Transition of Oil and Gas Dynamic Simulation to Nuclear Applications Delivers Big Rewards – 14466

David Cuming, DBD Limited (dcuming@dbdlimited.com)

ABSTRACT

DBD Limited (DBD) is working together with a major engineering organisation, Costain Natural Resources (Costain) and the Client Sellafield Limited, to provide the differentiating expertise in the area of nuclear plant commissioning and pre-operational strategy for a key multi million pound nuclear waste treatment plant design, build and commissioning project at Sellafield site in the UK. The waste treatment plant is vital to the UK's strategy to continue to support fuel reprocessing operations and meet commitments to reduce levels of highly active liquor (HAL) by processing it before it can be converted to a solid glass waste form suitable for long-term storage.

The plant design has incorporated learning from operating previous incarnations of this process, together with many innovative design features, such as a software control system. This paper focuses on DBD's approach to placing some of these novel features under scrutiny by the application of Dynamic Process and Control Simulation and presents the successful outcomes achieved to date.

DBD applied specialist simulation expertise, and has led the team to develop and implement the simulation which models the entire facility. The big rewards from this approach have been:

- Early identification of a significant design enhancement that could be made before the manufacturing stage, fully justifying the modest investment.
- Providing dynamic analysis information to the Client to further underpin the process and control design as the design moved into manufacture. In many cases seeing the model react as expected, in line with the design intent.
- The simulator has also played a role in reducing the requirement for test rig work, particularly for testing the novel design features of the facility.
- Providing a legacy as a tool to deliver high quality and accessible operator training to the commissioning and pre-operations team and beyond.

INTRODUCTION

DBD Limited (DBD) is working together with a major engineering organisation, Costain Natural Resources (Costain) and the Client Sellafield Limited, to provide the differentiating expertise in the area of nuclear plant commissioning and pre-operational strategy for a key multi million pound nuclear waste treatment plant design, build and commissioning project at Sellafield site in the UK.

The waste treatment plant is vital to the UK's strategy to continue to support fuel reprocessing operations and meet commitments to reduce levels of highly active liquor (HAL) by processing it before it can be converted to a solid glass waste form suitable for long-term storage.

The plant design has incorporated learning from operating previous incarnations of this process, together with many innovative or novel design features. This paper focuses on DBD's approach to placing some of these novel features under scrutiny by the application of Dynamic Process and Control Simulation and presents the successful outcomes achieved to date.

PROBLEM DEFINITION

The plant would be the first facility of this type in the UK to incorporate a modern Programmable Logic Controller (PLC) software Plant Control System (PCS) which relies heavily on the use of automated sequences. The plant design incorporates several novel design features and has been designed to operate within the bounds set by a rigorous modern UK safety case. As part of the project's pre-operational and commissioning support, DBD highlighted a key requirement for a Dynamic Process and Control Simulation in order to provide answers to the following questions:

- Can the Client gain reassurance that the process and control design, including novel design features, is capable of operating the plant?
- When the PCS has fully completed its Factory Acceptance Testing, can the code be subject to further scrutiny that reveals its performance against a simulated and interactive plant model?
- Can the offline performance testing be carried out before the plant is built, commissioned or operated?
- Can a capability be provided that has a legacy for the future in providing operator training and testing of appropriate plant modifications?
- Can this type of model be built at a sensible price and in a short timescale to bring benefits as early as possible?

Through DBD's applied approach, the answer to these questions is "yes".

THE RIGHT SOLUTION APPLIED

DBD applied specialist simulation expertise, and has led the team to develop and implement the simulation which models the entire facility that is connected to the PCS.

DBD were confident that the software product, with its long, proven track record in the Oil & Gas and Chemical industries, could be applied for the first time to model an entire nuclear waste treatment plant. DBD applied its nuclear engineering and simulation expertise to deliver success to the Client during the design stage and with future benefits in commissioning and plant operation.

The perceived, and eventually realised, benefits for the design stage (all critical before plant manufacture) were:

- The process plant, control system and safety system design can be analysed dynamically and can be developed or verified by the model output. In particular, the new software based control sequences which are required to control continuous, cyclic and batch elements of the process and placing novel design features under a high degree of scrutiny potentially avoiding costly test rig construction.
- The PCS can be developed or defined by the simulator, including the user interface (i.e. operator screens)
- The designers can operate the plant before it is built or commissioned. For example performing offline controller tuning, making corrections to the control system and verifying

the design.
- Commissioning critical paths can be pre-defined and tested

The plant is currently in the construction and installation testing phase and in the subsequent commissioning and operational stages it can be used for high quality operator training installed as a ‘Virtual Reality Control Room’, including full event logging of all trainee actions, emergency response, etc.

The ‘big win’ that the Client expected was that from a relatively modest investment in sponsoring the simulator development they would be able to achieve process and control design iteration optimisation and cost reduction.

The simulation models the process and control system for the entire plant, accessed by the user through fully navigable 'control room' screens. It was built and tested in five phases, with the core of the process being modelled first. In later phases the auxiliary systems (heating, cooling, services, effluents, etc.) were added to complete the modelling of the facility. This stage-wise delivery allowed the Client to receive the most benefits as early as possible, before commissioning and operation, as well as keeping stakeholders engaged in the work.

THE BIG REWARDS COME EARLY

The business case for this work was based on saving ‘a round of design iteration’ from the forthcoming commissioning stage. The stagewise delivery allowed us to gain important results from the model that could be used to refine the process and control design at the earliest possible opportunity.

The major technical and commercial success is that within a few months of the modelling development the first phase results were ready. This provided an early identification of a significant design enhancement that could be made before the manufacturing stage. If this type of enhancement had been identified in the traditional fashion during the commissioning stage then the resulting costs of implementation on the physical plant would have been greater than the total cost of the simulator. This type of result halted any remaining perception that the simulator was ‘a process engineer’s toy’, gaining recognition at management level.

The ability for the team and the Client to be able to ‘run the plant on a desktop computer before it’s built’ revealed a new way of understanding the predicted plant performance as ‘static aspects of the plant design’ were subjected to scrutiny under dynamic manipulation (e.g. seeing how control loops work in practice and early identification of issues). This information was very useful to the team to further underpin the process and control design. In many cases seeing the model react as expected, in line with the design intent, was very encouraging to the team as the design moved into manufacture.

The simulator has also played a role in reducing the requirement for test rig work, particularly for testing the novel design features of the facility. The cost savings of the simulator, compared to physical design, construction and operation of test rigs, are significant.

The simulator software was chosen by DBD so that it can provide a legacy as a tool to deliver high quality and accessible operator training to the commissioning and pre-operations team and later the operations team. Operator training is seen by DBD and the end user and Client, Sellafield Ltd,

as paramount to operating their plant safely and efficiently. The simulator can be used to place operators in situations that cannot be reproduced on the actual PCS. This is a powerful tool for increasing operator's skills in safely managing potential emergency response situations and systematically assessing operator actions as part of an 'accredited' training course.

The simulator has been installed at Sellafield Ltd and has been operated by plant operators from other facilities at the site. Figure 1 shows a typical screenshot from the simulator; the inherent familiarity of the control room style interface immediately engages the operator and this outcome cannot be underestimated to add credibility to the technical output of the model. The feedback from Sellafield Ltd is that educational and technical benefits are easy to see for future operator training.

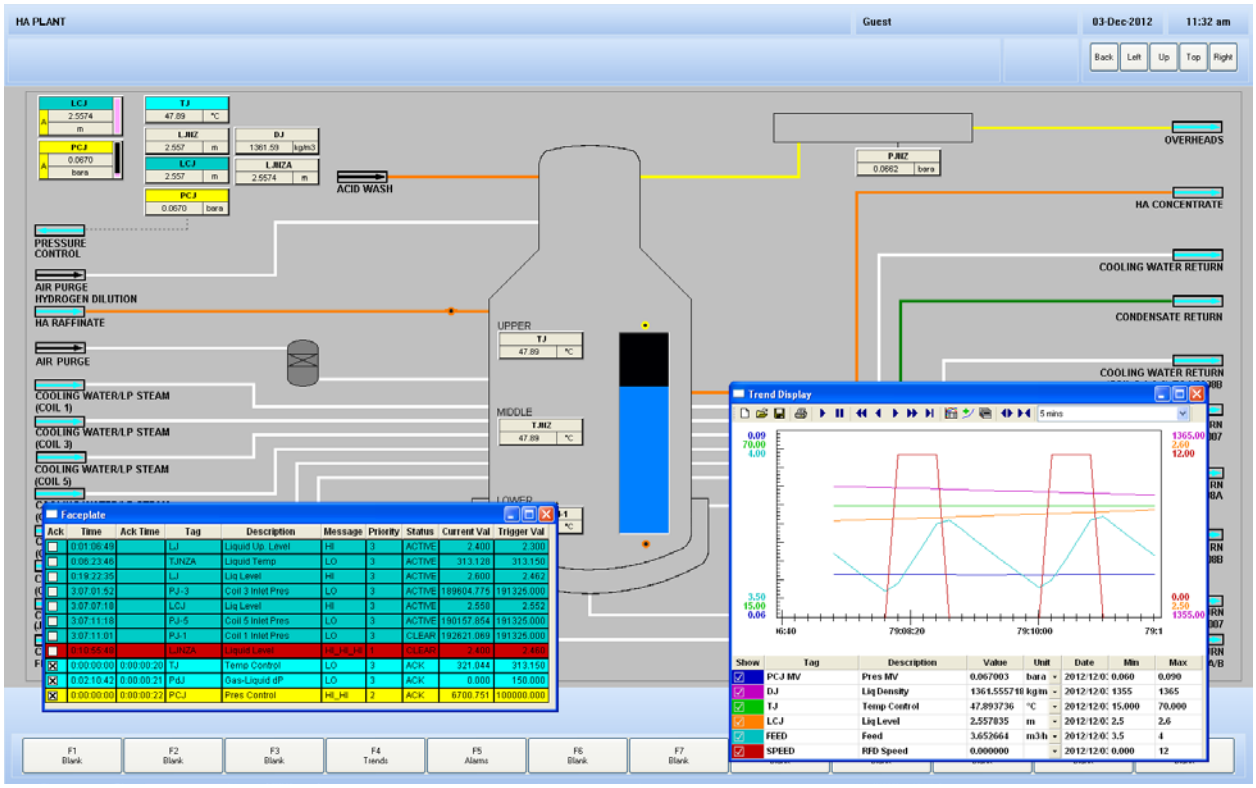

Fig. 1. Typical Screenshot from the Simulator

TRANSITION TO NUCLEAR – OVERCOMING THE CHALLENGE

DBD identified that the decades of innovation that dynamic simulation modelling has provided to other industries such as for Oil & Gas Exploration could be transitioned and successfully applied to nuclear plant. The industry connection was based around a core process that involved many traditional and comparable chemical engineering features (Chemical separation, liquid pumping, heat transfer, services, control loops, etc).

A modelling library required development of nuclear specific plant items. DBD's expertise, well supported by the Client's knowledge, allowed DBD to help 'fast-track' the development within a short timescale. In many cases DBD were required to go back to 'first principles in chemical engineering' as a way of looking past the 'nuclear' data to produce the underlying predictive

equations.

The modelling complexity itself pushed the simulation team to invent new complex modelling techniques to achieve the fidelity required by the design testing (e.g. Multi-phase, multi-component pipe network modelling with multiple points of heat exchange). This could have challenged the ability for the model to run at real time. The modeling team overcame this by 'multi-threading' the model so that different parts of the model could be run in parallel. The combination of novel nuclear modelling techniques ensured that the simulation was of a high integrity, realistic, real time and suitable for design and operational assessments.

This innovative transition of well trusted techniques from other industries has proven to be successful by delivering cost and time savings and risk reduction.

NEXT STEPS

DBD successfully delivered the completed simulation of the entire facility to the Client at the end of 2011 in order to maximise the benefits during the project design stage.

In early 2014 the simulator will have been connected to an offline copy the PCS following the development work being undertaken in 2013/14. The simulation will then be used to place the PCS under high degree of scrutiny to, again, provide early indication of any process and control design issues whilst the plant is still in the construction & commissioning phases. One example could be to confirm that the efforts made in design to manage and prioritise alarms work well under normal and abnormal scenarios using the simulator plus PCS as a dynamic test bench.

The simulator's adaptability to each stage of the project lifetime (design, commissioning, operations) means that it will continue to provide high quality operator training when the plant begins active operations and beyond.

There has been expression of interest from other facilities at Sellafield following demonstrations of the simulator and there would be many applications for this type of facility to be developed for nuclear applications worldwide, mirroring the worldwide applications of this software in industries such as Oil and Gas.

CONCLUSIONS

DBD identified that the decades of innovation that dynamic simulation modelling has provided to other industries such as for Oil & Gas Exploration could be transitioned and successfully applied to nuclear plant.

The value of the results to date for the Client from the simulator have more than justified the modest investment and the selection of this software by DBD during the design stage was forward thinking to ensure a legacy to benefit plant commissioning and provide high quality operator training for this plant.

ACKNOWLEDGEMENTS

The author wishes to acknowledge Sellafield Ltd for their support and knowledge in development of the modelling, Costain Natural Resources Ltd for continuing to sponsor this work and providing the technical support from the design and commissioning team throughout.