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Web-based Educational Research Reactor Simulator

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ABSTRACT

The recent COVID-19 pandemic has disturbed education and raised the need to distance learning. Besides, as a part of a national program to achieve research and development objectives, a web-based Nuclear Research Reactor Educational Simulator (NuRRES) development program is launched. NuRRES undertakes a variety of training and education programs on nuclear theory and reactor operation. The LabVIEW software package from National Instrument is exploited to implement the complex reactor's mathematical models and utilized for building an interactive GUI (graphical user interface). To provide the necessities of training, a dynamic animation is used to enrich the learning and awareness of a trainee about real problems. NuRRES has diverse key objectives that will be accomplished within a time-framed schedule. An authorized web-based network will be established between different nuclear educational institutes. This online learning tool facilitates sharing experiences and reactor experiments in learning nuclear science. Studying and imitating core physics and its applications and modeling and analysis of reactor thermal-hydraulics are also offered. Besides, NuRRES can be utilized to study different accidents (such as loss of coolant and flow accidents) and analyze their effects. On the other hand, using simulators such as NuRRES can ensure safe operators' training for various situations. Therefore, one of the contributions of NuRRES project is to deliver its analysis results to serve several safety-relevant activities. NuRRES have wide capacities of training tools that could be utilized to conduct a variety of training courses to guarantee a complete understanding of the nuclear physic principles and safe reactor operation and in turn, trainees will earn a massive benefit. It is anticipated that NuRRES will demonstrate its effectiveness in raising the skills of the human resources required by the nuclear industry and nuclear initiatives.

1- INTRODUCTION

Nowadays, providing training and development to students and staff through distance learning while utilizing a variety of technological technologies is highly necessary. Web-based simulators for learning are one tool for e-learning using computers and the internet. The matter of developing such simulators is a great technical matter combining modeling and instructional knowledge. Learning through simulators includes implicit educational strategies such as learning objectives, observation, instructional strategies, and interaction strategies between the student and a representation of the world. Besides, having appropriate tools and training environments will reinforce the expansion of modem cyber-physical systems [1].

On the other hand, building simulators facilitate understanding the fundamental principles of complex and complicated systems such as nuclear reactor. Simulators are used to strengthen theoretical knowledge, dynamics of the processes, and their interdependency and are discussed in the literature [2-8].

This paper presents the LabVIEW implementation of a web-based Nuclear Research Reactor Educational Simulator (NuRRES). NuRRES considered the software

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implementations of basic principles and the modeling of physics concepts regarding nuclear research reactors. NuRRES will be directed for academic research and training, especially during recurring crises including the recently discovered COVID-19 pandemic. This simulator uses the nuclear research reactors' design model and the basic principles that have been given in [9, 10]. [6, 7] illustrates the designs, the simulator engine and GUI-based LabVIEW implementations, and the results. The rest of the paper is structured as follows. The tools and software environment are outlined in section 2-2. Section 3**Error! Reference source not found.** gives an outline of the design, and implementation of the presented simulator, while section 4 introduces the targeted participant of the NuRRES project. Section 5 explains the different objectives of NuRRES while section 6 summarizes the main conclusion of the paper.

2- NURRES ENVIRONMENT AND TOOLS

As the development environment, a computer running the Windows operating system was employed. Utilizing Windows reduces costs and requires all processes to adhere to the default Windows GUI for user-friendly interactive usage. Building an "engine" and creating a "GUI" are the two basic modules of creating a web-based NuRRES simulator. Figure 1 demonstrates the web-based NuRRES simulator's schematic diagram. Due to its broad popularity and simplicity of use, LabVIEW [11] was selected as the development tool for the simulator's engine and GUI. In addition to being used to process and analyze the experimental data in laboratories [12], LabVIEW also serves as the front end of nuclear simulation software for large-scale system analysis [7, 13, 14].

To publish the developed simulator to the Web, the LabVIEW Web Server is used. Once the Web-Server is enabled, all LabView files (VIs) and applications are automatically accessible to all Web browsers. You can, however, restrict browser access to the front panels that have been published and choose which VIs are made available online. The VIs needed to be loaded in the memory on the computer for front panels to be shown on the Web. Front panel images in JPEG and PNG formats can be generated by the Web Server. The front panel is integrated into an HTML document made using LabVIEW's "Web-Publishing Tool" in order to add the ability to view and control that panel remotely by the client's computer. Static images of the front panel can also be embedded in an existing HTML document. Enable and configure the "Web-Server" in a standalone application to deploy an HTML document with the application.

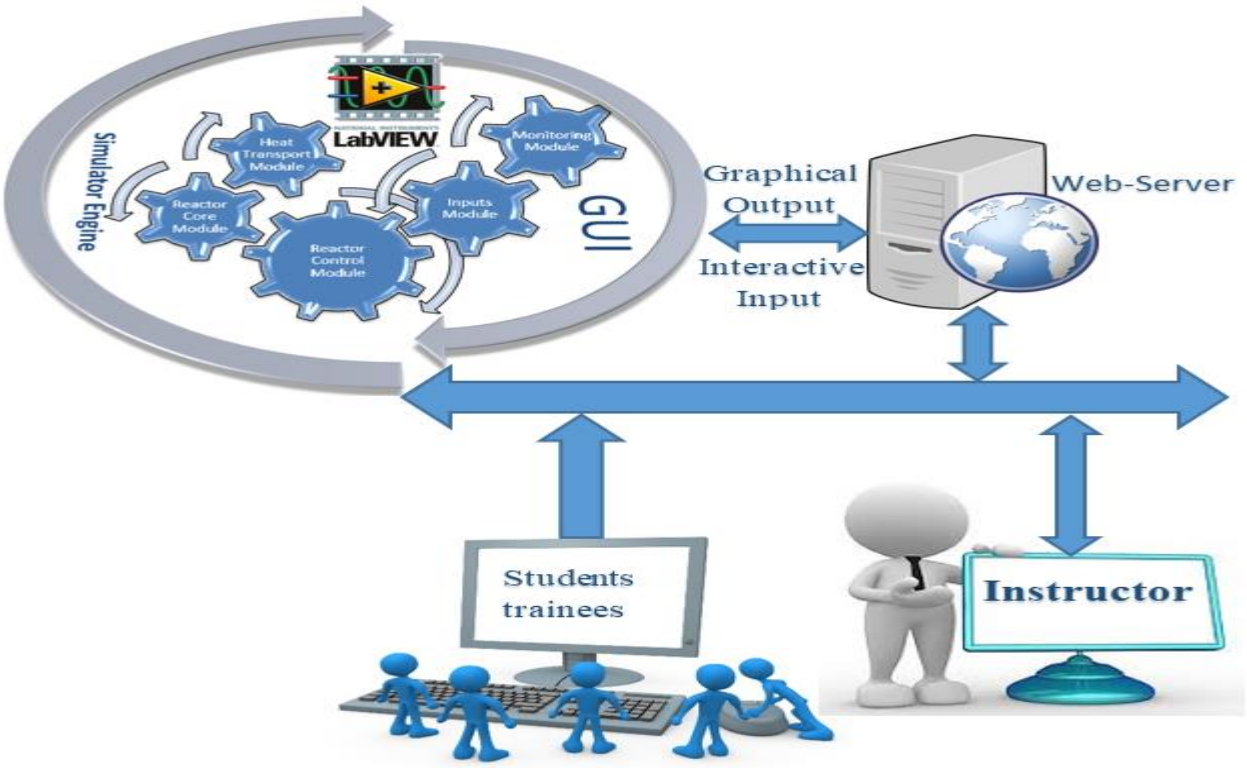

Fig. (1): Schematic diagram of a web-based NuRRES

3- DESIGNING WEB-BASED SIMULATIONS FOR LEARNING

The previously discussed and shown in figure1 internet-based educational tool allows the development and initiation of a virtual laboratories for electronic distance learning. The educational tool is hosted and operated on a server computer, while clients' or students' computers require only an internet connection and the Internet Explorer program to access it. As a result, they do not require any additional programs or costs. Figure 2 depicts the appearance of the developed virtual laboratory on the user's screen. Note that some updates for the developed NuRRES version will be needed to support other internet browsers.

The authorized users/students can interactively simulate the NRR behavior in interactive mode using control features through their web browser and examine the results online. Meters, switches, pumps, and other user interface elements may be found on each user interface panel of the web-based simulator, which was created utilizing LabVIEW's graphical programming features. These elements can be modified (i.e. their value or state) using simple mouse actions like *dragging* and *dropping*.

There are six main objectives of NuRRES that will be covered in the sections below. First, a world of stakeholders will be virtually connected. Secondly, studying and imitating core physics and its applications. Thirdly, modeling and analysis of reactor thermal-hydraulics. Fourthly, studying different malfunctions. Fifthly, ensure safe operators' training for various situations. Finally, the use of the NuRRES platform to develop a practical application usable for safety analysis or operation and design.

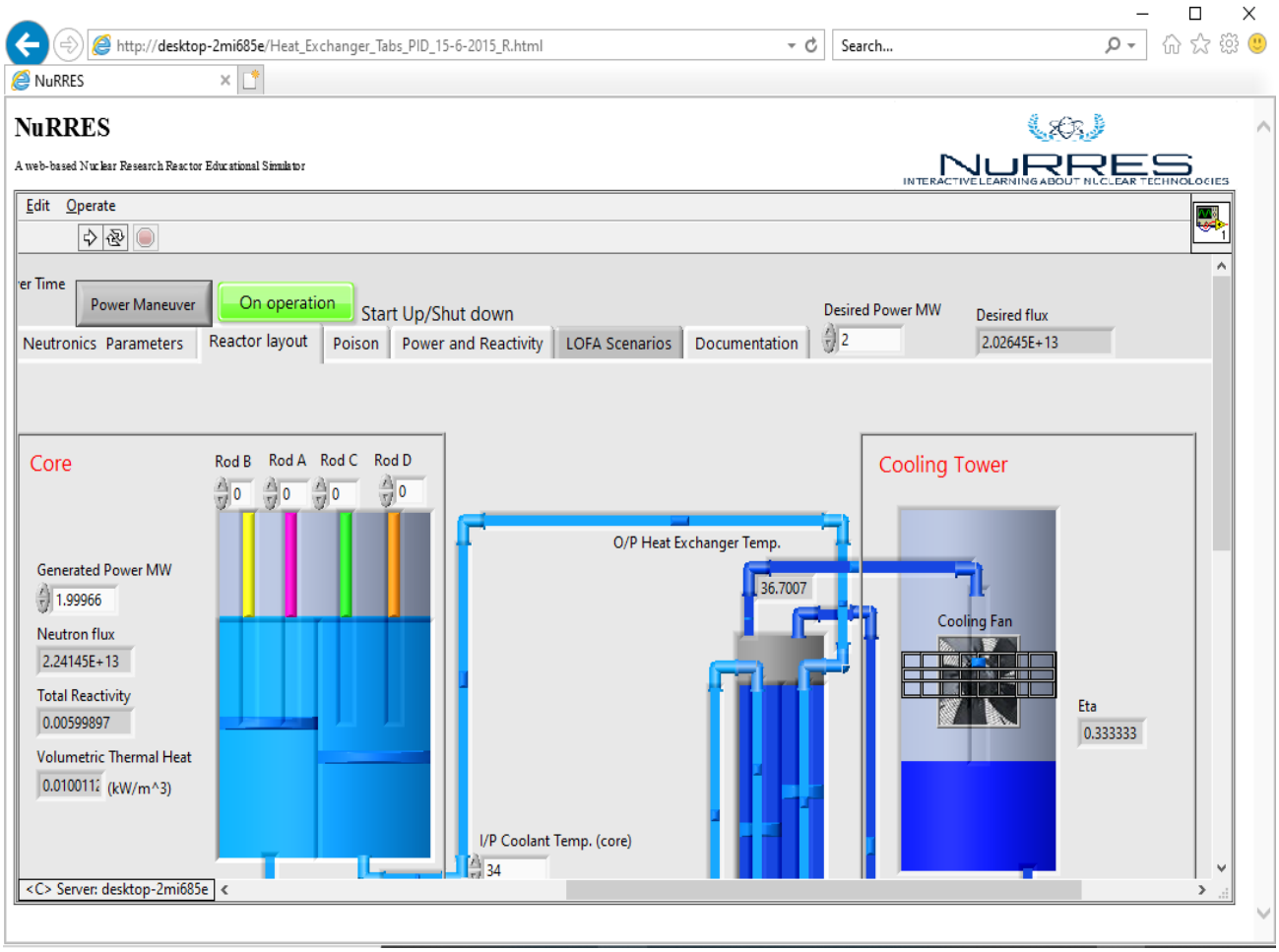

Fig. (2): NuRRES screen on the web

4- STAKEHOLDERS CONNECTED WORLD

With the rise of internet communication, a greater degree of freedom in cooperative data analysis can be achieved if simulation outputs (both data and respective graphs) are easily accessible in real-time from anywhere on the planet via the web. For example, in large, geographically dispersed research groups where real-time data must be shared, the NuRRES tool can serve as a bridging interface allowing interactive exploration of code output. The potential to access the real-time results through the web may also support improving the educational quality. Furthermore, an authorized web-based network will be established between different nuclear educational institutes all over the country. The nuclear stakeholder consists of the knowledge management working groups, the education and training institutes, and other undergraduate schools. This online learning tool facilitates sharing experiences and reactor experiments in learning nuclear science with experts all over the world.

Managing a stakeholder network is based on the idea that the notes, information on staff communications, and the working relationship networks of all institutes and members should not be kept in separate files or spreadsheets. Instead, stakeholders should centralize this private information to create a single source of truth. Stakeholders should prioritize the creation of a workspace to centralize their workflow, make knowledge accessible, and obtain a 360-degree view of any issue affecting their organization. By establishing a single system of record, you can foster bidirectional communication and collaboration with all the authorized stakeholders.

5- LEARNING OBJECTIVES

Many universities should encourage their instructors to make use of simulator tools instead of installing their large-scale software on the local machine which is located in high-end classrooms equipped with multi-media tools. These machines, however, are connected to high-speed internet. As a result, if the computer code can be run interactively through a web browser and the data is displayed in a web browser, instructors will be able to incorporate these codes into their regular classroom lectures. Therefore, many learning goals can be achieved starting from conceptual knowledge building for the basic theory of nuclear science and reaching various reactor operation experiences. These are the main categories of knowledge that have to be earned according to the basic taxonomy of knowledge given in [15].

5.1 Conceptual knowledge

The simplified scheme of nuclear research reactor (NRR) is given as a source of heat with controlled power [16]. The operation of the NRR consists of a series of processes. The NRR's operation is made up of several processes. The point-kinetic model [17] is one of the simplest, shortest, and most accurate replicas of the nature of the processes in the NRR. Figure 2 clarifies the NRR's processes and control effects which are included in NuRRES simulator. These processes are the main engine design of the simulator [7] that include nuclear reaction processes which are neutron kinetics, poisoning, and burnup of fuel and heat transfer processes.

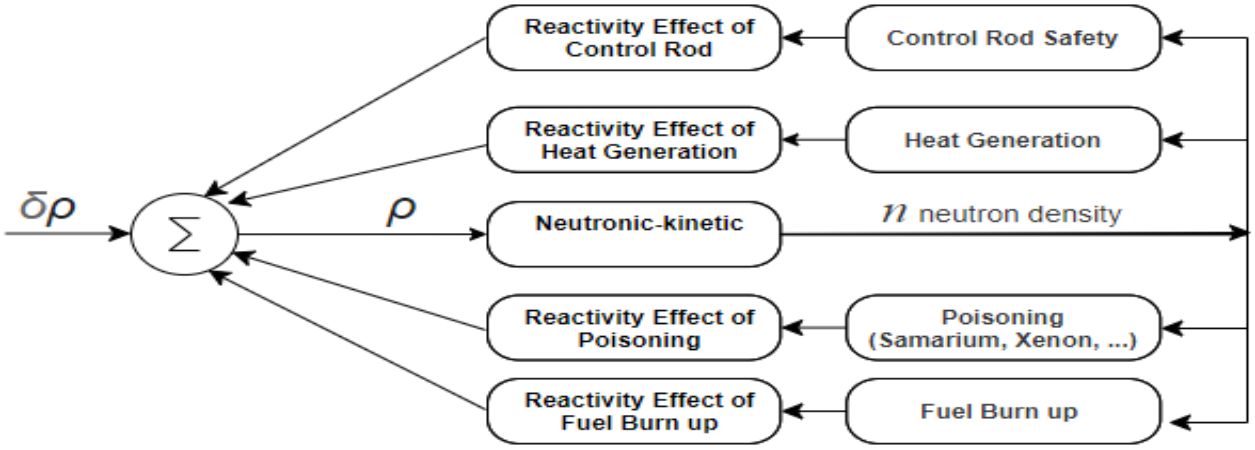

Fig. (3): The basic and essential physical processes happening in a nuclear research reactor impacting its state

The NuRRES simulation model consists of concepts, principles, facts, or events. The learners are expected to understand physical principles, concepts, and the phenomena that control the processes in the NRR. The conceptual knowledge can be categorized into reactor physics and reactor control as discussed below.

5.1.1 Reactor Physics Concepts

To implement the basic processes in modelling NRR, the presented NuRRES simulator build two key overlapped modules: the Engine and GUI as shown in figure 1. The “engine” module is composed of three main functions, Heat Transport, Reactor Core, and Control functions. While, the “GUI” consists of the Input, Monitoring, and Control functions. To raise the knowledge of physical concepts the first tab of NuRRES GUI permits the student to change the nuclear reactions’ parameters (neutron kinetics, burnup of fuel, and poisoning) and then notice its effect. This strengthens the studying and imitation of core physics and its applications.

5.1.2 Reactor Control Concepts

The Control function is shared by the "Engine" and the "GUI" since the reactor action may be changed manually or automatically depending on the reactor-parameters’ values. Pumps, valves, water, heat, and other common parameters may be easily adjusted with a mouse click. Accordingly, the student can learn the modeling and analysis of reactor thermal-hydraulics. Group-distance exercises for system simulating can be activated to strengthen the training capabilities.

5.2 Operational knowledge

The training through NuRRES will permit students to test various NRR scenarios such as nominal operation, incident and accident operation

5.2.1 Nominal Operation

NuRRES describes how systems can be controlled, as well as the procedures that can be used and their consequences. The learner interacts with the simulation during a typical operating task, modifying and altering to maintain or attain a desired condition, or to set off a chain of events. Consider, for instance, the learning objectives that teach trainee how to follow the reactor operational manual (individually and among group members). Determining the operations to carry out in order to establish a stable system is a typical learning objective in NRR.

5.2.2 Accident Operation

The trainee will study and analyze various malfunctions (such as loss of coolant accident “LOCA” and loss of flow accident “LOFA”). The learner may monitor the coolant status by observing the animated flow rate via the primary and the secondary loops, which have been controlled by the calculated coolant flow rates. As a result, the LOFA slows down the animation, and the user is aware of this loss. In addition, the animated height levels within the core and heat exchanger show a change in coolant volume, allowing the user to notice a LOCA. The chart on the core tank also reveals the temperature variance under different running circumstances (for example, normal, LOCA, or LOFA). The simulator replicates the reactor scram induced by the temperature spike caused by the LOFA incident.

5.3 Strategic knowledge

Strategic knowledge is a type of knowledge that describes meta-knowledge such as problem-solving methods, i.e., techniques for problem-solving effectiveness. NuRRES can also include a class containing strategic knowledge which is achieved by a package of classes about cooperation in emergency situations, distributed planning, coordinated actions, and communications between groups of learners to gain situational awareness. Moreover, learn and manage individual performance and its effect on other team member’s performance, and the use of the NuRRES platform to develop a practical application usable for safety analysis or operation and design

6- CONCLUSION

The web-based NuRRES application is intended for distant learning and provides several advantages owing to the properties of the web and the capabilities of simulation-based learning. One of the most major advantages of constructing web-based simulators is the availability of the systems on the internet. When the students are working in the environment, they are usually involved in problem-solving. It is necessary to identify learning objectives and instructional techniques in order for the system to employ the most appropriate educational strategy. NuRRES improves the learner's capacity to interact with and experience dynamic and interactive simulations, as well as explore and discover a simulation model. Additionally, the capacity to solicit instructional feedback from both students and teachers.

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