

Digital Instrumentation and Control Platform Determination Process for New Concept Nuclear Power Plants

Introduction

New nuclear reactors being proposed to be built in this country all involve digital Instrumentation and Control (I&C) systems, both safety related and non-safety related. For the plants currently being reviewed by the Nuclear Regulatory Commission (NRC), these I&C systems are based on existing digital platforms that were developed for plants either existing or currently under construction in other countries such as China, Japan, France, and Finland. Detailed descriptions of these systems have been submitted to the NRC for review and approval in the form of Chapter 7 of the Design Control Document (DCD) or Topical Reports that provide detailed information or supplement the DCD. These digital I&C systems or platforms are typically proprietary to the reactor manufacturer, especially the safety-related parts. However, a new series of reactor designs, in the form of small reactors, are being developed that have no particular I&C platform associated with them. These reactors include new concepts such as "Traveling Wave", updates of small modular design reactors (single or multi-modules) and others. Since in some cases, these reactors may have no associated reactor manufacturer involved, a particular I&C platform (Common-Q, MELTAC, TOSMAP, TELEPERM, etc) is not part of the design and only the concept for a control and information system exists. This paper provides an approach, from an architect/engineer (A/E) perspective, for transitioning from conceptual design, where only a general architecture, communication scheme, and some rudimentary rules exist, to preliminary and final design that will result in a platform appropriate for a particular new reactor technology or configuration.

Discussion

Architect/Engineers have historically designed and provided the balance of plant (BOP) portion of the overall nuclear power plant. This includes the non-safety-related instrumentation and control system. The nuclear island, which includes the reactor, containment, reactor support, and other reactor related portions of the plant were typically designed and provided by the nuclear steam system supplier (NSSS) and that includes the safety-related instrumentation and controls that are required to directly control the reactor and its associated safety systems (engineered safety features, emergency cooling, etc.). With the advent of innovative reactor designs or configurations (small multi-modules), an NSSS supplier may not be initially associated with the design of the plant and therefore a void exists in the case of the design of the control system for the reactor and associated safety systems, as well as the non-safety part of the control system. Since the substantial design of the instrumentation and control system is needed to allow many other design activities to proceed, it is important that this expertise be available at the start of preliminary design of the project. With no specific reactor manufacturer involved early in the process, a specific, proven, I&C hardware and software platform is not available so another approach is required.

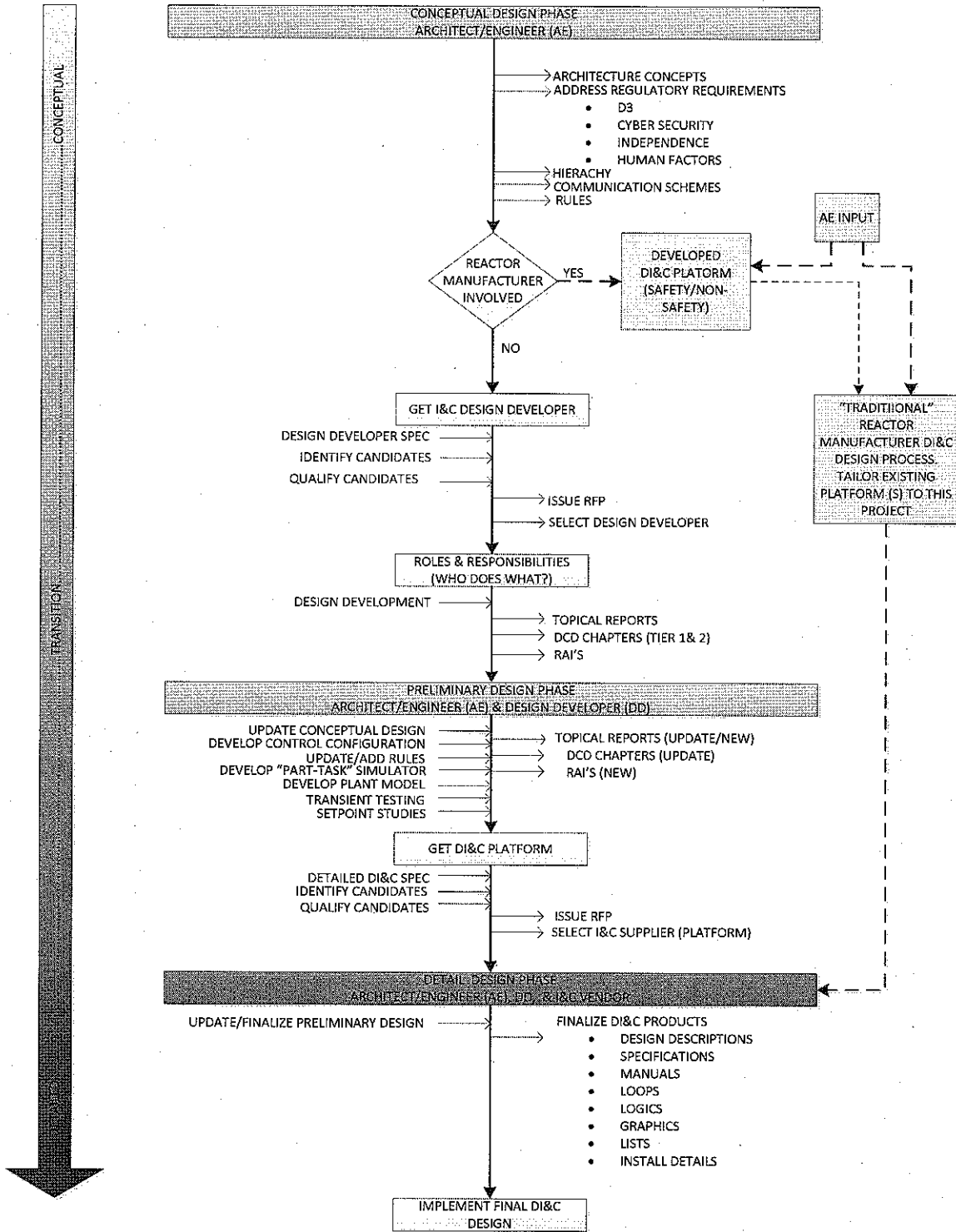
An A/E may be employed during conceptual design phase of a plant to support a reactor designer in early plant arrangements, supporting (BOP) systems design, and, due to a lack of a reactor manufacturer's control platform, conceptual design of the overall plant instrumentation and control systems. This is appropriate since the conceptual design lays the foundation for the design and application of the I&C systems and a concept must be presented that addresses the requirements that will be assessed, evaluated, and ultimately accepted by the regulator. A proven, existing platform is not mandatory at the conceptual design stage, although it makes it easier. Although a reactor manufacturer has to be onboard at some point, he may also not have a previously used or proven I&C design. One approach to fill this void is to obtain the services of a control system supplier or integrator that is not affiliated with a particular reactor manufacturer, that has experience in both safety-related and non-safety-related instrumentation and control systems to supplement the experience of the A/E. This "design developer" must, of course, have a proven track record in the design, development, delivery, and implementation of these types of systems, possibly in Nuclear Power Plant (NPP) I&C upgrades (to digital I&C systems) or in other, related I&C areas such as providing systems of similar complexity to the Nuclear Navy.

Figure 1 diagrams an approach for transitioning from conceptual design to delivery of a system when confronted with the type of situation described above. Recognize that this is by no means a fully detailed methodology or exhaustive listing and only synthesizes the activities and products involved. Of course, a detailed, structured, design program is to be followed including the systems engineering as well as addressing the software life cycle.

During conceptual design, a specific platform is not required. However, general and detailed requirements should be well understood and documented. The requirements should address the latest regulatory guidelines (Federal Codes, Regulatory Guides, NUREGS, etc.) with emphasis on NUREG-800 which the NRC uses to assess the acceptability of the digital I&C system (Chapter 7). Such elements as heirachy, diversity and defense in depth (D^3), cyber security, independence between safety and non-safety systems, human-machine interface considerations, and communication schemes are all topics that will be scrutinized by the NRC.

If a reactor manufacturer is onboard, and has a developed or proven instrumentation system and platform, then the design process follows the branch path shown on the right side of Figure 1. Typically, this platform will address the reactor safety systems such as reactor protection, reactor control, emergency safety features, and emergency core cooling, as applicable to the particular type of reactor (pressurized water, boiling water or some other type). The A/E however, is still involved for the BOP systems such as steam, feedwater, circulating water, turbine control, and others which need to interface with the overall plant control system.

FIGURE 1 - NPP I&C DESIGN PROCESS



If there is no reactor manufacturer in the early stages of the design process, then it is prudent to obtain the expertise of an I&C design development contractor to supplement the A/E.

The process as depicted in Figure 1, is to prepare a specification, identify potential candidates, survey the candidates to verify capabilities, issue the request for proposal (RFP) and finally, evaluate bids and select a supplier. There are a number of companies currently involved in upgrading existing nuclear plants with digital I&C systems as well as organizations such as system integrators, that can provide a platform that could comply with the requirements developed during the conceptual design phase. These companies are either providing or have provided systems to existing NPPs (or other facilities, such as nuclear fuel fabrication or processing facilities) or to government entities such as the Nuclear Navy.

Roles and division of responsibility between the A/E and the Design Developer must be clearly defined and understood by both parties. This not only pertains to portions of the design, but also to products that have to be submitted to the NRC for review and to who is responsible for responding to I&C questions from the NRC in the form of "requests for additional information" (RAIs). The Design Developer should also be responsible for substantial contributions to the Design Control Document (DCD) that needs to be submitted to the NRC for design approval.

Although the I&C design is mostly described in Chapter 7 of the DCD, other chapters also require I&C related descriptions or other inputs, and the responsibility for these inputs must be clearly defined between the A/E and the Design Developer.

During the preliminary design, the conceptual design advances including identifying a control configuration (feed-forward, feed-back, load following, etc.) for each subsystem and for the entire plant, adding rules (2 of 3, 2 of 4 logic, signal averaging, and communication rules, for example), developing a "part-task" simulator and plant model(s) to be run on the simulator. The "part-task" simulator can be an analytical simulator so that transient analysis and testing can be performed to verify and refine the model.

Topical reports may have to be updated or new reports prepared as the design progresses and DCD chapters may also need to be updated. Additional RAIs will probably be received that need to be resolved.

At this point, the I&C platform should be selected. The same approach that was used to select a Design Developer may be used. That is, prepare specification, identify and survey candidates (again, since others may have surfaced), issue RFP, evaluate and select. Note that the Design Developer may have a platform that could be considered and, if this is the case, the specification should be generic enough so that a competitive bid is possible. Consideration should be given to selecting the actual platform as late as possible to allow for emerging technologies to be included, as digital I&C design hardware and

software are continuously evolving. The NRC has recently approved implementation of field programmable gate arrays (FPGA) in some nuclear plant digital I&C upgrades, for example, and is in the process of reviewing proposed safety-related I&C platform designs that use FPGAs in new/proposed nuclear power plants, as part of their design certification.

Final or detailed design can then progress as shown on the diagram.

The approach described herein can be used in cases where the reactor technology is of a new design or configuration as described in the beginning of this paper and if the reactor manufacturer has no existing or developing I&C platform that can be used, modified, or customized for this application.

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