BENEFITS OF DIGITALIZING AND EMPLOYING SIMULATION TO INCREASE PLANT SYSTEM PERFORMANCE AND ENSURE COMPLIANCE WITH TECHNICAL SPECIFICATIONS

Ricardo García; Mateo Ramos
Control Rooms and Simulation
Tecnatom
Avda. Montes de Oca 1, 28703 San Sebastián de los Reyes-Madrid (Spain)
rgaparicio@tecnatom.es; mramos@tecnatom.es

ABSTRACT

The essential services water system in a BWR nuclear power plant was affected by corrosion, soiling and blockages due to ageing. Those episodes affected safety margins hindering the Technical Specifications compliance during periodic system testing.

Tecnatom designed, implemented and tested a design modification for the on-line monitoring of this system by integrating it in the existing Digital Control System (DCS). Key system parameters were acquired in real time to be displayed in the Human System Interface, used in performing calculations and stored their historical evolution. The objective was to optimize monitoring and surveillance of the essential service water system. Furthermore, Tecnatom developed an engineering simulator ("What if" simulator) consisting of a hydraulic model of the system. This simulator takes as inputs each heat exchanger performance parameters from the plant DCS, allows the user to change the essential services water system configuration (valves position, UHS level…) and calculates theoretical process values predicting the system real behavior. In a second stage, more system instruments were wired to the DCS for Technical Specifications compliance automatic surveillance regarding opening and closing times of system valves.

Operating experience shows important benefits after the digitalization. It enhances on-line information of system operation and automates calculation of load loss factor of each heat exchanger. It eases the evaluation of blockages and soiling in the system allowing optimization of cleaning proceedings. System Surveillance Requirements and Test Requirements reports have been automated optimizing the operation workload. The simulator use enables to identify optimal system configuration increasing safety margins of the system and ensuring Technical Specifications fulfillment.

Key Words: Digitalizing; Simulation; Performance; Technical Specifications; I&C integration

1 INTRODUCTION

This project was executed in a GE BWR/6 nuclear power plant. NPP's main heat sink comprises two natural draught cooling towers, which remove heat from the main condenser, and a battery of forced draught towers, which allow the thermal load of the auxiliary systems to be removed during normal operation.

The alternative heat sink (Ultimate Heat Sink, UHS) is made up of a pond and three cooling water pumping and distribution sub-systems (Essential Service Water ESW-P40 system). The cooling water is returned via a set of spray nozzles that discharge onto the pond itself, allowing the accident thermal loads to be dissipated. The pond provides autonomy for 30 days.

In the event of loss of off-site power (LOOP) and other transients, the residual heat from the reactor is removed either directly or through cooling of the suppression pool (SP) to the UHS via P40 system. This system is also designed to remove heat in the event of a design basis accident (LOCA), postulated to include a LOOP.

This NPP has a DCS installed since 1988. It was the Honeywell TDC 3000 and it is mainly controlling the Feedwater Heater Control System. This was the beginning of a process of modernization and migration from analog control systems to digital control systems. The digitalization process in nuclear power plants implies an important adaptation process at all levels.

Following the conversations between the utility, Tecnatom (engineering company) and the control system provider, the Tecnatom BWR full-scope simulator was selected as an engineering platform for evaluating the changes in the nuclear plant control systems previously to their implementation in the plant. With that objective, in 2002, the Honeywell DCS was incorporated into the full-scope simulator with identical configuration that in the NPP main control room.

Since then, TECNATOM has been involved in the control room modernization in three group of activities:

1) Helping to define the modernization strategy. This phase included providing a study of the Control Room evolution in a Virtual Reality environment.
2) DCS platform migration from TDC 3000 to Experion PKS (windows O.S), designing, implementing and testing the new IHM displays and consoles.
3) Systematically incorporating the design modifications requested by the NPP for each refueling outage on the DCS platform. That involves design, implementation, testing and start-up activities.

The modifications are previously designed and implemented in the full scope simulator, which includes a replica of the DCS. Once tested and validated, they are ready to be installed in the plant during the refueling outage or normal operation. These activities are complemented with specific theoretical and practical training for the I&C Maintenance and Operation staff.

This approach allows the early detection of errors, the execution of engineering test at the simulator and the anticipated training and familiarization of the operation personnel.

This paper presents another example of the benefits of digitalization, combining the power of DCS technology and simulators: The ESW-P40 simulator. In 2009 the ESW-P40 essential cooled water system signals were introduced in the Experion PKS platform to facilitate system adjustments and compliance with the associated surveillance requirements.

2 PROJECT PHASE 1

The essential services water (ESW-P40) system in a nuclear power plant is affected by the corrosion of carbon steel pipes in contact with chemically pretreated water, mainly producing iron oxide accumulations. These episodes affect the flow margins by reduction of effective section of the pipes, which hinder the compliance of the Technical Specifications during the periodic tests of the system.

Due to this potential problem, a plan was developed for the execution of different improvements over the ESW-P40 system. One of these improvements was the on-line monitoring of this system by integrating it in the existing Experion DCS. The objective was to optimize monitoring and surveillance of the essential service water (ESW-P40) system.

Tecnatom was responsible for the integration of the ESW-P40 process signals to the Experion DCS and the development of a set of computer applications that are integrated with the DCS to optimize monitoring and surveillance of the ESW-P40 system.

This improvement designed, implemented and validated (following an exhaustive verification and validation process) by Tecnatom, has three main components:

1. Integration of ESW-P40 key system parameters into the Experion DCS.
2. Set of tools for the automated fulfillment of surveillance reports.
3. Engineering simulator to provide theoretical process values, predicting the system real behavior f or different valves configurations.

2.1 Integration of ESW-P40 key system parameters into the Experion DCS

Key system parameters (flow, pressures, valves position, level and temperature in the pond of the Ultimate Heat Sink, UHS) are acquired in real time by a PLC and being displayed in the Human System Interface of the Experion DCS. It has been developed a display for each division (division I, II and III) and one display for the monitoring of the K factor (pressure drop) at each heat exchanger.

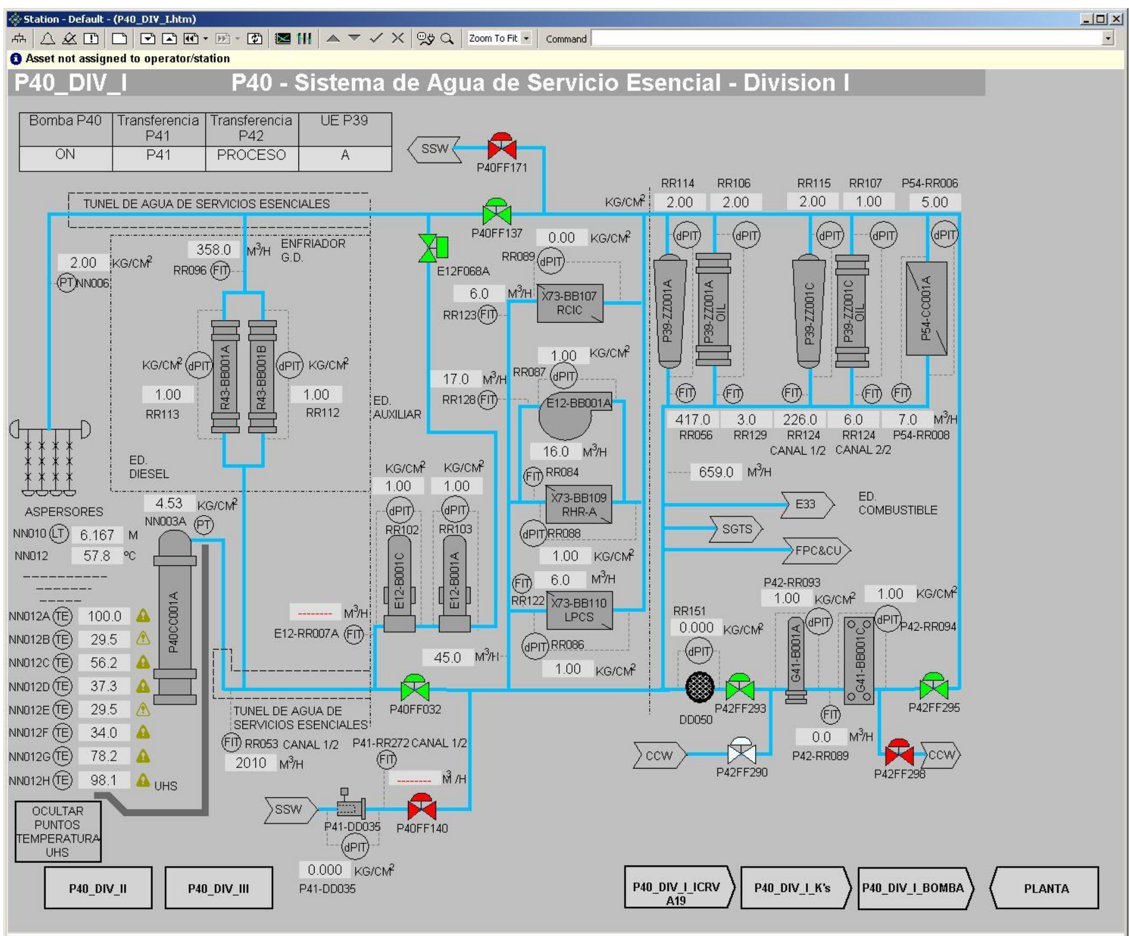

Figure 1. System display

At each display, there are a set of navigation buttons. With the buttons on the left,it is possible to navigate to the other division displays. The buttons on the right provide access to three different Excel files which functionality is explained below.

2.2 Set of tools for the automated fulfillment of Surveillance Reports

For each division, a set of 3 computerized tools has been developed in Microsoft Excel environment. Each of them has different functionality, but all of them obtain the ESW-P40 values from the SCD by an OPC communication. The uses of the OPC standard for the communication ensures the portability and the long-term use of this developments. In case of a migration or modernization of the SCD these Excel developments will continue working thanks to the use of the OPC standard.

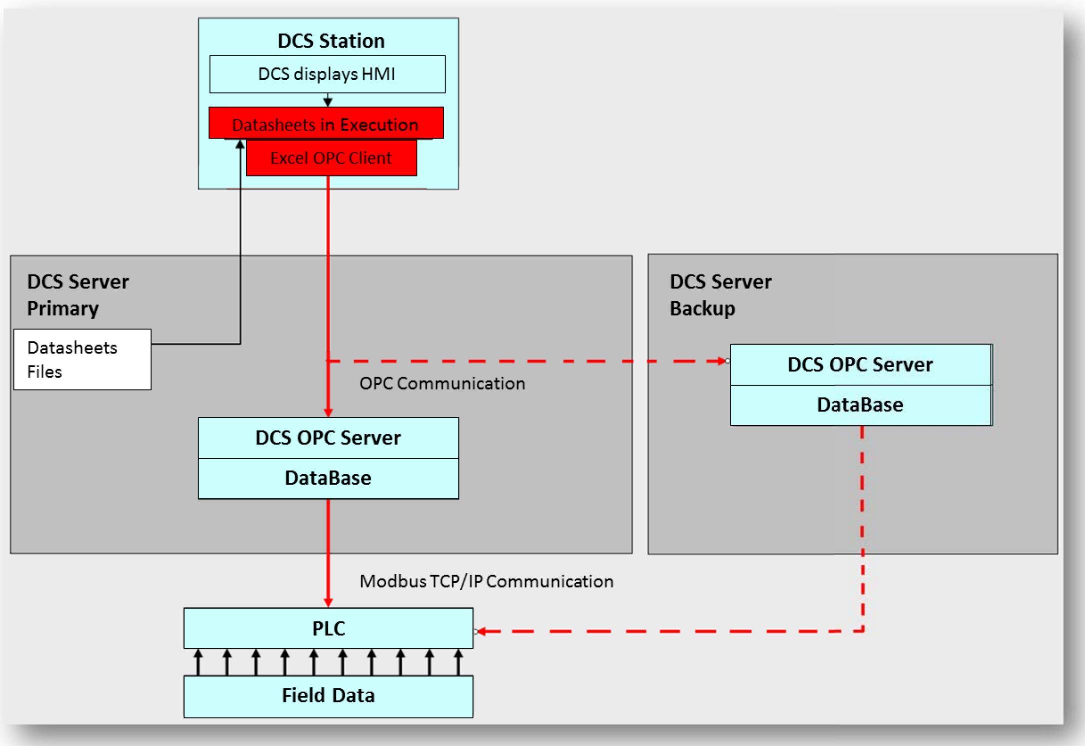

Figure 2. Architecture

The Excel developments are divided in three books per division:

1. *ICRV 24M*: Evalustion that all the components of the ESW-P40 system satisfy with the minimum flow required, and fulfil the corresponding surveillance reports: ICRV and ICRP.
2. *ICRV-03M*: Current and historical working point of the system pumps are shown. It provides the report for the surveillance of the functional capacity of each division pump.

3. *Pressure drop factor*: Evaluation of the pressure drop factor K=dP/Q2 for each Heat Exchanger and filters. The values of flow and differential pressure is obtained from the SCD and the K factor is calculated. The K factor is stored when is required for the surveillance and its value is represented in a graph over the time. Alarms are also included in this graph for each component (filter o heat exchanger).

Books *ICRV 24M* and *Pressure drop factor* need to collect a set of representative data of the system before start with the calculations. In both cases an algorithm obtain the medium of the values that are acquired for a period of 5 min with a scanning time of 2 seconds. Both, the period and the scanning time can be changed by the operator from the "*data acquisition sheet*".

In addition, it can be defined the value for discarding values that are different of the medium value more than that value in %. By default, this value is established in 20 %. So, values higher than 120% of the medium and lower 80% of the medium value are discarded.

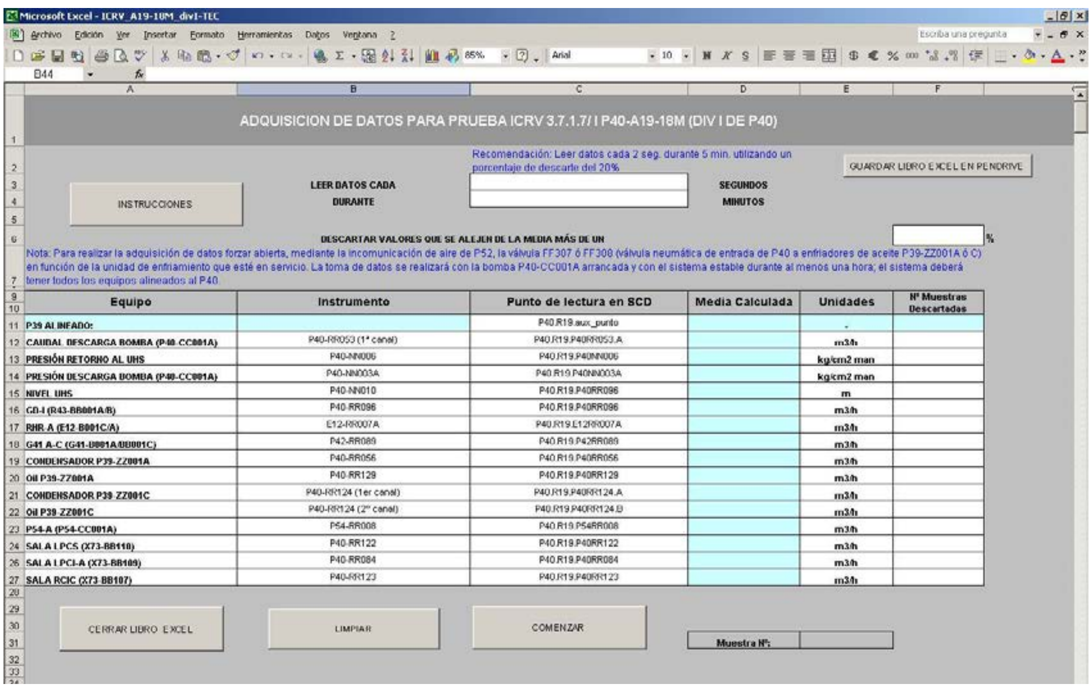

Figure 3. Data acquisition

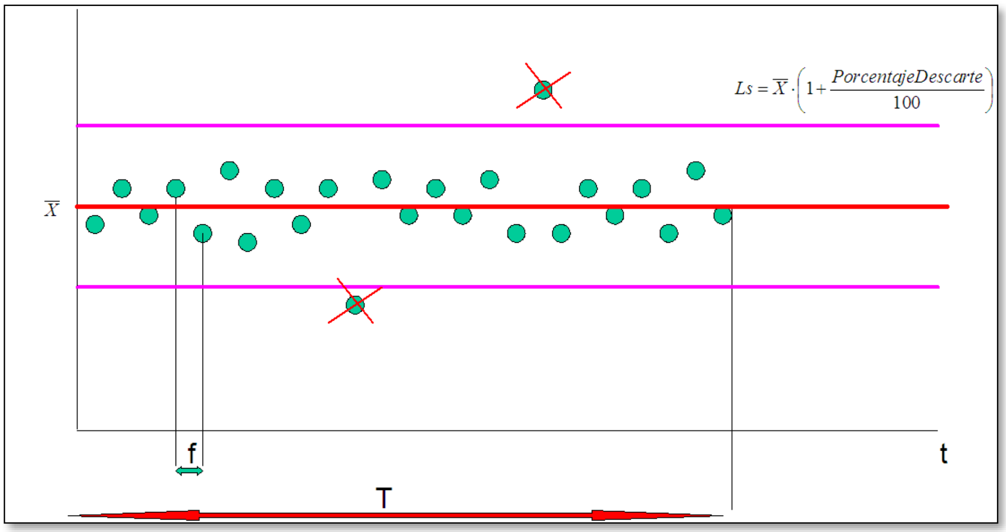

Figure 4. Medium value algorithm

Other functionality of the books *ICRV-03-M* and *Drop Pressure factor* is the generation of data for the ESW-P40 simulator. From this books a file is generated that contains the data needed by the simulator.

2.3 Engineering simulator

In case of a hypothetical incompliance of any of the surveillance requirement, it would be necessary to correct it by modifying any local valve position or scheduling maintenance or cleaning works on any pump, tube or heat exchanger.

Thanks to the surveillance of the parameters collected in *ICRV-03-M* and *Drop Pressure factor* books (working point of the pumps and pressure drops) it is possible to detect in a qualitative way a potential degradation process of the system.

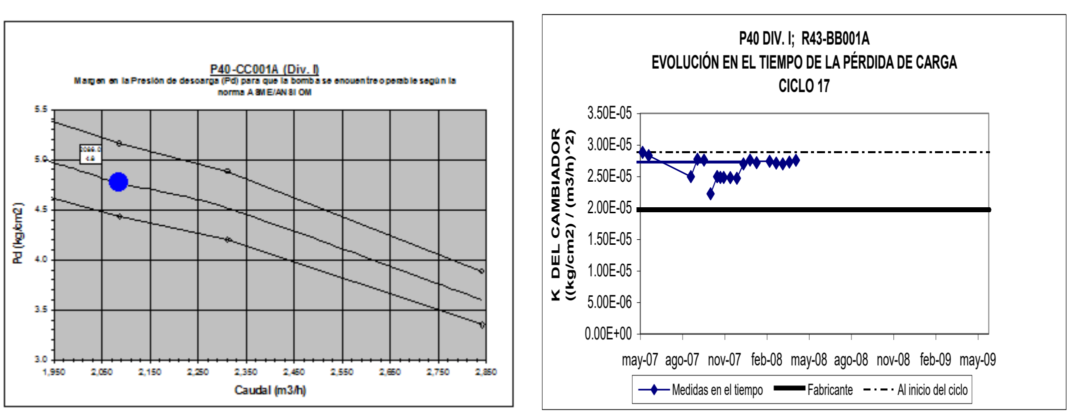

Figure 5. Collected parameters

Nevertheless, the individual analysis of the evolution of these parameters does not provide quantitative values of the consequence of the degradation, in the eventual case of starting the system for a surveillance test or in an emergency.

In this context, the utility identified the convenience of a simulation tool that with a base line in the last global surveillance test (ICRV 24M report) of the system, could be update in an automatic way with the different partial measures (pressure drops in individual components and current working point of the pumps).

The objective, thus, was to develop such engineering simulator that could predict quantitatively, from the last data available, the results that would be obtained in an eventual surveillance test to be performed today. Furthermore, in the case that any of the equipment does not satisfy the surveillance test requirements in that simulation, it could help to establish the best configuration in the system valves for the compliance, and/or optimize the preventive maintenance tasks.

With that objectives, the P40 simulator was developed with a model that resolves a Bernoulli net of the system with drop pressures adjusted against the last surveillance test. The simulator can read the files generated by Excel books *ICRV-03-M* and *Drop Pressure factor*. With that data, the drop pressures in each heat exchanger are readjusted. The user can:

- Select the baseline (adjustment with global surveillance test) between the historical of all the baselines performed.
- Update the baseline with the last data available (ICRV-03-*M* and *Drop Pressure factor Excel* books).
- Simulate any operation in the system: Pumps, valves...

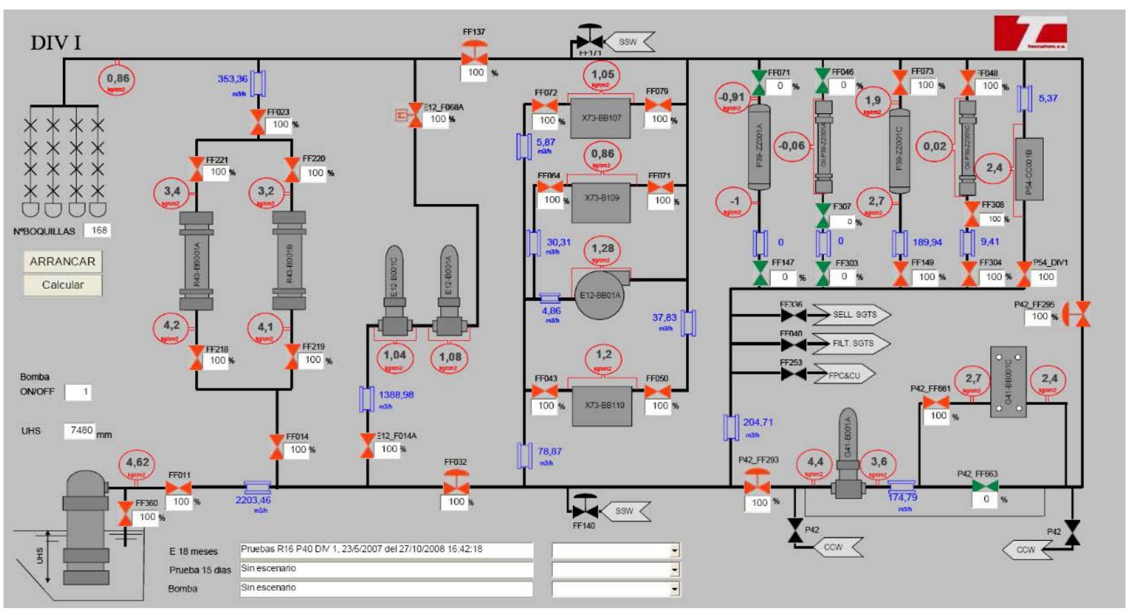

Figure 6. Simulator HMI

The simulator is installed in a laptop and runs in the same simulation environment than the plant full scope simulator.

2.4 Updates

From its first installation in 2009 the three main components (HMI displays, Excel books and simulator) have been update to introduce design modifications (new equipment in P40 system) in 2011, or changes in the procedure for the surveillance tests in 2013.

In 2015 the Experion SCD was updated to a new release without any problem for the communication with the Excel books thanks to the robust architecture based in OPC standard.

In 2017, new design modifications in the power plant has requested a new update of the main components.

3 PROJECT PHASE 2

Another system surveillance test requires to measure the opening and closing time for 20 valves of the system. In some operations, four valves are timed in a simultaneous way, thus requiring of 4 people measuring times.

The utility identified the convenience of measuring this times in a digital way through a PLC that could monitor the valves states and the command signals to the valves.

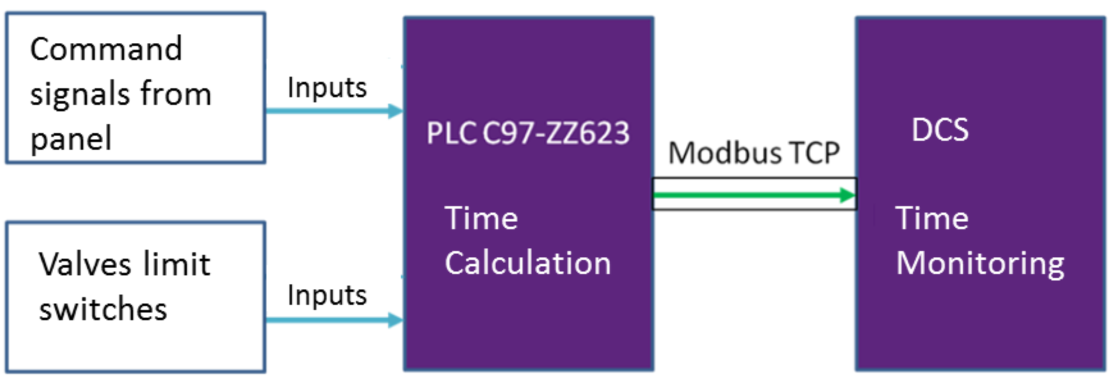

Figure 7. Phase 2 architecture

Tecnatom designed, developed and validated the design modification for measuring these times from a PLC and monitoring it through the SCD IHM. For each valve and each movement (opening and closing) following times are measured:

- the time that the valve starts to move since the order is given
- the time that the valve finish to move (to the required position) since the order is given

These values are measured with timers in the PLC and communicated to the SCD by Modbus communication.

One of the design modification requirements was to calculate the maximum error in the time measurements. This error is affected by different characteristics as the timer resolution, the cycle time of the CPU, the time that the card needs to read and communicate a change to the CPU, etc. This maximum error depends on the internal configuration of the PLC (software and hardware). So, if the PLC software change (program) or PLC hardware change (Input / Output cards, for instance) this should be recalculated.

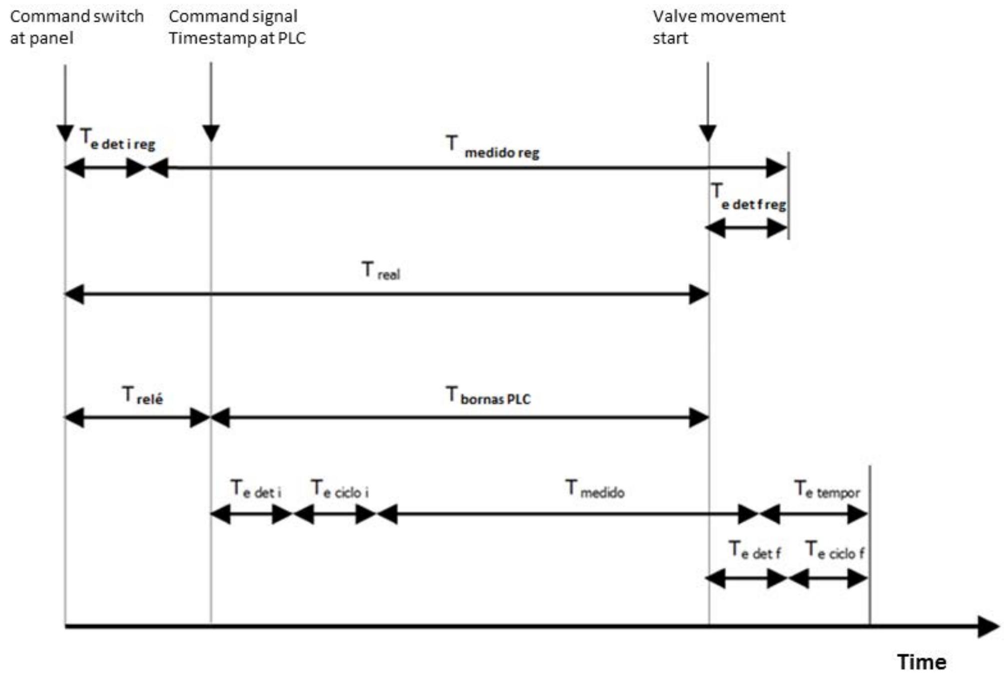

Figure 8. Real time vs PLC measured time

For calculating this measurement error, the 3 sigma (σ) method was selected. In this way, the maximum error for measuring transferences time from P40 system is less than 0,05 seconds. The maximum error for transferences to P40 system is less than 0,13 seconds. Both values are much lower than the margins in the System Operating Procedures.

4 CONCLUSIONS

Combining digitalization and simulation is an effective way to resolve some of the power plant challenges such as those explained in this paper.

This successful project has been one of the factors to allow the plant to continue operating without the need of a maintenance shutdown while increasing the system safety margins.

Some of the benefits of that project are the following:

- It enhances on-line information of system operation and automates calculation of load loss factor of each heat exchanger.
- It eases the evaluation of blockages and soiling in the system allowing optimization of cleaning proceedings.
- System Surveillance Requirements and Test Requirements reports have been automated optimizing the operation workload.

- The simulator use enables to identify optimal system configuration increasing safety margins of the system and ensuring Technical Specifications fulfillment.

Tecnatom approach for design modifications integrating Instrumentation and Control, Simulation, Human Factors Engineering and Plant Operation expertise is its differential factor and a clear added value to the plants and utilities. To conclude, amongst the main key factors to the success of the project, the close cooperation between the utility, its subsidiary engineering company, and Tecnatom may be highlighted.