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Integration of Advanced Process Control and Information Systems in an Electronic Manufacturing Industry

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Abstract:
This paper presents an approach that is employed in the integration of advanced process control and information systems in an electronic manufacturing industry. The approach used here is to introduce electronic sensors that will sense and control the process parameters such as level and temperatures within the electronic manufacturing equipment and ensure that the signals are linked to an automated system so that efficient monitoring and control is achieved with high yield in product quality.

Keywords: Process, Monitor, Transmitters, ladder logic program, controllers, Control system

I. INTRODUCTION

Electronic manufacturing industry is the industry that is concerned with the application of physical and chemical processes to alter the geometry, properties and appearance of a given starting material to parts or products that are electronic. This industry has produced products over the years by the use of manual means resulting in slow speed. To enhance the production of product that are of high quality and reduction in manual means of production there is need for advanced process control and information systems integration.

Advanced process control and information system integration in an electronic manufacturing industry in modern system technology is entirely a fully automated systems with the use of control systems like numerical control, programmable logic control and other industrial control systems etc in consonance with application of other information technology such as computer aided manufacturing (CAM), computer integrated manufacturing (CIM) and computer aided design (CAD) to control industrial machinery and processes, reducing the need for human intervention.

Advanced process control (APC) system also refers to the use of advanced statistical and analytical techniques to manipulate process control parameters and inputs on process tools to improve output quality. It is algorithm-based, and indicates the adjustments necessary (from one lot to the next) to reduce systematic variation.

In integrating advanced process control (APC) with information systems the sensors and their communication signal medium are used to link signals to the controllers and microprocessors in the control room and the controllers are finally linked to the human machine interface (computer) through routers or switches. As a general rule, for advanced process control and information system integration in an electronic manufacturing industry to be adopted, it means that a totally manned operated machine will be transformed into an automated one. In doing this, a programmable logic controllers and other related equipment will be put in place to achieve this. This system will consist of sensors, junction boxes, cables, control system cabinet, power supply module, controllers, input/output cards, Ethernet switches, Human machine interface (HMI) etc.

II. METHODOLOGY

The methodology used in this paper considered the key equipment operations involved in manufacturing process, the instruments process parameters, the signal line communication to the control room, the interconnection wiring terminations of the marshalling and system cabinet in the control room and the programmable logic functions implemented on the control system for efficient monitoring and control.

II.1 Key Equipment process operations involved in manufacturing process

Every manufacturing process involves the processing and assembly operations. The processing operations comprises of the shaping operation, property enhancing operation and surface processing operation while the assembly operation consist of the permanent joint and temporary joint. The shaping operation comprises of five stages which are the solidification process, particulate processing, deformation process and material removal process.

The property enhancing operation consists of heat treatment, while the surface processing operation consists of the cleaning, surface treatment and coating & thin film deposition. The key equipment as considered in this article is the equipment which is used for mixing of raw material into a finished product. The equipment is composed of an agitator motor which mixes the raw materials into finished product and it is controlled automatically with the help of an electronic instrument transmitters.

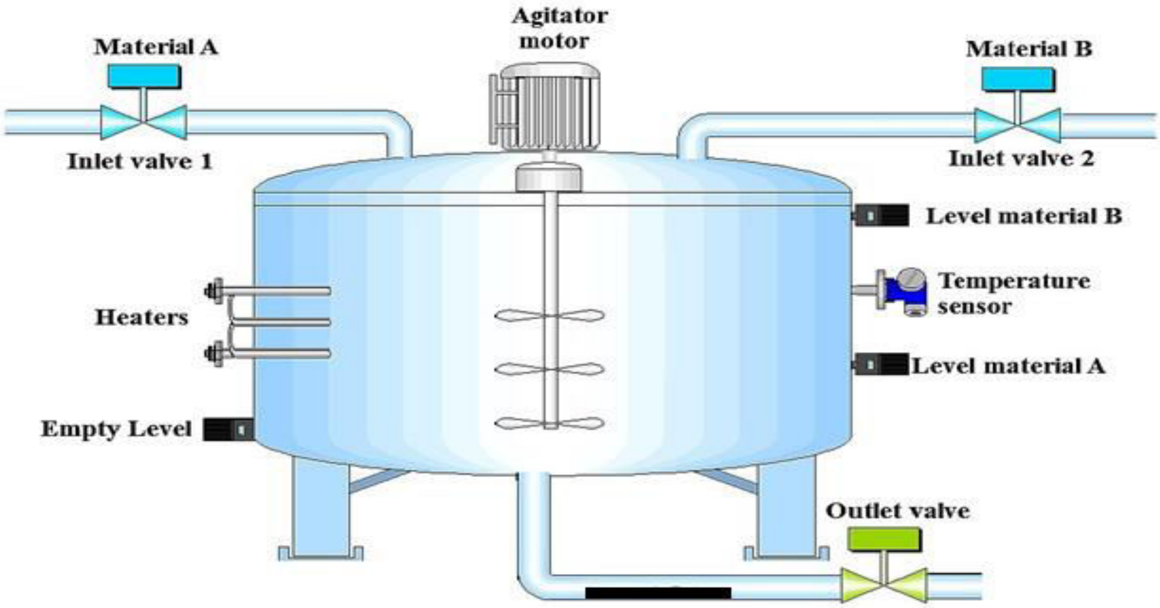


Figure.1. Automatic and Mixing of Products design diagram

II.2 Instrument Process Parameters:
Considering the manufacturing equipment in fig 1. The field instruments that will be used to achieve the automation process include the temperature and level sensors, inlet 1 and 2 control valves and the outlet control valve. Based on the analysis of the instrument, the input/output list used for fig 1 above is shown in the below table.

Table.1. Instrument input/output (IO) List

S/N	INSTRUMENT	SIGNAL TYPE	QUANTITY
1	Level Switch	Digital Input (DI)	3
2	Temperature transmitter	Analog Input (AI)	1
3	Control Valve	Analog Output (AO)	3

II.3 Signal Line Communication Field to the control Room.
Instrument signals are conveyed through a medium from one location to another. The medium through which these signals are transmitted is through cables. The cables can be of fiber optic or copper media type. Fiber optic medium is associated with the technology involved in the transmission of information as light pulses along a strand of glass. A fiber optic strand carries much more information than conventional copper wire and far less subject to electromagnetic interference and this cable is usually considered for long distance communication. Copper media type consists of the coaxial and twisted pair cable. Coaxial cable is a primary type of copper cable used for signal distribution between community antenna and user homes and businesses. The twisted pair is composed of two insulated copper wires twisted around one another. The twisting is done to prevent opposing electrical currents travelling along individual wires from interfering with each other. There are two major types of signals in signal line communication for electronic instrument devices and these are analog signals and digital signals. These signal line communication uses a protocol known Profibus, Highway addressable remote transducer (HART) Communication, Foundation fieldbus (FF) etc. In this article the 4-20mA HART communication was used for the electronic instrument transmitters. The single pair cables (also known as the secondary cables) were used to connect the instrument to the junction boxes while multi-pair cables (also known as the primary cables) were used to connect the junction boxes to the control room.

II.4 Interconnected wiring connection in the Marshalling and System cabinet.
The control system of the advanced process control is located in the control room. This control room is 100m away from the manufacturing factory area. The control room is a safe zone and contains the marshalling and system cabinet. The marshalling cabinet contains the terminal blocks, surge suppressors, intrinsic safe barriers and power supply module. The multi-pair cables from the junction boxes containing the instruments are terminated in the terminal blocks of the marshalling cabinets. An interconnection wiring is done from here to link the suppressors, barriers etc together. The power supply module is 24Vdc which feeds the system cabinet where controllers and the input/output cards are situated. This is known as loop configuration arrangement.

II.5 Programming language used for Automatic Heating & Mixing of product.
The IEC 61131-3 standard specifies five distinct forms of programming language for industrial controllers. They are ladder logic diagram (LD), Structured text (ST), Instruction List (IL),

Function block diagram (FBD) and sequential function chart (SFC). Not all logic controllers support all five language types but nearly all of them support ladder diagram. Limited variability language are utilized or considered for ladder logic and function block diagram while other instruction list and traditional computer programming languages such as C/C++, FORTRAN etc are considered full variability languages. In this article, the ladder logic program was used to write the logic for the automatic heating and mixing of product. In fig 1 above, three level switches of digital input (DI) were used to detect the level of materials i.e material A, material B and empty level of material. The control valves were used for level control while motor agitator is used for mixing of product materials. The heater and temperature are installed inside the tank and when materials which are mixed reaches the set point of the temperature after mixing, the outlet valve will be activated to allow for the outflow of the mixed product. The PLC program used is Siemens PLC (S7-1200) and the following addressable codes are used for the programming input and output contacts.

Table .2. Input Action list with address code

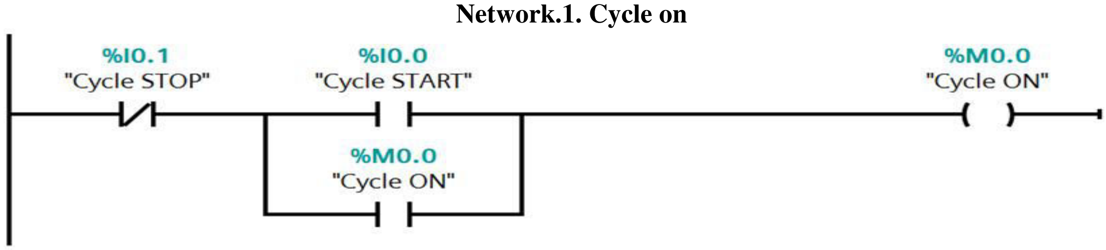
S/N	INPUT ACTION	ADDRESS CODE
1	Cycle Start	I0.0
2	Cycle Stop	I0.1
3	Material level B	I0.2
4	Material level A	I0.3
5	Empty level switch	I0.4
6	Temperature	I0.5

Table.3. Output Action list with address code.

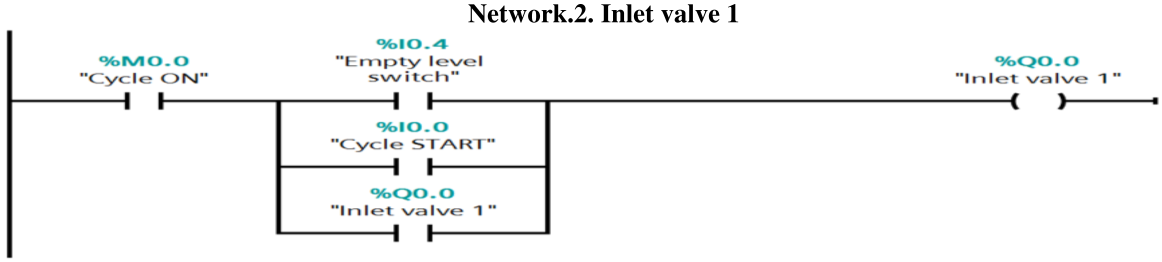
S/N	OUTPUT ACTION	ADDRESS CODE
1	Inlet valve 1	Q0.0
2	Inlet valve 2	Q0.1
3	Agitator Motor	Q0.2
4	Heater	Q0.3
5	Outlet valve	Q0.4

In this logic there are five networks that are considered for the rungs in the program. The below logic is the ladder logic used for the implementation of the program in fig 1 above. The Network 1 depicts a single latching circuit for cycle on and off. The cycle activation uses normally open contact (I0.0) for start button and normally close contact (I0.1) for stop button. Network 2 shows the inlet valve 1 (Q0.0) operation when low level of the tank is detected (I0.4). The valve is closed when level material A is detected by a switch with address (I0.3). The start push button (I0.0) is also connected in parallel, so if low level is not detected, inlet valve can be started by pressing start push button (I0.0). Network 3 shows the operation of the inlet valve 2 (Q0.2). The valve is operated when material A is filled with its desired level. Hence when cycle is running and level of material A is detected, inlet valve 2 (Q0.1) will be ON. Network 4 is used for the operation of the agitator motor and heater. When tank is full with material B, heater (Q0.3) and agitator motor (Q0.2) will be ON. Network 5 is used to for entire mixing process. When this is done, outlet valve (Q0.4) will be ON. Normally open contact of empty level switch (I0.4) is used to stop the outlet valve when tank is empty.

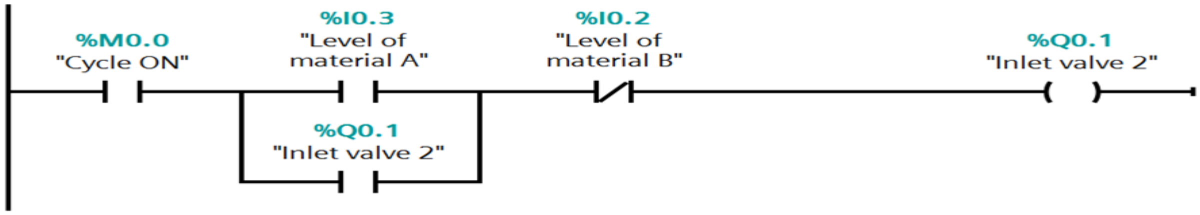
Network.1. Cycle on



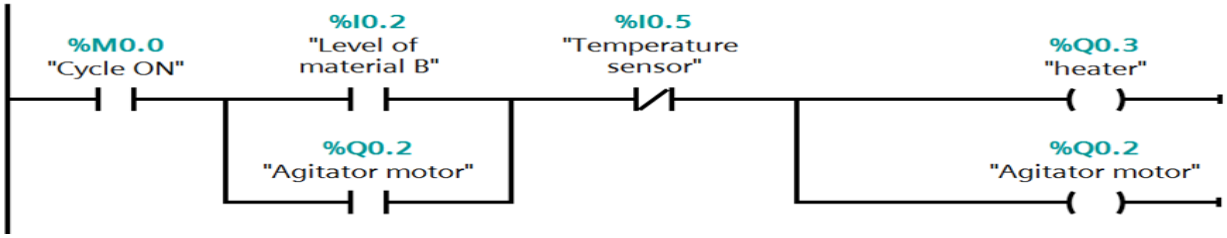
Network.2. Inlet valve 1



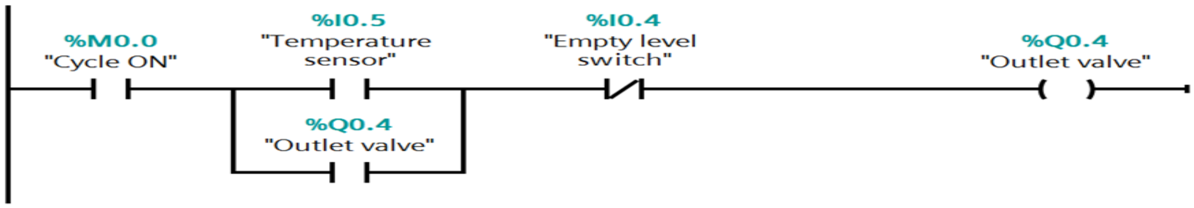
Network.3. Inlet valve 2



Network .4. Heater and Agitator Motor



Network .5. Outlet valve



III. RESULT OBTAINED

Upon the completion of the ladder logic programming. The offline program is downloaded to the controller and the system is initiated in the online mode. The result derived is indicated in the table below:

Table.4. Results of the control system for an input signal.

INPUTS	OUTPUTS	PHYSICAL ELEMENTS
I0.0 =1	M0.0 =1	Cycle ON
I0.4 =1	Q0.0 =1	Inlet Valve 1 ON
I0.3 =1 & I0.2 =0	Q0.1 =1	Inlet Valve 2 ON
I0.2 =1 & I0.5 =0	Q0.2 & Q0.3 =1	Agitator & Heater ON
I0.5 =1 & I0.4 =0	Q0.4 =1	Outlet Valve ON

The table analysis shows that the input contacts uses the OR and "AND" gates to derive the outputs. For network 1, the output contact will be ON when the input start push button is toggled. In network 2, when the empty level switch is detected, the inlet valve 1 becomes operational. Also in network 3, when the level switch of the material A is detected and level switch of material B is inactive, the inlet valve 2 comes into operation. For network 4, when the level switch of material B is active and that of temperature sensor is inactive, the heater and agitator motor comes into operation. Finally in network 5, when the temperature sensor is detected and the empty level switch is not inactive, the output valve comes into operation.

IV. CONCLUSION

The advanced process control integration technology in manufacturing processes could be practical and valuable. With this integration in place, good quality products could be manufactured in addition to the increased speed of production and downtime reduction. From the results gathered above, we can deduce that a perfect integration of this process will lead to optimal manufacturing processes and factory challenges such as high mix low volume loadings involving shorter production runs and frequent changeovers will be addressed.

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