The potential of OPC technology for monitoring and maintenance of hydropower plants

D. KRANJČIČ[1]
DEM – Drava River Power Company
Slovenia

SUMMARY

This paper describes the system based on the OPC technology that is used to collect, validate, analyze, present and centrally archive process data obtained from eight hydropower plants belonging to the Slovenian Drava River Power Company (DEM). The main focus of this paper is on the potential use of such system for maintenance of the hydropower plants, with particular emphasis on practical custom solutions that arise from the experiences of DEM specialists who perform deep analysis of the power plants operation. Furthermore, the paper also describes recent approaches where modern mathematical tools are used for condition-based maintenance (CBM) of power plants.

KEYWORDS

Process automation, OPC technology, condition-based maintenance, power system simulation, artificial neural networks, MATLAB/SIMULINK

[1] E-mail:dalibor.kranjcic@dem.si

I. INTRODUCTION

In the last decade, the development of modern process control systems (PCS) is being continuously influenced by new information technologies (IT) that are rapidly changing the “conventional” view of the distributed control system (DCS). While in the past the IT layer of the PCS was based on a single PC the purpose of which was to host the SCADA (System Control and Data Acquisition) software, nowadays the PCS architecture contains a variety of specialized servers the purpose of which is to provide new functionalities typical for the business IT. Despite the continuous influence and introduction of the new IT, the IT development of modern PCS still substantially lags behind that of the business IT. This can be seen in the common practices of the PCS vendors who apply rigid rules for upgrading of the operating systems and the respective service packs. This means that the new functionality has to be first verified against the SCADA software and the respective applications.

There is, however, another aspect of the lagging, which consists in the inability of serving SCADA users with adequate modern interfaces and tools – e.g. ability to present data in modern graphic styles, export data for further analysis in various known file formats (e.g. Excel, Access …) and to allow large number of users to access data via internet browser (via so called Web SCADA).

This can be improved by introduction of systems based on OPC technology [1] (OLE for Embedded Control) that are used to collect, validate, analyze, present and centrally archive process data obtained from various process/technical systems. There are many such systems on the market today with the common characteristic of using the following software tools:

- Specialized historical database – used to obtain and archive data from various process/technical systems.
- Web SCADA – used to create and present process pictures.
- Analysis tool – used for trend analysis of the process data.
- Calculation tool – used to apply mathematical operations on process data.

All the above characteristics were taken into account by the Slovenian Drava River Power Company (DEM) upon selection of the system that would be capable to collect and centrally archive data obtained from the chain of hydropower plants located on the Drava River – i.e. the ZVAPS system.

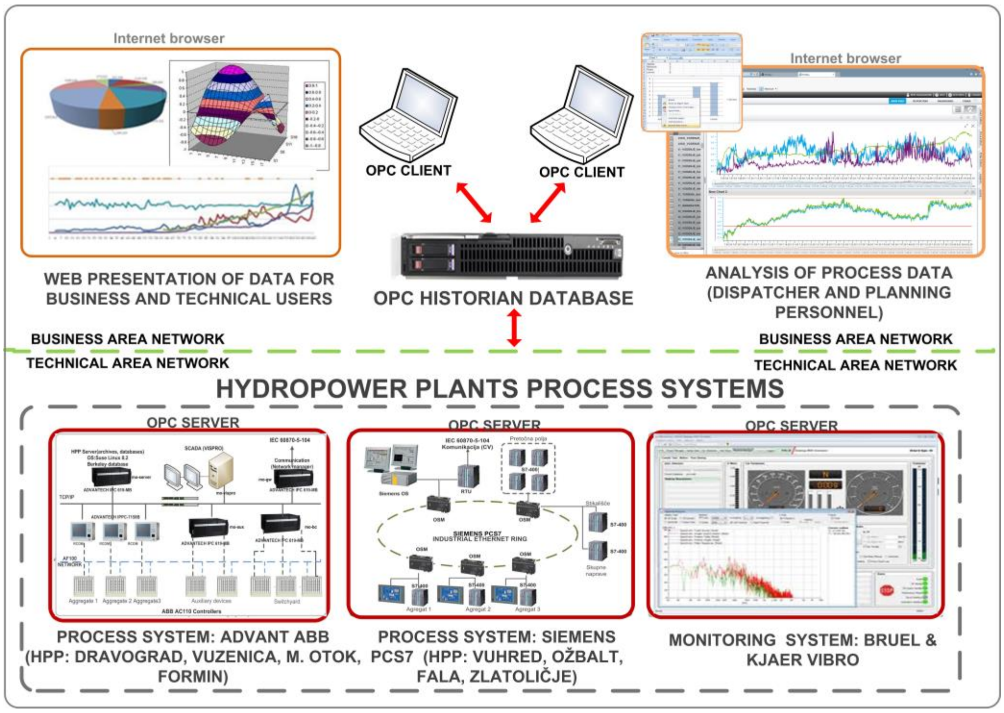

Fig. 1. The concept of the ZVAPS system.

II. THE ZVAPS SYSTEM

The ZVAPS system refers to the system based on the OPC technology that is used to collect, validate, analyze, present and centrally archive process data obtained from eight power plants belonging to the Slovenian Drava River Power Company (DEM). The idea of the system is to collect data from various sources (i.e. hydropower plants process/technical systems) and to represent it in a modern web-accessible environment (see Fig. 1). The system is built on Proficy Historian database (GE Intelligent Platforms) and accompanying tools: iFIX Web SCADA, Proficy Historian Analysis and Proficy Historian Calculation. Around 4000 data points (measurements) are being collected, mainly in real-time, via the OPC protocol from the following process/technical systems (see Fig 2):

- Siemens PCS7 – installed in the hydropower plants Vuhred, Ožbalt, Zlatoličje and Fala (releases from 6.1 to 8).
- ABB ADVANT with the SCADA Vispro – installed in the hydropower plants Dravograd, Vuzenica, Mariborski otok and Formin.
- Bruel & Kjaer Vibro – installed in all previously mentioned hydropower plants belonging to the Slovenian Drava River Power Company.
- MAXIMO asset management system – this technical system will be included by the end of the year 2016.
- Remote control center – based on the ABB Network manager technology, release 5.3.

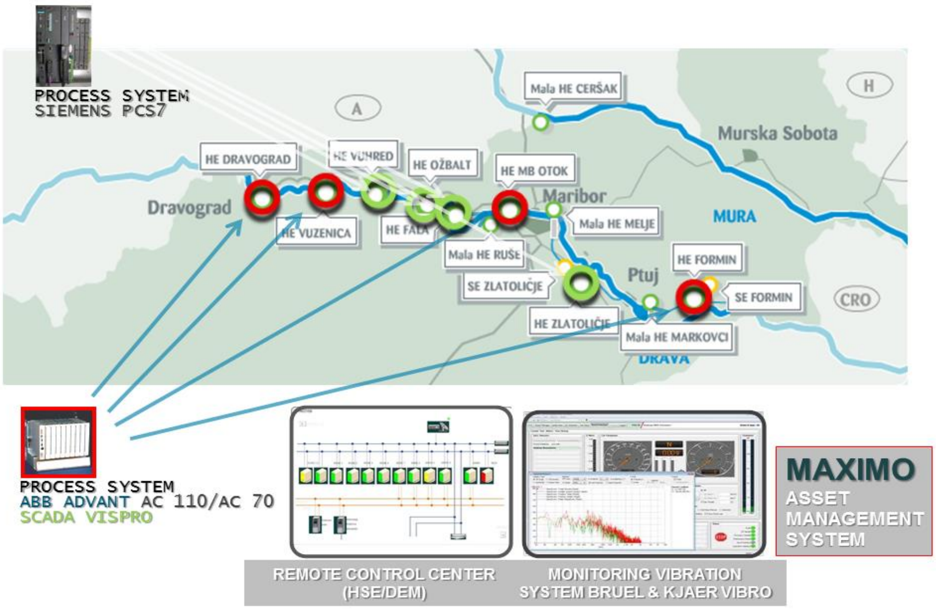

Fig. 2. Process/technical systems providing data to the ZVAPS system.

Besides the above presented real-time sources of data, a minor amount of data is imported manually from different technical systems – e.g. measurements related to the state of batteries and insulation resistance of windings.

The ZVAPS system was set up in two phases and itis still being amended. During the first phase, started in October 2013 and finished at the end of 2014, the complete Proficy Historian environment was installed and configured and, moreover, the OPC servers were introduced into each hydropower plant's process system and connected with the Historian database. The intention of this phase was to apply the OPC technology in such way to be potentially accessible by all users – i.e. all the process data is available to specialists for deep analysis of power plants operation, but it might also be used by other less experienced personnel that partially monitor the process data. The second phase of the project started in October 2015 with the objective to upgrade the system by introducing custom applications for advanced data analysis. These applications are being implemented within MATLAB/SIMULINK mathematical environment.

From the maintenance perspective, the main achievements of the first phase is introduction of the Historian Analysis tool that allows specialists to instantly access process data gathered from all the hydropower plants on the Slovenian Drava River. In the Historian Analysis tool the data points can be simply dragged and dropped into trend analysis tab and detailed analysis reports can be generated for future data analysis – see Fig. 3.

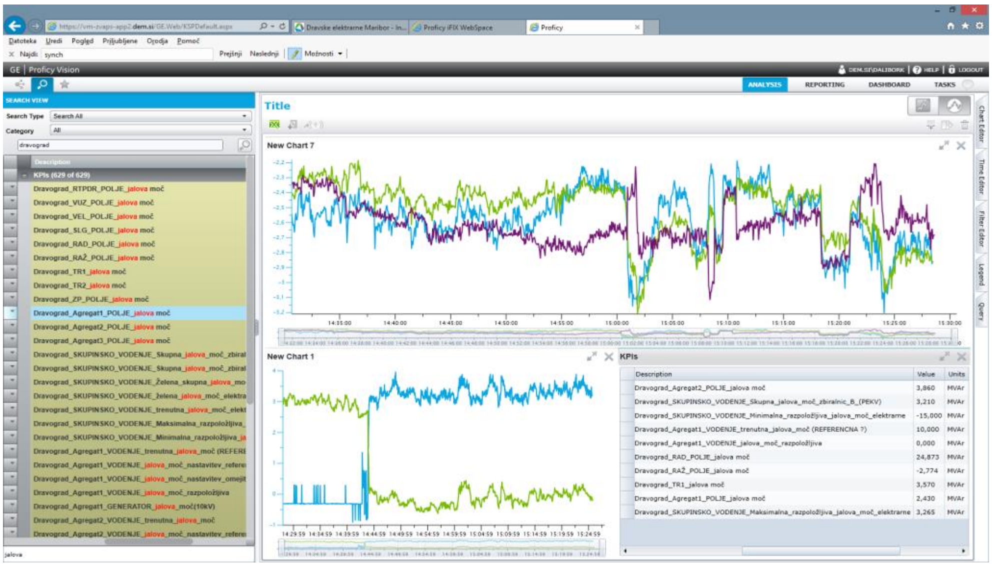

Fig. 3. The Historian Analysis tool.

Furthermore, the usage of the Web SCADA (i.e. iFIX) allows creation of custom process pictures that can be easily exported in the web browser environment. An example of the web process picture created for machinery department is shown in Fig. 4. This picture represents the crucial process data gathered from the chain of hydropower plants on the Slovenian Drava River and thus it can also be used, to a certain extent, as an alternative to the remote control center in case of malfunction.

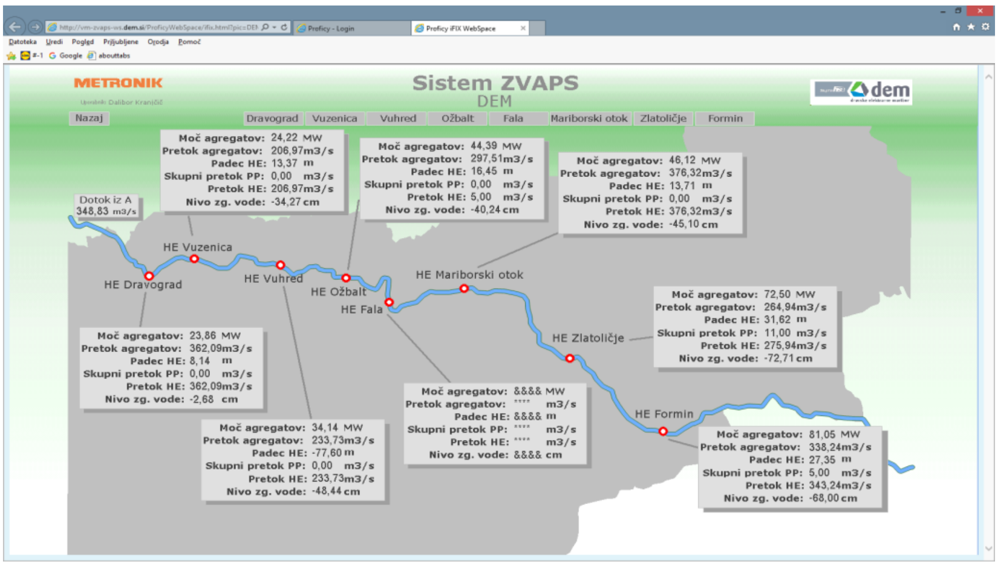

Fig 4. The Web SCADA (Proficy iFIX) showing the chain of hydropower plants on the Drava River.

III. THE PROJECT UPGRADE – INTRODUCTION OF MODERN MATHEMATICAL TOOLS AND CUSTOM APPLICATIONS

The availability of crucial hydropower plants data, gathered in the centralized database from various process/technical systems, holds an enormous potential for deep analysis of the hydropower plants operation. This potential becomes even bigger when modern mathematical tools, with the capacity of communicating via the OPC protocol, are being applied. Thus, with the possibility to access live and historical OPC data (i.e. OPC DA and OPC HDA respectively [2]), the widely used MATLAB/SIMULINK mathematical environment allows a wide range of options in terms of data analysis. Within the MATLAB environment the OPC data can be accessed by executing the OPC toolbox functions directly from the MATLAB command line or by using the OPC client application that allows creation and configuration of OPC Toolbox objects for reading, writing and logging of the process data. Furthermore, the SIMULINK environment offers an attractive option to access the OPC data during simulation of a system, allowing thus progressive functionalities as e.g. system identification based on the OPC data [3].

Based on the previously described MATLAB/SIMULINK possibilities and experiences of DEM specialists acquired during the development of the first project phase, it was noticed that sole use of trend analysis tool, despite many benefits it offers, is insufficient for complex data analysis that may possibly involve calculations performed on large sets of data. Therefore, it was a logical step to foresee the potential of the MATLAB/SIMULINK environment and to include it in the second phase of the project, with the aim to perform complex calculations with data gathered in the Historian database (i.e. the measurements gathered from the hydropower plants). This would allow all possible users to access the calculated data from the Historian database and respective applications (i.e. in the Web SCADA and trend analysis tool) – see Fig. 5.

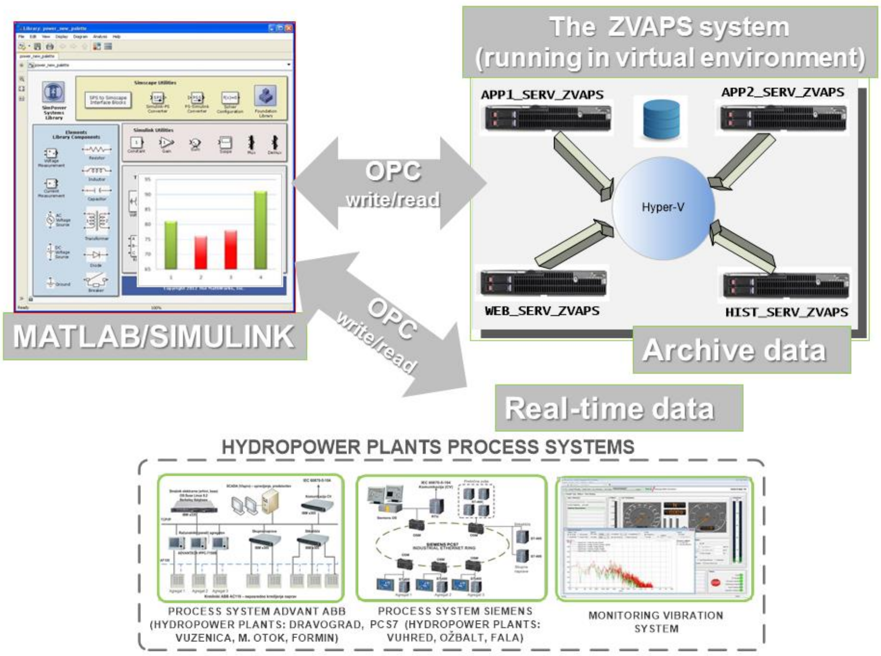

Fig. 5. Communication between MATLAB/SIMULINK environment and the ZVAPS system.

In this sense, the following new functionalities are being introduced in the second phase of the project:

- Integration of the vibration monitoring system Bruel & Kjaer Vibro [4].
- Creation of automated measurement system – tests of the hydropower plant operation procedures (e.g. turbine start-ups and shut-downs) are implemented within custom made web-based SCADA

application that relies on the data gathered in the Historian database. The measurement procedure is started in the Web SCADA user interface by a simple button press and a detailed report is automatically generated when the testing procedure is stopped (see Fig. 6).

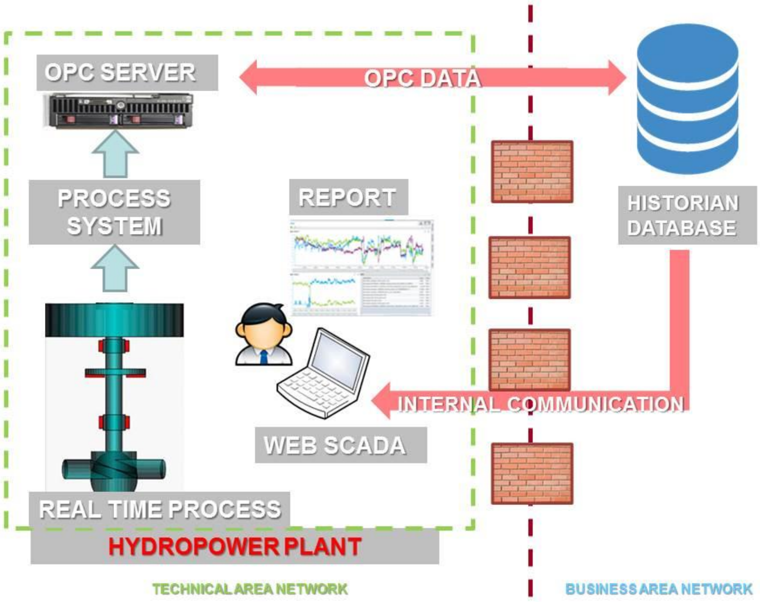

Fig. 6. Automated measurement system.

- Dynamic visualization of process data – this feature allows dispatchers and planning personnel to visually track crucial parameters (e.g. rate of change of heads, discharge…) in the process of generation of power. The observed data is gradually colored depending on the current values (see Fig. 7).

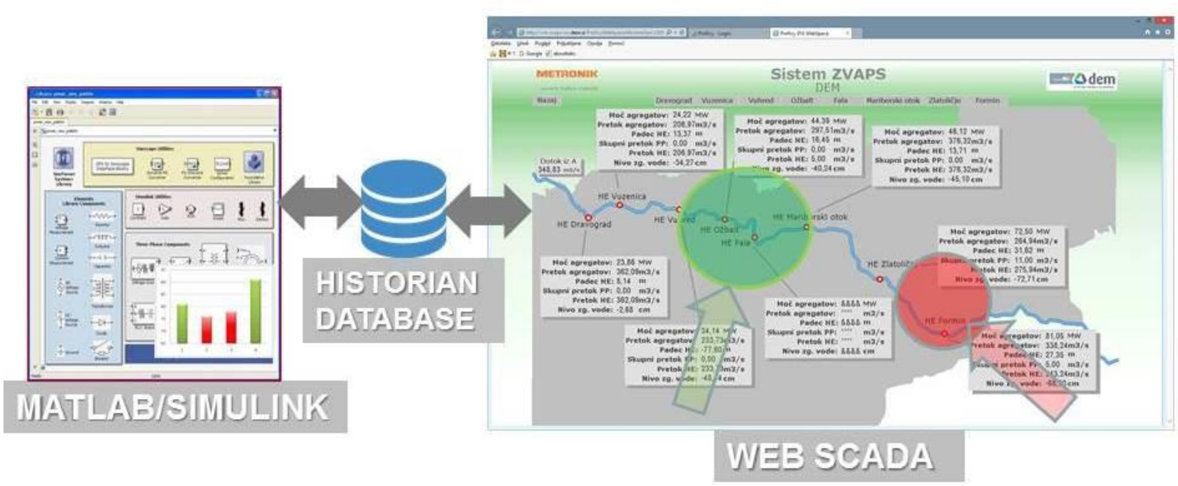

Fig. 7. Dynamic visualization of process data – an example.

- Importing of the process data gathered manually from automation and protection systems.
- Public presentation of the process data on the company (internet and intranet) web pages.
- Integration of the asset management system MAXIMO (IBM) – the integration is performed by using the OLE-DB technology.

IV. TRENDS IN CONDITION BASED MAINTENANCE (CBM) OF HYDROPOWER PLANTS : MATLAB/SIMULINK, OPC TECHNOLOGY AND ARTIFICIAL NEURAL NETWORKS

It is obvious from the previous chapters that the simultaneous use of the MATLAB/SIMULINK environment and the OPC technology opens many new possibilities in the field of maintenance of hydropower plants. Indeed, there is a growing trend towards the use of the MATLAB/SIMULINK environment and the OPC technology in the CBM of power plants, with the particular emphasis on the introduction of artificial neural networks (ANN). Thus, the paper by Simeon et al. [5] describes the SIMPREBAL system for prognostics and health management based on the OSA-CBM standard [6]. This system also acquires process data from an online OPC server (containing instruments data) and historical database. The database contains information of the maintenance and operation personnel and it is used to store failures, variables related to failures and decisions. The system also relies on the FMEA (Failure Mode and Effect Analysis) [7] tool that defines relations between the monitored variables and equipment failures, and furthermore, it is used for construction of the knowledge base. To perform failure mode isolation the system uses a trained ANN model based on the information gathered in the knowledge base and historical data.

This is not a sole example of application of ANN in decisions related to the equipment failures. Similar approaches were described in [8], [9] where ANN is used to detect anomalies in the gearbox component of a wind turbine. In these works, the ANN is used to recognize functional relationship between the variable determining the state of a certain component (i.e. the output variable of an ANN) and input variables assumed to have an influence on the condition of that component. To determine this functional relationship, the ANN is first trained offline by using as set of historical input and output data gathered during normal operation of the wind power plant. After completion of the learning phase, the real-time data (i.e. the control data) is applied to the ANN. The results obtained with the real-time data showed clearly the ANN effectiveness in detection of the subtle deviations from the normal behavior that correlate with the actual equipment failure. The Fig. 8 shows an example of the ANN model described in [9] that is used to monitor the health condition of the wind turbine gearbox – the gearbox oil temperature (i.e. the ANN output variable) is verified in dependence of bearing temperature, generated power, nacelle temperature and environment temperature (i.e. the ANN input variables).

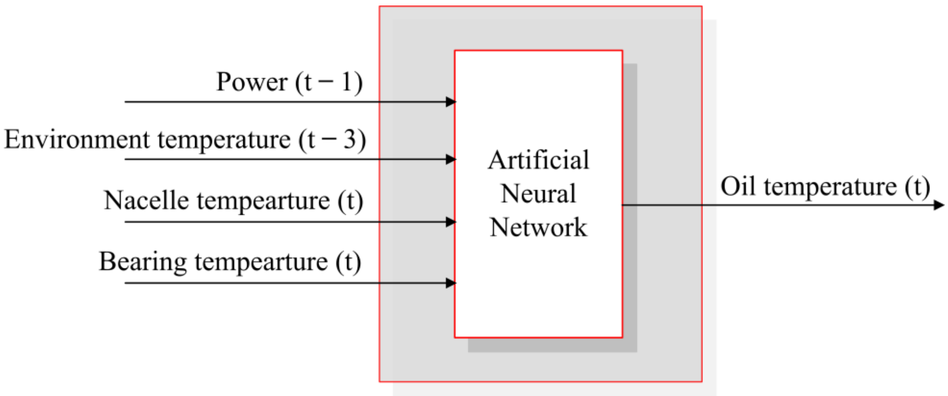

Fig. 8. An example of the ANN model used to monitor the health condition of the wind turbine gearbox [9].

V. CONCLUSION

The paper presents a system based on the OPC technology that is used to collect process data obtained from eight hydropower plants situated along the Drava River in Slovenia. The system gathers a large amount of process data in the central historical database and makes it available to all potential users – from specialists that perform deep analysis of the power plants operation to the less experienced personnel. Currently, around 4000 measurements are saved in the Historian database and as the project continues, it is estimated that this number will grow above 10,000 in the next two years. The focus of the paper is to show a wide range of possibilities and advantages that arise from synergy between the OPC technology and the MATLAB/SIMULINK environment, especially in the field of maintenance of the hydropower plants. The paper also describes new emerging approaches where artificial neural networks are used for condition-based maintenance of power plants.

BIBLIOGRAPHY

[1] OPC Foundation – The Interoperability Standard for Industrial Automation, Available: https://opcfoundation.org/ .

[2] Mathworks. OPC Toolbox – Read and write data from OPC servers and data historians, Available: http://www.mathworks.com/products/opc/ .

[3] Doug Eastman "System Identification and Control Using OPC Data", Available: http://www.mathworks.com/videos/system-identification-and-control-using-opc-data-68792.html .

[4] Bruel & Kjaer Vibro, Available: http://www.bkvibro.com/en.html .

[5] Edgar Amaya Simeón, Alberto José Alvares "A data-driven framework for predicting the remaining useful life of hydroelectric equipments" (ABCM Symposium Series in Mechatronics, Vol. 5, 2012).

[6] MIMOSA OSA CBM – Open System Architecture for Condition-Based Maintenance, Available: http://www.mimosa.org/mimosa-osa-cbm .

[7] Quality Digest – Failure Mode and Effect Analysis – Tutorial, Available: http://www.qualitydigest.com/inside/six-sigma-article/failure-mode-and-effect-analysis-tutorial.

[8] Mari Cruz Garcia, Miguel A. Sanz-Bobi, Javier del Pico "SIMAP: Intelligent System for Predictive Maintenance: Application to the health condition monitoring of a windturbine gearbox" (Computers in Industry, Volume 57, Issue 6, August 2006, Pages 552–568).

[9] R. F. Mesquita Brandao, J. A. Beleza Carvalho, F. P. Maciel Barbosa "Neural Networks for Condition Monitoring of Wind Turbines" (Modern Electric Power Systems, 2010, Wroclaw, Poland).