Supervisory, Control and Automation System Study for an Utilities Facility

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ABSTRACT
The main focus of this thesis was the study of a new Supervisory, Control and Automation System for an Utilities Facility (case study of IBEROL, S.A.) to enhance control efficiency and to improve process management. The different stages that conducted this study established a standard methodology that sets down 11 steps needed to develop any study carried by an industrial organization aiming to improve their process control and their plant management operations. After the survey of the current situation and creation of a new supervisory scenario, it was developed a set of specifications in a contract provision and sent to pre-selected suppliers for quotation. The investment project analysis (5 years) for the best proposal (with better economic indicators) provides a NPV of 455.385 €, an IRR of 197% and a payback time of 20 months. In combination with the Supervisory System project, suppliers were also consulted in order to present their best quote of a portable test bench for verification of several flowmeters in IBEROL, S.A. facilities. The investment project analysis (8 years) for the best proposal provides a NPV of 53.939 €, an IRR of 66% and a payback time of 27 months. At the same time, a new operational control and aid for decision making tool, was created, using software Microsoft Excel®, promoting daily recorded information management, including quality parameters, consumption and production indicators, KPI’s, etc., at IBEROL, S.A.’s Steam Plant.

Keywords: Supervisory and Control System; Automation; Energy Efficiency; Steam Plant; Compressed Air System; Utilities

INTRODUCTION
The Portuguese company IBEROL, S.A. belongs to one of the largest industry groups of Food and Agriculture Sector, at national level. It is responsible for the production and trading of biofuels and their by-products and for the industrial use and trade of oilseeds and derived products (IBEROL, 2004). IBEROL’s facilities is mainly composed by a Preparation and Extraction Unit (for oilseed processing), a Biodiesel Production Unit (for vegetable oil transformation into biodiesel) and a Utilities Facility composed by a Steam Plant and a Compressed Air System, supporting several processes applications.

For many reasons, steam is one of the most widely used commodities for conveying heat energy. Its use is popular throughout industry for a broad range of tasks, from mechanical power production to space heating and process applications (Spirax Sarco USA, 2007). The IBEROL, S.A.’s Steam Plant is responsible for the production of saturated steam necessary for multiple operations, which required direct or indirect steam application.

Compressed air is also a very versatile utility for industrial facilities. Uses include powering pneumatic tools, packaging and automation equipment, and conveyors. (U.S. Department of Energy, 2003) At IBEROL’s facilities, the Compressed Air System is composed by a production plant (includes compression and air treatment operations) and a large branching distribution network.

In the light of rising energy costs, limited deposits of raw materials and global warming due to CO₂ emissions, the efficient use of energy is continually gaining importance. In fact, the existing Utilities Systems in the Manufacturing Industries are responsible for a big part of their energy costs. Therefore, energy management plays a very important role to control energy usage in the most efficient manner to make production more economical and efficient. To achieve this goal, energy use
must be optimized with the same rigor as how product yields and process safety are managed.

For better process management and operations control it is mandatory to have a process control system that provides stability, accuracy and eliminates harmful transition status in production processes (MikroElektronika D.O.O.). The Supervisory Control and Data Acquisition Systems (SCADA) are a complex integrated architecture system linking hardware (controllers and instrumentation) to software (data acquisition and management), providing details and local operations control.

In an automated system, a PLC controller (Programmable Logical Controller) is usually the central part of a process control system. With the execution of a program stored in program memory, PLC continuously monitors status of the system through signals from input devices. Based on the logic implemented in the program, PLC determines which actions need to be executed with output instruments. To run more complex processes it is possible to connect more PLC controllers to a central computer (MikroElektronika D.O.O.). A system could look like the one pictured below.

![Network of SCADA system using PLC controllers](image)

**Figure 1 – Network of SCADA system using PLC controllers (MikroElektronika D.O.O.)**

The implementation of Supervisory, Control and Automation System will provide measures in real-time and historical trends for data analysis. With this kind of information available, KPI’s (Key performance Indicators) can be created and used as a benchmarking of the operational performance in order to identify operational problems and develop new efficiency solutions. An effective energy optimization consists of four key elements: target setting, measuring, gap identification, and implementation. Achieving continuous energy improvement occurs only when all these four elements are working in good order as shown in Figure 2 (Zhu, 2014).

![Four elements of energy management system](image)

**Figure 2 – Four elements of energy management system (Zhu, 2014)**

A Supervisory, Control and Automation System combined with the implementation of an energy management system, represent a major step towards a substantial annual energy costs reduction that can reach several million of euros in industrial activity. The benchmarking of energy savings provided by the improvement of control and maintenance of existing processes in a Steam Plant can reach 10%. The payback time expected for an investment project in this context is 2,4 years (ADENE - Agência de Energia, 2010). Regarding the Compressed Air System, the combination of a new control and metering system with the raise of awareness of all users to the proper use of compressed air (reduction of avoidable waste) can generate up to 30% of energy savings, without the need of capital investment in new technologies. (The Carbon Trust, 2005)

While most of production process at IBEROL, S.A. are already automated and integrated in a Supervisory and Control System, the Utilities Facility became the biggest gap of information available for an implementation of an energy management system, regarding the ISO 50001 specifications. The lack of a Supervisory and Control System fully integrated and automated in the Utilities System is mostly responsible for the current information access difficulty promoting a less efficiency process control. Therefore, it was also the great motivation of this work.

The implementation of the Supervisory, Control and Automation System for IBEROL’s Utilities Facility will be carried out by external entities...
to be consulted for purpose. The main goal of this study was to evaluate the current status of the Utilities Facility (definition of its State of The Art) and assessing all requirements for the success of the implementation of the new Supervisory and Control System, at lowest possible cost.

METHOD AND PROCEDURES

The different stages that conducted this study were highlighted in a decision flowchart (see Figure 3) that establishes the methodology that sets down 11 steps needed to develop any study carried by an industrial organization that aims to improve their process control and their plant management operations. The following is a brief description of the stages mentioned.

Stage 1: Definition of Existing Processes

At this first stage, the aim is the general understanding of all existing processes and operations in the plant. It might be useful the creation of a generic representation of the current operations flow.

Regarding to the existing processes at IBEROL’s Steam Plant, the water harvested from drilled wells passes through a physical and chemical treatment, so dissolved and suspended solids, dissolved gases and scum forming substances can be removed before feeding the existing steam boilers. The main stages of water treatment consists of a reverse osmosis, to filtrate most of the suspended solids, an ion exchange (sodium cycle) and soda softening, to remove temporary and permanent hardness, and a deaeration, to remove the corrosive dissolved gases as oxygen and carbon dioxide. Afterwards, the feedwater will be ready to enter into the steam boiler for steam production, after the addition of O₂ scavengers, antifoam and antifouling agents. In this Steam Plant there is three active steam boilers, all using natural gas combustion based system. After steam production, the steam is sent to the distribution system making steam available for all users.

For Compressed Air System, the production plant is composed by five oil-injected rotary screw compressors that compress the intake atmospheric air to 7 bar. The air is filtered to remove impurities and contaminants and is treated in a refrigerant air dryer to remove moisture. The treated compressed air is finally distributed to its points of use.

Stages 2 and 3: Site Survey and Creation of an Updated Process Diagram

After definition and comprehension of existing processes, a site survey of all equipment, pipelines, instrumentation and associated variables should be performed. Then, the creation of a Piping and Instrument Diagram (PID) is a critical step, providing the current control arrangements between equipment. Concluding the third stage, we have defined the state of the art of the existing plant’s process automation. All diagrams produced in this study were made using Microsoft Visio® software.

Stages 4 and 5: Critical Process Variables Assessment

Not all process variables should be included in the Supervisory and Control System, at the risk of increasing the investment project costs. Screening should be done, based on their importance in the process.

For Steam Plant critical process variable’s assessment were considered all that, allows operations to start and stop (such as reverse osmosis or steam boiler operation), controls quality parameters (as temperature, pressure, pH, TDS, etc.) and consumption and production records, for better operational control and process management. All variables that were measured by analog equipment (with no digital output) for redundancy to the remote supervision reading were dismissed.

Not so complex when compared to a Steam Plant System, a Compressed Air System is no different than any other cost center in an organization. Its performance has an impact on production quality, plant efficiency, operating costs and ultimately profitability. Proper attention to the key aspects of the compressed air system can go a long way in solving production problems and reducing waste (Compressed Air Challenge, 2013). Therefore, to achieve an efficient supervision and management of compressed air operations, variables as energy (for power consumption of compressors), pressure (for compressors control), flow (for air production and consumption measurements) and temperature (as an equipment efficiency and air quality indicator) were considered critical.
1. Definition of Existing Processes

2. Site Survey

3. Creation of an updated Process Diagram

4. Critical Process Variables Assessment

5. Critical Variable?
   - Yes: 5.1. Integrate in Supervisory System
   - No: 5.2. Dismissed for Supervision

6. Development of a new Supervisory scenario

7. Creation of a new Supervisory Process Diagram

8. Changes in the process towards efficiency?
   - Yes: 8.1. Integrate in Supervisory Study
   - No: 8. Changes in the process towards efficiency?

9. Existing Control and Automation Network Survey

10. Network compatible with Supervisory System?
    - Yes: 10.1. Integrate in Supervisory Study
    - No: 10.2. Creation of a new Supervisory scenario

11. Preparation of specifications and submission of the contract provision

**Figure 3 – Decision Flow Chart of the established methodology in the execution of this study**
Stages 6 and 7: Development of a new Supervisory scenario and creation of a new Supervisory Diagram

In this stage, a new scenario must be defined, with new control strategies and all required instrumentation. After setting the new strategy, it should be created a new Supervisory PID (updating the stage 3 diagram) that clearly identifies all the necessary changes for the new Supervisory, Control and Automation System implementation. With Microsoft Visio® software’s features, a list of current equipment (stage 2 and 3) and future equipment was made and analyzed. 89% of equipment work, assessed for quotation, will result in variables integration in Supervisory System.

Stage 8: Assessment of process improvements

After all these steps, it is natural that some process improvements arise, providing better optimization and operations efficiency. After careful analysis, it might be wise to include them in this study, in order to capitalize the investment to be made (cutting payback time).

The following tables summarize the most common energy saving opportunities for both Steam and Compressed Air Systems.

Table 1 - Energy Optimization Measures that are normally practiced in Steam Power Plants (ADENE - Agência de Energia, 2010)

<table>
<thead>
<tr>
<th>Actions</th>
<th>Energy Saving</th>
<th>Investment</th>
<th>Payback Time (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control of combustion/cleaning of the heat transfer surface area</td>
<td>24,8%</td>
<td>5,2%</td>
<td>0,30</td>
</tr>
<tr>
<td>Improvement of water treatment (includes blowdown optimization)</td>
<td>1,2%</td>
<td>2,2%</td>
<td>1,30</td>
</tr>
<tr>
<td>Improved control and/or equipment maintenance</td>
<td>12%</td>
<td>21,3%</td>
<td>2,38</td>
</tr>
<tr>
<td>Installation of O2 control system</td>
<td>16,8%</td>
<td>5,5%</td>
<td>0,42</td>
</tr>
<tr>
<td>Improvement of thermal insulation</td>
<td>2,5%</td>
<td>2,1%</td>
<td>1,44</td>
</tr>
<tr>
<td>Blowdown heat recovery</td>
<td>2,3%</td>
<td>3,6%</td>
<td>2,01</td>
</tr>
<tr>
<td>Installation of flue gas heat recovery equipment</td>
<td>40%</td>
<td>58,8%</td>
<td>1,85</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100%</td>
<td>100%</td>
<td>1,44</td>
</tr>
</tbody>
</table>

Table 2 - Energy Optimization Measures that are normally practiced in Compressed Air Systems (The Carbon Trust, 2005)

<table>
<thead>
<tr>
<th>Management Actions</th>
<th>Energy Saving</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raise the awareness of all users to the proper use of compressed air</td>
<td>10–15 %</td>
<td>Low</td>
</tr>
<tr>
<td>Develop and implement a maintenance programme for the whole system</td>
<td>5 – 8 %</td>
<td>Low</td>
</tr>
<tr>
<td>Install metering and implement monitoring</td>
<td>5 – 10 %</td>
<td>Medium</td>
</tr>
<tr>
<td>Use only trained and competent personnel for installation, servicing and system upgrades</td>
<td>5 – 10 %</td>
<td>Low</td>
</tr>
<tr>
<td>Develop and implement a purchasing policy</td>
<td>3 – 5 %</td>
<td>Low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical Actions</th>
<th>Energy Saving</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implement a leak reporting and repair programme</td>
<td>20 – 40%</td>
<td>Low</td>
</tr>
<tr>
<td>Do not pressurize the system during non-productive periods</td>
<td>2 – 10%</td>
<td>Low</td>
</tr>
<tr>
<td>Fit dryer controls (refrigerant and desiccant)</td>
<td>5 – 20%</td>
<td>Medium</td>
</tr>
<tr>
<td>Install compressor drive and system control measures</td>
<td>5 – 15%</td>
<td>Medium</td>
</tr>
<tr>
<td>Install heat recovery measures where appropriate</td>
<td>Up to 75%</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Stages 9 and 10: Existing Control and Automation Network Survey

This step is extremely important to understand the current status of automation network (PLCs, controllers, communication protocols, etc.) in order to assess their compatibility with the future Supervisory, Control and Automation System. At this point, it might be useful to use automation software (such as SIMATEC from SIMENS) which shall contain all control programming schedules between devices and controllers currently installed.

The current automation network of the Utilities Facility proved to be poorly organized and unable to support the required Supervisory System. After the definition (with creation of a block diagram) of the state of the art for the current automation network, a new organization was projected allowing the implementation of the Supervisory System and promoting new information standards with new control hierarchy, seeking to minimize the passage of cables along the pathways between instrumentation and responsible automation.
Stage 11: Preparation of specifications and submission of provision contract

The preparation of the specifications that meet all the necessary changes will conclude this study, seeking the quotation by the selected suppliers. The provision contract must contain all the necessary elements, in order to eliminate ambiguities with the use of a simple and objective language.

PORTABLE TEST BENCH

Along with the Supervisory, Control and Automation System project, the suppliers were also consulted for their best solution for flow measurement calibration. IBEROL, S.A. was seeking a calibration solution to improve basic maintenance actions, allowing increased productivity and ensuring consistency, comparability and reliable records of production and consumption indicators.

Two major proposals were considered:

- External calibration service

This proposal is based on an annual calibration program for 80 flowmeters, carried out by specialized technicians (external supplier), ensuring safety and operation efficiency. It has the great advantage of not requiring large initial investment, being agreed a final price for the service. It has the disadvantage of not allowing the flexibility that calibration needs may require.

- Portable Test Bench

In this case, the solution was to acquire a portable test bench, with a stainless steel structure, wheels and standard flowmeters. This option provides greater flexibility in calibration operations. The biggest disadvantage is undoubtedly the initial investment that will be needed and can be difficult to get the desired financial return (high payback time).

DEVELOPMENT OF AN OPERATIONAL CONTROL TOOL

Along with the work developed for the Supervisory, Control and Automation System, a new operational control and aid to decision making tool was created, using the Microsoft Excel® software. In operation terms, there are several deviations that may occur in process variables measurement, caused by paper registry problems and malfunction of the measuring equipment itself. Besides human registry errors, the most frequent case is undoubtedly water flowmeters installed in Steam Station, which frequently suffers from a major deviation to its standard. For a proper management of Steam Station processes and its costs, it was mandatory to create a tool that would allow:

- To reduce human;
- To create flowmeter deviation reports;
- To determine consumption and production measurements;
- To create daily and monthly reports;
- To generate historical data for analysis (KPIs, trends, reports, etc.);
- To promote a better monitoring and control of Steam Plant operations, while Supervisory, Control and Automation System is not installed.

For better control and real-time analysis of several existing operation parameters, it was programmed an automatic comparison between input values and objective values, returning different colors into the cell, for quick conclusion whether the value is within the expected range, or not.

To determine the overall performance of water-counting system, regarding product production, movement and consumptions, to confirm the mass and energy conservation law, it was developed a Mass and Energy Balance to the water/steam system.

The results of the development of this tool are resumed in following reports and graphics:

- Steam Station’s Consumption and Production Report;
- Individual Boiler Report;
- Flowmeter Deviation Report;
- Graphic of Blowdown vs TDS in feedwater;
- Graphic of Blowdown vs TDS in boiler water graphic;
- Graphic of Steam Production vs Specific Consumption.
In addition of all previous results, this Excel® tool will promote a greater detailed analysis to boilers efficiency behaviors. The regular and reliable monitoring of boilers rates could develop new strategies for their use, taking into account steam consumption needs.

The boilers rates assessment is quite relevant for the economic evaluation of this work, since it is the studied alterations on the operation mode of STB 1400 Boiler (replacement with GEVA Boiler, seeking STB 1400’s lower specific rate, and installation of heat recover to warm up feedwater), that represents 64% of the considered profits (project energy savings).

ECONOMICAL ANALYSIS

The previous point constituted the ground base for Supervisory Project profit assessment. The implementation of this project will generate very interesting energy savings in all Utilities System. It was determined the amount of 243.354€ of energy annual savings during the investment project.

The proposals received were economical analyzed through cash flows method. It was considered a project life-time of 5 years for Supervisory, Control and Automation System project, and 8 years for the Portable Test Bench project.

Analyzing the Table 3, we can conclude that is the proposal D that represents the more profitable solution. The Net Present Value (NPV) reaches 430.438 € at the end of the project time, with an Internal Rate of Return (IRR) of 56 %. The expected payback time is 2,86 years (35 months). Screening the economic data, we can rank the proposals as shown in Figure 4, where the proposal D is considered the best economic solution, and C the worst.

Table 3 - Summary of the economic analysis of all received proposals for the Supervisory, Automation and Control project

<table>
<thead>
<tr>
<th>Economic Data</th>
<th>Proposals</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment (€)</td>
<td>313.425</td>
<td>368.383</td>
<td>397.626</td>
<td>304.420</td>
<td></td>
</tr>
<tr>
<td>NPV (€)</td>
<td>412.685</td>
<td>381.714</td>
<td>359.583</td>
<td>430.438</td>
<td></td>
</tr>
<tr>
<td>IRR</td>
<td>53%</td>
<td>45%</td>
<td>41%</td>
<td>56%</td>
<td></td>
</tr>
<tr>
<td>PB (years)</td>
<td>94</td>
<td>3,24</td>
<td>3,41</td>
<td>2.86</td>
<td></td>
</tr>
</tbody>
</table>

Regarding the Portable Test Bench project, as mentioned, two different solutions were presented. The External Calibration Service, was annually quoted in 16.000 €, with no further costs. This cost, was taken as the benchmark for economic evaluation of the Test Bench project, assuming the cost of the external service as the annual savings for not ordering the service.

Through Table 4 the proposal C tends to be the best economic solution for the Portable Test Bench project. At the end of the project, we have a NPV of 53.939 €, a IRR of 66%, and the expected payback time is 2,23 years (27 months). Following the same rank strategy, we find the proposal C as the best solution and

Table 4 - Summary of the economic analysis of all received proposals for the Portable Test Bench project

<table>
<thead>
<tr>
<th>Economic Data</th>
<th>Proposals</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment (€)</td>
<td>64.189</td>
<td>51.917</td>
<td>23.000</td>
<td>93.750</td>
<td>30.583</td>
<td></td>
</tr>
<tr>
<td>NPV</td>
<td>12.414</td>
<td>23.955</td>
<td>53.939</td>
<td>(21.786)</td>
<td>44.893</td>
<td></td>
</tr>
<tr>
<td>IRR</td>
<td>17%</td>
<td>24%</td>
<td>66%</td>
<td>5%</td>
<td>48%</td>
<td></td>
</tr>
<tr>
<td>PB (years)</td>
<td>7,87</td>
<td>5,37</td>
<td>2,23</td>
<td>N/D</td>
<td>3,53</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4 - Economic ranking of all received proposals for the Supervisory, Control and Automation System

Figure 5 - Economic ranking of all received proposals for the Portable Test Bench project
To promote a better investment decision-making process, it was performed a sensitivity analysis to estimate how the changes of certain input values (income, costs, value of investments, etc.), produced due to inappropriate prediction or for some other reason, influence certain criteria values and the total investment project evaluation. In this case, the strategy was to maintain the project investment value and to vary the revenue (±20%), in order to assess the impact on NPV and IRR indicators. Only proposals with the best profitability ratios were considered in this analysis.

For a 20% reduction in revenues, the project suffers a NPV decrease down to 298,066 € (31% reduction) and also a TIR reduction of 23%, down to 44%. Simulating the better scenario (20% increased revenue), we obtain a NPV of 562,809 € and 68% for IRR. Based on this facts, the proposal D, presents good risk indicators regarding investment.

CONCLUSIONS

Seeking efficiency and process optimization, this thesis had as main goal the study of a Supervisory, Control and Automation System for Utilities Facility at IBEROL, S.A. To conduct the study, it was created a standard methodology, including 11 steps, from the state of the art pant definition to the development of a new Supervisory scenario supported by PID diagrams and instrument list. The definition of the current equipment status with the need of critical variables monitoring integration, 106 equipment work were counted, in which 89% will led to variables supervisory integration.

To complete the study, it was designed a set of specifications providing contract with clear and objective description of all the work needed to be quoted. After all proposal reception, an economic analysis was performed to establish the most profitability proposal, with the already known results.

It was also discussed with suppliers, solutions for flowmeters calibration at IBEROL, S.A.’s site. It was suggested an external calibration service (more economic) and a portable test bench for internal verification. The investment for this
last solution was larger, therefore an economic analysis of this solution was also performed.

Simultaneously with the previous points, it was developed an operational control and aid to decision making tool, using Microsoft Excel® software, promoting daily recorded information management, including quality parameters, consumption and production indicators, KPI's, etc., at IBEROL, S.A.'s Steam Plant. This new tool allows the creation of new reports, historical trends and enables the study of new operation strategies for existing steam boilers.

FUTURE PERSPECTIVES

Energy is critical to organizational operations and can be a major cost to, whatever their activities. Individual organizations cannot control energy prices, government policies or the global economy, but they can improve the way they manage energy in the here and now. Improved energy performance can provide rapid benefits for an organization by maximizing the use of its energy sources and energy-related assets, thus reducing both energy cost and consumption. The organization will also make positive contributions toward reducing depletion of energy resources and mitigating worldwide effects of energy use, such as global warming. (International Organization - ISO, 2011)

The implementation of a Supervisory and Control system is the basic rock of an automated organization, providing critical information for management operations and process control abilities.

IBEROL, S.A. current strategy relies on updating every important, automated field on its facilities, seeking the implementation of an Energy Management System (ISO 50001) that allows the creation a clear picture of the current status of energy consumption and production. New objectives and targets can be set, reaching more efficient use of its energy resources, reducing costs and the associated environmental impact.

REFERENCES


