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System engineering improvement through advanced reliability assessment

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***Abstract*- Oil & Gas environment, during the last ten years, has experienced the need to improve product performance covering aspects going from its increased functionality, maintenance, reliability and safety, towards reduced time delivery and cost. Some of them have been required by customer and some of them are indeed essential to meet even more stringing international regulations, imposing high standard of product quality. Nowadays the product process improvement has scored by implementing lesson learnt, rose during the manufacturing phase or by means of feedback coming from field. It's easy to understand that, this way of product improvement affects, consistently and negatively, cost, time and, above all, customer satisfaction. The emphasis on products performances development has encouraged designer to look at strategic management, engineering, marketing, and other disciplines to study the new design process focused, not only on reaching a good compromise among the afore mentioned aspects, but the optimum. Deep Analysis on this obsolete product improvement process, has carried out the necessity to move the validation and verification phase product directly during the design phase, looking at it as, not only an isolate design phase, but inserted in a design cycle where solutions on product functionality and its reliability are continuously validated and verified. This new way to conceive design, directly on the early stage of a project, leads towards the optimum compromise between: functionality, maintenance, reliability, safety, and reduced time delivery, cost reduction, and reduce cycle time to better incorporate customer and supplier requirements in the product and process design. Computer aided design, modelling and simulation of product, involving different design disciplines, (system, instrumentation, control and reliability) in the same environment, becomes an imperative to target this goal.**

I. Introduction

Turbo-machinery auxiliary systems have been subjected to high performance requirements. High performance means, not only better functionality but also high availability and safety. High quality design for auxiliary system consists of integration of all the disciplines involved in the system design process, which are: system, instrument, control and reliability, building up, what known as "Concurrent Design". Concurrent design allows designing, analyzing and verifying new innovative solutions, looking at all the, afore mentioned, disciplines.

During the last years, design has been based on a static evaluation of the hydraulic system behavior, and all the hazard operability analysis have been conducted without any type of simulation, but going through each system and analyzing it, in normal operation and failure conditions. This way to make analysis brings to rough result, to be verified only once the system has been built. System modeling, based on the concept of model based design, represent a new way to make design, consisting on an iterative design and verification, allowing detecting defect and improving system in the earlier stage of a project, saving cost and time delivery.

The presence of a model allows verifying and testing innovative solution directly during the early stage of design, reducing risk on adopting new technologies focused to control and diagnose the system itself, increasing consequently the system reliability and availability. As summarized in the Fig., 1This also means, simulation and verification make possible mistake detection and changing implementation during the detailed design phase, instead of production, allowing a reduction of Cost/Change of 100.

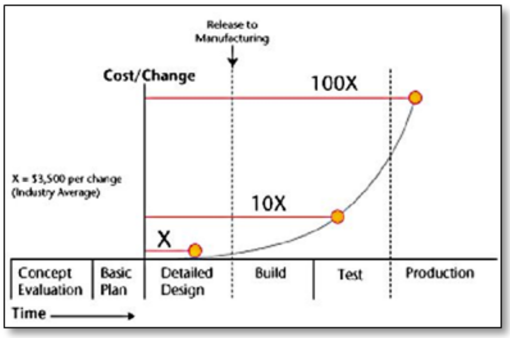

Figure.1: Design versus cost impact for modification

In the first section of this article is illustrated the way how models are generated and how the simulation can be used to analyze the behavior of the system automatically. In the same section is also illustrated the reliability block diagram, semi-automatically generated from a dedicated tool developed internally. Finally it is illustrated how this new way to conceive the design, based on a concurrent engineer can be adopted in the industries field entailing all the outcome and innovative solution designed, tested and verified by means of these tools. In the conclusion section is illustrated also how the new technologies based on the foundation field bus, can be adopted to implement control on the system itself.

II. Automatic physical and RBD model Generation

The starting point to make design of hydraulic system is based on the use of a tool, developed internally called "Pid-Xp". This tool allow end users, not only to draw hydraulic system but also evaluate, for each component or equipment as motors, heaters, valves or pumps, their attributes, sizing each of them on the base of static operation condition. The tool is also able to enclose information regarding range of flow, pressure and temperature, becoming also the sharing point for the concurrent design, where all the discipline, system, control and instrument are involved on the design process of a product.

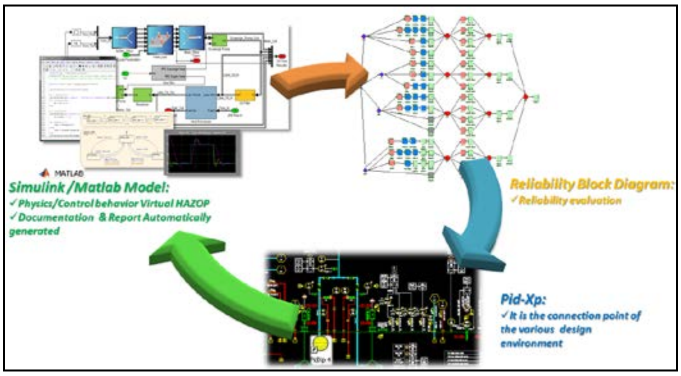

Figure.2: Continuous design simulation and verification design

Starting from Pid-Xp, two models are generated: the first one is known as SIMULSCHEMA, and, as illustrated on the paper [14], this model allows user to simulate and verify system behavior, the second model is the Reliability Block Diagram, which is the model allowing end user to make analysis on reliability and availability of the system under analysis.

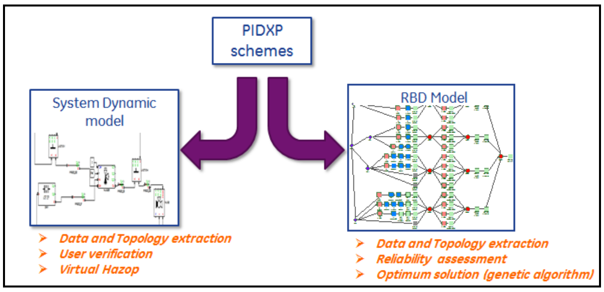

Figure.3: Models Generation from Pid-Xp tool

System Dynamic Model: Simulink/Matlab is an integrated and shared environment, able to include in the same environment different disciplines (system, control, mechanical and instrumentation) it is possible to integrate, along with physical model of the system, its control software, hence, having the possibility to analyze and verify its physical behavior understanding how the control system operates with it. But the most important, is that the analysis can be performed, not only considering the normal operation conditions, but also off design conditions, which means verify the robustness of the system in case of failures, exploring also, if the simulated failure of certain components, represent an Hazard for the system itself or not.

Reliability Block Diagram Model: Reliability allows evaluating design feasibility, compare design alternatives, identify potential failure areas, trade-off system design factors and track reliability improvement. The reliability model tool generated, make possible reliability prediction in the early product design stages, giving feedbacks to design engineer about the way to improve product. Processing phase and output generation are achieved on Matlab® platform and the outputs shown are:

- Reliability vs. time plot (up to default time, 300000h)
- Reliability vs. time plot (up to user set-in time)
- Hazard rate vs. time plot (up to default time, 300000h)
- Hazard rate vs. time plot (up to user set-in time)
- Reliability value calculated at user set-in time value
- Hazard rate value calculated at user set-in time value
- System MTTF (Mean Time To Failure)

III. Simulation results and product improvement

The use of models and simulation, aimed to evaluate physical and reliability/safety system performances, make possible to deeply understand how the system behaves, allowing the development of control algorithms finalized to guarantee high performance in terms of system and reliability aspects. This design process has been successfully applied on a real project fig.x shows the hydraulic circuit under test, aimed to analyze two main aspects:

- The use of an accumulator
- The use of 1oo2 logic instead of 2oo3, for temperature sensor.

Mineral oil console is a system used to lubricate correctly bearing of the power turbine, compressor and gear box. In order to lubricate correctly load, the mineral oil must have a fixed value of pressure and temperature, in all the operation conditions. In the figure is shown an example of a mineral oil console.

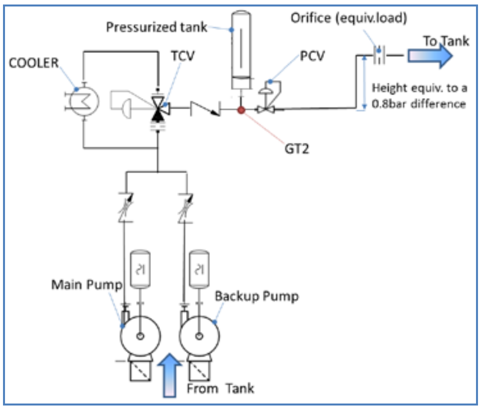

Figure.4: Models Generation from Pid-Xp tool

The circuit is composed of two centrifugal pumps, Main and Backup pumps, and during normal operation condition, only the Main is turned on. Next to the two pumps there is the thermostatic valve, aimed to fix the mineral oil temperature to a value of 50°C, mixing the hot flow (coming from tank) and cold flow (coming from cooler). Next to thermostatic valve, there is a filter and finally the pressure control valve, whose function is to keep the pressure on a value of 1.7 barg. In case of failure of the main pump, pressure downstream the pump goes below a threshold value and the control panel activates the Backup Pump. During the switch off, between two pumps, the pressure on the point GT2 (as represented on the figure), has an oscillation that leads the Pressure Control Valve to be unable to regulate pressure value on the load, determining an increasing pressure value. To reduce the risk of not well lubricated bearings, normally it is placed an accumulator, which has the purpose to eliminate pressure oscillation. In order to understand deeply the behavior of the system the model simulation is the only method to be used. By using, in fact, “SimulSchema”, it was possible to simulate an off design scenario, where a failure of the pump was activated, allowing the activation of the stand by pump. The simulation results revealed that, even if there was an oscillation of the pressure (PIT) its value was able to maintain the PCV valve working in the right operation range with no impact on the normal operation of the entire system.

Moreover, the simulation allowed regulating the control algorithm, in such a way the failure of the main pump was promptly detected and stand by pump readily activated, reducing the entity of the pressure oscillation before the valve.

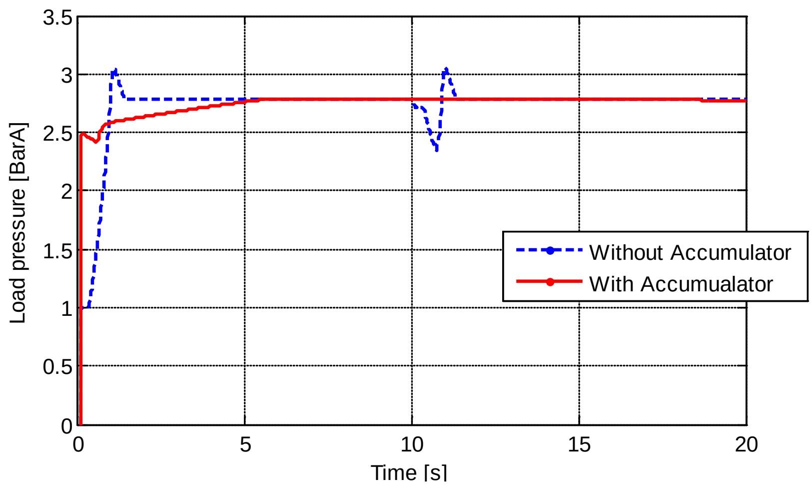

Figure.5: Pressure behavior with and without accumulator on GT2

The second aspect analyzed, was related to a customer requirement based on the use of configuration of 2oo3 (2-out-of-3) for temperature sensor logic, to control the stop of the system in case of high temperature value of the mineral oil.

In case of mineral oil temperature rising, its viscosity decreases, and its lubricant function is lost. Since it can damage the system this kind of trouble must be detected and the entire system must be stopped. In order to guarantee a higher degree of reliability without affecting safety, several customers ask to use a configuration of 2oo3, which means that if two sensors detect the high temperature, a trip of the machine is activated. By means of the Reliability Block Diagram model, has been proved that this type of evaluation must be correlated to the reliability of entire system, considering the probability of failure, not only of the sensor, but of all equipment composing the hydraulic system (cooler, pumps, filters and thermostatic valve). The result of the analysis is illustrated below.

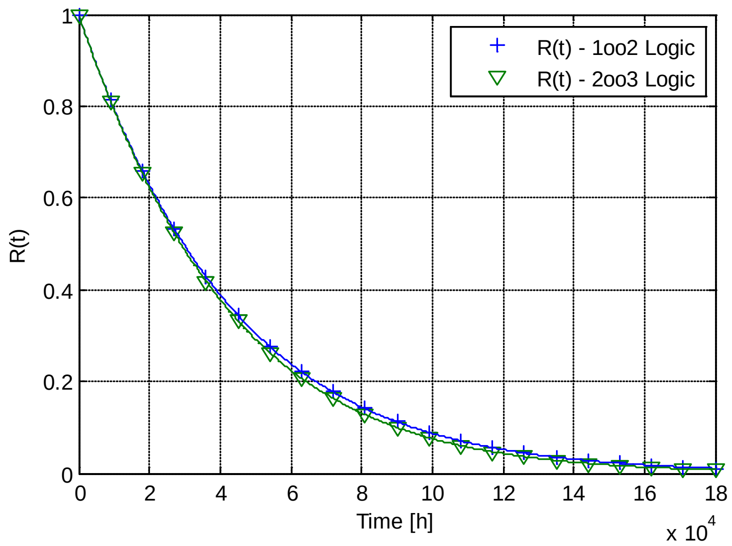

Figure.6: Comparison reliability between configuration 1oo2 and 2oo3

The analysis of these two aspects has made possible to improve products, in terms of its functionality and reliability aspect, but it has also made possible to make robust design starting directly on the early stage of the project, with a terrific impact on cost reduction, weight, performance.

IV. Conclusions

The new design processes presented in this paper illustrates how the use of physical and reliability models can lead towards product improvement. Improvement achieved in terms of functional and operation performance, reliability and also reducing cost and time delivery. The design is no more based on the evaluation and forecast of the behavior of the system under static and design condition, but its behavior is analyzed and verified under off design condition. The strength of this process is related to the possibility to move toward the early stage of the project, all the evaluation of the system behavior.
As future steps, using this new design process foresee the possibility to generate automatically the software code to download on the microprocessor of the control system.

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