Integrate Digital Twin to Exist Production System for Industry 4.0

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***Abstract*— Nowadays, Industry 4.0 is widely known in the industry. Many large companies have pushed and adapted to Industry 4.0 to increase their business competitiveness, so small and medium-sized companies must adjust to improve their production capabilities to keep up with the technological development of Industry 4.0. Industry 4.0 development can be done in many ways as outsourcing or self-developing systems, but outsourcing and purchasing systems Installation have a high cost. This paper proposes a digital twin focuses on self-development. By using digital twins combined with existing production systems to develop data following the concept of Industry 4.0, digital twins are used to creating digital data from physical forms to inspect, record production data and create digital communication channels to other systems. In summary, this paper uses a digital twin to show another way to develop into Industry 4.0, which starts with the development of data. This way is using the cost of starting a very lower without automation structure and get the data to analyze for adapting with automatic layer systems in maximum efficiency.**

***Index Terms*— Industry 4.0; Digital Twin; Production**

I. INTRODUCTION

In the current time, the industry has been developed by the development of technology starting point at the industry 1.0. Industry 1.0, called the steam engine era, is an era in which humanity began to invent invigorating machines or mechanics but also used primarily human or animal labor until the steam was brought to help drive machines, so most of the production uses human labor and steam primarily. Until electric energy use in the industry and resulting in both small and large industrial machines for the production of large quantities of products (Mass production) call industry 2.0. After, technology has developed to another level as the era of computers. This level is used electronic devices and various sensors until another form of operation is called automation or industry 3.0. Until the industry 4.0 has a complete internet system structure to bring to use in the industry by introducing the concept of IoT (Internet of things) into the industry 4.0 [11]. Various systems in the industry are linked together through a protocol. The industry not only has a machine that can calculate the conditions or decisions, but the system can be linked to various networks at anytime and anywhere. The strength of industry 4.0 is the flexibility of production that can connect the needs of consumers directly to the system in the industry. The structuring of Industry 4.0, according to the automation hierarchy from the ISA95 standard [1]. The structure is sequenced through the basic automation systems linked up to the planning level and the ERP system, but automatic system development in all parts of the production line uses high costs and needs to change production systems in many parts.

With the rapid development of technology, the industry needs to adjust rapidly to catch up with the technology and gain a competitive advantage in increasing the efficiency of the product, Increase the amount of production and reduce production costs. Most small and medium-sized companies are under development to Industry 4.0, so in developing a structure of industry 2.0 and industry 3.0 use high cost for buy machine and program. Before, development must development planning process. The planning in each form of the production line is also different. Both in terms of process modification from the exist production to automation and the benefit of development. Industry 4.0 can be developed in many ways system purchases, outsourcing and self-development, and every method needs to be planned for compatible with the system to be developed. Also, this paper focuses on self-development by using a digital twin. The digital twin is shown real data in real-time in the production line and shows the behavior of the production line [7]. The result from a digital twin can use to see data and analysis and help small and medium-sized companies planning to transform exist production to full automation. In addition, the digital twin is adapted to exist production systems for creating digital data compatible with the planning system and ERP to easily link the production system to the needs of customers directly and gradually develop the automation system to be useful in the future.

II. RELATED WORK

The following literature review provides work in using digital twin in many conditions and research about a structure to get data from the production line. Ján Vachálek et al. [6] create an automation system for the simulation production part. The production line simulation consists of the gravity conveyor, the drilling, and the control of the hole after the drilling for assembling products. Next, use a simulation tool call Plant Simulation program by SIEMENS to made the digital twin simulation model form a virtual copy of the

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physical process. The result, compare physical simulation and digital twin simulation to develop the physical process a total reduction in real production time by 5.2% and refer further work to increased effects by big data analytics. Pengfei Wu et al. [7] develop a digital twin by using Virtual Reality Synchronization at Shanghai University. Virtual Reality Synchronization creates with Unity3D by used the intelligent production line of the intelligent Manufacturing and Robot Key Laboratory model and data form workshop communication with Virtual Reality Synchronization by OPC program call KEPServerEX and transform to JSON format for use in Virtual Reality Synchronization. The result, the digital twin with Virtual Reality Synchronization, collected the data to an interface, real-time, and operational state awareness. Florian Biesinger et al. [8] built a digital twin in Body-in-White Production Systems for Case Study. The concept is combined Planning data, Cyber-physical system, and Geometry in real-time to create an on-demand production line. In conclusion, the cost can be saved by real-time planning and the described concept is possible. Yunpeng Gao et al. [9] divide digital twin in the production line to 4 parts. First of all, the physical production line mainly composes production equipment, production materials and production personnel. Second, the digital production line has a four-level system model, geometric model, process model, simulation model in the order. Third, the intelligent sensing system is a sensor, position sensor, pressure sensor, temperature sensor and an RFID reader. Finally, an intelligent decision-making system collects data and information form the production line to analyzing for decision making and optimization of the production process. In summary, from the research review, the digital twin has a physical and digital. The digital twin can be used for reduces cost, reduces time, monitoring, and get real-time and real data for optimization and decision making to the production line. Jinfeng Liu et al. [12] design the data flow of a digital twin into three layers. First, the data mapping layer aim to collect data from machining by a signal from the sensor. Second, the data analysis layer is simulating the behavior, physical counterpart's characteristics and performance in real-time from data. Finally, the data decision layer is feedback data for design strategies to the machining process.

III. Theoretical Background

The automatic pyramid is one of the images showing the structure of industry 4.0 that is easy to understand [1]. This image has been referenced in many applications related to industry 4.0 and automated systems. The automation pyramid has 5 layers. Layer 1 is the level of sensors and actuators communication to layer 1 by a digital and analog signal. Layer 2, controller level by get digital I/O and analog I/O to a programmable logic controller (PLC), and program logic to control machine and connect to process control level, Layer 3, by Ole for Process Control (OPC). In layer 3, present about data form layer 1 and layer 2 for monitoring, analysis data and advance process control. This layer is managed many PLC or controller for an optimization production line. Layer 4, Plant management level, is uses data to plan and optimize production line by communication between layer 3 and layer 5 for connecting a business process to the production system. Layer 5 is an enterprise layer [2] see the structure in Figure 1. In summary, the automation pyramid shows the entire structure of the industry. Industry 4.0 is a picture of connection all systems from sensors and actuators layer at the production line to enterprise layer management for connecting business processes directly into the production line.

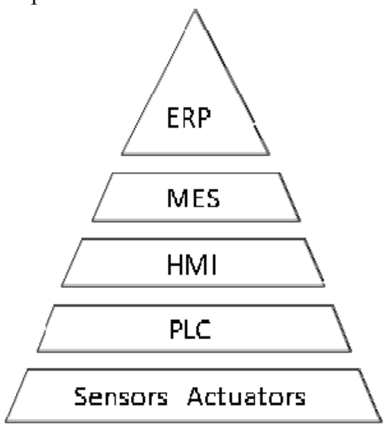

Fig. 1. Automatic pyramid

Digital Twin is the creation of digital data from physical to collect data, data communication, simulation, predictive maintenance. As shown in Figure 2 the digital twins include 3 main dimensions physical product, virtual product, data connection [3]. In addition to the above, the data can be simulated for development to achieve higher efficiency in the production system. The easy way to understand digital twin conceptual architecture follows six-step. First, create steps in the design and installation of devices to bring data into the digital system, and designing the installation of sensors from the production planning data and business management system makes the data continuously updated with the enterprise system. Second, the communicating step is a necessary process that creates real-time between the physical process and the digital platform. Third, the aggregate step is the collection of all data stored in the database, both online and offline. Next, analyze step can be done by using an analysis program from data analysts and data scientists. Next, insights from the analyze step are present by visualizations, highlighting unacceptable differences in dashboards. Finally, the action step is to use insights data feedback to a physical and digital asset to achieve the impact of the digital twin [3].

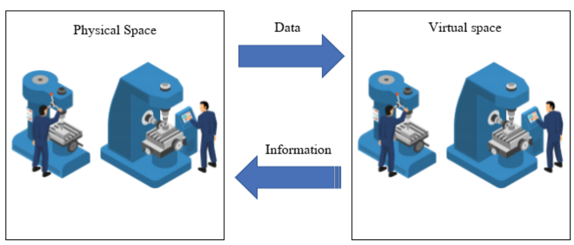

Fig. 2. The digital twins 3 main dimension.

IV. RESEARCH METHODOLOGY

In this research, it is starting with the selection of the production lines that bring digital twins to be used. Study the system of production lines to design and develop digital twins to match the chosen production line. Design system by the automatic pyramid. Collect data from sensors send to the computer, HMI to analytic data and display to the operator. After the developing phase, the information obtained from a digital twin was analyzed to summarize results and benefits. Including guidelines for future work in connection with the planning system and ERP system.

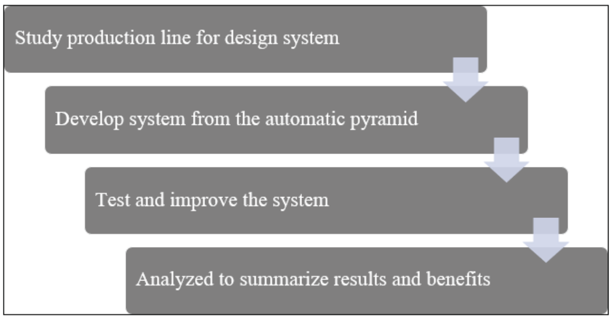

Fig. 3. Process step.

As shown in Figures 3, the First step studies the production system form from exist production line and studies the vital parameter for the design device to acquire data from the production line. In this paper, use OEE (Overall Equipment Effectiveness) for an analysis product line. OEE contain with Availability, Performance and Quality [10]:

OEE = Availability Rate x Performance Rate x Quality Rate (1)

Availability is show percent of machine running time from work time:

Availability Rate= (running time / planning time) × 100% (2)

Performance is calculated from standard cycle time, which is show working speed compare with cycle time:

Performance rate = (theory processing cycle / actual processing cycle) × 100% (3)

Quality is show percent between finish good and defect in production line:

Quality rate = (quality product / all product) × 100% (4)

See the parameter in Figure 5 shown the overall effectiveness in the production line. Also, collecting data in log data can be used for analyzing data to forecast from a digital twin in the future. Second, develop a system based on the automation pyramid structure by design in the three-part sensor part, interaction with the operator part and store data part in Figure 4. Next, the test system for check data compares with physical and improves the system for data correct. Finally, analysis data from LabVIEW program to calculate OEE and use the result for concluding the research.

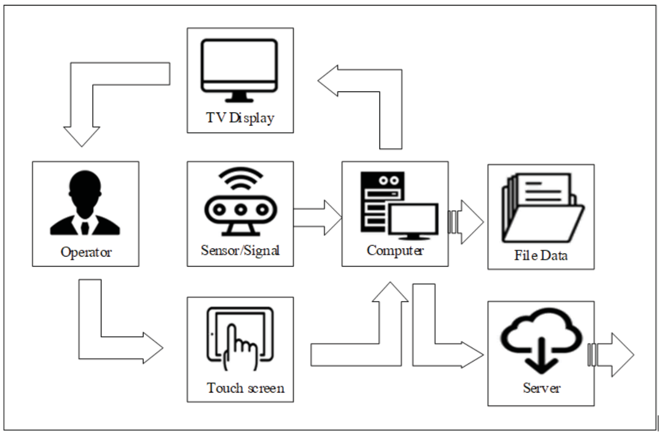

Fig. 4. System design.

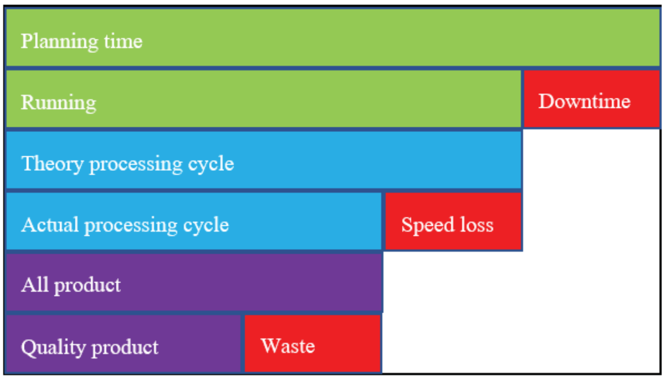

Fig. 5. Parameter for calculate OEE.

V. RESULTS

A. Study production line for design system

The production line that is selected, the production of automotive parts called clip K. Improving the production line selected in the system lean with TPS systems and have a system to process orders and materials that are systematic, which is suitable for the development of digital twin in order to track the efficiency of the production line effectively. There is 3 process of the K clip line in production. According to the study of the process in the production line, it was found that the parameters used to measure the efficiency of the production line were the number of workpieces, the loss number of workpieces and the time loss of the system at last process in log data form for calculate the value OEE, Availability, Performance, Quality To see the efficiency of the production line in all aspects [5].

B. Develop system from the automatic pyramid

System design starts from Layer 0 of the automation pyramid. Collect target machine data with sensors to send signals to the computer, Layer 2, To communicate or interact with workers by HMI and TV display. Data is stored at the MYSQL database on the server and files on the computer. In addition to data collection, the database on the server also brings data to analyze data and display various values on the website. To be a channel for linking with the planning system and the ERP system. Develop system using protocol Modbus TCP / IP, primarily OPC server [4] and receiving data into the computer Use OPC to convert Modbus TCP / IP protocol into a LabVIEW program on the computer. On the computer, a program with LabVIEW to Real-time Monitoring, communication with HMI, Display, store data as log data every 1 minute, upload data to a server, calculate data. The last system to develops a website for. The last system is a website system for secure data distribution (see Figure 6).

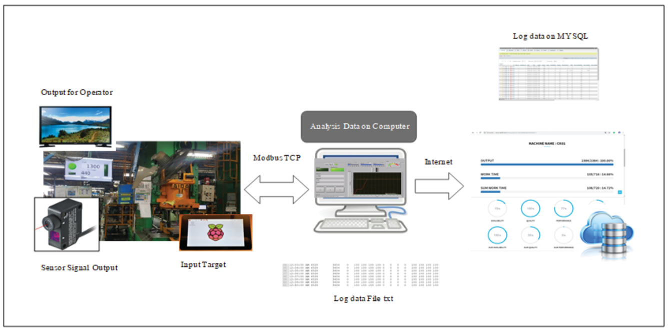

Fig. 6. Develop system.

C. Test and improve the system

After completing the system development, the system has been tested by checking several actual product systems compare with the physical production line piece per piece to check the data accuracy.

D. Analyzed to summarize results and benefits

The data can recognize the working state in real-time, so the data have been collected in log data form by timestamp in a minute by minute. Primary data consist of an actual product, all product and time stamp. After collect data, log data have been calculated to Availability Rate, Performance Rate and Quality Rate. Availability Rate calculates by counting a number of changes in the actual product to running time, counting the number of a timestamp to planning time and calculating running time and planning time to Availability Rate. Performance Rate has been calculated by Theory processing cycle time and actual processing cycle. The actual processing cycle time is calculated from the speed of change in the actual work compared to the running time. Quality Rate is obtained from the total number of all products compared to the number of quality products. The quality product in this system is the number of actual products, so the waste product does not count in the system (Calculate follow in Figure 7). Consists of the number of workpieces, Availability, Performance, Quality, OEE. And from the application of digital twins to use data that can also be used to predict future trends from old data. For the development of OEE, the system is more accurate from the original system that uses estimation. With this difference, get more accurate information. Can view historical data. Cause the improvement of the production line is efficient. (see Table 1)

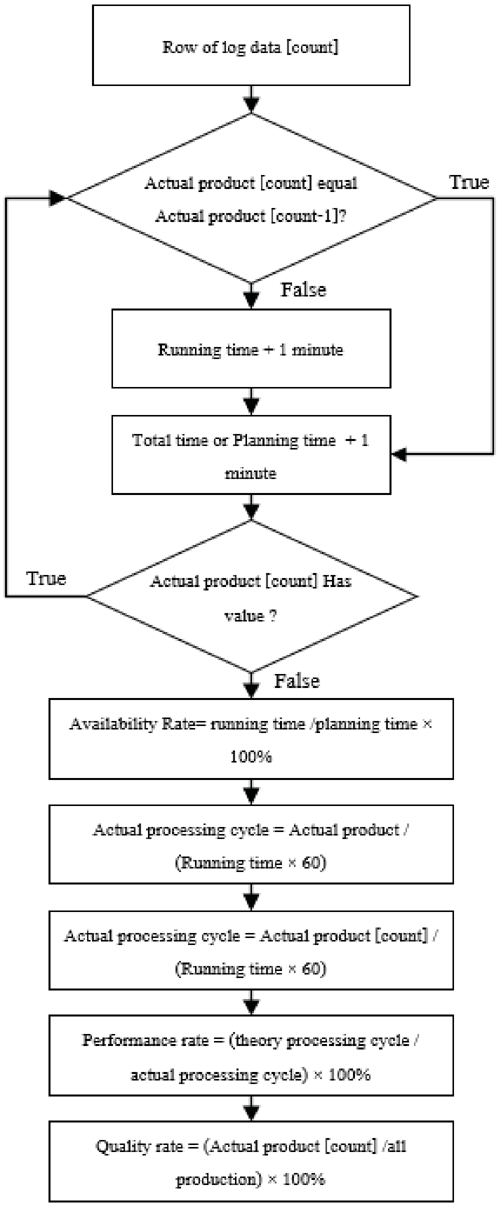

Fig. 7. Calculate Flow Chart.

Table 1 Compare Estimate Data and Digital Twin.

Results	Manual	Digital Twin
Availability	94 %	47 %
Performance	91 %	73 %
Quality	100 %	100 %
OEE	86 %	34 %

VI. CONCLUSION

In this paper, it shows another way to develop into Industry 4.0 based on the structure from the Automatic pyramid, but the proposed approach is to apply the digital twins to the existing production system. Creating digital data of production lines is a communication channel with the real world and a tool to receive real data from the production line. The system 3 division according to the elements of the digital twins. The physical product is the part of the sensor, display and HMI, which is responsible for retrieving actual data from production. The display and HMI are used as a channel for Interact between people and systems. The digital product consists of LabVIEW programs for data communication, data recording, data processing and data analysis. The data connection use Modbus protocol TCP / IP and convert data by the OPC server. Which, when all systems have been used in the existing production line. That like creating the Automatic pyramid structure automaton using people as a working base and using a digital twin system to communicate with the upper system of the Automatic pyramid and making it possible to develop into Industry 4.0 without having to adjust the structure of the production line much and useless cost. Also, the data from digital twins can be used in predictive maintenance or can be used to analyze data before adjusting the production base to be robots or machines efficiently by data OEE value. The OEE value consists of availability, Performance and Quality, and the data with time dimension can see behavior and characteristic in the production line to forecast behavior, benefit and performance. In the future, Full Automation Industry in Industry 4.0 more effective from the digital twin.

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