DEVELOPMENT OF AN IIOT-READY CONVEYOR SYSTEM

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Abstract: *In recent years, there is a growing trend of developing diverse Industrial Internet of Things (IIoT) devices and systems to support the advancements in industrial systems known as the Industry 4.0. New devices and systems are often developed with connectivity capabilities, however there are many already functioning devices and systems that are initially not able to connect to the network and become a part of the IIoT. This paper presents the development of an IIoT-ready conveyor system, where a traditional conveyor system is enhanced with an IoT module to adapt to the new industrial paradigm. Through the IoT module, the conveyor system can connect to the network and become part of the IIoT, thus allowing data acquisition, remote monitoring and control of the conveyor. The developed system consists of a conveyor belt, electric motor, variable frequency drive (VFD), programmable logic controller (PLC) and a dedicated IoT module that enhances the traditional PLC and enables the integration of the whole system into IIoT.*

Key words: Industrial Internet of Things, conveyor system, IoT module

1. INTRODUCTION

In the recent years, the industrial world has significantly changed through a digital transformation where an increasing number of devices are getting interconnected and becoming able to seamlessly communicate, share and analyze data, collaborate among themselves as well as with other services, processes and people. This transformation where traditional industrial systems are augmented with advanced digital technologies is also known as the fourth industrial revolution, or the Industry 4.0 (Al-Zubaidia et al. 2022, Bajic et al. 2020, Hauge et al. 2021, Hermann et al. 2016, Lasi et al. 2014, Salunkhea et al. 2022, Vaidya et al. 2018). One of the main aspects of the Industry 4.0 is networking, communication, exchanging data between devices, systems, services, which is known as the Industrial Internet of Things (IIoT). Through IIoT, smart devices and systems are embedded throughout the industrial ecosystem, generating real-time data insights that empower decision-makers to optimize operations, boost productivity, and unlock new levels of efficiency and innovation.

In order to achieve the IIoT paradigm, new devices and systems are often developed with inherent connectivity capabilities. However, many existing traditional devices and systems were not initially designed to connect to the network and be part of the IIoT. To enable the integration of these devices and systems into the IIoT, they need to be expanded with networking and communication capabilities, as well as other subsystems as required, such as sensing and data acquisition, identification and tracking, processing, data storage and analysis, etc.

One of the omnipresent systems in various industrial settings is the conveyor system, which plays a crucial role in carrying and transporting materials and products throughout the system. Among the different types of conveyor systems, the most commonly used variant is the conveyor belt. These belts typically consist of a rubber loop attached over two or more rotors, powered by electric motors. Traditionally they are controlled locally through a programmable logic controller (PLC). In today's era of IIoT, conveyor systems also need to be expanded with additional networking and communication capabilities, in order to enhance efficiency and productivity by enabling real-time monitoring, data collection, and analysis, predictive maintenance and streamlined operations. The addition of these capabilities facilitates seamless communication between conveyor systems and other components of the industrial system, enabling a more agile and responsive production environment. Such real-time monitoring and control capabilities offer insights to the state of the conveyor system at all times, and enable timely reactions in case of unwanted behavior or events.

This paper presents the development of an IIoT-ready conveyor system, where a traditional conveyor system is enhanced with an IoT module that allows the conveyor system to connect to the network and become part of the IIoT, thus allowing data acquisition, remote monitoring and control of the conveyor. The developed system consists of a conveyor belt, electric motor, variable frequency drive (VFD), PLC and a dedicated IoT module that enhances the traditional PLC and enables the integration of the whole system into IIoT. The dedicated IoT module also enables upgrades to existing conveyor systems with low-cost investments and in short time since it uses widely available reliable components.

2. CONCEPTUAL SOLUTION

The simplest way of controlling the operation of the conveyor belt is by directly supplying voltage to the electric motor drive. This is typically achieved by using switches, buttons, and contactors, allowing easy on/off control and, with additional switches and contactors, changing the conveyor belt's rotation sense. However, this basic approach of controlling the conveyor belt lacks the ability to change the speed of the conveyor belt in a simple way. To enable control of both speed and direction of the conveyor belt, it is necessary to use additional control elements such as VFDs. VFDs allow users to easily adjust speed of the conveyor belt from 0 to 100% and change its rotation sense. The aforementioned ways of controlling conveyor belts allow only manual control. The disadvantage of manual control is that the operation of the conveyor belt is not automatically adjusted depending on the current state and needs of the industrial system. For automatically controlled conveyor belts, it is necessary to use additional control devices to coordinate the operation of the conveyor belt with other elements of the industrial system, such as changing the speed and direction of the belt movement depending on the current needs of the industrial system. One of the frequently used control elements in industrial systems are programmable logic controllers. PLCs are industrial computers that, using digital and analog inputs as well as communication interfaces for communication with other devices, collect data on the state of the industrial system. Based on the collected data, PLCs control the operation of industrial systems through their digital and analog outputs and communication interfaces. Consequently, PLCs can control the operation of conveyor belts to adapt their performance to the current needs and conditions of industrial plants.
The idea of this paper is to enable the implementation of the Industry 4.0 concept in a simple way on existing conveyor belts within industrial systems, thereby elevating their functionality to a more advanced level. The proposed conceptual solution is shown in Figure 1.

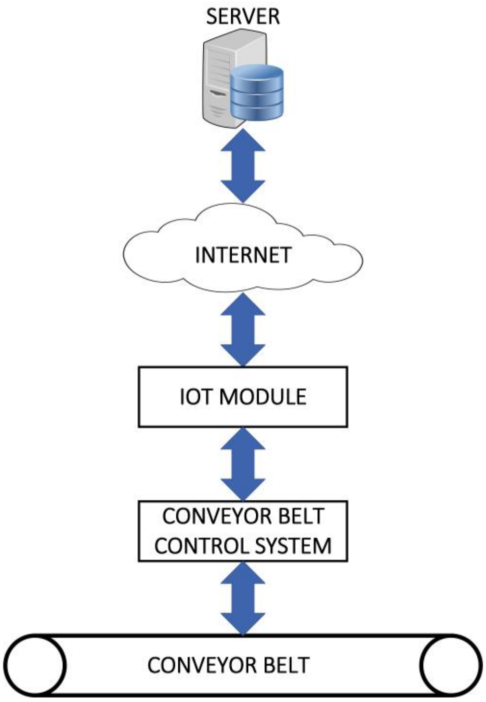

Figure 1: The conceptual solution

The conceptual solution is based on implementing of the Industry 4.0 concept using the IoT communication module on traditional conveyor belt transport systems. The IoT communication module is additionally implemented and connected to the existing conveyor belt control system and represents both the conveyor belt control system and the server application connection. The server application collects data about the operation of the conveyor belt through the IoT module and based on data processing can send commands to control the operation of the conveyor belt. Additionally, the server application can be used to monitor the operation and assess the condition of the conveyor belt to plan the maintenance of conveyor belt elements in real time. This way, the proposed conceptual solution represents a straightforward and practical method for upgrading conventional conveyor systems, enabling them to seamlessly integrate into the Industry 4.0 paradigm, leading to improved efficiency, productivity, and overall performance.

The IoT module can be implemented in different scenarios, depending on the underlying type of conveyor belt control. If the simplest method for turning on and off the conveyor belt and changing its rotation sense using switches, buttons, and contactors is used for control, the digital outputs of the IoT module can be connected in parallel with control switches, buttons, and contactors. This way it is possible to control the conveyor belt manually from a remote location or automatically by sending commands from the server application. If the conveyor belt is controlled with a VFD, the IoT module can be connected to the VFD, which enables sending commands to the VFD. This way, the operation of the conveyor belt, changing the rotation sense of the conveyor belt as well as the speed of movement of the conveyor belt can be controlled from a remote location, manually or automatically based on the processing of collected data on the server application. If a combination of a PLC without and with a VFD is used for the operation of the conveyor belt, the IoT module can be connected to the PLC and in this way additional commands and parameters for the operation of the conveyor belt can be sent to the PLC from a remote location. In this case, the PLC remains the main control element for controlling the operation of the conveyor belt, and the IoT module only forwards additional information on how the operation of the conveyor belt should be controlled.

The proposed solution offers multiple advantages, whether implemented on existing conveyor systems or integrated into new transport systems. When applied to existing conveyor belts, it eliminates the need for major infrastructure changes, as it involves simply adding a communication module to enable new functionalities. This leads to significant cost savings and a streamlined upgrade process, since the IoT module uses low-cost widely available components, which have proven to be very reliable during operation. On the other hand, the implementation of the proposed solution on new transport systems requires only a minimal increase in initial financial investments, making it a cost-effective approach. In both cases, the conceptual solution empowers industrial plants to embrace Industry 4.0 principles without substantial disruptions or excessive financial burdens. By adopting this approach, companies can enhance their operations, improve efficiency, and unlock the full potential of their conveyor systems within the context of Industry 4.0.

3. IMPLEMENTED SOLUTION

A didactic model of a conveyor system was used to test the functionality of the proposed solution. The conveyor system consists of a 4m long conveyor belt driven by a motorized drum roller AX135 by Dyno Conveyors with a power of 250W and rotational speed of 25rpm. This is a three-phase asynchronous electric motor with a gearbox that comes in an IP66 packaging (Dyno Conveyors 2017). To control the operation of the conveyor belt, Mitsubishi didactic equipment is used, which includes a Mitsubishi PLC and a VFD. The motor is controlled by a VFD Mitsubishi D700-SC with 0.4 kW rated power at 200-240V, 2.5A rated current. The VFD parameters are given in Table 1. The rotational speed of the electric motor is set on the VFD by an analogue signal from the PLC, and the rotation sense by two digital signals (STF and STR signal at the VFD). The way of control of the rotational speed and sense is set in the P79 parameter.

The control PLC in the Mitsubishi didactic equipment is a small modular controller Mitsubishi X5UC-32MT/DSS-TS (MITSUBISHI ELECTRIC 2023) in combination with Analogue output module FX5-4DA-ADP and a 7“ HMI GT2107- WTSD which enables creating virtual command buttons and display of the current system settings. To add communication functionality with the server application, the IoT module presented in Tegeltija et al. 2023 was used, which was connected to the PLC via digital inputs and outputs. Figure 2 shows the used conveyor belt with connected Mitsubishi didactic equipment and the IoT module.

Table 1: VFD parameters

Parameter	Description	Value
P 1	Max. operation frequency	50 [Hz]
P 2	Min. operation frequency	0 [Hz]
P 7	Acceleration time	5 [s]
P 8	Deceleration time	5 [s]
P 9	VFD Over current	1.5 A
P 72	PWM frequency selection	4 [kHz]
P 79	VFD external control	3
P 80	Motor power	0.25 [kW]
P 82	Motor excitation current	1.17 A
P 83	Motor voltage	230 [V]
P 84	Motor frequency	50 [Hz]

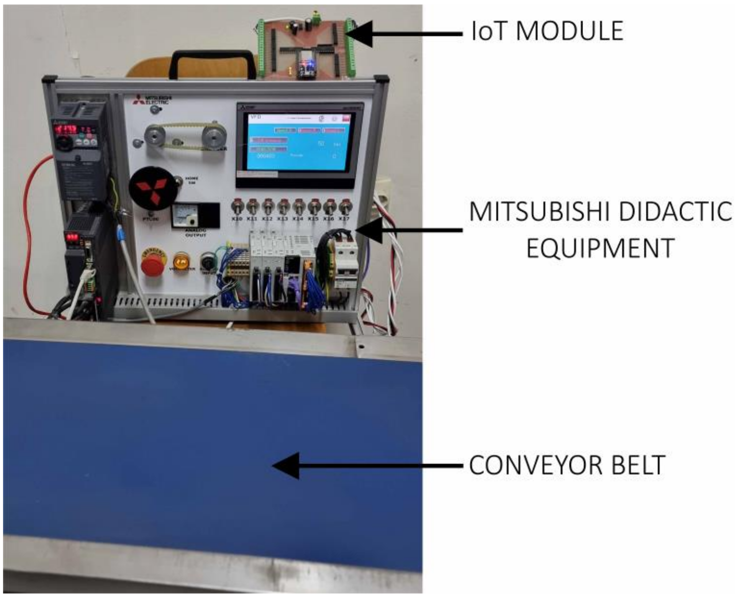

Figure 2: The implemented solution

In the implemented solution, the control of the conveyor belt is performed by the PLC that controls the operation of the VFD. Based on the commands from the PLC, the VFD controls the operation of the three-phase asynchronous electric motor, which in turn controls the operation of the conveyor belt. In this way, the rotation sense of the conveyor belt as well as the speed of movement of the conveyor belt are controlled in the interval from 0 to 100%. The PLC is connected to the IoT module, which is in turn directly connected to the internet, thus enabling the connection between the PLC and the server application, forwarding commands for controlling the operation of the conveyor belt from the server application and collecting data on the operation of the conveyor belt and forwarding them to the server application.

The WAMP server was used for implementing the server application with PHP scripts. The IoT module communicates with the server application to send collected data about the operation of the conveyor belt and to download data from the server application on how the conveyor belt should be operated. JSON (JavaScript Object Notation) data format is used for data exchange between the IoT module and the server application. The MySQL database management system was used to store the collected data. The database is organized in such a way as to monitor the current state of conveyor belt operation, as well as to track historical changes in conveyor belt operation. To test the control of the conveyor belt from a remote location, the C# test application of the IoT module described in the Tegeltija et al. 2023 was used, in which the values of the digital inputs were read, and the values of the digital outputs were directly set. In addition, an Android test application has been implemented that also enables the control of the conveyor belt operation in a frame where the operator can set the direction of the conveyor belt and the speed of the conveyor belt. Part of Android test application is shown in Figure 3. Notifications to operators or personnel in charge of conveyor belt maintenance in case of problems or necessary interventions are also implemented in the Android test application. Figure 4 shows an example of notifications when it is necessary to check the belt tension and when it is necessary to lubricate the bearings, which represent some of the most common tasks of conveyor belt maintenance.

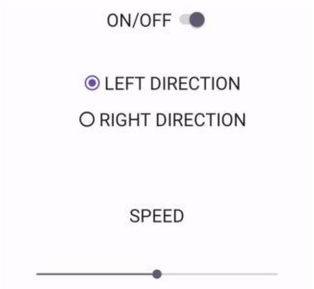

Figure 3: The implemented solution in Android application

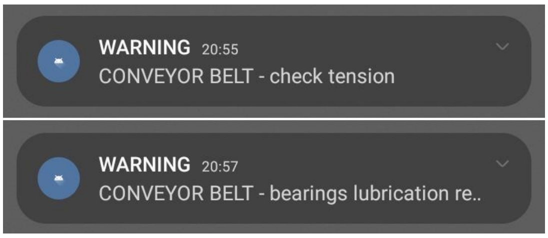

Figure 4: Examples of notifications

Moreover, a matrix based on WS2812B LEDs (WORLDSEMI CO., Limited 2017), with dimensions 8x32, is used to display additional information about the operation of the conveyor belt. The matrix arrangement of LEDs enables the display of various alphanumeric characters, allowing for the display of a more extensive information that is visible from a greater distance. The great advantage of controlling this matrix is that it is sufficient to use only one control signal, as the diodes are connected in series. Figure 5 shows an example of the displayed information, indicating the movement of the conveyor belt to the left by the two arrows and the current selection of the third speed of the conveyor belt, denoted as “S3” (shortened from Speed 3).

Figure 5: Additional information displayed on the LED matrix

4. CONCLUSIONS

This paper presents the development of an IIoT-ready conveyor system by upgrading a conventional conveyor belt with additional control systems and an IoT module, enabling connectivity and communication capabilities to integrate the conveyor system into Industry 4.0. The proposed conceptual solution is implemented and validated on a test conveyor belt with didactic control equipment. The experimental validation confirmed the system's operational status, allowing communication from the server application and an Android application for real-time monitoring and control of the system. The Android application also displayed timely notifications with suggested actions for users in predefined scenarios.

The main advantages of the proposed system lie in its ease of use and cost-effectiveness, as it only requires adding an IoT module to the existing conveyor system. This allows for easy upgrades of functional conventional conveyor systems, enabling their integration into the digital transformation of Industry 4.0. As much as the off-the shelf widely available components used for the IoT module are reliable in initial tests, they are non-industrial components and require additional testing and analysis in real-world industrial plants. As a proof of concept, the Android application currently offers basic control and monitoring of the system's speed and rotation sense, along with displaying preset notifications in certain scenarios. However, there is potential for further development to incorporate more advanced functionalities. The presented research opens the door to future improvements and possibilities for enhancing industrial systems' capabilities in line with Industry 4.0 principles.

6. ACKNOWLEDGMENTS

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