveyor belt using PLC for technicians training and demonstration. The work further highlight PLC Applications and Economic Advantages. Also, the use of PLC system has been achieved in the design and implementation of this work. This project can be early tailored to any electric gate and all forms of control, which has the use of sensors. For an effective design of this kind of system, it is imperative to have a good understanding of the basic sensor characteristic. Generally, PLC controlled Belt conveyor are durable, reliable and less maintenance cost. Conveyors should use only the highest quality premium belting products, which reduces belt

stretch and result in less maintenance or tension adjustment. Belt conveyors can be used to transport product in a straight line or through changes in elevation or direction. In certain application, they can be used for static accumulation of cartons.

A more effective and sensitive sensor is recommended for better performance. For example a sensor such as RADAR sensor that could detect contraband goods in vehicles is recommended. Also, achievement of a full automation, a real time system may be employ a biometric scanner that will provide a proper monitoring and security purposes.

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