Application of the MIAS methodology in design of the data acquisition system for wastewater treatment plant

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Abstract. This paper presents application of MIAS (Manufacturing Information Acquisition System) methodology to develop customized data acquisition system supporting management of the Central Wastewater Treatment Plant (CWWTP) in Gliwice, Poland, being example of production systems leading continuous flow, automated production processes. Access to current data on the state of production system is a key to efficient management of a company, allowing fast reaction or even anticipation of future problems with equipment and reduction of waste. Overview of both analysis and synthesis of organisational solutions, data sources, data pre-processing and communication interfaces, realised according to proposed MIAS methodology, had been presented. The stage of analysis covered i.e.: organisational structure of the company, IT systems used in the company, specifics of technological processes, machines and equipment, structure of control systems, assignments of crew members, materials used in the technological processes. This paper also presents results of the stage of synthesis of technical and organisational solutions of MIAS for CWWTP, including proposed solutions covering MIAS architecture and connections with other IT systems, data sources in production system that are currently available and newly created, data pre-processing procedures, and necessary communication interfaces.

1. Introduction
Contemporary market challenges mostly connected with worldwide competition between manufacturers calls for new methods of improving the operation and management of companies. Everyone agrees that efficient management of a company is currently possible thanks to the software supporting almost every area of a company operation, including resources planning [1], human resources management, accounting, relations with customers, production preparation [2] (development of product’s design [3] and technological processes planning [4]), advanced methods of production scheduling [5] (including maintenance operations [6]), down to the systems supporting automated control of technological processes. Competition between software producers results in development of complex software platforms, integrating many aspects of a shopfloor operation and management, there are new classes of software arising, fulfilling the needs of different branches of industry. Almost every IT system (ERP, MES, etc.) supporting management of different areas should be provided with data on current state of production system [7].

In that context, acquisition of data on the state of production system is crucial in the management of company, because access to real-time information describing the state of production system (including completion of production orders, state of crew, machinery and equipment, OEE, flow of material and semi-finished products, etc.) is the basis for decision making in every company. Detailed
issues of data acquisition and data sources, as well as fundamentals of the MIAS (Manufacturing Information Acquisition System) methodology itself was described in prior publications [8], thus only main rules will be reminded here. Availability of data in any given company strongly depends on specific of its production processes (discrete, batch, continuous), branch of industry, level of automation and share of manual operations, etc. In modern company acquisition of data on the state of the production system should be carried-on automatically, mostly without involvement of workers. The MIAS methodology is an example of multi-stage, multi-level methodology, where process of development of data acquisition system, understood as a set of cooperating hardware and software solutions, is divided into 3 main stages: analysis of various aspects of the company in which MIAS is applied, synthesis of technical and organisational solutions, and evaluation of proposed solutions. There are 4 proposed levels of analysis: level of company as a system, level of data sources, level of data pre-processing, and level of communication [8].

This paper presents example of application of the MIAS methodology in the company leading continuous, automated production processes – Central Wastewater Treatment Plant (CWWTP) in Gliwice, Poland. Overview of both analysis and synthesis of organisational solutions, data sources, data pre-processing and communication interfaces had been presented.

The stage of analysis covered i.e.: organisational structure of the company, IT systems used in the company, specifics of technological processes, machines and equipment, structure of control systems, assignments of crew members, materials used in the technological processes. During the stage of synthesis of technical and organisational solutions of MIAS for CWWTP, the solutions covering MIAS architecture and connections with other IT systems, data sources in production system that are currently available and newly created, data pre-processing procedures, and necessary communication interfaces had been proposed. The main reason to create information acquisition system for CWWTP was to provide better information on usage of equipment and assignments of crew members in order to achieve better management of production system, as well as to create complete database containing data on operation of wastewater treatment plant, necessary for fulfilling law requirements concerning compulsory information on the chemical composition of intake wastewater and outtake water cleaned during mechanical and biological treatment processes.

2. Dependence of data acquisition possibilities on a level of technological processes automation

Characteristics of a company and type of production processes strongly influences availability of data on the state of production system and realized tasks. Types of production classification can be based on products variety or volume and branch of industry. Production systems/processes can be broadly classified as continuous production systems (process/flow production, mass production) or intermittent production systems (batch production systems, job-shop production systems, project production systems).

Despite other characteristics of a production system, level of automation of technological processes is one of the most important factors in context of data acquisition [9]. This is caused by the fact that automatic process control requires the installation of hardware (PLCs, sensors and measuring devices) allowing control over production processes. Selected data obtained from automatic control systems can be extracted and reused for tasks that are not directly connected with the control of the processes. It can be stated that presence of industrial control systems can guarantee easy access to information on the state of manufacturing system (automated data acquisition). Data obtained from automated production system often do not carry all the information needed because usually not all activities in the factory are automated (i.e. maintenance).

In the production systems characterized by a predominance of tasks performed manually the basis of information retrieval is the method called manual data acquisition (mainly direct, verbal communication between workers and managers, sometimes formalised - forms or reports).

Requirements of IT systems supporting management (ERP, MES) calls for more reliable and faster solutions. This is a reason to define semi-automatic (assisted-manual) acquisition method, in which technologies like automatic identification systems (barcodes, RFID, machine vision systems), mobile or stationary data collectors, GPS, and other methods (3D scanning, photogrammetry, sound and voice
analysis, triangulation) can be used. Semi-automatic data acquisition method can provide us with data, that cannot be collected from automatic data sources. All devices and software responsible for data acquisition should constitute integrated data acquisition system, combining data sources in the shop floor, middle-layer sub-systems responsible for the pre-processing and reduction of the amount of data, as well as communication interfaces and industrial database responsible for data archiving, aimed at providing information for IT systems supporting management.

3. Data acquisition in continuous flow processes production system

The application of MIAS methodology to create data acquisition system for a company, in which continuous flow production processes are main part of operation, is presented on the example of Central Wastewater Treatment Plant (CWWTP) in Gliwice, Poland.

CWWTP is modern facility, completed in 2005, main technological processes of wastewater treatment are automated, it receives wastewater from about 200,000 population city and cleans it in continuous, relatively slowly pacing biotechnological flow process, that cannot be interrupted. Characteristics (operation and structure of CWWTP) has been analysed according to MIAS methodology. CWWTP is a part of the Water and Sewerage Company (WSC) in Gliwice, using the PerfectExpert/ERP as an IT system integrating management of the whole company.

However, there is an information gap between WSC and CWWTP, because there is no direct connection between WSC’s ERP and CWWTP IT systems. Most of the data from CWWTP are exported in standard MS Office (doc, xls) documents and then entered into ERP terminals. Communication between WWTP and the rest of company (ERP) should be necessarily improved. There are no MES or other middle-layer IT systems used. Wastewater treatment plant is specific example – this is not a typical profit-oriented company, the main objective of CWWTP is to run technological processes in a way that meet the quality requirements of cleaned wastewater at minimal operating costs. These quality standards requires collecting and archiving of data on chemical composition (content of the particular substances) and quality of input sewage, sludge and treated wastewater.

3.1. Technological processes of wastewater treatment, sludge processing and co-generation

The CWWTP plant has been designed for the removal of organic matter and nitrogen by simultaneous denitrification and nitrification, and removal of phosphorus using biological dephosphatation and chemical precipitation with iron salts [10]. Technological scheme of CWWTP consist of two main branches (figure 1): wastewater treatment line (bar screens station, aerated vertical grit chambers, circular primary settling tanks, activated sludge tanks, pre-denitrification tank, anaerobic tank and aerobic-anoxic tank, biological reactors, etc.), and sludge processing line (gravity and mechanical thickeners, anaerobic digestion chambers, filter presses, etc.) [11]. Additional devices are responsible for processing gases (e.g. methane) produced in biotechnological processes. Gases are used to generate thermal and electrical energy.

3.2. Control system of CWWTP

Most of the technological devices are tanks of various shapes and sizes, open or closed, often equipped with a agitators and aerators. Devices are often large, and distributed over a vast area, that creates problem of long distance communication. The flow of wastewater and sludge between objects is possible through pipelines and forced by gravity or pumps. Valves and adjustable shunts allow control over the flow. Control system consists of PLCs, sensors and measurement systems (liquid levels, temperature, chemical composition, etc.) and frequency inverters, motors, electrovalves, etc.

The core of the control system consists of 8 Siemens S7-300 PLCs, located in separate areas nearby the group of controlled devices (figure 1). Each of PLCs has 2 fieldbus interfaces: close-range copper wired Profibus, responsible for control over devices in its areas, and long-range fiber-optic link, configured in closed-loop redundant topology, connecting all area’s PLCs. One of the PLCs is used for controlling of HMI synoptic table in the control room, which is currently used as a secondary HMI device. Primary HMI system is based on the computer with HMI/SCADA PRO-2000 system, allowing supervisory control over technological wastewater treatment processes and data archiving.
Except signals from controlled devices (state of machinery, frequency inverters, softstarts, valves), control system processes data from measuring devices (e.g. wastewater/sludge flowmeters, wastewater temperature and pH sensors, chemical substances sensors – ammonia nitrogen, nitrate nitrogen, phosphorus – measured every few seconds or minutes, depending on the substance), allowing applying automatic control algorithms to obtain proper progress of wastewater mechanical, chemical and biological treatment processes, as well as providing data required because of reporting wastewater treatment results to the relevant institutions.

3.3. Objects and activities not included in existing data acquisition system

Control system of CWWTP has been designed only for control over wastewater treatment processes, not covering arising needs of data exchange with ERP system and only containing data on the state of main technological processes. Activity of workers (mainly technological processes operators and maintenance crew) is not reported and cannot be managed from ERP system, as well as handling and usage of materials, side products and means of local transport. Activity of crew (about 30 workers) is currently managed and reported manually. Workers are divided into 3 process operator teams (plus 3...
HMI/SCADA operators), responsible for uninterrupted operation of CWWTP on 3 shifts, and one team of maintenance workers (electricians, mechanics). CWWTP is supervised by plant manager, chief process engineer and maintenance foreman.

Materials handling in CWWTP are relatively not complicated because material needs are low – only small amount of reagents, allowing better control over biochemical processes is necessary. However, in a modern production plant, usage of these substances, as well as handling of wastewater treatment residues, should be, without delays, reported to ERP system.

3.4. Proposed MIAS for CWWTP

As a result of MIAS analysis stage, it can be stated that newly designed data acquisition system for WWTP should cover information needs in three main areas:

- improved, direct ERP reporting of automated control system state, augmented with data from additional sensors, archived and processed in advanced event precognition software, allowing better control in case of weather changes, and rationalised maintenance,
- reporting of workers activities to the ERP system – it should be based on newly installed local HMI panels in selected plant areas, and automatic identification systems (mobile data collectors with barcode scanners), supported by organisational solutions,
- reporting of materials and residues (waste) flow to the ERP system, based on automatic identification systems (mobile data collectors with barcode scanners) and SCADA-connected vehicle scales, supported by organisational solutions.

The core of the new data acquisition system (figure 2) is based on industrial database (Proficy Historian), equipped with collectors for available data sources. Architecture of industrial database divided into main database engine and data collector modules, allows purchase of necessary modules only. OPC collector is the most important in case of CWWTP, allowing access to data from SCADA and new data sources. SCADA system will remain the main source of data on state of technological processes, including data from newly created sources. Proficy Historian contains calculation collector, allowing development of scripts responsible for real-time data pre-processing, reduction and interpretation. Data is presented as pre-defined reports and in operator dashboards, and exported to ERP system. Additionally, advanced fault and problems anticipation software [12] (e.g. Proficy Troubleshooter), detecting coincidence of signals [13], leading to problems in CWWTP operation in the past (problems can appear in specific weather conditions, melting of snow causing wastewater temperature drop, or composition of wastewater) will be used. Full acquisition of data on activities of workers and materials handling will be possible thanks to additional HMI panels in specific plant areas (allowing reporting of faults and tasks completion), and portable data collectors. Labels will be attached to material containers or tanks (liquid materials), also workers will get personal barcode identifiers and typical tasks barcode charts.

4. Conclusions

Design of integrated data acquisition system for continuous flow automated production system, based on MIAS methodology, is easier than in case of non-automated production system, thanks to availability of control system and SCADA, providing access to existing data sources and allowing further expansion. Only activities of workers, flow of materials and transport system have to be included in expanded data acquisition system. Concept of MIAS for CWWTP, allowing reporting of this additional data has been developed. Newly designed data acquisition system should provide information on state of technological processes, machines, OEE, KPIs, crew activities, material flow, etc. MIAS is currently in phase of development and initial application, based on Proficy Historian, allowing easy data collection (from SCADA and new data sources through OPC server), pre-processing, presentation and interfacing with ERP. Data on activity of workers and material are collected using HMI panels and mobile data collectors, that should provide more detailed information on the state of CWWTP. Full evaluation of results of operation of MIAS will be possible after complete introduction, but first impressions shows improvement in the data exchange between CWWTP and the ERP system – there is less need for time-consuming manual data entry and availability of detailed data allows better planning and management of CWWTP.
MIAS (Manufacturing Information Acquisition System) for CWWTP in Gliwice

Industrial database core
SCADA collector
Proficy Historian

Calculation collector
File collector

Advanced data analysis and precognition module (e.g. Proficy Troubleshooter and Cause+)

Visualisation and reporting module
ERP data interface

Optional MES system
PerfectEXPERT/ERP

SCADA

8 x Simatic S-317 PLCs
Sensors, meas. devices
Electrovalves, drives etc.
HMI panels
Barcode/RFID Scanners

Figure 2. Proposed structure of data acquisition system for CWWTP.

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