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Ladder Diagram Design Based On Cascade Method For Selection And Assembling Part On Dual Conveyor Plant

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***Abstract*— The transfer of goods from one place to another in the production process in a common industry we encounter using conveyors. Conveyors have replaced human labor used in moving production goods from one place to another in the industry. By using conveyors, the transfer time can be reduced and not dependent on humans anymore. Conveyor control can use a controller in the form of a PLC. PLC programming can use many methods, one of which is the cascade method. The beginning of the development of this method is widely used in pneumatic systems, but as time goes by this method is used in completing sequential systems. The ideal cascade method is used for sequential processes without an iterative process, the theory is easy to understand, the results are easy to implement. In this study the type of PLC used is CPM1 from OMRON. By using Cascade method, the result from construction of ladder diagram is obtained by 59 rung, 6 timer, 18 relay, and the program capacity is 3 KB.**

Keywords—Conveyor, PLC, Ladder diagram, Cascade method, relay group.

I. Introduction

Previous research on making ladder diagrams with the sequence chart method whose results need to use many internal relays but is easier to convert from the sequence chart to the ladder diagram. In this study using a different tool from the previous research, namely the state diagram, and hope to produce a clear and easy to implement method in producing ladder diagrams.

Dual conveyor workcell systems are intended to process material while passing over the conveyor in stages. In this project, Dual conveyor workcell systems are used as the main device for the selection and assembly of components or workpieces with predetermined criteria. The part of the driver or PCB interface that has a role to connect the sensor and actuator with the controller which is a Programable Logic Control (PLC). The following are parts of the conveyor work system that play an important role during the assembly of the workpiece. Among others :

1. Conveyor
2. Workpiece
3. Opto-detector
4. Dispenser
5. Inductive sensor
6. Heigh-detector
7. Power Supplies
8. Flippers
9. PLC
10. PCB Interface

In the dual conveyor workcell plant there are several sensors and actuators installed. Detection of the sensor and the action of the actuator at the plant results in a size selection process, material selection that occurs on the upper conveyor and assembly of workpieces that occur at the bottom of the conveyor, which has the same process as the actual assembly industry. The sensor and actuator on the plant will be the I / O of a controller called a PLC.

The conveyor is driven by a DC motor, which serves to send the washer that will go into the material selection and thickness selection process and finally the assembly process. The conveyor itself is divided into the top and bottom.

On the upper conveyor the workpiece will be selected based on the height and type of material. If the workpiece does not meet the height and type of material, it will not be forwarded to the next process, which is assembly, but will be discarded at the top of the conveyor. Furthermore, the selected workpiece will be distinguished based on the type of plastic and metal material by flipper 1 and flipper 2 which makes the workpiece turn and fall into chute 1 and chute 2. if the chute 1 and chute 2 are active then the workpiece will fall onto the peg who walks on the lower conveyor. Furthermore, the opto sensor will count the number of workpieces that are successfully assembled by the system.

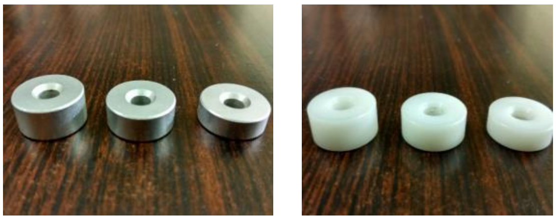

Fig. 1. The Workpieces

Table 1 Criteria of workpieces

Height	Part
8 mm	feasible
7 mm and 9 mm	Not feasible

II. METHOD

The Cascade method is a classical method that can design a sequential system with design results Ladder diagrams. There are four steps to be done with this Cascade method[1]:

1. Define the program sequences of the system
   Write all the program sequences of the actuator based on the operating sensor
2. Divide into grup
   Divide the program-sequence steps into groups, so that no letter is repeated within any group. Each actuator condition ON/OFF assigned by different group. It is why cascade method avoid contradictory (i.e., concurrent) control signals in the same actuator but different condition ON/OFF. This make cascade method prevent circuit malfunction.
3. Write logic function for relay group and output
   Make output function from cycle and their relay group
4. Draw Ladder diagram & Simulation
   Draw relay group function and output function as Ladder diagram and then simulate them.
5. Validation
   From time chart simulation we can validate with program sequence.
6. Implementation on PLC
   Running program on PLC and test Dual Conveyor Workcell plant.

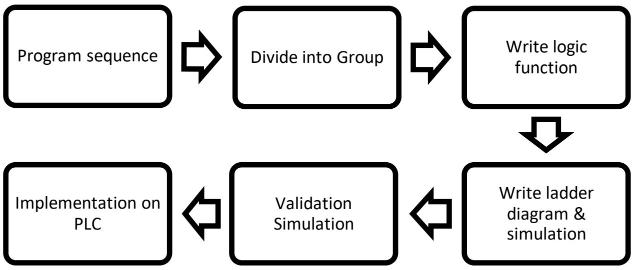

Fig. 2. Cascade method procedure.

To facilitate an understanding of the process sequence of a dual conveyor workcell system it is necessary to know the main components of the system, ie the sensors and actuators used, and the location of the placement of each component so as to support the desired automation process. Therefore, as shown in Fig. 3 and 4 there is the naming of sensor components (inputs) and actuators (outputs) to accelerate their understanding.

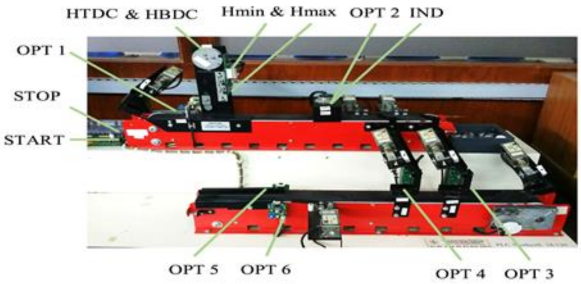

Fig. 3. Input System

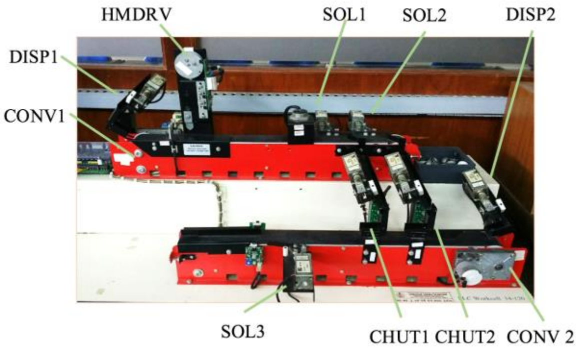

Fig. 4. Output System

Next understand the assembly system workflow from this Dual Conveyor.

a. Define the program sequences of the system

Before making a group division for the ladder diagram design, the working order of the system must be known in advance, basically the work of the system can be divided into two parts, the first is the part selection part that occurs in the upper conveyor and the second is the assembly part that occurs in the lower part conveyor.

The first part is the selection of parts that occur in the upper conveyor where there are three possibilities in part selection, the first is if the height of the washer does not fit well made of plastic or metal, because the system used in this final project there is no wide detector we note in terms of size is the height of the washer, then the second possibility is if the height of the washer is suitable and the washer is made of plastic, then the third is if the height of the washer is suitable and the washer is made of metal.

In the first possibility that is if the size of the height of the washer does not match, either the washer is made of metal or plastic then the metal washer or plastic will experience the same process.At the start button is pressed then the dispenser 1 will be active and the washer will be dropped to the upper conveyor and the motor at the height detector will be active until the HTDC photoelectric sensor is active. When HTDC is active, dispenser 1 will close again with the cessation of the motor, after that the upper conveyor will be active and bring the washer up to the opto sensor 1 where the opto sensor 1 is the opto sensor that is before the height detector, when opto sensor 1 is active, the upper conveyor will stop momentarily (0.9s) then the upper conveyor will be active for 1.4s carrying the workpiece to just below the height measuring sensor and the upper conveyor stops again. Then the motor activates again to make the height measuring sensor move down until the HBDC sensor is active. In the first possibility is the condition where the washer has a height that is not appropriate where one of the sensors is too small or too big is not active, then after the height of the washer is measured then the conveyor upper will run again (10s) and the next process is the upper conveyor will carry the washer until it enters in disposal and the process will restart from the beginning.

In the second possibility that is if the size of the height of the washer is suitable and the washer is made of plastic. When the start button is pressed the dispenser 1 will be active and the washer will drop to the upper conveyor and the motor at the height detector will be active until the HTDC photoelectric sensor is in condition active. When HTDC is active, dispenser 1 will close again with the cessation of the motor, after that the upper conveyor will be active and bring the washer up to the opto sensor 1 where the opto sensor 1 is the opto sensor that is before the altitude detector. When opto sensor 1 is active, the upper conveyor stops momentarily (0.9s) then the upper conveyor activates as long as 1.4s brings the workpiece to just below the height measuring sensor and the upper conveyor stops again. Then the motor activates again to make the measuring sensor the height moves down until the HBDC sensor is active. At the second possibility the condition of the washer has a high size which is suitable where the sensor is too small and too big both are active, then after selecting the height of the conveyor upper will run again carrying the washer to opto sensor 2, where opto sensor 2 located before the inductive sensor, after the washer arrived at the opto sensor 2, the conveyor upper will stop for 0.7 seconds to detect the material. At the possibility of the two washer made of plastic, therefore only opto 2 sensors are active, while the inductive sensor is not active. material selection is made and it is known that the washer is made of plastic then the upper conveyor and solenoid 2 will active for 10 seconds to make the plastic washer on the chute 1. After 10 seconds, the upper conveyor will stop and the solenoid 2 will close together with the chute 1 active and make the washer fall to the lower conveyor and make opto sensor 4 active then enter assembly process.

In the third possibility that is when the height of the washer is appropriate and the washer is made of metal. When the start button is pressed the dispenser 1 will be active and the washer will drop to the upper conveyor and the motor at the height detector will be active until the HTDC photoelectric sensor is in condition active. When HTDC is active, dispenser 1 will close again with the cessation of the motor, after that the upper conveyor will be active and bring the washer up to the opto sensor 1 where the opto sensor 1 is the opto sensor that is before the altitude detector. When opto sensor 1 is active, the upper conveyor stops momentarily (0.9s) then the upper conveyor activates as long as 1.4s brings the workpiece to just below the height measuring sensor and the upper conveyor stops again. Then the motor activates again to make the measuring sensor the height moves down until the HBDC sensor is active. In the third possibility the condition of the washer has a high size which is appropriate where the sensor is too small and too big both are active, then after selecting the height of the conveyor upper will run again carrying the washer to opto sensor 2, where opto sensor 2 is located before the inductive sensor, after the washer arrived in opto sensor 2, the conveyor upper will stop for 0.7 seconds to detect the material. In the third possibility the washer is made of metal therefore the opto 2 sensor and inductive sensor will be active. After selecting the material and it is known that the washer is made of metal, the upper conveyor and solenoid 3 will be active for 10 seconds, making the metal washer on the chute 2. After 10 seconds, the top conveyor stops and the solenoid 3 closes with the chute 2 active and make the washer fall to the lower conveyor and make the opto sensor 3 active to enter the assembly process.

The second part is the assembly of parts that occur on the lower conveyor, where the washer that enters the assembly stage has the appropriate high size so that at this stage there are only two possibilities in the part assembly process, namely the plastic part assembly and metal part assembly.

In the first possibility is the assembly of plastic parts, in the previous process, namely the selection process of parts, the washer made of plastic will enter the chute 1 to drop to the lower conveyor, then after the washer is dropped by chute 1, the washer will be read by opto sensor the fourth is the 1st chute opto sensor, after the active opto sensor, the dispenser 2 containing the base peg activates and drops the base peg to the lower conveyor, then the lower conveyor activates and brings the base peg to chute 1, at base peg until on chute 1, the plastic washer will automatically be attached to the base peg, after the plastic washer is attached to the base peg, the assembly process has been carried out, then the lower conveyor will run again to bring the assembled parts to the final storage area, because the assembled parts are made of plastic then the 4-part solenoid sort is not active and the part will go into storage 1, before the part goes into storage 1, the part will pass opto sensor 5, that is plastic sort opto sensor, with opto sensor 5 active then the whole process has been completed.

In the second possibility is the assembly of metal parts, in the previous process of part selection process, metal washer will enter chute 2 to be dropped to the lower conveyor, then after the washer is dropped by chute 2, the washer will be read by opto sensor the third is the 2nd chute opto sensor, after the opto sensor is active then the dispenser 2 containing the base peg will be active and drop the base peg to the lower conveyor, then the lower conveyor will be active and bring the base peg to chute 2, at the base peg until in chute 2, the metal washer will be automatically attached to the base peg, after the metal washer is installed on the base peg the assembly process has been carried out, then the lower conveyor will run again to bring the assembled parts to the final storage area, because the assembled parts are made of metal then the 4-part solenoid sort will be active and the part will go into storage 2, before the part goes into storage 2, the part will pass through the opt o sensor 6 that is metal sort opto sensor, with opto sensor 6 active then the whole process has been completed.

b. Divide into grup

Based on the working order of the system that has been known, it is divided into groups where the rules in each group may not have different members (output) status (Set / Reset), then the work order of the system can be divided into 18 groups where the group will be created in the form of a relay named Y1 to Y18. The work order of the relay can be seen in Figure 5.

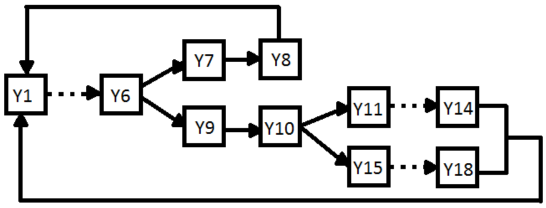

Fig. 5. working order of relay

1. The first relay is Y1 where the members are M1 +; M2 +.

2. The second relay is Y2 where the members are M1-; M2-; M3 + -.

3. The third relay is Y3 where the members are M3-; M15 +

4. The fourth relay is Y4 where the members are M3 +; M15-; M16 +

5. The fifth relay is Y5 where the members are M3-; M16-; M2 +

6. The sixth relay is Y6 where the members are M2-; M4 +; M5 +

7. The seventh relay is Y7 where the members are M3 +; M17 +; M5-

8. The eighth relay is Y8 where the members are M3-; M17-

9. The ninth relay is Y9 where the members are M4-; M3 +

10. The tenth relay is Y10 where the members are M3-; M18 +; M6 +; M7 +

11. The eleventh relay is Y11 where the members are M3 +; M18-; M8 +; M19 +; M6-

12. The twelfth relay is Y12 where the members are M3-; M8-; M9 +; M19-

13. The thirteenth relay is Y13 where the members are M9-; M10 +; M11 +; M12 +

14. The fourteenth relay is Y14 where the members are M10-; M11-; M12-

15. The fifteenth relay is Y15 where the members are M3 +; M18-; M13 +; M20 +; M7-

16. The sixteenth relay is Y16 where the members are M3-; M13-; M14 +; M20-

17. The seventeenth relay is Y17 where the members are M14-; M10 +; M12 +

18. The eighteenth time is Y18 where the members are M10-; M12-

c. *Write logic function for relay group and output*

here are 20 memories as a relay member, where the memory equation is based on the input and relay associated with the memory, the equation is:

M1 SET = Y1
M1 RESET = Y2*HTDC
M2 SET = Y1 + (Y5*Timer 2)
M2 RESET = (Y2*HTDC) + (Y6*HTDC)
M3 SET = (Y2*HTDC) + (Y4*Timer 1) + (Y7*Koil *Reject*) + (Y9*Koil *Height* OK) + (Y11*Timer 4) + (Y15*Timer 4)
M3 RESET = (Y3*Opto 1) + (Y5*Timer 2) + (Y8*Timer 3) + (Y10*Opto 2) + (Y12*Timer 5) + (Y16*Timer 6)
M4 SET = Y6* HBDC**too small***too big*
M4 RESET = Y9*Koil *Height* OK
M5 SET = (Y6* HBDC**too small**$\overline{too\ big}$) + (Y6* HBDC*$\overline{too\ small}$**too big*)
M5 RESET = Y7*Koil *Reject*
M6 SET = Y10*Opto 2*Induktif
M6 RESET = Y11*Koil Metal
M7 SET = Y10* Opto 2*$\overline{Induktif}$
M7 RESET = Y15* Koil Plastik
M8 SET = Y11*Koil Metal
M8 RESET = Y12*Timer 5
M9 SET = Y12*Timer 5
M9 RESET = Y13*Opto 3
M10 SET = (Y13*Opto 3) + (Y17*Opto 4)
M10 RESET = (Y14*Opto 5) + (Y18*Opto 6)
M11 SET = Y13*Opto 3
M11 RESET = Y14*Opto 5
M12 SET = (Y13*Opto 3) + (Y17*Opto 4)
M12 RESET = (Y14*Opto 5) + (Y18*Opto 6)
M13 SET = Y15*Koil Plastik
M13 RESET = Y16*Timer 6
M14 SET = Y16*Timer 6
M14 RESET = Y17*Opto 4
M15 SET = Y3*Opto 1
M15 RESET = Y4*Timer 1
M16 SET = Y4*Timer 1
M16 RESET = Y5*Timer 2
M17 SET = Y7*Koil *Reject*
M17 RESET = Y8*Timer 3
M18 SET = Y10*Opto 2
M18 RESET = (Y11*Timer 4) + (Y15*Timer 4)
M19 SET = Y11*Koil Metal
M19 RESET = Y12*Timer 5
M20 SET = Y15*Koil Plastik
M20 RESET = Y16*Timer 6

d. Draw Ladder diagram & Simulation

After getting 18 relay equations and 20 memory equations, this equation will be implemented on the PLC ladder diagram.

e. Validation

From time chart simulation we can validate with program sequence.

f. Implementation on PLC

Running program on PLC and test Dual Conveyor Workcell plant.

III. Result and Discussion

The Result from procedure make ladder diagram from cascade method have many internal relay, but have simple rules in the procedure. Cascade method suit for this process. Process with no or not many repetition. Simulations are carried out using software to see the correctness of the course of the program made with process descriptions. If the sequence is the same, it can be said that the ladder diagram has been made according to the system description. Then the next step is to program the ladder diagram into the PLC and use it to control the dual conveyor workcell.

in Figure 6 is the result of section 1 simulation.

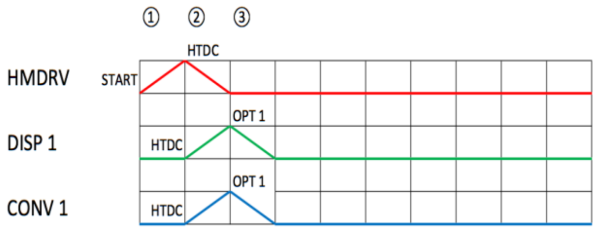

Fig. 6. *Figure sequence of section 1*

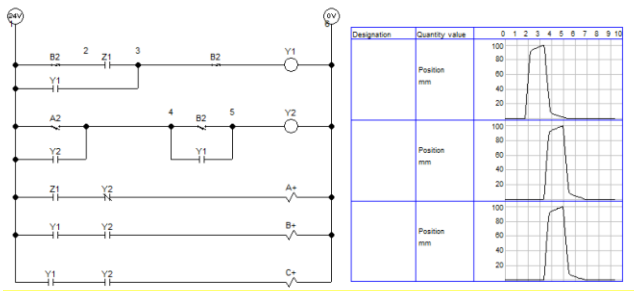

Fig. 7. *simulation ladder diagram from section 1*

Based on the sequence of program results and system descriptions, it can be seen to have the same form. Therefore, it can be said that the ladder diagram is correct and can be implemented.

To connect the controller with a double conveyor plant requires a connection for both to communicate. For this connection a PCB interface is available which allows cabling between PLCs [6] and factories. Inside there is a special socket terminal for PLC input and output cabling to connect with sensors and actuators contained in a double conveyor plant.

Figure 8 below is the cable between the PLC and PCB Interface.

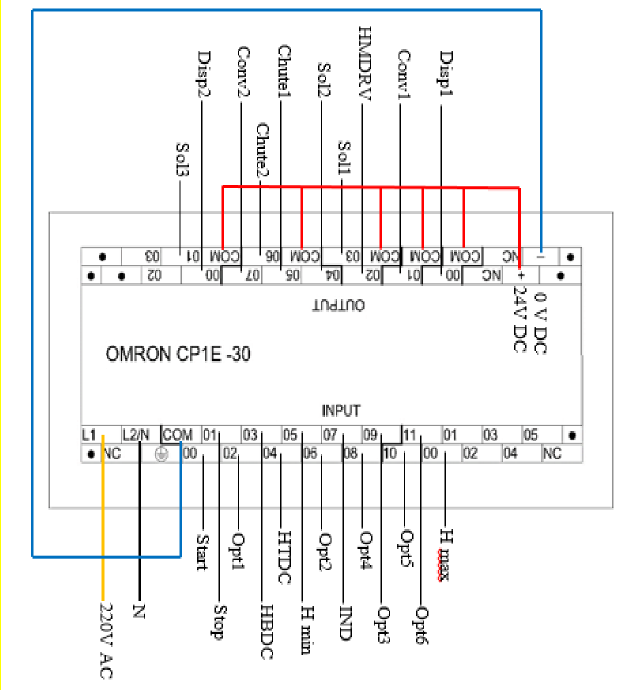

Fig. 8. wiring on the PLC

we can use multi meters to test the connection from the PLC to the PCB interface. And we make sure all cables are installed correctly. Also test the connection from the interface to the sensor or actuator if needed. This test process can also be done to solve the problem if there is a difference between the program that is running on the ladder diagram in the PLC and the actual conditions on the dual conveyor workcell.

Table 2. Test Results from 10 cycles

Standard Workpiece Testing Data (8 mm)		
Cycle number	**Metal (second)**	**Plastic (second)**
1	37.23	33.32
2	36.74	33.20
3	36.97	32.97
4	37.11	33.20
5	37.74	33.13
6	35.88	32.88
7	36.86	32.06
8	38.02	32.88
9	38.18	33.10
10	36.95	33.40
Avg. Time per Cycle (second)	**37.168**	**33.014**

IV. Conclusion

After doing the testing on this Project using Cascade method on dual conveyour plant can be drawn the following conclusion:

1. Programming using cascade method we can get number of relay to 18. The number of rung is 38 rung, 6 timer, and the program capacity is 3 KB.
2. Per cycle of the selection process and assembly of standard workpieces has an average time of 37.168 seconds for metal parts and 33,014 seconds for plastic parts.
3. The Cascade method is proof easy, suitable for non-repetitive process sequences

The results on the "Dual Conveyor" plant have three possibilities:

a) The first possibility is that the parts have an inappropriate height,

b) the possibility of both parts having a height that is suitable and made of plastic,

c) is likely that the three parts have a suitable height and are made of metal.

4. The size and material selection process occurs in the Top Conveyor, while the part assembly process occurs in the Bottom Conveyor.

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