ARCHITECTURE OF RECONFIGURABLE CONVEYOR SYSTEM IN MANUFACTURING SYSTEM

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Article History: Received 14 August 2017; Revised 12 October 2017; Accepted 19 December 2017

ABSTRACT: In today's global competition, a concept of reconfiguration is required for a company to stay competitive in manufacturing industries. The conveyor system is one of material handling system that commonly used in production. This paper aimed to propose an integrated system architecture for Reconfigurable Conveyor System to support the frequent changes of customer demand in a manufacturing system. The PC-based controller is used for the communication between the controllers in the main system controller and sub-system controller by using a PROFIBUS interface and Local Area Network (LAN) cables. The proposed architecture will be validated by using the physical Reconfigurable Conveyor System in the future work.

KEYWORDS: *Reconfigurable Conveyor System; Programmable Logic Controller (PLC); Architecture; Manufacturing System; Local Area Network (LAN)*

1.0 INTR ODU CTION

The manufacturing industry is one of the important foundation that has approximately 20% of account in US Gross Domestic Product [1]. But, the recent issue is the current manufacturing industries now have to face the unpredictable market changes including increasingly frequent changes in customer demands and rapid introduction of new products due to the growth in high technologies [2].

A new concept of reconfiguration is introduced to solve this problem. Reconfiguration is defined as the ability to change quickly and cost-effectively [3] from its current configuration to another configuration without being taken offline from the maintaining system [4].

In addition, most industries used automated manufacturing system as their main material handling system. One of the famous automated manufacturing systems is conveyor system [5]. The conveyor system is used to transport the products from one place to another efficiently [6]. Thus, a new concept of Reconfigurable Conveyor System (RCS) can be adapted to convert the production of new models with cost-effective way, by improving the capacity, productivity [7] and functionality of the existing conveyor system.

Nevertheless, the design and development of Reconfigurable Conveyor System face two major challenges. The first challenge is the development of hardware modules that can support the reconfiguration. Meanwhile, the second challenge is about the software of RCS where the distributed control is developed according to the requirements [8].

Therefore, in this manuscript, the authors want to propose a novel RCS architecture to support the increasing requirements of customized product in the manufacturing industry.

2.0 METHODOLOGY

Most of the automated material handling systems are designed using PLC as its main controller [9]. PLC uses ladder diagram as their communication interface. The disadvantage of using PLC is it is user customized automation in which the control system is designed based on the mechanical structure. For example, the control system needs to be changed based on the function needed in actual control in order to support the requirements [10].

To solve the above-mentioned problem, a PC-based controller is introduced. The PC-based controller can act as an intelligent controller since it provides a flexible and cost-effective alternative and at the same time, the system can be easily configured to cope with the changing requirement from the user. Other than that, PLC can be defined as a microcomputer-based controller that uses stored instructions in the programmable memory to implement logic, sequencing, timing, counting and arithmetic functions through digital or analog input/output (I/O) modules for controlling machines and processes [11]. In this system, the PC-based controller is acting as the main system controller while PLC is acting as the sub-system controller.

Figure 1 shows a generic systematic approach for a PC-based control system development, which consists of four steps. The first step is to determine the sequence of operation and control strategies. This step needs an understanding of the desired hardware and software architecture in order to draw a general flowchart of control system sequence of operation. Second is hardware-software configuration and assignment of I/O modules. All the I/O drives will be listed to the respective I/O points of the PLC. Next, the sequence of operation is translated into a logic control for testing and commissioning of the system.

At the end, the control logic program is debugged to simulate and test the real system operation. This step can be called as programming of the logic control system.

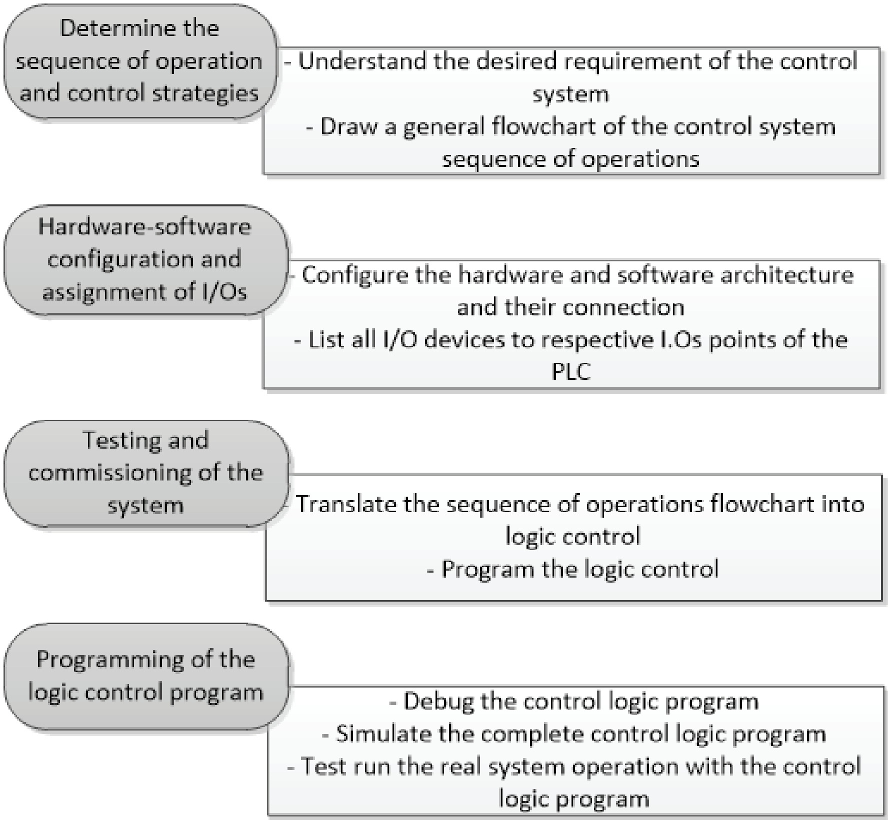

Figure 1: A general systematic approach for a PC-based control system development [10]

Based on the previous research about reconfiguration, there are different types of reconfigurable architectures. Most of the researchers are focused on the Reconfigurable Manufacturing System. This architecture's advantage is its potential in runtime reconfiguration that can increase the performance of the application [12-13]. Besides, there are several architectures that reconfigure the entire hardware implementation and its control system [14].

Figure 2 shows the hardware configuration and control architecture of the material flow system. The concept of the control system is to determine the position of the control task, level of control model and which task should be implemented. While the system hardware including PLC and system controller PC is being set together with the security and emergency data in case of failure [10].

Based on the control structure, there are 6 levels of material flow control. Level 1 is for sensors and actuators. It is built as an interface between material flow control and physical material flow. Level 2 is element control. It controls one of the drives of the conveyor element. Level 3 is section control to regulate the operation of the conveyor. The level 4 is sub-system control. Its function is to control all the operation of the closed sub-system. Lastly is Level 5 which is system control. It assigns the transport order to the conveyor and transfers them to the sub-system control.

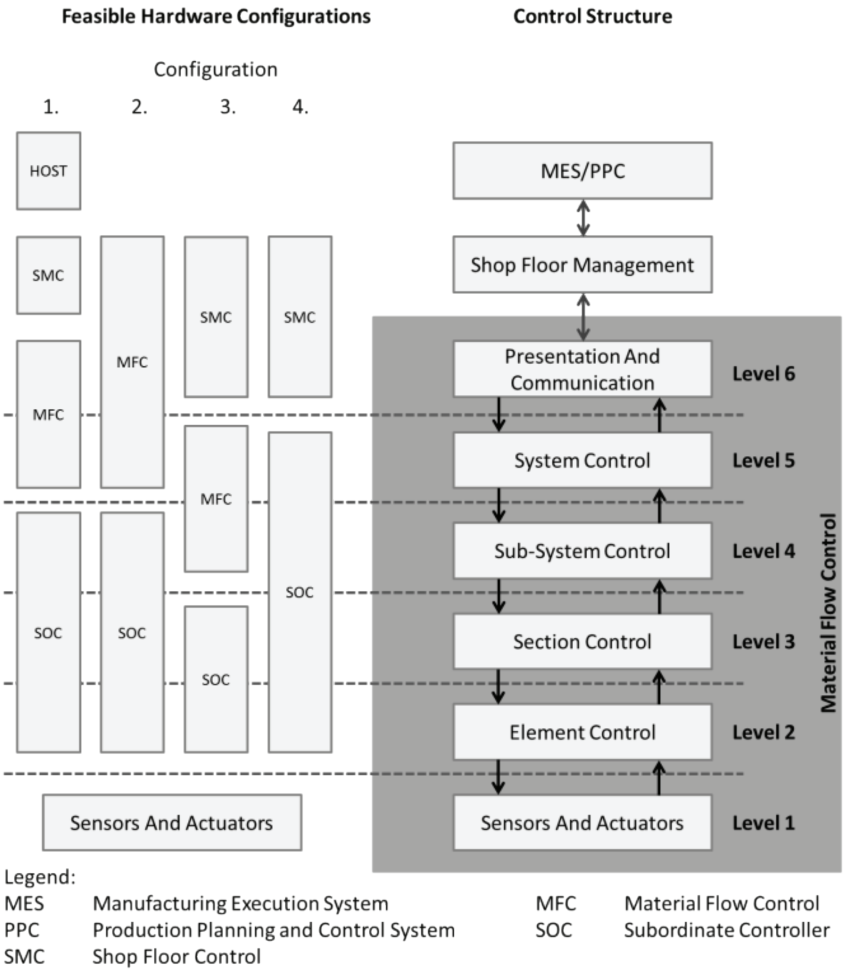

Figure 2: Hardware configuration and control architecture of the material flow control [15]

3.0 THE PROPOSED ARCHITECTURE

The proposed system is designed with 6 modules of the lab-scale conveyor which their own system operation. Figure 3 shows the modeling of the Reconfigurable Conveyor System. The model consists of 6 modules of the conveyor. Each module has three outputs which are sensor, actuator and motor drive.

In addition, every module has an Omron CP1L – EL20DR-D controller to control the operation. This controller is built with Ethernet function for adding, modifying or removing the command program online without stopping the operation. The physical configuration has two types of conveyors which are straight line conveyor and pneumatic cylinder conveyor.

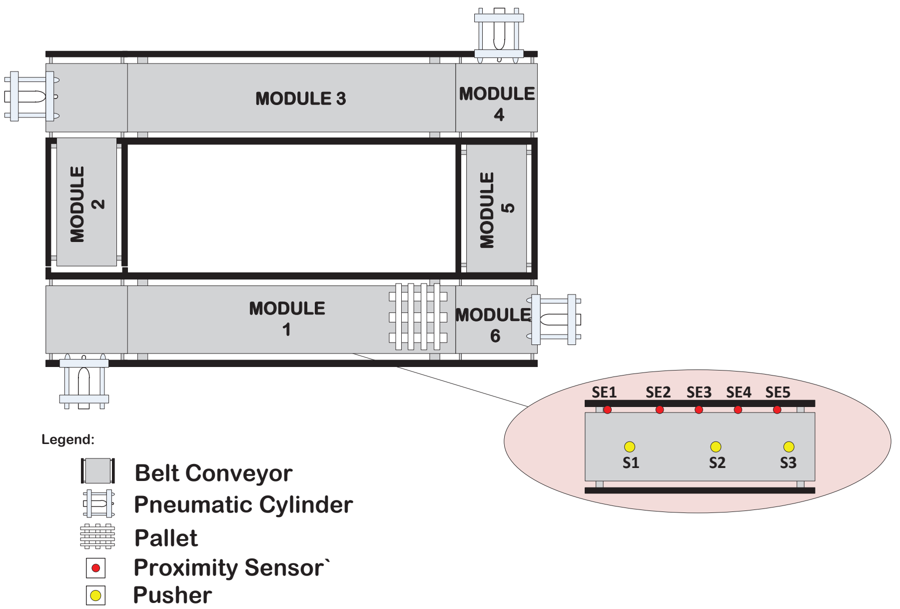

Figure 3: The modeling of reconfigurable conveyor system

From these conveyors, there are four possible configurations that can be produced, which include straight line-shaped, U-shaped, L-shaped and closed loop-shaped. The types of possible layout are shown in Figure 4.

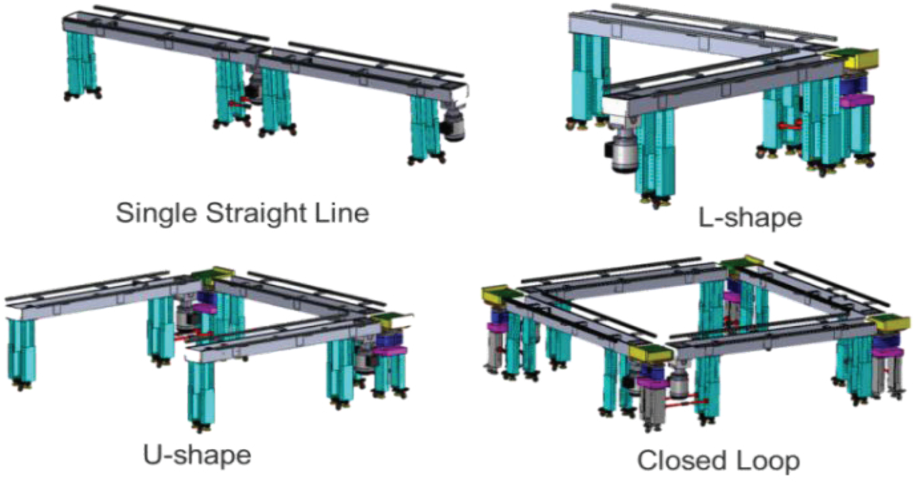

Figure 4: Types of possible layout operation

Figure 5 shows the proposed Reconfigurable Conveyor System Architecture. The system is distinguished into two categories which are main system controller and sub-system controller. The main system controller is used Siemens controller as their main control. An application-oriented integration of three software program is used in a realizing concept for reconfiguration. This software includes Siemens TIA Portal, Siemens Step 7 Professional V13, and Siemens Sematic WinAC RTX-F 2010 SP2. In this research, Siemens Sematic WinAC RTX-F is used as the software controller. A PC-based controller is used as the basis for the connection. All software used must support each other to make sure the connection and program control can be transferred without any error.

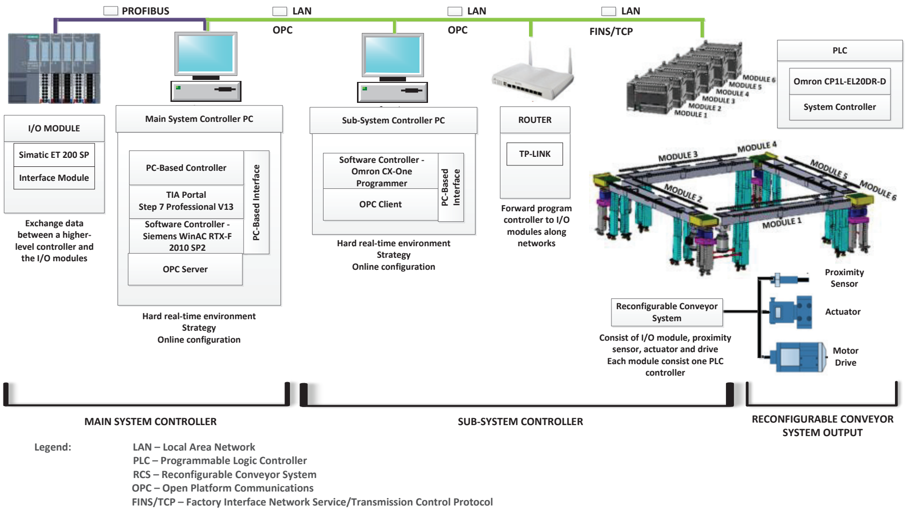

Figure 5: The proposed reconfigurable conveyor system architecture

Furthermore, a Profibus card reader is installed at Siemens Simatic ET 200 SP to exchange data between high-level controllers to I/Os module. After that, the control program will be transferred to I/Os module through a TP-Link router. The control program consists of logic controls program. All the relevant I/Os need to be considered based on the program that has been designed according to the mechanical structure. The control logic is drawn in a ladder diagram. The control program will be transferred to 6 modules of Omron CP1L-EL20DR-D through OPC server and FINS/TCP network by using Local Area Network (LAN) cables. OPC is used for communication of real-time implementation between controllers that have different manufacturers. Meanwhile, FINS/TCP Ethernet network is used to connect PLCs through multiple segments of the same network to obtain an IP address. Omron CP1L-EL20DR-D comes with Ethernet function for the communication. The Ethernet is used as a communication method between each controller in this system. IP and MAC address from each controller will be considered to transfer the control program to each sequence of operation. After all the program is transferred successfully, the Reconfigurable Conveyor System outputs will be functioning.

Lastly, the main system controller software which is connected to I/Os modules will receive the signal from the Reconfigurable Conveyor System. If the condition is satisfied, the conveyor will continue to move based on the control program. But, if there are any errors, the main system controller PC will show the error and the user can change and modify the program on-line directly without stopping the conveyor.

4.0 RESULT AND DISCUSSION

The architecture proposed in this article will give a full understanding of the system before it is developed in future work. The critical step in this architecture is on how to communicate between two different controllers in one system operation. The two controllers are Omron and Siemens which in theory have their own address for communication. Figure 6 shows some example of the function block in the main system controller.

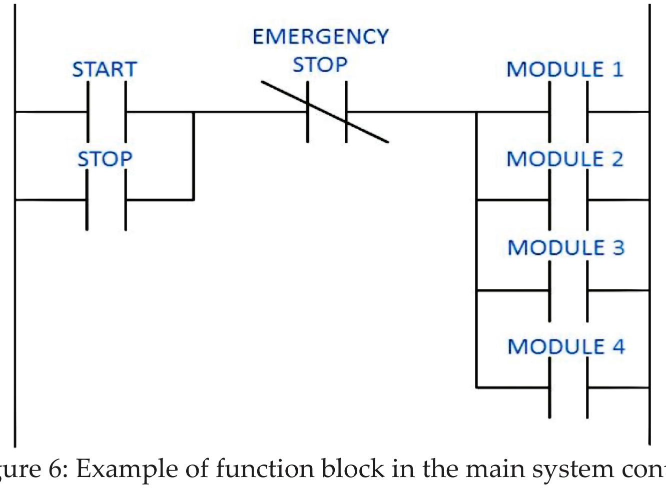

Figure 6: Example of function block in the main system control

The program contains three inputs, which is Start button, Stop button and Emergency Stop button (EM). When Start button is switched on, it will energize all four outputs, which are M1, M2, M3 and M4 which represent four modules of Reconfigurable Conveyor System. EM is used to cut off all the operation directly if there is any problem occurred during the operation. The program of sub-system controller has been applied in the real case study by using the lab-scale Reconfigurable Conveyor System in the laboratory.

Figure 7 shows some example of working operation in sub-system controller. The operation starts with the switch on the Start button to activate the motor. When the sensor 1 (SE1) is triggered, the pusher 1 (PU1) is activated and stopped the pallet. At the same time, Timer 1 (T1) is activated to timing for 10 seconds. After that, the PU1 is switched off and the pallet moves to the other station.

In the next implementation, the overall program of system control will be applied together with the program in sub-system control, so that, the objective of the experiment can be validated. The technologies of the architecture are arranged according to the standard requirement of the implementation of the system requirement. The system requirement is to develop a Reconfigurable Conveyor System that can support both hardware configuration and software configuration in order to support the sudden change in manufacturing industries. The critical point for the whole design architecture is to implement this architecture into the real application. The successful implementation is hoped in order to support the reconfiguration.

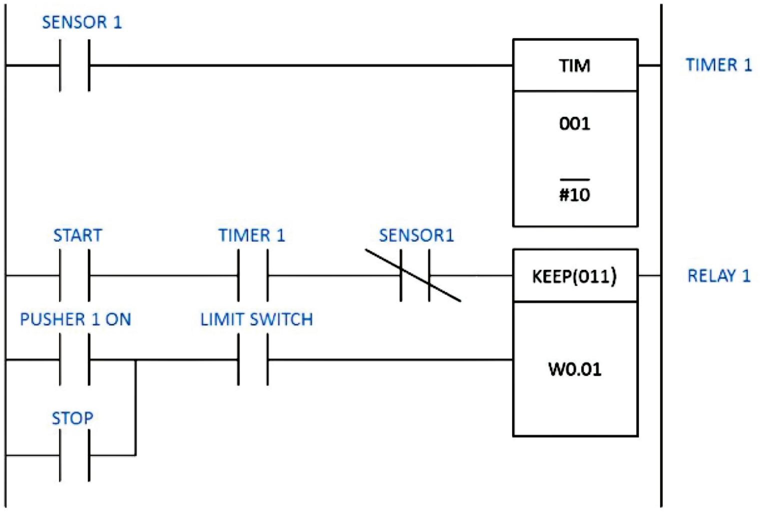

Figure 7: Example of program in sub-system control

5.0 CONCLUSION

This research proposes new reconfiguration architecture for the implementation of Reconfigurable Conveyor System in a manufacturing system. Reconfiguration plays a critical role to support the new challenge in manufacturing industries due to the impact of globalization. This architecture provides the control strategies of the reconfigurable conveyor system in this research. The results can be further validated when it is tested experimentally by using both main system controller and sub-system controller in a physical Reconfigurable Conveyor System.

ACKNOWLEDGMENTS

The authors are pleased to acknowledge the financial and administrative support from the Minister of Education (MOE), Malaysia and Universiti Teknikal Malaysia Melaka under the FRGS/1/2014/TK01/FKP /03/F00229 Research grant Project entitles "A novel concept of reconfigurable material handling system to support changeability in manufacturing". The authors would also like to thank all the FRGS's members who contributed and provided feedback on the project.

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