Investigation on Industry 4.0 and Virtual Commissioning

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Abstract - The human being had been busy with mostly agricultural economy for a long history when the steam was considered as a resource of kinetic energy. Using the steam machine in textile industry for the first time in the UK at the beginning of the 18th century, would be called as "Industrial Revolution" many decades later. Respectively, second industrial revolution with the invention and utilizing of electricity, then third industrial revolution with the rise of electronics and automation followed this period. And today, we have been facing with the fourth industrial revolution via internet of things, augmented reality, learning machines, etc. One of the key technologies that are improved in this period is virtual commissioning. The aim of this contribution is to suggest a definition to the Industry 4.0 with its historical precursors, and to give a focus on virtual commissioning technology as an output of the fourth industrial revolution.

Keywords: Industry 4.0, Big data, Virtual Commissioning, Siemens, Process Simulate, Simulation

1. Introduction

When the "Industry 4.0" concept was verbalized in Hannover Fair in 2011 for the first time [1], the historical improvement of the industry became an interesting topic again. Since this statement was used, many people from various fields have focused on the main milestones of the industry to understand the meaning of the fourth industrial revolution and to give a satisfying definition to this period.

The first industrial revolution emerged with the invention of the steam machine and its utilization in textile industry in the UK, in early 18th century. The second one can be stated as the invention and utilization of electricity and the emerging of the serial production lines in parallel to this. The third one can be defined as the electronic control systems to be used in serial production lines as PLCs, robots, etc. And with the utilization of the huge data that is generated by the smartened things, the world has been talking about the Industry 4.0.

Many new technologies have emerged during this new period. [2,3] They are Internet of things, smart factories, 3D printers, augmented realities, wearable technologies, etc. [3] Virtual commissioning is one of these shining technologies.

In traditional commissioning, the automation program is tested on the real machine or production line. Virtual commissioning has emerged as an answer to the necessity of a technique that brings cost and time efficiency in commissioning process, and shortens the time to market. [4]

In the first part of this contribution, the Industry 4.0 concept is analyzed in historical process and is tried to be defined in technological aspects. In the next part, its gainings and effects are observed. In the last part, virtual commissioning is explained with its advantages as cost and time efficient, and more flexible alternative to the traditional commissioning approaches. Besides, Siemens Process Simulate and VR system with ABB RobotStudio and HTC Vive are observed at the end, as simplified, flexible and state of the art virtual commissioning solutions.

2. Industry 4.0

At the beginning of the 18th century, the first steam machines, a sample can be seen in Fig. 1, had been invented and were used in textile industry. As soon as the steam machines took the place of the human muscle force, the labour force that was earlier working in agriculture shifted into mechanized production eventually.

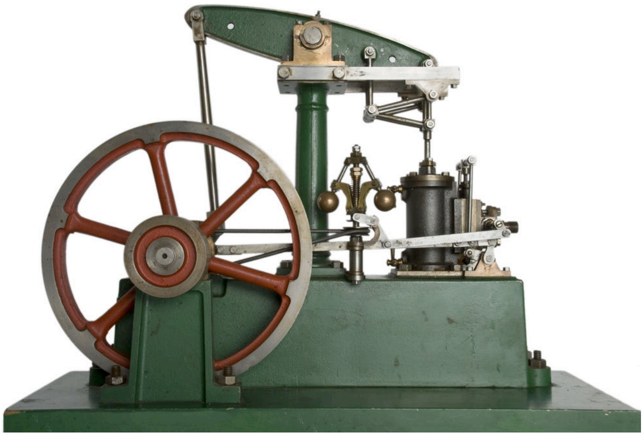

Fig. 1. Steam Machine [5]

This situation caused migration from rural to urban areas and led the powerful states researching raw materials in order to produce even more. This period is named as industrial revolution in world history.

Almost 100 years later, via the invention of electricity and the integration of the electrical machines, a sample can be seen in Fig. 2, to industry, serial production lines emerged. As a result of people to work in serial production lines, the production outcomes increased rapidly. Thus, more industry products were released to market in less time. The topics such as decreasing costs and increasing reachability of the products affected the societies as well. As a cycle effect, the increasing populations of the urban areas caused more labour force and more industry products to emerge. This period that the industry was transformed with the electricity is named as second industrial revolution.

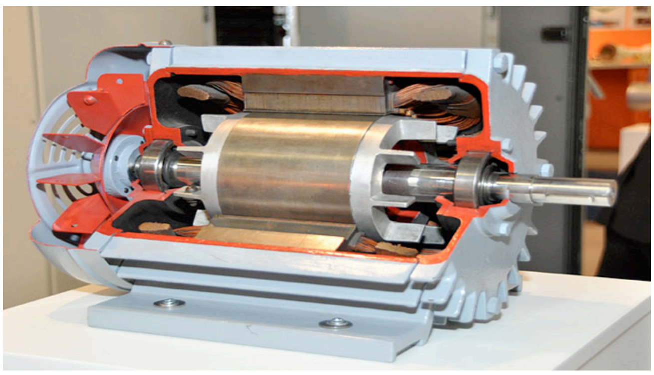

Fig. 2. Electrical Machine [6]

Along with the electronics was improved in 20th century and the PLCs, some sample models can be seen in Fig. 3, were integrated into industry 40-50 years ago from today, the automation era began. As a benefit of the PLCs to be used in the industry, the serial production lines became more controllable and flexible. This situation led the quantity and the diversity of the industry products to increase. At the same time the requirement to the human muscle force decreased, the need of the technical knowledge and skills increased. This period that the automation systems transformed the industry is named as third industrial revolution.

Fig. 3. Programmable Logic Controllers (the one in the front is an I/O module) [7]

In automated serial production lines, huge information is generated by various sources such as sensors, valves, motors and robots. This unprocessed information is called as big data. The processing and reuse of this big data and beyond this, the pursuit of transforming all things to be able to produce data, gave birth to the fourth industrial revolution. In this regard, "Industry 4.0" statement was used in Hannover Fair in 2011 for the first time.

According to a study [3], the integration of Internet of Things to the manufacturing environments is forcing the fourth industrial revolution. The cyber-physical systems allow the companies to incorporate their machinery, warehouse and production systems under one unique network. This facilitates the smart machines and production facilities to exchange information autonomously and to control their jobs independently. In Industry 4.0 concept, the smart factories let the smart products to be produced with more flexibility, considering not only the market demands but also the individual customer requirements. The core factor behind this dynamic business model is the big data that is generated in the manufacturing environment.

2.1. Big Data

The key point of fourth industrial revolution is creating value from the huge information that is generated by various objects.

Along with the analyze and reuse of the data that is generated from the things, new research and application fields emerged that are recently named as "smart factories", "cyber-physical systems", "augmented reality", "autonomous robots", "additive manufacturing", "cloud computing", "Internet of Things" and further can be seen in Fig. 4.

As stated by Ninan et al. [8], almost all objects are likely to be turned to source of data by Internet of Things technologies. According to them, the sequence of activities to create value from information can be defined as the Information Value Loop Fig. 5.

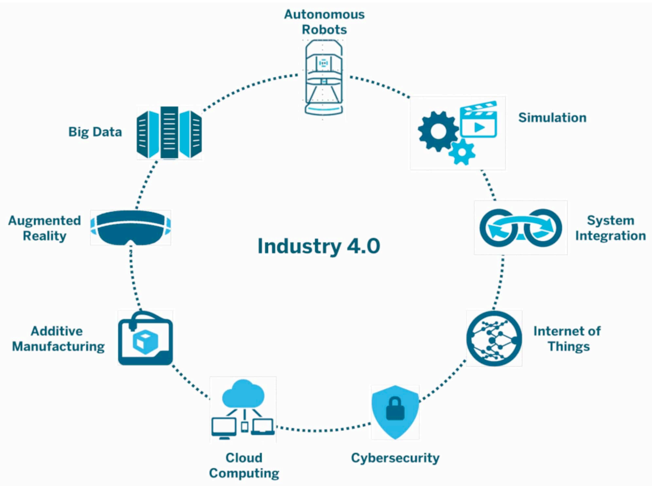

Fig. 4. Industry 4.0 components [9]

According to this loop, an act is defined by sensors and information is created by this way. Then this information is communicated via network and is aggregated by standards. Augmented intelligence techniques allow the information to be analyzed. At the end of the loop, improved action is reached by augmented behaviour techniques.

2.2. Changing Business Lines

This value created data changes the industry and also the society in various aspects. In this period of the industry to be transformed, many business lines have been disappeared while new business lines have been appeared.

In automation era, the robotic systems rapidly invaded in the places of the nonskilled work force by performing the repetitious jobs in manufacturing. However new specialties that emerged in this period like automation, robotics, mechatronics provided new job fields. In Industry 4.0 era, the smart systems will be likely taking the places of the skilled work force those are performing repetitious jobs in manufacturing and in offices as well, such as complex assembly, quality control, planning, etc. Same as in automation era, this repetitious job killing process have led new specialties to emerge like:

- 3D manufacturing engineering: Along with the improvement of 3D printers, the additive manufacturing entered into focus in various industries. This technology necessitates specialized technical people.

- Big Data Analyst: Since the core topic of Industry 4.0 is big data, the requirement of specialized people for analysing this data has emerged.

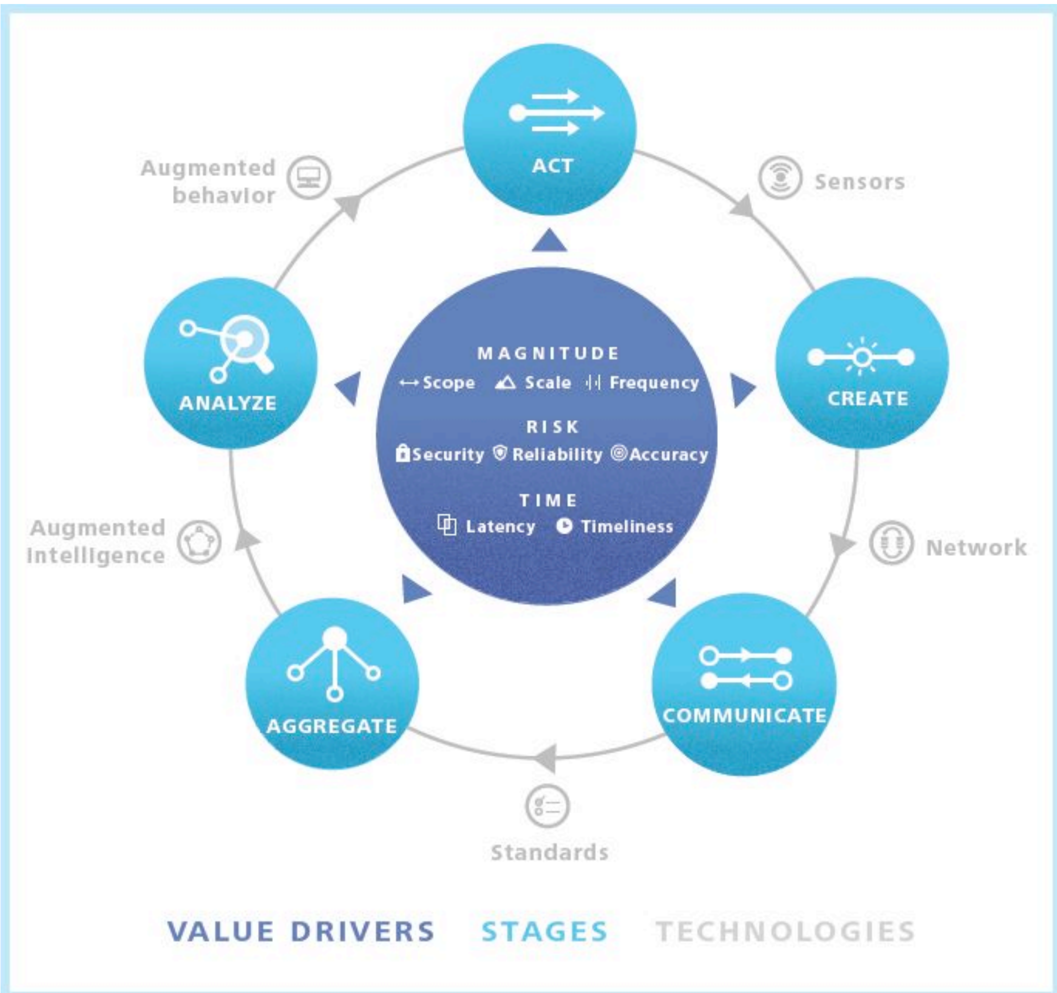

Fig. 5. Information Value Loop [8]

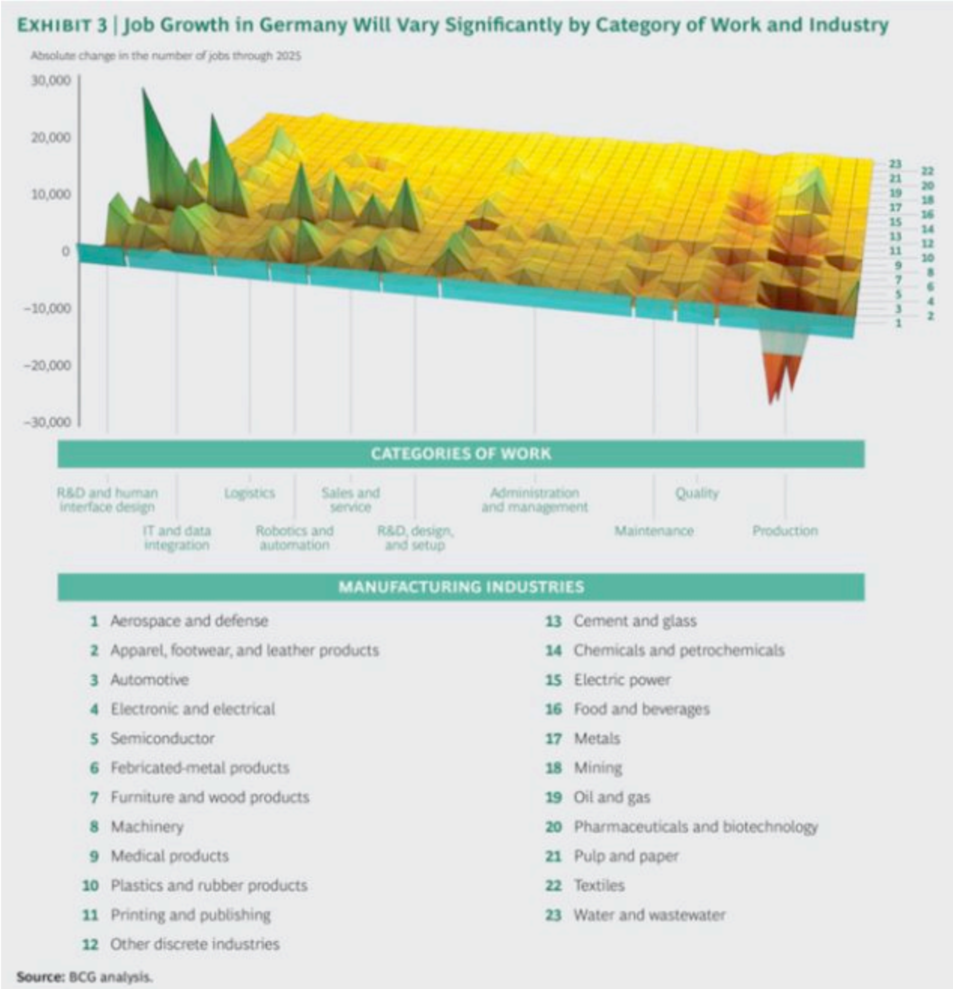

Fig. 6. Shifting in the Jobs in Industry 4.0 Era [10]

- Robotics engineering: Since robots have already invaded in manufacturing industry, along with the advanced dynamics technologies, the robots have been taking their places in society step by step in logistics, warehouse operations, personal assistance, etc. These functions point out the requirement for specialized robotics experts.

- Drone pilot: Drones have already been used in photography and film industries, logistics, security, etc. Although this field is very new, drone pilot jobs are likely to be more popular.

- Simulation engineering: Utilizing the big data, the manufacturing systems can be simulated. This technology has led virtual commissioning as it is explained in a detailed way in this article.

In order to reveal the shifting in jobs in Industry 4.0 era [10], the below graphic in Fig. 6 would be beneficial.

2.3. Revenue, Cost and Efficiency Benefits of Industry 4.0

Along with the transformation of big data to smart knowledge, there have been outstanding revenue, cost and efficiency benefits of the fourth industrial revolution.

A study [11] demonstrates that Industry 4.0 is increasing the revenue by digitizing the products and services, creates new digital products, utilizing big data analytics as service, personalizing products and etc. Besides this, Industry 4.0 is increasing the efficiency of the systems by utilizing big data analytics for real-time quality control, increasing the flexibility and adaptability of production, using predictive algorithms to increase the equipment efficiency and etc.

Considering these benefits of Industry 4.0, the Virtual Commissioning is one of the technologies that stepped forward in this new period. In the next part, virtual commissioning systems for serial productions lines are explained and virtual communication software is observed.

3. Virtual Commissioning

Virtual commissioning for the serial production lines stepped forward as one of the innovations that were brought by the fourth industrial revolution. In traditional approach, the automation program is prepared and after that, the production line is mechanically installed in real environment. Subsequent to this, the automation program is tested on the site components (sensors, motors, valves, etc.) via PLC and thus the commissioning of the production line is performed. In this process, the errors in the automation program and mechanical design are detected and fixed. At the same time, the product prototype quality is aimed to be reached to the requested level for the serial production.

According to a study [12], the commissioning period takes up to 25% and correcting errors in the automation program takes up to %15 of the time that is used for plant engineering and construction. As a possible solution to these problems the authors propose virtual commissioning.

In virtual commissioning concept, the process is performed in the computer environment via a real PLC or soft PLC. The purpose in this process is to detect and fix the errors in early phase. In order to realize this, the simulation model of the production line is prepared in simulation software including all of the components (sensors, motors, valves, etc.) that will be used. By means of the automation program to be communicated with the simulation software, the process of the machine or the production line is virtually observed and all program and design bugs can be fixed in this virtual environment.

An experimental study in virtual commissioning [13] shows the advantages of this technique to the traditional commissioning. The study was performed with two groups, each of them containing 30 people. One group used virtual commissioning for programming a machine. The other group did not use virtual commissioning and the results were compared. The tested system was a tin can be moulding press and the PLC was Siemens S7-300 model that uses 10 actuator outputs and 17 sensor inputs. The first group prepared the PLC program and then tested it on the real machine. The second group made the programming and testing on a virtual model. They performed real commissioning after verifying their program on the virtual model. The second group achieved a %75 shortened commissioning times. This result mainly caused by the improved accuracy of the program at the virtual commissioning period and shows the advantages of this technique. However, the virtual model was ready at the beginning of the second group's work so the time required for preparing the virtual model was not taken into consideration. In the conclusion, the authors indicate the necessity of a simplified and accelerated virtual model building approach. [14]

As a simplified and flexible solution to virtual modeling and commissioning, Siemens Process Simulate software is observed in the following section.

3.1. Siemens Process Simulate

Process Simulate, sample screenshots can be seen in Fig. 7 and Fig. 8, is software that is developed by Siemens and it is used to digitalize and verify the manufacturing processes in 3D environment [16].

In this software, manufacturing systems can be comprehensively designed and validated via advanced 3D environment. In order to simplify and accelerate the virtual commissioning process on Siemens Process Simulate, these steps are defined in a study [17] to be followed respectively: Characterizing the system, computer aided design, virtual environments, testing the virtual environments, and virtual environments as a monitoring system.

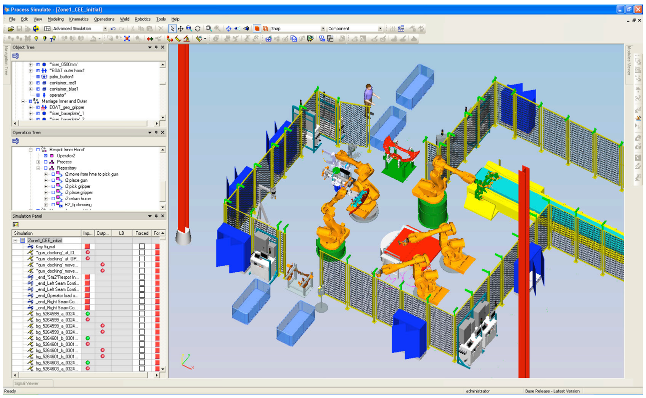

Fig. 7. Siemens Process Simulate – 1 [15]

These steps can be detailed like that: characterizing the system means to specify the working principles of the system. Then the system is needed to be designed in a CAD program like NX (Siemens PLM Software) or CATIA. Any CAD programs can be used for the design; however, the file then should be inserted in NX at the end, in order to convert it into. JT extension file. Then the design can be put into Process Simulate because it only needs JT file to be able to convert it to a COJT file. Then the virtual environment should be created via defining the movements. In this process, the internal logic blocks are also defined. Then the PLC program is prepared. The PLC program can be connected to Process Simulate using PLCSIM. The PLCSIM is software that allows the PLC programs to be simulated and tested. After the PLC program works properly on simulation, then it is downloaded to the PLC and tested on the real environment. And when it works properly on the real system, the simulation can be used as a monitoring system. The connection between the PLC and the Process Simulate is done via Siemens OPC software. Then the authors suggest utilizing these five steps to establish a simulation methodology for the manufacturing processes.

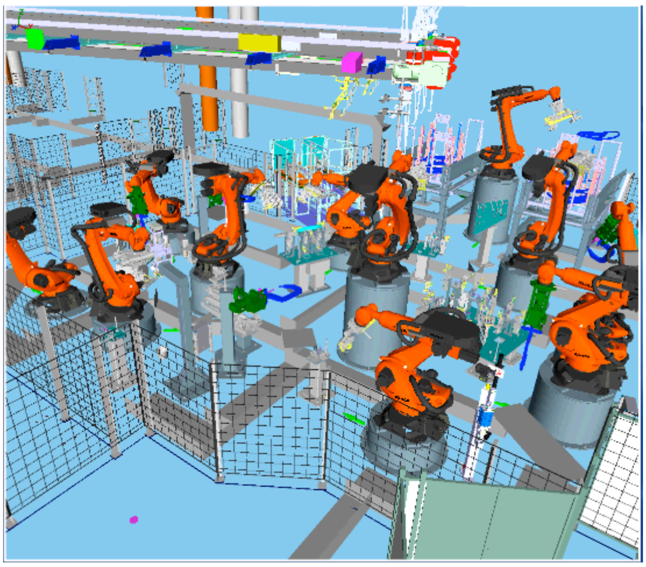

Fig. 8. Siemens Process Simulate - 2

4. ABB RobotStudio and HTC Vive VR System

ABB RobotStudio is software that allows robotic production lines to be designed and simulated on computer environment. Offline robot programming also can be performed in this software. Using HTC Vive VR system with this software, the robotic production lines can be virtually realized. The block diagram in Fig. 9 shows the hardware scope of the VR system.

HTC Vive is a virtual reality system. HTC Vive VR system consists of three main components. They are the main stations, controllers and headset as shown in Fig. 10. The headset and the hand controllers are tracked devices. With the help of the main stations, they can locate themselves in the virtual world.

Once the robotic production line is simulated in ABB RobotStudio, HTC Vive virtual reality system can be connected to the simulation. So that it gives the opportunity to feel as if you are in the virtual world of the simulated line. With the movement of the headset and the hand controllers as it can be seen in Fig. 11 and Fig. 12, the person can move in the ABB RobotStudio virtual environment and observe any point that the controllers are aimed. The laptop screens in Fig. 11 and Fig. 12 shows the change in the point of view, according to the movement of the controllers with the person.

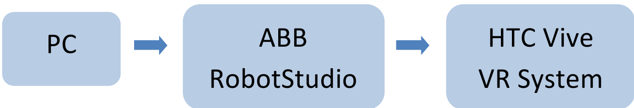

Fig. 9. Block diagram of VR simulation system

Fig. 10. HTC Vive main components [18]

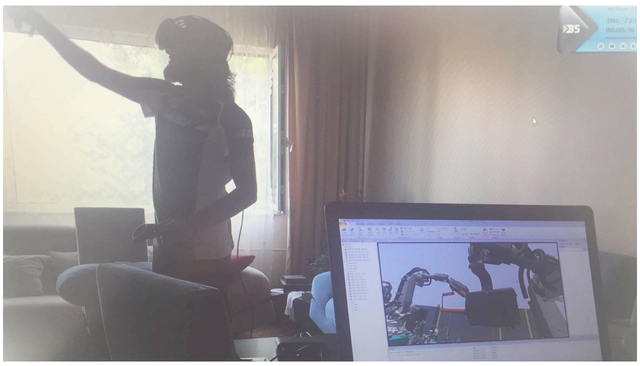

Fig. 11. VR System Application -1

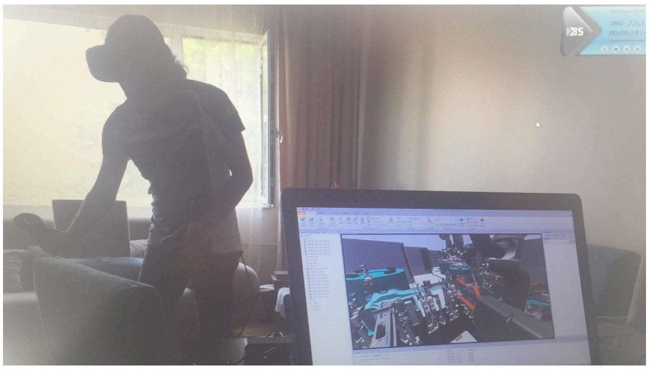

Fig. 12. VR System Application -2

5. Conclusion

In this contribution, Industry 4.0 concept and its components are explained with their effects on production lines. Via the observation of the virtual commissioning technology with different software, it is shown that this technology is cost and time efficient, and more flexible alternative to the traditional commissioning approaches.

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