

# A Method for Executing Integrated Control and Safety System Projects by Using Dynamic Process Simulation Models

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*Yokogawa has completed many integrated control and safety system projects using the main automation contractor method for risk reduction in projects. These days, markets demand use of dynamic process simulation models during each phase of the project lifecycle in order to reduce risk even further. Taking an LNG liquefaction process as an example, this paper introduces how to meet such market needs, and what value-added services Yokogawa can provide to customers by innovating processes in the project lifecycle.*

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## INTRODUCTION

When a project is executed following the main automation contractor (MAC) method, front-end engineering and design (FEED) is conducted before actual delivery phases such as design, implementation, inspection, and shipment, to identify risks in advance and mitigate risks in delivery phases through the standardization of the basic functions and components. These days, in addition to applying the existing MAC method, markets demand the use of dynamic process simulation models (hereafter, this is simply “model”) during the key phases of the project lifecycle (Pre-FEED, FEED, delivery, commissioning, start-up, operation, maintenance), to reduce risk further and ensure a flawless startup and robust plant operation. Re-using proven models is expected to efficiently conduct the following processes: validation of plant design, validation of control and safety functions of the integrated control and safety system (ICSS), validation of plant operation procedures in accordance with state transition of plants (plant operating mode transition), development of alarm management solutions, and education of operators.

This paper describes the following aspects by taking an LNG liquefaction process as an example:

- 1) Preparing reusable modules including models,
- 2) Effectiveness of models when validating ICSS control functions,

- 3) Procedures to apply reusable modules to actual projects

## EVOLUTION OF PROJECT EXECUTION METHODS

A common challenge in executing projects is how to manage changes. End users determine when to start manufacturing products by the final investment decision (FID), and contractors including a MAC must meet the deadline. Although various changes may always arise due to miscellaneous conditions, the deadline is usually unchanged because the delay of the manufacturing start date (Ready For Start-Up date) leads to loss of business opportunities. Therefore, to reduce the risk of delay due to changes, end users work with control system suppliers to promote the standardization of basic functions and components of control systems such as system component devices, control and safety loops, human machine interface (HMI) and alarm management functions, and re-use them in actual projects. However, depending on the complexity of plant processes, there are many problems that cannot be resolved by the standardization of basic functions and components: such problems as in complex control functions, tuning of control functions, changes and late decisions of plant design, changes and late decisions of plant component equipment and devices, training of operators, and so forth. These problems often create new risks of delay, and cases where final products are not manufactured by the deadline are often reported.

To overcome these problems, a method which uses models in FEED and delivery phases is becoming the standard for validating plant design and ICSS functions, establishing alarm management design, validating plant operation procedures

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and delivering operator training, and accelerating decisions on specifications. This method is based on the concept of not bringing risks into the actual operation site. The following sections introduce Yokogawa’s commitment to the evolution of project execution methods and their future development.

**ROLE SHARING IN PROJECT EXECUTION AND APPLICATIONS OF MODELS**

Figure 1 shows the roles of end users, FEED contractors, engineering, procurement and construction (EPC) contractors, and Yokogawa in key phases of a project lifecycle (PLC).

Phase	FEED	Delivery and Site Work	Operation and Maintenance
Provide Design Data	END USER or FEED Contractor	END USER or EPC Contractor	END USER
Configure Models	YOKOGAWA	YOKOGAWA	END USER or YOKOGAWA
Approve Models	END USER or FEED Contractor	END USER or EPC Contractor	END USER
Validate Plant Design	FEED Contractor	EPC Contractor	END USER
Validate ICSS Configuration		YOKOGAWA	END USER or YOKOGAWA
Design and Build OTS		YOKOGAWA	
Validate Standard Operating Procedure		END USER, EPC Contractor, YOKOGAWA	END USER or YOKOGAWA
Test Unit Interactions		END USER, EPC Contractor, YOKOGAWA	END USER or YOKOGAWA
Maintain and Improve OTS			END USER or YOKOGAWA

**Figure 1** Role sharing in project execution

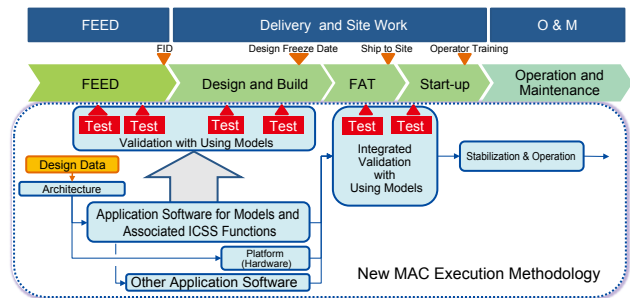
A model is used for the following purposes<sup>(1)</sup>.

- To validate plant design:  
Yokogawa receives the design data from FEED or EPC contractors and creates a model. FEED or EPC contractors use the model to verify dynamic characteristics of the plant against the design criteria, and confirm their validity.
- To validate ICSS control and safety functions:  
The model is used to validate the ICSS control and safety functions designed and implemented by Yokogawa for the internal test and the acceptance test. The model can also be used to decide control parameters and verify alarm management functions.
- Operator training system (OTS):  
The model is used for an operator training system.
- To validate plant operation procedures:  
The model is used to verify the validity of procedures for plant operations created by end users or contractors.
- To test unit interactions and dynamics:  
The model is used to inspect the validity of the plant design and ICSS functional design by simultaneously operating multiple units and executing related ICSS control and safety functions using plant operation procedures for them.

**YOKOGAWA’S EFFORTS**

There are some examples of applying models to the inspection process of actual projects, but only in project-based applications. To standardize the execution method and accelerate the inspection process, YOKOGAWA proposes a new MAC method shown in Figure 2. With this new method, the iteration-based inspections using models are repeated in

the key PLC phases to improve the quality of the application software, and after approvals from end users are acquired, the normal change management process starts. Using the model approved by end users at the acceptance test helps validate the plant operation procedures, execute the verification scenario (which is difficult to check at sites), and adjust control parameters. Moreover, it provides an environment equivalent to that of actual operations immediately after the acceptance test, to ensure earlier operator training. In other words, the field work can be accelerated while risks are not brought into the field.



**Figure 2** New MAC project execution method

A pre-engineered service product (PESP), engineering service functions of which operability is already confirmed, is being developed as a preparation for applying the new MAC method to an actual project. The PESP includes reusable models for typical units, equipment and devices to be used in processes, in addition to conventional reusable modules such as graphics, control and safety loops. The models and modules above are intended to be used as templates for each industry process. These templates cover processes for LNG re-gasification, LNG liquefaction, LNG carriers and re-liquefaction units, and various other processes. An actual project would be executed making use of the PESP as much as possible, and its templates would be adjusted if there were any difference from the actual project.

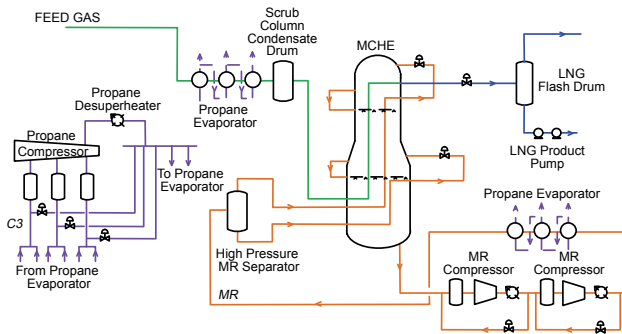
With the reusable modules and models, the PESP not only contributes to reducing costs but also enables identification of risks in an early phase of sales promotion. For example, they can be used to clarify the portions of the system to which existing methods can be applied, and those to which new technologies need to be introduced. As a result, the PESP helps to improve response capabilities of sales engineers when communicating with end users.

**AN EXAMPLE OF MODEL APPLICATION**

This section introduces an effective usage of a model for validating ICSS functions in the role sharing in project execution shown in Figure 1, especially the verification of DCS functions.

Figure 3 shows a block diagram of the process. This diagram depicts the propane pre-cooled mixed refrigerant process (C3-MR), and the model covers the pre-cooling unit including C3 compressors, condensers and evaporators, the

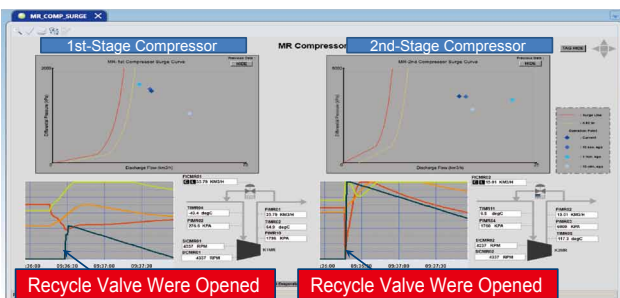
mixed refrigerant unit including MR compressors, and the main cryogenic heat exchanger (MCHE) unit.



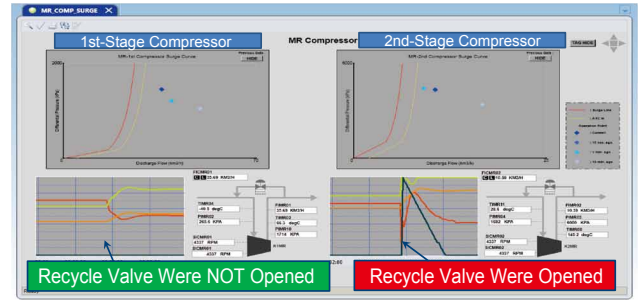
**Figure 3** Block diagram of an LNG liquefaction plant

In an LNG liquefaction plant, multiple compressors are used, and the anti-surge control is installed in the DCS for these compressors. It protects the compressor physically by opening the recycle valve when the compressor is getting close to the surge range. Conventional verification methods accept the verification results if the recycle valve only works as per specification when the process value is manually changed. However, this does not always guarantee that the control function works properly in actual conditions, and it requires a lot of tuning during the commissioning. As described later, the use of models allows some tuning during the internal test by a DCS supplier or factory acceptance test, and part of the field test can be omitted.

When opening the recycle valve, it needs to be opened instantly. On the other hand, when closing, the valve needs to be closed slowly with the ramping function. The ramping constant must be tuned to avoid unnecessary opening of the recycle valve. **Figure 4** shows the case of the inappropriate setting of the ramping constant causing recycle valves for the first and second compressors to open. **Figure 5** shows the condition with the optimized ramping constant. Only the recycle valve for the second compressor opens, and this tuning is preferable for securing the performance of the plant. This verification is not possible without models. The tuning time in the field can be shortened if models are used during the internal test by a DCS supplier or factory acceptance test.



**Figure 4** Inappropriate setting of the ramping constant



**Figure 5** Optimal setting of the ramping constant

## OUTLINE OF PROJECT EXECUTION PROCEDURE WITH MODELS

Fidelity level and covering range of models at delivery time are not yet clear during the sales promotion, Pre-FEED and FEED phases, but are gradually specified in the delivery phase. Because the PESP cannot be actually used as it is, it must be customized to meet actual project requirements. This section introduces guidelines for sales proposals, design, implementation and inspection.

### Guidelines for sales proposals

The development of the PESP also reforms the guidelines for sales proposals. Specifically, the PESP enables one to shift proposals from the traditional accumulation of I/O and hardware, i.e., man-hours & material based types, to overall proper assessment based on functions and their risks, i.e. risk assessment type. Although man-hours & material based types can clearly quantify costs, they only empirically estimate risks during the early project phase of quotations. The PESP can clarify the portions of the system to which technologies the supplier owns can be applied, and those to which the introduction of new technologies is required, and enables the explicit estimate of risks. In addition, by referring to and making use of the PESP, conventional engineering cost calculation which starts from the understanding of end user requirements from the beginning can be changed into the function estimation, which adds functions requested by end users to standardized functions offered by the supplier. This shortens the time required for quotations, and increases their accuracy.

When proposing project execution using models, it is necessary to extract the outline of the verification which end users want with models through demonstration and so on and to summarize it. Then, usability of the current PESP is judged considering the accuracy of the design data, which are available from end users and EPC contractors at each phase, and the proposal is created. The scope of the proposal is different from that of a conventional operator training system. Design and verification tasks required for each phase must be clearly estimated. The proposal must be created while understanding the scope of processes for various types of industries provided by the PESP and comparing it with user requirements.

### Guidelines for design

In design, it is crucial to appropriately separate units and to define the scope. In models, each parameter changes with time in accordance with material or heat balance equations and change in the parameter propagated across the entire process. Thus, it is important not only to create each device module of the model corresponding to the actual process but also to build the model considering each parameter of the actual process such as a temperature, pressure, and flow rate for each area or unit. Taking the C3-MR process as an example, MCHE and MR cooling cycles including pre-cooling by C3 are defined as an area, and C3 cooling and MR cooling are defined as individual units. The important parameters in the whole area are gas composition, supply pressure, and temperature. They determine heat and pressure balances in the area. On a unit basis, the number of stages of compressors and the number of associated drums may differ depending on the capacity of the plant or manufacturers. Choice of compact coolers might be changed depending on locations in the plant. The capacity of each piece of equipment, such as compressors, pumps, or valves, should be adjusted for the plant capacity or installation conditions. In recent years, expanders are often added to depressurize high-pressure fluids for improving the efficiency of the whole plant. However, because the entire process flow of these units is almost the same on the whole as long as they are part of the C3-MR process, the project-specific model can be developed in a relatively short time based on an optimally tuned typical C3-MR model with adjustment of individual components of units to meet the requirements for each project. However, if a high-fidelity model is requested, accurate design data is indispensable for such a model. When even any single part of it cannot be obtained, an individual measure for it is needed for analyzing the design data by using a static simulator or so forth.

### Guidelines for implementation and inspection

Design data is not accurate in the FEED phase, so an iterative approach is recommended to improve the quality of the model at that time. In this approach, reusable standard

modules are customized based on the design data and estimated values available for each area or unit. Afterwards, a model is developed, and then its inspection is repeated with end users.

In the delivery phase, the design data for construction can be obtained. The data are used to update and integrate the model for each area or unit which has been developed in the FEED phase. It is recommended to simultaneously develop the ICSS application based on the same data and to conduct integration tests of the model and ICSS for each plant operation category. Changes in design data after inspection phase must be appropriately managed by a strict change management process, to maintain consistency between the model and the ICSS application.

### CONCLUSION

This paper introduces effective verification of ICSS control functions by using models and outlines the procedure for applying the PESP to an actual project. Although this method has not been proven in actual projects yet, Yokogawa is preparing for this by creating a mechanism to offer end users Yokogawa's standard products and their prices. The mechanism includes the standardization of project execution procedures including quotation, pricing of the PESP and its customization, and the starting timing and pricing of change management. Yokogawa will also review contracts, for example applying a mixed-type contract which combines the time and materials contract for the design phase and the lump sum contract for work after implementation, further development of the PESP, investigation of automatic verification of ICSS functions making use of models, and the conducting of training of Yokogawa engineers at the same time.

### REFERENCES

- (1) Abdelwahab Aroussi, Farid Benyahia, "Proceedings of 3rd International Gas Processing Symposium," 1st Edition, Qatar, March 2012, Elsevier B.V., 2012