Web-based, Interactive, Nuclear Reactor Transient Analyzer using LabVIEW and RELAP5 (ATHENA)

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1. Introduction

In nuclear engineering, large system analysis codes such as RELAP5 [1], TRAC-M [2], etc. play an important role in evaluating a reactor system behavior during a wide range of transient conditions. One limitation that restricts their use on a wider scale is that these codes often have a complicated I/O structure. This has motivated the development of GUI tools for best-estimate codes, such as SNAP [3] and ViSA [4], etc.

In addition to a user interface, a greater degree of freedom in simulation and analyses of nuclear transient phenomena can be achieved if computer codes and their outputs are accessible from anywhere through the web. Such a web-based interactive interface can be very useful for geographically distributed groups when there is a need to share real-time data.

Using mostly off-the-shelf technology, such a capability - a web-based transient analyzer based on a best-estimate code - has been developed. Specifically, the widely used best-estimate code RELAP5 is linked with a graphical interface. Moreover, a capability to web-cast is also available. This has been achieved by using the LabVIEW virtual instruments (VIs) [5]. In addition to the graphical display of the results, interactive control functions have also been added that allow operator's actions as well as, if permitted, by a distant user through the web.

2. Tools and Methodology

A best-estimate reactor system analysis code, RELAP5, is selected as an engine to demonstrate the capabilities of this approach. The LabVIEW VIs are coupled with the system code as a dynamic link library (DLL). Since the user interaction is via a web browser, the analyzer developed here can be used with other computers and operating systems as long as it has access to the web.

Figure 1 shows a schematic diagram. LabVIEW coupling with RELAP5 makes it possible to run the code through the network without having the code and/or input file in the end user's computer. Users who are connected to the server through the internet can interactively simulate the transient (with interventions) by using interactive control features through their web browser, and examine the results on-line.

A typical Westinghouse two-loop PWR (Pressurized Water Reactor) was modeled as the target plant for this application. LabVIEW-based interaction and data-visualization windows consist of six LabVIEW VI's; (i) a main control and an interaction window, and (ii) five output visualization windows.

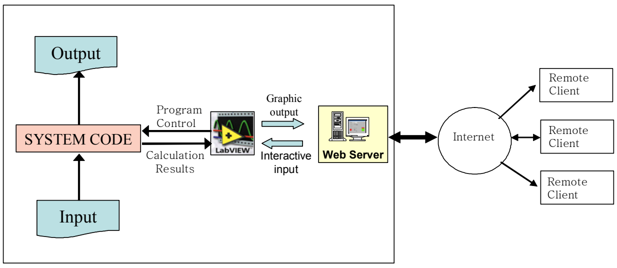


Figure 1. Schematic diagram of the DLL-based web-casting approach

Figure 2 shows the main window of the transient analyzer. It consists of a main tool bar and six tab sheets. The tab sheets include the "main control", "nodalization", "reactor power", "pressure & level" and "temperature" tabs. Pop-up windows are also available for all the tabs if requested by the user. Local or remote users can select the I/O files, execute the code and simulate operator's actions through the main control page.

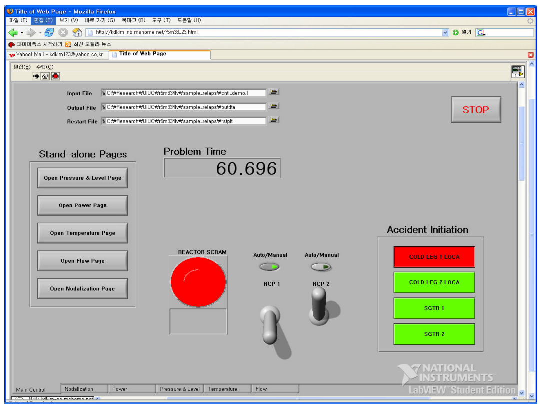
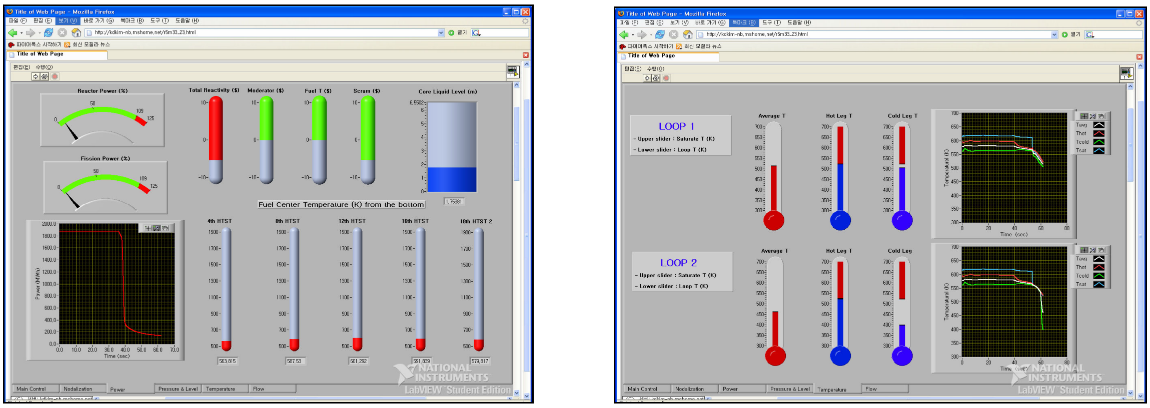


Figure 2. Main control module and tab pages

Although the RELAP5 input data can be used without any changes, additional input cards in the existing input decks must be modified to utilize the capabilities of this tool. Built-in trip control functions such as a reactor scram and a reactor coolant pump ON/OFF, as well as accident initiation functions are provided. Additional control functions are being added. Calculated output data can be seen in a graphical format by selecting appropriate tabs in the web-browser.

Figures 3~4 show a few samples of the output pages. Figure 3.a shows the reactor power related parameters through level indicators as well as a power level as a function of the time. This window provides the total reactor power, fission power and major contributions to reactivity, fuel centerline temperatures, and reactor core collapsed water level. Figure 6.b shows the primary side temperatures and saturation temperatures.

Nodalization page is designed to show a color coded void distribution in the reactor system. Figure 7 shows the void fraction distribution during a large loss of coolant accident. The figure on the left shows the void distribution during nominal operating conditions, and the one on the right shows it after the accident. Clearly, such a graphical display can provide a much better understanding of the transient than copious amount of text data.



a. Reactor power window b. Primary temperatures

Figure 3. RELAP5's output in web-browsers

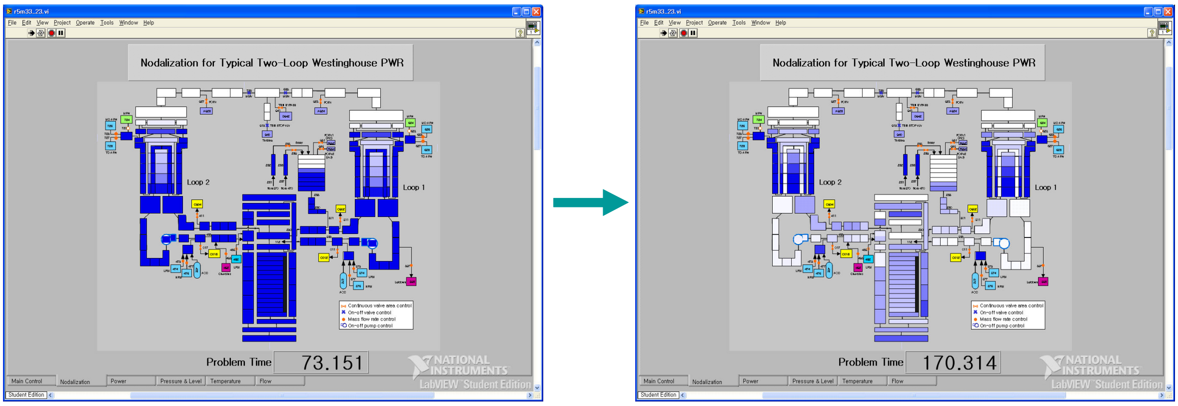


Figure 4. Nodalization window showing color coded void fraction distribution.

IV. SUMMARY AND CONCLUSIONS

The web-based transient analyzer takes advantage of off-the-shelf technology to web-cast data and graphics and to provide interactivity from remote locations with a system code. Effort required to implement these features in the system codes is not prohibitive. From collaborative projects with collaborating teams in geographically remote locations to providing system code experience to distance education students, these tools can be very beneficial in many areas of teaching and R & D.

ACKNOWLEDGEMENTS

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