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Effect of SCADA Implementation to Productivity in Ammunition Industry: A Review

Within the last years, global industries are hyping over Industry Revolution 4.0. Utilizing the computer science combining with the mechatronics, each industry strives to increase productivity and efficiency. Of those industries is the ammunition industry. Regarded as one of the strategic industry of a nation, the ammunition industry needs to quickly adapt to the technological advance, the beginning of a new era. The old-schooled method in production control is outdated and needs to be replaced. Supervisory control and data acquisition (SCADA), one of the newest method for production control, has been developed for several years. The exact form of implementation is however yet fixed. It has to be specifically developed for each industry, i.e. the ammunition industry in this case. With the rapidly growing information technology and science, the ammunition industry is expected to be able to implement the best suited control system to increase and to optimize its production capacity.

Keywords: Ammunition Industry, SCADA, Control System.

1. INTRODUCTION

Total world military expenditure rose to \$1822 billion in 2018, representing an increase of 2.6% from 2017 [1]. The five biggest spenders in 2018 were the US, China, Saudi Arabia, India, and France. It was accounted for 60 percent of global military spending in which the biggest part was allocated to ammunition. The firepower of a country is directly related to ammunition. Ammunition is one of the most important factors for a successful national defense strategy. Ammunition plays a vital role in national defense and military power [2].

Ammunition main components are mostly made of metal. The main components of ammunition are cartridge case, bullet/projectile, propellant, and percussion cap/primer (**Figure 1**). Several ammunitions also have a fuse on the tip of the projectile to initiate an explosion or burning effect regarding the projectile type. The widely applied fuses are impact and proximity ones. The impact fuse starts to initiate when impact to target occurs. Proximity fuse, instead, starts initiating when an object enters its detection range. While fuse is the initiator of an explosive train, the propellant is the source of energy for discharging the projectile. Propellant is chemical composition that provides energy to eject the projectile through the gun barrel. The purpose of a solid propellant is to generate gas, which expands to accelerate a gun projectile so that it achieves the desired launch velocity at the muzzle. Some of the important properties of propellant are the burning rate and vivacity, both of which strongly influence gun performance and projectile range [3]. Considering the base formulation, there are four kinds of propellants widely applied in ammunition. Those are single base propellant, double base propellant, triple base, and composite propellant. The single base and double base propellant are commonly used for small-caliber ammunition while the triple base propellant is mostly used for large-caliber ammunition. The composite propellant is mainly used for rockets. Aurell *et al.* [4] denoted that a single base propellant consists of Nitro-Cellulose (NC) while the double base propellant consists of both NC and Nitro-Glycerin (NG). The triple base propellant has both NC and NG with the addition of Nitro-Guanidin (NQ) as the third base component. NC, NG, and NQ are energetic materials that can provide adequate force if ignited. Most of ammunitions have the same components. However, ammunition can be classified in several ways.

Figure 1. Ammunition for anti-air and anti-vessel [2].

There are various methods to classify ammunition. Based on its caliber, ammunition can be classified into small-caliber, medium-caliber and large-caliber ones. The small-caliber ammunition is an ammunition that can be operated by using hand guns, rifles, or sniper rifles. Meanwhile, medium-caliber and large-caliber ammunitions are ammunitions that are operated by using cannons or tanks. Based on the application, ammunition can be grouped as anti-personnel, anti-air and anti-vessel ammunitions. Moreover, Carlucci [5] categorized ammunition by the construction or assembly method, i.e. fixed ammunition, separable ammunition, or separately loaded ammunition.

Fixed ammunition, usually called a cartridge, consists of a container for the propellant charge, called the cartridge case which is firmly attached to the projectile by crimping or cement. For some application, cartridge case remains in the weapon after firing. On the other hand, other cartridge cases are ejected outside the weapon or consumed during firing, and the projectile flies downrange to the target. The charge, primer and ignition system are assembled inside the case and are not alterable. This type of ammunition is characteristically used in tank, anti-aircraft, aircraft weapons, and in most small arms (rifles and pistols). Separable ammunition is different from this kind of ammunition.

Separable ammunition (also called semifixed ammunition) consists of the cartridge case and projectile. In this kind of ammunition, the cartridge case is not firmly attached to the projectile. The case can be removed in the field to adjust the propellant charge, which can be incrementally changed. This type of ammunition was used in older howitzers and is still used in shotguns. The third category is separate-loaded ammunition.

Separate-loaded ammunition is also called separated ammunition. It consists of the projectile which is loaded first into the weapon, the propellant charge loaded next, and finally, the primer and igniter loaded last. The charge is in bagged increments. The quantity of propellant charge is altered, along with the quadrant elevation of the weapon, to shoot different target range. The primer is usually loaded into the breechblock of the weapon. The block is self-sealing and assumes the same function as cartridge case in fixed ammunition. This ammunition type is used in modern howitzers and large naval guns.

2. AVAILABLE TECHNOLOGY

Small arms ammunition industry consists of several production lines. Improvement of production efficiency is required so that the domestic ammunition industry can compete with foreign ammunition industry [6]. Those lines are case production line, primer production line, projectile production line, and cartridge assembly line. The first three lines produce the main components of ammunition, and the last assembles the components into a complete cartridge of ammunition. Each production line consists of several machines working on different processes. In total, there could be dozens of machines operating simultaneously to produce even the smallest caliber ammunition. Each machine has sensors, controllers and actuators. Therefore, a control system is essential for collecting data from variously distributed sensors and controllers, to control the system in real-time [7].

A control system (CS) can be defined as a manual or automatic mechanism used to manage dynamic processes [8]. It works by adjusting or maintaining physical quantities such as mass, temperature, or speed. There are two main classes of a control system, i.e. open-loop control system and closed-loop control system (**Fig. 2**). The open-loop control systems generate their output based on input only, while in the closed-loop control systems the current output is used as a feedback mechanism together with inputs to generate new output. A simple example of a closed-loop control system is a home central heating system where the desired temperature is set on the thermostat, which also measures the current temperature and decides when the heating element needs to be switched on and off. The term of control used in industrial process is industrial

process control.

Figure 2. Basic operation of a control system [8]

The terms industrial control system (ICS) or process control system (PCS) are used as umbrella terms for the types of automatic control systems used in industrial production environments [8]. Industrial automation and control systems are very complex architectures including various software tools [9]. The types of automated control are distributed control system (DCS) and supervisory control and data acquisition (SCADA). DCS is a control system in which the individual controller elements are distributed and connected by high-bandwidth, low-latency networks for data gathering and control. DCS devices are located in a remote area. DCS systems are used in industrial processes like electric power generation, oil refineries, wastewater treatment, and chemical, food, and automotive production. This type of control system is used earlier than SCADA.

SCADA is a control system located on different locations connected by low-bandwidth, high-latency links, which are used for collecting data and open-loop control [8]. SCADA systems are used for instance in distribution applications like transport of oil, gas, and (waste) water but also in electrical power grids and railway systems. The main purpose of this system is automated data collection and data processing on energy consumption objects. Today SCADA is a system for measuring, data collection, monitoring, and control of industrial systems [10]. SCADA systems generally consist of sensors, actuators, programmable logic controllers (PLCs), and a human-machine interface (HMI). HMI and other SCADA services (such as engineering workstation and historian) are installed at a control room so that operators can remotely observe and control the processes [11]. A PLC is deployed at a distant field site to provide immediate observation and management of a physical process.

A PLC communicates with its respective center to send the current state of the physical process, which is then displayed by HMI diagrammatically for control operators. It uses sensors to obtain the current state of a physical process (such as the pressure of the gas in pipeline), and actuators (such as solenoid valve) to alter the current state reckoning on the logic in the PLC. For example, a PLC could also be programmed to maintain pressure in a gas pipeline between forty and fifty PSI. Based on readings from the pressure sensor, if the pressure is over fifty PSI, the PLC opens the solenoid valve to release some gas until the pressure is reduced to forty PSI. An engineering workstation at the center runs PLC programming software, that is employed by control engineers to program and transfer the control logic to a PLC over the network. Regardless, there are several differences in each application of both types of control systems (DCS and SCADA) in industrial production.

In industrial production, distributed control is perceived to be a promising approach for dealing with challenges arising from the increasing dynamical and structural complexity in that field [12]. Currently, future production systems are envisioned to be digitalized and networked systems bearing names such as

“Industry 4.0”, “Manufacturing 2.0”, “Internet of Things (IoT)”, and many others. These visions share the idea of assigning tasks of production control to “intelligent” objects, such as machines, parts, and products, in order to attain higher flexibility, higher adaptability, and therefore a higher logistics performance. However, limited information and restricted computation capacity may have negative effects: The production system behavior depends on the decisions made by intelligent objects with individual and selfish systems of objectives. SCADA is increasingly being used in modern industries. Devices with smart sensing capabilities, PLCs, actuators, intelligent electronic devices (IEDs) of industrial control systems (ICS) and SCADA network are connected over IoT platform [13]. IoT platform has facilitated modern industries efficient monitoring and controlling of physical systems resulting in intelligent data acquisition, processing and highly productive and profitable management of business. Large scale industries such as oil refinery generally rely on a Distributed Control System (DCS) to provide all process and equipment control functionality. Despite this, SCADA also has its own target industries. SCADA systems are usually employed to monitor and control the industrial equipments or infrastructure such as communication systems, water supply control, power plants, oil and gas refining and transportation [14]. Therefore, the system has to be robust and reliable.

In constructing a stable and reliable SCADA/PLC system, it is important to understand the automatic management and process control so that no waste of manpower, physical resources, and also increase worker safety [15]. In order to automate a factory such as oil refinery and minimize human intervention, there is a need to develop a SCADA system that monitors the plant and helps to reduce the errors caused by humans. SCADA works in system monitoring, while PLC is used as the internal storage of instructions for implementing functions. Those functions are logic, sequencing, timing, calculation and arithmetic to control varieties of machine processes through digital and analog input/output equipment. SCADA refers to the combination of measurement and data acquisition. Three of the main parts of a SCADA system are Master Station, remote terminals (RTU, PLC, and IED) and the communication devices. It includes collecting data via a Remote Terminal Unit (RTU), PLCs and Intelligent Electronic Devices (IED). It has to be able to transfer data back to the central site to carry out any necessary analysis and control. The information is then displayed on a number of operator screens. There are some advantages of using SCADA instead of DCS. The advantage of using SCADA/PLC system is that scan time used for monitoring the system, for detecting the problems, and for executing the actions are much faster than DCS. DCS tends to be more expensive and tends to use proprietary hardware and software. SCADA system can archive a large amount of data. SCADA screens are more realistic than DCS screens for the user and the operator can monitor the process of the plant from any place all over the world. SCADA can also be used to provide the necessary data to support the maintenance department of a company.

A maintenance department has to be able to ensure that every machine, with its mechanical and electrical components, in the production works correctly. Certain mechanical and electrical components, exhibit degradation phenomena, which may develop slowly over time or suddenly [16]. A malfunction detection indicators from analog signals recorded by SCADA can be helpful in creating behavioral models of the equipment. It also can model the development of a series of status indicators. It is useful in detecting malfunctions when operation SCADA are unable to detect an error. Then, it helps in determining whether the component is beginning to degrade when certain normal limits are exceeded. Nevertheless, the digital signals from operation SCADA can also act as additional information that could be used to detect possible malfunction. Detection must be followed by an investigation of the remaining life of a component so that the remaining useful life of the component before failure can be estimated before losing its functionality. SCADA can detect a malfunction and determine when the component will break, then the maintenance department will have valuable time to intervene prior to failure at an optimum time.

3. FUTURE OPPORTUNITIES

The SCADA networks have a vital role in critical infrastructures (CIs) [17]. Considering the ammunition industry is one of the critical infrastructures, a robust control system has to be implemented. In SCADA implementation, there are steps that have to be done, i.e. designing the system architecture, procuring the hardware, developing the software, installing the components, connecting the existing equipment to the SCADA mainframe, and then system integration. By defining the system architecture, the main components of the system can be listed (**Figure 3**).

The main components are master station, remote terminal units, and communication devices. The specification of each component depends on the scale of the factory itself. The master station is connected to the PLC via Profinet and I/O module. The remote terminals or field instruments' main panel is connected to the master unit through hardwire connected to I/O module. The communication device can be Ethernet cable or even wireless modems.

Figure 3. SCADA system architecture

Graphical interface unit (GUI) of a particular SCADA is displayed in two positions. First position is the HMI which is located near the machine. The HMI is to be operated by the personnel that is stationed to the machine. The second position of SCADA GUI is the engineering workstation located in the control room. If needed, expansion monitors can be deployed to get a detailed and more comprehensive interface. Every data that is sent from the machine is stored in the SCADA controller memory. By using the UI on the workstation screen, the user can also interact with the machine actuators (e.g. turning the machine off/on, switching a motor off/on, etc.). Productivity data such as product output, machine utilization, downtime and rejects count can be extracted from the machine sensors and displayed on the work-station screen. By operating the SCADA workstation, Production Planning and Inventory Control (PPIC) department have access to productivity data in real-time. If the PPIC can do that, then any judgment regarding production problems can be decided swiftly. Quick action to any problems on the production floor can reduce any delays in the production cycle. This, in turn will bring about a massive boost to productivity.

4. CONCLUSION

It is necessary to improve the production control of an ammunition factory. One of the most reliable control systems is SCADA. SCADA can ensure that everything that happened in the production facility is recorded and can be analyzed for further improvement. SCADA also minimize the human error factor in production control. To be able to implement SCADA, some equipment must be prepared. However, investment is needed in order to improve the reliability of production control, which in turn will increase productivity.

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