Batch process in connection with industry 4.0

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Abstract—This project deals with the creation of autonomous liquid storage cell with a cooling system. The cell is part of a larger project called the Self-Acting Barman. Project Barman serves to demonstrate the principles of Industry 4.0 and is gradually made up of student works. The aim of the project is to create a cell that can dispense the required amount of fluid. The cell is cooled by an external cooling cell. The entire liquid batch process is controlled by a PLC located at the cell interface. By default, the process would be controlled by a superior batch system that complies with the ISA-S88 standard. The paper aims to clarify the fusion of the S88 standard with the new 4.0 approach.

Keywords— Industry 4.0, Self-Acting Barman, Testbed, Autonomous Cell, Batch control, Asset Administration Shell

1. THEORETICAL INTRODUCTION

This chapter deals with a brief description of the term industry 4.0 and its basic principles.The Self-Acting Bartender project is also described here.

1.1. Industry 4.0

The term Industry 4.0 is a name for another industrial revolution that is currently underway. The main idea of this revolution is to create a global network for the entire factory, which will include all machines, storage facilities, production systems and security systems, as one large cyber-physical system.

These factories are called Smart Factories. Smart factories produce products that are easily identifiable, can be located in every part of the production process and know their history, current state and the way to achieve the desired state.[1] The entire journey of the product is documented by its assignment to production to distribution logistics.

1.2. Principles of industry 4.0

Industry 4.0 uses several basic principles such as: Virtualization, Decentralization, Modularity, Reconfigurability and Interoperability[2].

Virtualization means converting the entire production process (in our case an autonomous cell) into digital form. The whole digital model can be created to work exactly like the real model. This model is called the digital twin. The functionality of the entire proposed solution can be tested on a digital model before the start of the physical creation. This allows us to quickly detect errors and shortages of the proposed solution and thus avoid the production of non-functional prototypes. The advantage of digital twin is the simple replacement of components, actuators and all other elements if we find that they do not suit us. Cell virtualization is created in the Siemens NX design environment.

Each component of Industry 4.0 is in a kind of envelope called an Asset administration shell (AAS). AAS covers the entire component and creates an interface between the physical and software part. AAS is basically a standardized digital representation of a component (digital twin). AAS is the core of Interoperability. The body of the AAS contains certain structured information in the form of submodels for the specification of properties, parameters, functions given component[3].

Decentralization means a situation where each part of the production process requests the necessary information and materials. The product itself carries information about what it needs for its production and passes it on in individual parts of the production process. The individual parts of the production process communicate with each other without the help of any higher layer. We call such a network IoT.

Modularity means that the individual parts of the production process are physically independent of each other. These individual modular parts are interconnected by robotic arms, conveyors and other manipulators.

Interoperability means the ability to connect all parts of the production process (machines and workers) into one system, where all parts can communicate with each other.In our case, this is provided by the AAS.

1.3. Self-Acting Barman

The testbed Barman is divided into several cells according to the principles of Decentralization and Modularity. The cells are a glass storage, a soda maker, a shaker, an ice dispenser, a storage of alcoholic liquids and a coolant cell. All cells except the storage of alcoholic liquids are the same size, have same connectors and the user interface according to the principle of reconfigurability.

In the middle of the testbed is a robotic manipulator that moves the glass between the individual cells. The last part of the testbed is a conveyor belt, which is used to take already made drinks.

2. PROJECT CONCEPT

The hearth of the cell is a stainless steel tank, which consists of four separate containers for liquids. The containers are not closed from the top and there is an outlet at the bottom. Around these containers is a hollow tank housing that serves as a space for cooling liquid. The whole design of the cell is based on this tank.

2.1. Cell concept

The key idea of the liquid storage cell concept is pumping the liquid from tank containers. The liquid flows down into the hose to the pump which drives the liquid back up over the glass into which it falls. A peristaltic pump was chosen for this purpose. The main advantage of peristaltic pumps is that they are relatively easy to manufacture using parts printed on a 3D printer, bearings and hoses. The peristaltic pump is driven by a stepper motor. This gives us the possibility to change the direction of liquid pumping in case of leakage of redundant liquid.

2.2. Cell instrumentation

There are two types of sensors in the cell for measuring quantities. The first are ultrasonic sensors which are used to obtain information about the height of liquids in the containers of the tank. This sensor is located in each cover that closes the top of the tank container. The second type of sensor is a strain gauge. Sensor is located under the glass holder and is used to determine the weight of the liquid already pumped in the glass. The amount of fluid pumped can be also calculated with knowledge of number of stepper motor steps. All sensors are connected to a universal PCB board called SKUseCon. It is used to connect the sensor, process the signal from the sensor and then send the signal to the PLC using output pins.

Two different pump models were purchased and a third model was manually created on the 3D printer to select the correct peristaltic pump. These three models were then compared by the fluid pumping speed and the fastest of them was selected for use. The pumps are driven by a NEMA17 stepper motor. These are connected to the TB6600 4A drivers. Drivers can be used to set the amount of current supplying the motor and the number of microsteps of the stepper motor. The driver is then connected to the PLC.

Every element in the cell is connected to the Siemens PLC S7-1200. PLC can than be commanded from HMI Panel KTP400 Basic. These are connected together in switch which is located under the HMI.

At the top of the cell is a three-colored beacon that shows the current state of the cell. There is also a emergency stop button.

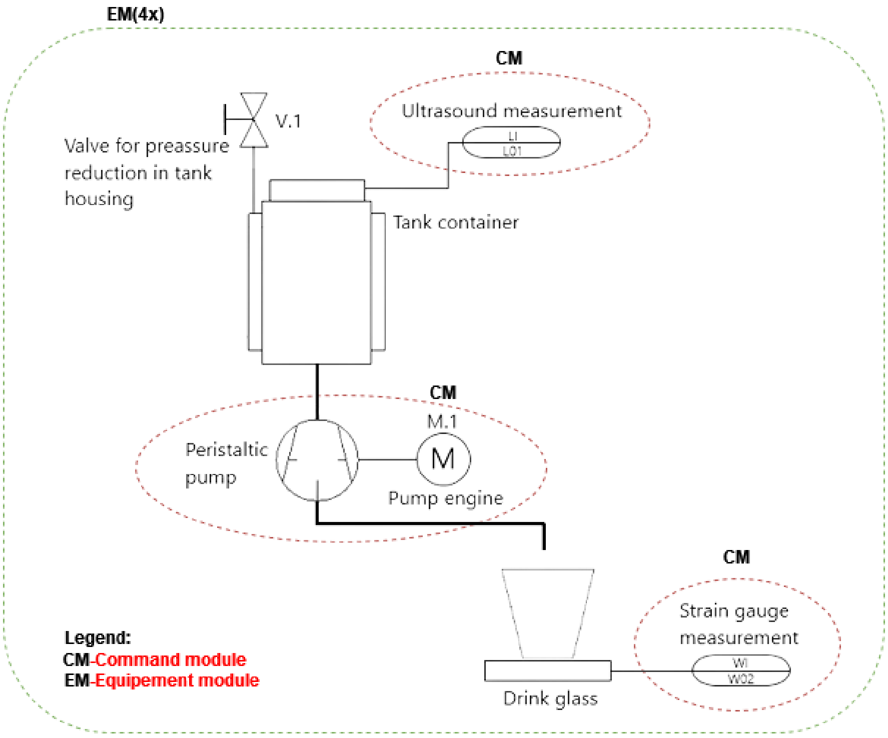

Figure 1: P&ID diagram

3. BATCH PROCESS

The batch process is standardized according to the standard ANSI/ISA-S88. This standard divides our technology into certain parts by three models.

The first part is a physical model. The physical model is used to describe the equipment needed to make the product. Specifically, our physical model begins with a unit (our cell). The unit is further divided into individual device modules. There are four of them in our case. It is a one tank container together with a pump, motor, ultrasonic sensor and a common strain gauge. The lowest part of the structure is the control module. This is, for example, a separate sensor or a pump.[4]

The second part is a procedural model.The procedural model combines the physical model and process model and describes the hierarchy of functions that needs to be done during batch production. The most important part for us in this model is phase. Phase is connected to the device module. In our case, it will be, for example, the liquid pumping phase or tank cleaning.[4]

The third part is a process model. The process model represents the product production process.[4]

3.1. PackML standard

Another similar standard to the batch process is a PackML standard. PackML standard was created for better implementation of the packing robots into the industry. PackML standard was based on the ISA-S88 standard. That's why the packaging line hierarchy has a lot of similarities. The batch process standard is more suitable in our case.

4. AAS TO BATCH

The physical model part of the batch control standard is cut between the unit(our cell) and the process cell. On the procedural level, the highest part is the phase. Unit is then covered in the AAS which makes the connection between the Batch control standard and the Industry 4.0 system. These shells communicate with each other without other superior system. The AAS compares their capabilities to the required service and decides to perform the phase.

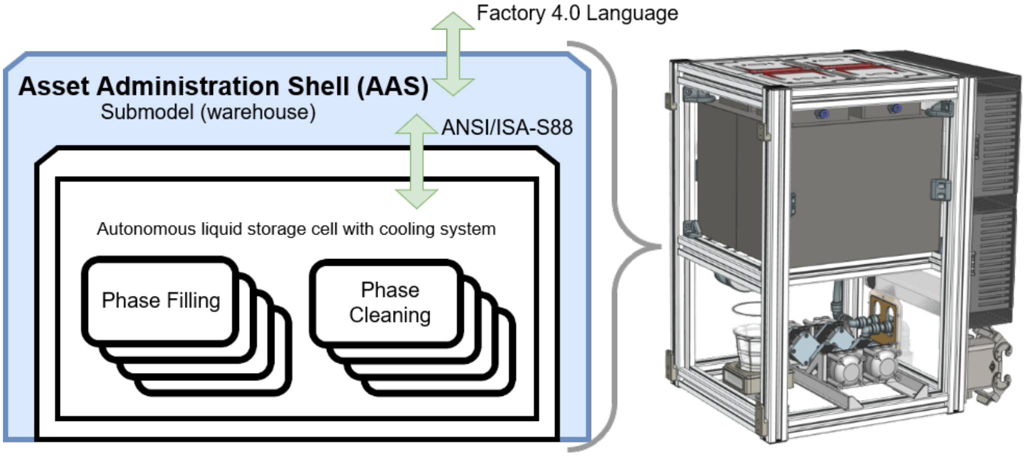

Figure 2: Aset administration shell

The phase is connected to the equipment module which contains all the necessary control modules for successfull completion of the phase. AAS gives the first signal to start the phase. Signal from the AAS also contains all parameters about the volume of batch. State machines then goes from state idle to state working. After completion of the phase, state machine moves to state done. AAS than obtains the information about the state and resets the state machine to state idle.

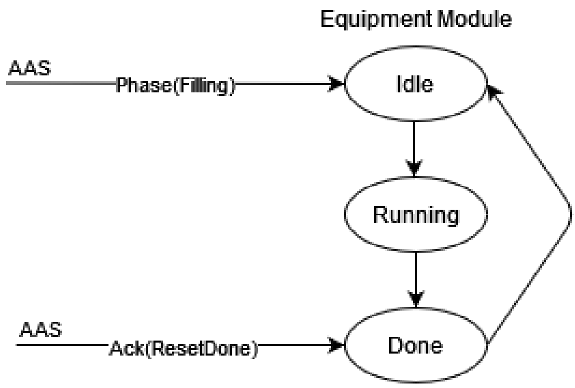

Figure 3: State Machine of the Phase

The main difference between the batch system and the factory 4.0 system is that the batch system is controlled by a superior layer (process cell), which has the whole system under control. The Factory 4.0 system is not controlled centrally from the superior unit, but all cells are able to communicate with each other using AAS envelope (Interoperability). In case of need, the AAS envelope can be changed with process cell to control the whole system very easily.

5. CONCLUSION

The autonomous cell created meets all the requirements to demonstrate the principles of industry 4.0. This work shows a real connection between the bach process and elements of industry 4.0. AAS makes the connection between the batch process system and the factory 4.0 ecosystem. Batch process system ends on the unit level in the physical model and on the phase level in the procedural model. The phase is then being launched by the AAS and the state machine of the process works as shown in figure 3. The AAS serves as a translator between the recipe procedure, which is included in the product image, and the phases of the production unit.

The aim of this project was to create an autonomous cell that will operate according to the principles of Industry 4.0. The software ends at the phase level, which includes the state machine as shown in Figure 3. Assigning an AAS to a cell is part of another project.

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