

Automation of Tire Curing Machine Using IOT

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Abstract

Objective: To obtain several analog and digital inputs and outputs in tire curing process and to develop algorithm for the tire curing process and then interfacing PLC to HMI and SCADA to establishing communication between PLC and cloud so that the PLC is accessible from remote location. **Methods:** On the effective study of the plant, the PLCs are calibrated and programmed using Rockwell software package, a model of tire curing machine is simulated in Factory Talk View Studio platform and the corresponding behavior of curing machine to change in inputs are studied remotely. Further using Open Automation System software the data from PLC is stored and retrieved from cloud to ensure loss of data and remote operation of PLC. **Findings:** In the current system, the plant operations cannot be remotely monitored. Through the implementation of cloud technology Real time data can be monitored and recorded thus loss of data is greatly minimised. Troubleshooting becomes much easier for site engineers as they need not be present at the hazardous machine environment. Data can be moved from anywhere to everywhere. Open Automation System provides high end security of data. In current system the SCADA screen will be available only within the plant to monitor the on-going processes but in the proposed methodology the SCADA screen can be accessed by authentic users globally. **Applications/improvements:** The areas of data monitoring and recording systems are improvised by the implementation of cloud computing and IoT techniques, it is suitable for process industries with high risk factors in the work environments where the site engineers face difficulties in programming or troubleshooting PLCs.

Keywords: Green Tires, Mechanical Bladder, IIOT, OAS, PLC, SCADA

1. Introduction

The Operation of curing process has huge impact on the ability to meet the goals in the manufacturing of tire¹. The tire curing process usually accounts for 60% to 90% of the steam consumption of the factory². The manufacturers depend on curing process for fast, reliable and repeatable performance. Tire curing involves two important process namely vulcanization and tread or track pattern forming in the tires. Vulcanization is one of the most important steps in tire curing process³.

Pressure, temperature and time are the vital parameters in vulcanization process. The quality of the tire is directly affected even for the small variation in the temperature 2.6 °C and pressure 1.5 Kg/cm².⁴ If the tire is in

low temperature, it produces low sulphur content thus resulting in low wear resistance. Also, if the tire is in high temperature, it produces too much of sulphur content resulting in short life time of tire³.

Treads plays major role in tires and it traces the pattern in the circumference of the tire⁵. These traces allow water to expel from beneath the tires thus preventing Aqua planning. When the water on the roadway acts as a lubricant then this phenomenon is called as aqua planning. This leads to the loss of traction of vehicle when a layer of water builds between the road and the surface of the tire, thus resulting the vehicle from responding to controller inputs. The thread patterning helps the tires of the vehicle to stop in a correct position that the controller wants to position. Curing⁴ is the process of applying

pressure to the green tire in order to give a final shape, and applying heat energy between the rubber compounds and other materials to obtain a finished tire. A green tire is placed inside a large mold for the curing process. A tire mold is shaped like a huge metal which opens a big balloon like structure called as bladder. The bladder is filled with heat transferring medium such as steam, hot water and inert gases.

Testing is the last and important process in the tire manufacturing. Testing is required for any finished product before it should be released in the market for consumer use, the tire also undergoes many testing process before going market. Industry standard evaluation includes Indoor Testing and Outdoor Testing. Outdoor testing involves the testing of the tire with surrounding parameters, and to check that the tire is suitable for the external environment. These testing process involves Government compliance, Accelerated aging, Failure analysis and forensics, Force and moment, Snow and ice traction, and OTR. The indoor testing involves testing the tire with the shape size and structure and the thread patterning of the tire. The process involves Laser tread Profilometry, Subjective ride and handling, Burn tests, Competitive benchmarking, Indoor tread wear, Footprint Characterization for modeling, Rolling resistance, Traction /tread wear/noise.

IOT expands and improves the data by connecting billions of devices capable of sharing, receiving, and analyzing massive amounts of it to better meet business needs and improve decision-making. The hierarchy of IOT is emerged as follows: The first website was come in 1991. In no time the internet took over the world. In 1995, multiple websites and systems came online. These were major for the birth for IOT. The argument of internet of things came from Nikola Tesla in 1926 when he commented that “when wireless is perfectly applied to over world earth will be converted into big brain”. In 1998 the real IOT was introduced by Mark Weiser which will rise and fell according to the stock price of the NYSE. The first example of IOT was introduced in COCO-COLA vending machine which is connected to the internet so see that any drink is available and to check the temperature of the drink and if it was sold. The simple IOT system will have ON/OFF switch controlled over internet. The paper is organized as follows. Section 1, explained the introduction part, Section 2, depict the various related works with respect to tire curing and its methods.

2. Literature Survey

Tire curing press in Rockwell automation explained about the importance of the vulcanization process in the tire manufacturing process, and results of the improper vulcanization process². It states about the control of the tire curing process using PID control, its features, and disadvantages and why we prefer PLC over this controller and tell about the classic control system in tire manufacturing and the optimization of the process. It also depicts the software structural layer of the total process and the software used in every layer².

Industrial automation and control system (IACS)⁶ is used to describe the type of control systems such as input, output devices, systems and controls used to operate the industrial process. Industrial automation and control system has been separated from the digital network such as Information and communication techniques (ICT)⁶. The author has improved the existing definitions of industrial IOT and to work with the IIOT components in industrial settings. The characteristics of the devices can be identified by the systematic manner and capable to analyze the various threats, vulnerabilities and to identify patterns employed on technology. The system provides an analytical approach towards industrial systems such as Cyber Physical Systems (CPS), Industrial control systems (ICS), Supervisory Control and Data Acquisition (SCADA), Industrial IOT and sensors⁶.

The solid tire sulphation control system based on PLC and Fuzzy adaptive PID control algorithm stated about the tire curing system on military industry of Mongolia China. They control the tire process by Fuzzy adaptive PID control algorithm using PLC with the software of MCGS, and tell the importance of the Fuzzy adaptive PID system over normal controller. Internet of things is used for the intelligent operations and industrial domains such as smart city, smart energy, healthcare, food and water, tracking, logistics and retail and transportation. Industrial Automation deals with the process of real time data collected from the large number of physical hardware units for developing new intelligent applications⁷. It gave the brief overview of research projects with IOT as well as the usage of IOT in the industrial automation and also described the general IOT challenges and some of its technical solutions in industrial automation⁷.

Multitasking Control for modern tire machines provided the need of multitasking control for the improvement of product quality and cost. It served the integration between modern computer tools, low level control and machine control for plant management⁸. This results in the usage of PLC and mini-computer features over manual control. The main advantage of this system is that its flexibility and can be employed on any practical system. In tire building process, the unique multitasking techniques can be explored in three types and they are an extruder, tire builder and tire curing⁸.

Simulating system for vulcanization³ integrates product planning, adjusting, production starting time, adjusting number of input and output devices inserting and withdrawing orders. The vulcanization process is very important for improving production efficiency and product quality. In vulcanization process, the production efficiency can be increased with the help of Heuristic algorithm which is used to find the solutions among all possible ones, but they do not guarantee that the best will be found³. Zigbee based wireless monitoring system² explained about the monitoring, controlling and connecting PLC with the SCADA using ZIGBEE module to get wireless automation system. ZIGBEE module is connected with the PLC and then other receiver with the RS232 port of computer. Thus the control can be done by the industrial computer². Punched card control provided the curing process evaluation process description and steps and control it with the punch cards but this process is done manually hence cannot be that much efficient since it is done by human hands. Only states about the time given for each steps in the curing process. The time allocated for each steps is collected⁴.

3. Proposed Method

In the proposed method, the development of tire curing press is automated with PLC and connected with IOT using TCP/IP protocol. The process can be automated using PLC (Allen Bradley 1756-L71 processor) and connected to the device in the SCADA room via Ethernet port. The Ethernet port is connected to the IOT Gateway and internet. The PLC is connected to the internet can be accessed from the remote location by authentic users in

the company can be controlled and monitored. Further the data are stored in the cloud for future use of the company.

3.1 Block Diagram for Iot Connection to the Curing Process

Figure 1, 2 explains about the process of the connection of the tire curing press in the industrial area to the computer in the remote location by the help of the internet with the TCP/IP protocol which is widely used in the industrial areas for the communication. The PLC acts as a controller for the device and the control of the input and the output devices and any further information will be conveyed through the PLC. The PLC is connected to the i/o's and then through the Ethernet port of the PLC the computer in the SCADA room for the monitoring is connected through the TCP/IP serial communication protocol¹⁰.

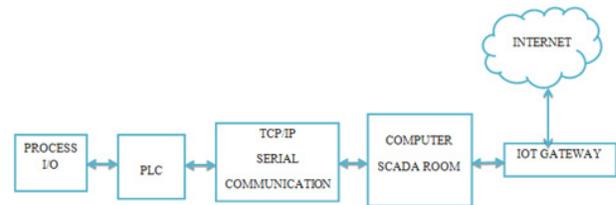


Figure 1. IOT Transmitter.

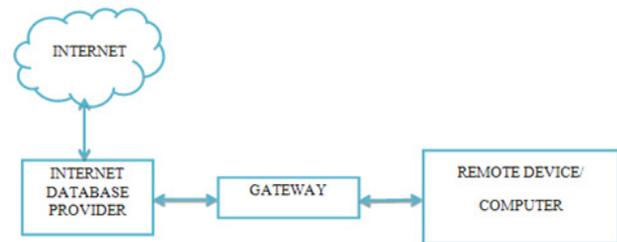


Figure 2. IOT Receiver.

The computer in the SCADA room is further connected with the internet through the IOT gateway which will connect the computer in the SCADA room to the internet thus allowing to share and store information in the server and the company's web service provider. This is the block in the industrial site, this will further be gathered and then used in the remote location. This information is stored in the internet database provider which provides the storage area

in the internet for the industries and then it is frequently send to the gateway in the remote location of the company which requests that address in the internet can be accessed only by the authentic persons in the company. The data is finally reached to the computer in the remote location thus can be monitored and the process can be controlled from the remote location by the same process in the reverse direction from the remote location to the PLC.

3.2 Block Diagram for Input/Output of PLC

Figure 3 depicts about the flow of the inputs and the outputs according to certain parameters in the curing press like temperature, pressure, and position that is required by the Allen Bradley PLC that act as the controller for the total curing process and thus to change the output devices accordingly². The input devices are Resistance temperature detector (RTD), Bourdon Tube Pressure gauge, linear variable differential transformer (LVDT), Proximity sensor, Selector switch, and emergency shutdown button¹¹. The output devices are Pneumatic control valve, Solenoid control valve, Motor driver, Contactor, relay, Alarm and buzzer.

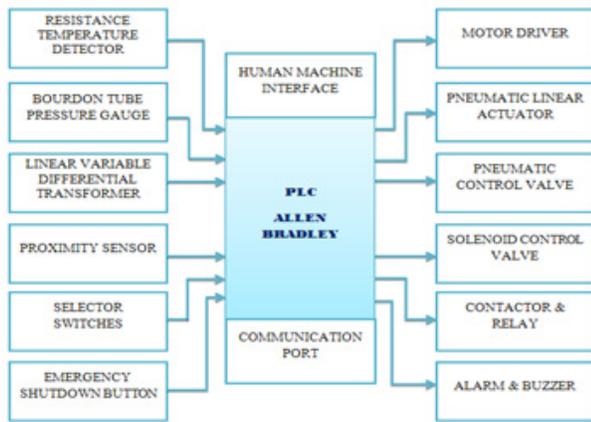


Figure 3. Tire curing process controller.

The temperature is measured with the RTD sensor which will be feed to the PLC and then according to the requirement the valve are operated to maintain the required temperature. The Bourdon Tube Pressure gauge will give the value of the pressure in the bladder then the PLC will compare it with the requirements and then will control the blow down valve with the solenoid valve according to

the pressure to be maintained. The alarm and buzzer is used to indicate any emergency situation thus the power and the blow down valves are set open. The HMI (human machine interface) is connected to the PLC to indicate the process steps and current state of all field devices thus it helps the operator and the site engineer to monitor the curing press. All the devices are connected to the PLC with necessary safety interlock schemes.

The circuit diagrams of PLC, power supply, IO cards, HMI and various other input and output parameters are depicted in the Figure 4 and Figure 5, the circuit diagrams are specially designed by engineers to encounter all demands of the process and safety interlocks. Each field devices are uniquely identified used respective tag names, these tag names are used to mention the use of a particular field device. Standard electric, pneumatic and hydraulic picture representations are used to draft the circuit diagrams. The input devices keep reporting to the PLC IO cards in sync with the scan cycle scheme of PLC. With a predefined time delay the input parameters are processed by the controller and the calculated outputs are written on the output channel of the PLC.

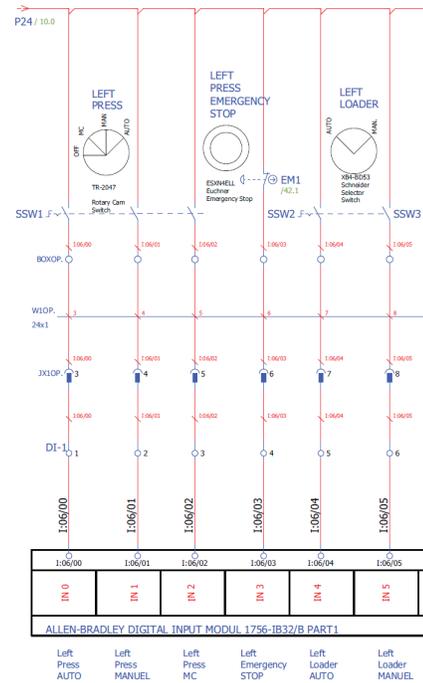


Figure 4. Inputs to PLC.

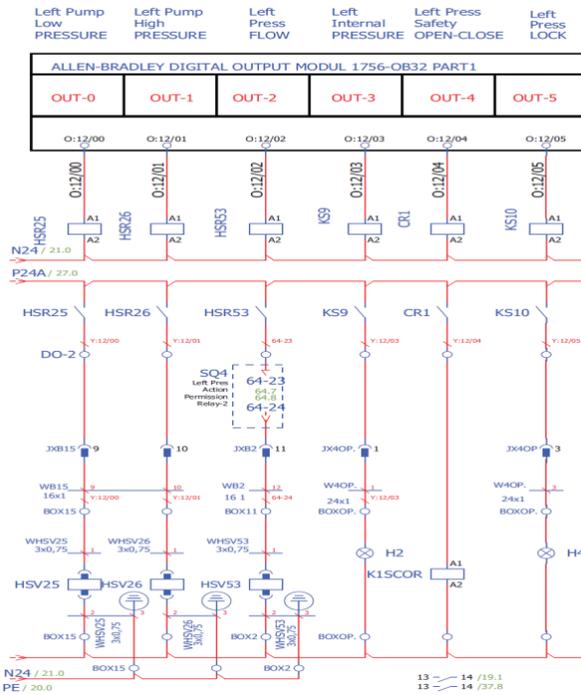


Figure 5. Outputs from PLC.

The output devices include relays, contactors and motor drivers along with emergency indicators such as alarms and siren. The field devices are segmented and grouped based on their operating parameters such as hydraulic, pneumatic and solid state devices. The output channels of the PLC run through individual fuses before hitting the drivers and starters of the hydraulic and electric motors, the current to pressure converters are used to proportionally convert controller output to pressure signals which are used to actuate pneumatic control valves. Sick safety laser scanner S3000 is used to detect the presence of humans within the working area of the curing press, if any human actions are found within the boundaries of curing press the process is halt and siren light are illuminated. Similar actions take place whenever the Emergency stop buttons are actuated. LVDTs are used in co-ordination with the input channels of PLC to fetch the precise position of the loader, the loader position is varied by moving it up and down using the respective motors¹².

4. Software

4.1 Tire Curing Process Operations

1. Loading into press with loader ARM

Green tire placed inside the press over the bladder for Curing process.



2. Curing press closing for curing
After Green tire placed into the press over s bladder, Low Stream into the bladder to hold the green tire in correct position and closing press at the same time.



3. Locking and Squeezing
Locking the press cylinder with the height of mold present on the press and squeezing force will apply on the other direction to avoid flues on the tire.



4. Curing Process
High pressure stream passes inside the bladder for vulcanization (curing the tire) process in 209 degree Celsius with 17 bar pressure.
Hot Water passes inside the bladder for vulcanization (curing the tire) process in 160 degree Celsius with 28 bar pressure.
Cold water supply passes inside the bladder with 60 degree Celsius with 26 Bar Pressure.



5. Unlocking and press opening
Unlocking the press and press will open for unloading the finished tire.



6. Unloading the finished tire
After Curing Process finished tire will be around 80 degree Celsius, It will be unloaded with Unloading arm and placed in the surge conveyor for next process.

The Ladder program is coded using RSLogix 5000, the respective tag names are created for inputs & outputs associated with the process. Communication is established between PLC and computer via RSLinx classic, the code is downloaded to PLC and PLC is put to run mode. Virtual PLC is activated using RSLogix Emulate 5000, the controller is synced with Factory Talk View Studio to create and execute simulated model of tire curing process using virtual inputs.

4.2 Internet of Things Operations

The algorithm for fetching of data from the controller and uploading data to controller through remote node using internet¹³⁻¹⁴ as communication medium

1. PLC controller

Programmable Logical Controller is used to control and manipulate Tire curing process variables.



2. Establish local communication

All the digital and analog data are communicated to SCADA and HMI via TCP/IP serial communication with the aid of Ethernet switches



3. Enable intelligent internet gateway

Intelligent IOT gateway with effective firewall is employed in the communication node to read and write data in the communication network



4. Creating database with effective firewall

Online database is created in cloud with unique log-in credentials. The database is used 24 × 7 for effective data logging of process variables. Loss of connectivity is minimized with smooth and uninterrupted internet facility.



5. Remote controlling of process

As the PLC is connected online with the cloud, all parameters associated with the PLC can be viewed from anywhere with proper internet connectivity, new programs can be downloaded to PLC¹³ from remote location.

Open Automation System (OAS) software is installed in the server of the tire plant. OAS aids in establishing communication between Process controller and Internet. OAS is configured with log-in credentials, IP address and API keys¹⁵, Factory Talk View Studio is synced with OAS to transfer real time data from SCADA to the connected server. OAS is also installed in the remote receiver node, the authentic user can log-in and monitor the parameters associated with the channel synced with the channel's API and domain/IP address.

5. Results And Discussion

The tire curing machine is thus automated using the demanded software package, resulting motions of the loader and jacket of curing machine are viewed in the SCADA system at the site and at the remote node by authentic users using TCP/IP communication protocols and OAS software as shown in Figure 6.

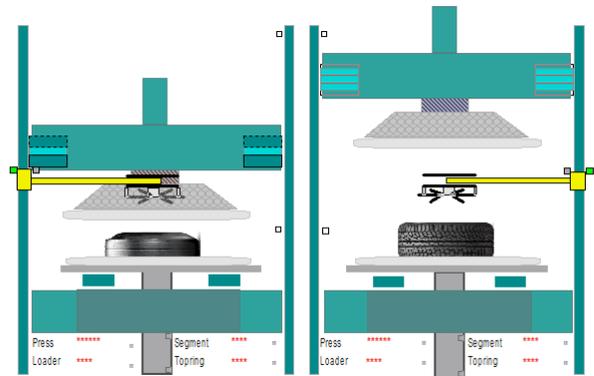


Figure 6. Simulated model of tire curing machine.

The crucial output parameters are maintained at set point within pre-calculated tolerance using reliable control valves and drivers. Alarms are activated when manipulated variables exceed tolerance

High Pressure Steam Temperature

Set point $208^{\circ}\text{C} \pm 4^{\circ}\text{C}$

Cold Water Supply Temperature

Set point $40^{\circ}\text{C} \pm 10^{\circ}\text{C}$

Figure 7 depicts the current analog values of various temperature sensors installed in the trench, similar SCADA screens depicts the values of real time pressure of trench and position of loader.



Figure 7. SCADA screen for temperature monitoring.

6. Conclusion

Humans are vulnerable to tire curing process because of hazardous environment and high process temperature. Thus, remote operation of PLC is unavoidable. IOT and automation has met this need which greatly reduces workload on site engineers. Tire curing machine could be further simplified by installing smart transceiver making it completely wireless. IOT system could be effectively employed in Distributed Control System linked with entire tire manufacturing plant.

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