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THE IMPORTANCE OF SCADA SYSTEMS IN THE AUTOMOTIVE INDUSTRY FOR REDUCING THE IMPACT ON CLIMATE CHANGE

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Abstract:
The automotive industry plays key role in global gas emission, contributing to the greenhouse effect. This paper explores the importance of SCADA (Supervisory Control and Data Acquisition) in optimizing industrial processes within automotive manufacturing and engine management. By real-time monitoring, optimization, control of industrial processes and data collection, SCADA contribute to reduce energy consumption and emissions of harmful pollutants such as carbon dioxide and nitrogen oxides. This paper analyzes technical architecture, specific applications in diesel engine control, and environmental benefits that are supported by relevant case studies and empirical data. SCADA systems may offer considerable advantages, but there are also challenges such as cybersecurity vulnerabilities, integration complexity and implementation costs that are also discussed.

Keywords: *SCADA systems, automotive industry, climate change, industrial automation, emissions reduction*

Introduction

Climate change is one of the most serious challenges in today's world, and the automotive industry, which is among the leading sources of gas emissions, plays a significant role in finding solutions. In urban areas, for example in Europe, more than 70% of the population lives in cities, where traffic and industry contribute to elevated concentrations of pollutants such as nitrogen oxides and particulate matter. This pollution creates more problems for the population, such as health risks, rapid deterioration of buildings and houses, collapse of historical monuments and sites, and damage to vegetation in and around the city [1].

Smog and long-term average concentrations of harmful compounds such as lead, benzene, benzopyrene and particulate matter significantly

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increase emissions from road traffic, which also contribute to more than half of nitrogen oxide emissions and 35% of emissions of volatile organic compounds. Diesel engines, which are still present in passenger and freight transport, also contribute to the emission of particles that easily reach the respiratory system [1].

In order to mitigate the negative impact, increasing importance is being given to digitized management and control systems. One of the key tools that can be used in this context is the SCADA (Supervisory Control and Data Acquisition) system, which enables data collection, detection of various deviations and process optimization in real time. Due to its adaptability and functionality, SCADA systems are increasingly used to increase energy efficiency and reduce emissions [2, 3].

1. Climate Change and the Automotive Industry

According to a report by the European Environment Agency (EEA), road traffic accounts for approximately 72% of emissions in the transport-related sector, with passenger vehicles accounting for more than 60% of carbon dioxide emissions from that sector [3]. Emissions do not only come from traffic, they also come from production and logistics processes in the automotive industry. In production facilities with robotic cells and automated processes, complex management often leads to increased energy consumption and pollutant emissions [4].

Diesel engines have been identified as sources of nitrogen monoxide, nitrogen dioxide and PM2.5 particles that have been linked to respiratory and cardiovascular diseases. The European Union (EU) has introduced the "Euro 6" emissions standard, which aims to limit the emission of nitrogen oxides from diesel vehicles [5]. In addition, further research shows that emissions from vehicles often exceed the prescribed limit values, especially in older vehicles with poorly maintained exhaust gas systems [6].

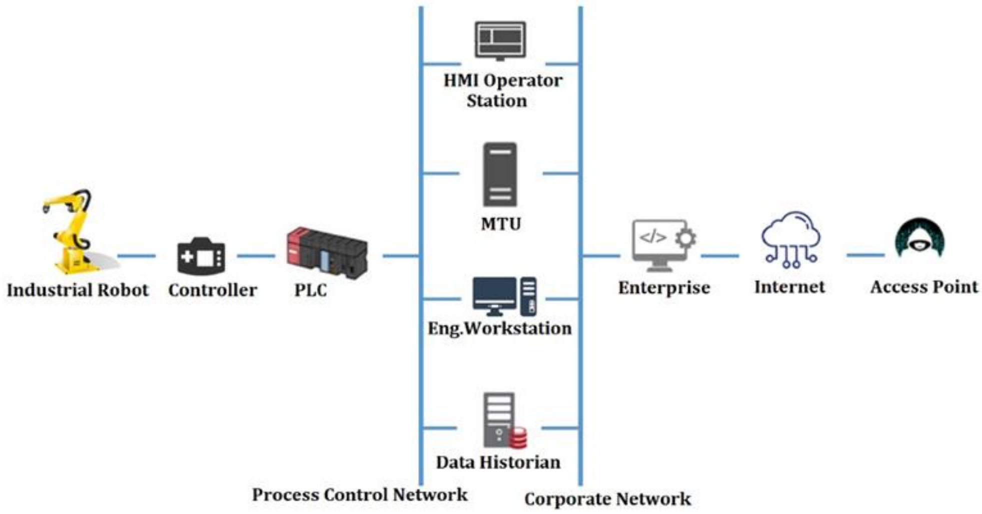
As part of its strategies, the auto industry has been relying on the digitization of production processes in recent years, with the goal of better monitoring of energy flows and emissions. By using the SCADA system, it would be possible to monitor parameters in real time, optimize consumption and detect automatic inefficiency with performance indicators (KPI), which contributes to environmental responsibility and reducing operational costs [3, 7, 8].

2. SCADA System Architecture and Core Functions

SCADA represents a system for supervisory control, management of industrial processes and data collection. The role of the SCADA system is not only to monitor, collect and process data, but to react based on assigned or predefined automated functions. SCADA systems operate in complex environments where they rely on a network of existing devices and software components that enable real-time monitoring [8].

The basic architecture of the SCADA system is based on three key levels [9, 10]: (1) Hardware – includes sensors, actuator units, controller, such as PLC (Programmable Logic Controller) and monitors. These devices aim to collect process data from physical locations and send it to a central system. (2) Software – represents the core of the SCADA system. It includes an HMI (Human-Machine Interface) that allows operators (users) to visualize data and intervene as needed, a RTU (Remote Terminal Unit) and control logic. (3) Communication networks - these includes Ethernet, Modbus, OPC UA. They enable the transfer of data between physical devices [11] .

A schematic representation of the SCADA architecture is shown in Figure 1. It includes key system layers and interconnections between components



Picture 1. *Architecture of an industrial SCADA system showing the layered organization of field devices, PLC controllers, SCADA servers, HMI panels and corporate network [12]*

SCADA systems are designed to include the following functions [8, 10]: (1) Alarm management – automatic recognition of errors that are visually displayed and which the operator must confirm (2) Data history – logging of process values used for analysis. (3) Control logic – execution of user-defined programs that can activate, modify or disable tasks. (4) Advanced numerical processing - providing support for performing arithmetic and logical operations in real time [13] (5) Interface and visualization - includes custom display, process displays, saving results, data export to other analytical tools or physical media.

3. Application of SCADA Systems in the Automotive Industry

In the automotive industry, the efficiency and environmental aspects of internal combustion engines (diesel engines) are the subject of improvement. Although diesel engines show a higher degree of energy efficiency compared to gasoline engines, they also emit higher amounts of nitrogen oxides and particulate matter [5].

Modern SCADA systems enable detailed monitoring and control of engine operating parameters, including exhaust gas temperature, cylinder pressure and mixture composition. Based on the data collected, it is possible to perform certain corrections in real time with the help of PLC units and PID controllers, where combustion optimization and reduction of pollution emissions will be performed [14]. One of the concrete examples of a SCADA System is a leak detection device that is placed on the intake manifold to improve engine performance. With this solution, the PID controller generates a control signal, and the PLC activates the electromagnetic valve that adjusts the flow to the cylinder, thereby achieving the optimal AFR (Air-Fuel Ratio) in all operating modes [9]. In addition to engine control, SCADA systems are used to monitor exhaust system emissions, exhaust gas recirculation (EGR), integration with OBD (On-Board Diagnostics) systems. In combination with IoT (Internet of Things) sensors and wireless networks, SCADA enables the collection of data from multiple vehicles, which opens up space for maintenance and analysis of vehicle performance in real driving conditions [6].

4. Ecological Benefits of SCADA Systems

The introduction of the SCADA system in the automotive industry enabled the improvement of monitoring and control of processes that affect energy consumption and the emission of harmful gases. Through insight into the operation of plants and components of the production process, SCADA optimizes engine operation and manages combustion and emissions of exhaust systems [2]. One of the key functionalities of the SCADA system is the continuous monitoring of emissions of carbon dioxide, nitrogen monoxide, nitrogen dioxide and volatile organic compounds and their automatic recording and alarming when limit values are exceeded. With the help of this function, operators can react to deviations, and the system will automatically perform corrective actions through the PLC controller [6]. In manufacturing plants, SCADA enables measurements and analysis of energy consumption of machines, lines and shifts, which enables the identification of inefficient processes. By using KPI indicators in the SCADA system, one can systematically work on reducing losses and planning more energy efficient operations [8].

A study conducted in an electric bus factory showed that the introduction of the SCADA System reduced energy loss by 13% and carbon dioxide emissions by 11% compared to the previous system without automated monitoring [4]. In another study, the SCADA system was used to optimize combustion in engines where it led to a reduction in nitrogen monoxide and nitrogen dioxide emissions by 18% and an increase in the overall efficiency of the system [6].

5. Challenges and Limitations of SCADA Systems

One of the key problems of SCADA systems is their vulnerability to cyber attacks. Traditional SCADA systems are not designed with security as a priority, making them vulnerable to manipulation through unauthorized access to the network or physical system [12]. Attacks using SCADA system vulnerabilities can cause serious plant disruptions in the context of automated processes in the automotive industry.

The introduction of a SCADA system requires large investments. This mostly applies to older plants that have not been previously digitized. The costs of hardware upgrades, software licenses and employee training can be an obstacle for rapid implementation, especially in medium-sized and small factories [15].

Many factories use different equipment and software platforms from different manufacturers. The lack of standardization can lead to problems during the integration of SCADA systems with existing production lines and IT infrastructure [10].

Although SCADA allows for automation, the system still depends on operators who must review data, respond to alarms, and make decisions based on them. Poor training, carelessness or misreading of data can undermine the advantage of automation [8].

6. Conclusion

The application of SCADA systems in the automotive industry is one of the most significant technological solutions in the direction of energy and efficient production. Through real-time monitoring and management of industrial processes, SCADA optimizes energy consumption, reduces harmful gas emissions, and improves production lines and plants. SCADA systems are capable of precisely identifying inefficient power sources, the management of internal combustion engines and the integration with control systems, making them a very important tool for the transformation of the automotive industry.

However, several challenges remain, particularly related to cybersecurity vulnerablities. In addition, high costs of implementation and integration within existing infrastructure pose barriers in older and less developed companies and factories.

In the future, the development of SCADA systems is expected to be further enhanced with the help of IoT technology, machine learning and big data sets. Such integration will make decisions faster and more intelligently, will bring long-term stability and sustainability of the process.

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