## Project Title:

Feasibility Study of a Research Laboratory for Simulation and Analysis of Modern Power Systems

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## Keywords:

Real-Time Simulator, Power System Lab, Hardware-in-the-Loop (HIL) Simulation, Simulator, Microgrid Implementation, Technology Localization.


## Project Necessity:

These days, the operation of modern power systems is highly dependent on simulation pre-tests in research laboratories. In fact, to ensure the technical and non-destructive interaction of new equipment on the power system performance prior to their connection and operation, the setting up of real-time simulation laboratories for the study of power grids is essential; especially, in the implementation of electrical microgrids at the level of world-wide standards. In addition, the simulation of different elements of the power system and the study of their technical effects on the grid and the reciprocal effects of the network on the equipment, will certainly avoid incurring heavy costs due to their potential damaging effects on the system. In other words, with the help of real-time laboratories and by performing various simulations and analyzes, the interaction effects of a desired technology on the network can be measured before investing in the purchase or construction. Accordingly, if the expectations are confirmed, the next actions (e.g., purchase, installation and operation) can be decided.

There are a variety of simulation tools for modeling and planning of power systems, from high-voltage transmission systems to low-voltage distribution networks or even small controllers and electric devices, from rapid transient analysis to long-term planning studies. Also, in today's electric power systems, renewable energy resources in the form of *Distributed Energy Resources* (DERs) are widely developed. On the other hand, intelligent devices such as smart meters are being implemented and deployed under *Advanced Metering Infrastructure* (AMI). Therefore, the complexity and interdependence of infrastructures is increasing day by day in such a way that telecommunication systems have been used alongside energy systems (electricity, gas and heating). These developments are such that the generation of cyber-physical networks is being formed, which is a combination of real and physical system performance along with algorithms and software programs in the virtual world. In this regard, it is obvious that research and development in the field of electrical energy systems in terms of equipment and methods of their simulation and advanced control is inevitable.

According to what is mentioned above, the necessity of using real-time simulators of energy networks (electricity, gas and heat) can be summarized as follows:

1- To investigate the behavior of the network in different operating points with the aim of conducting operation and planning studies;
2- To technically test of new electrical equipment and/or novel technologies when connected to the grid and analyze their interaction with the real power systems;
3- To evaluate the performance of operation solutions and analytical algorithms before applying on the real power systems;
4- To educate students, engineers, and operators in a fully-simulated real environment and in the face of different operation situations.

## Project Goals:

The deployment of new technologies and their interaction with power systems needs pre-implementation testing and validation. In other words, the interaction of new equipment on the main grid must be tested in a virtual environment before the connection of their prototypes. This requires testing the electrical equipment in an environment as close as possible to the real world (i.e., HV to LV electrical systems). In addition to equipment test, the novel operation and control approaches of such emerging technologies must be virtually evaluated before physically connecting to the grid or using in the field. Thus, the setting up of a research laboratory can provide a virtual equivalent of power systems for the researcher or operator in which technical solutions and strategies for the use of novel technologies can be tested before practical and real-world implementations, and examine their accuracy, effects and benefits. Therefore, prior to using or connection of new electrical equipment to the real networks with the aim of ensuring the technical and

non-destructive interaction of them on the operation of system, the implementation of bulk power grid simulation labs and electrical microgrids simulators at the level of world-class standards is necessary.

In brief, the outlook of electric power industry in the world shows that in the coming years, having the technical knowledge necessary to manage the future power systems, from the point of view of advanced operation and control methods of emerging technologies will be inevitable. In this vein, one of the fundamental requirements is to have real-time simulation research laboratories.

For this reason, the main purpose of this research project is to assess the feasibility of establishing a laboratory for the study of modern power grids. The most important advantage of real-time simulation laboratories is the possibility of replacing physical devices with virtual ones, which not only reduces costs but also makes it possible to test the technical performance of the power system and its interoperability without any interruption. In this case, many possible changes can be safely tested without physical modifications and under potentially hazardous conditions. Note that the purpose of establishing this laboratory is to provide the necessary research platform for power system studies, and only technical aspects of the system will be considered by lab researchers. Therefore, the analysis, testing and examination of physical, thermal and chemical aspects of the equipment and devices that are specific to the technology itself and can be studied in their specialized laboratories, is not considered by this laboratory.

In brief, the main goal of this simulator as the nucleus of our research lab is to pave a path for validation of different equipment in power system according to national and international standards.

## Abstract:

Due to the recent transformation in power systems (from HV to LV levels) and emerging concepts of smart grids, microgrids, virtual power plants, active distribution systems, high penetration of DERs, new power quality challenges as well as IoT-based monitoring and measurement platforms, the real-time modeling and simulation is absolutely required for the control, analysis and operation of modern power systems. In fact, using real-time simulators, technical studies and control strategies for utilizing new technologies can be safely tested before in-field implementations. In this regard, the setting up of a real-time simulator research laboratory of modern electrical networks in the country can provide a very suitable research platform for various studies of electrical energy systems by researchers, practitioners and system operators.

Accordingly, in this project, the setting up of a real-time simulator-based research lab with the aim of analyzing modern power systems is investigated first. In addition, the primary requirements of real-time simulators are analyzed. After that, the required facilities will be determined in accordance with

international and national standards, and with its help, the technical specifications of the equipment required for the set-up of this research laboratory will be extracted. Finally, the benefit/cost ratio of the decision to purchase or localize this technology will be presented.

## Steps and Methodologies:

Specifically, the main steps of this research project are fourfold:

**Step 1)** To survey the world experiences and extract the fundamental requirements *(the main purpose of this section is to show the necessity of this research)*;

- Expressing the necessity of real-time simulator laboratory by conducting a review of all technical reports and relevant international standards;
- Providing a brief report of visits to similar laboratories abroad;
- Presenting a description of tests that can be performed by standards and guidelines.

**Step 2)** To determine the technical specifications and estimate the purchase price of the lab equipment *(the main purpose of this section is to specify the required equipment of the lab, their technical specs, brands, catalog and price);*

**Step 3)** To design the Laboratory layout*;*

**Step 4)** To provide financial evaluation plan, approximate schedule and estimated validity for equipping and setting up the laboratory *(the main purpose of this section is to estimate the payback time and prioritize, schedule the simulator purchase, and evaluate the cost-benefit of this decision).*

The steps are performed in such a way that after reviewing the experiences of the world and within the country, studies will be carried out to extract the basic necessities, justify the need for equipment, and identify the necessary tests and standards.

Then, the technical specifications of the necessary technologies along with their priority for supplying laboratory equipment (especially, real-time simulator as the critical one) are determined and their prices are extracted.

Next, a preliminary layout of the designed laboratory space and economic evaluation and market study to provide laboratory and research services (for industry and universities) along with forecasting the payback period as well as a schedule including for purchasing, installing and commissioning laboratory equipment to the construction and operation phase will be presented.

## Main Results (technical outputs, patents, papers, books, reports, etc.):

In order to establish a real-time digital simulator laboratory, which imposes significant costs on our institute (i.e., *NRI*), two important questions must be answered:

- **Question 1)** How to provide the main equipment of the laboratory, i.e., the real-time simulator ?
- **Question 2)** How to maintain or technically support this simulator ?

In this regard, we have two solutions ahead, both of which have unique advantages and disadvantages :

- **Solution 1)** To purchase equipment from foreign companies ;
- **Solution 2)** To rely on the knowledge and experience of our young researchers within the country.

However, due to sanctions and currency problems, the second solution can be considered more seriously than in the past, and in fact, in a relatively long-term plan, serious investment can be made in creating indigenous knowledge and expertise in designing the fully-fledged technology of real-time simulators. We believe that by the thorough knowledge and expertise of our scientists in the country in the fields of electronics engineering, power electronics and computer hardware/software engineering, it is possible to think about self-sufficiency in the designing of Hardware-In-the-Loop (HIL) technologies (at least a prototype of Iranian own-built real-time simulator) in a medium-term horizon time and take steps toward the development of by-products and then the main product. Certainly, this requires the development of a technological roadmap which is achievable with the support of a research team of Iranian scientists consisting of digital electronics and microelectronics, computer hardware and software as well as electrical engineers. The detailed descriptions of the proposed solutions and also, the experiences gained from the correspondence with the worldwide pioneer companies in HIL technologies (as the main achievements of this research) have been published in the form of a technical report; perhaps the future researchers can find new paths and opportunities for our country's electricity industry by considering the challenges ahead and without re-experiencing them. The main results of this research project are briefly summarized below.

- To justify a research Lab as an essential workplace for the conduct of cutting-edge research projects.
- To learn more about different applications of real-time simulators in research and practical projects.
- To evaluate and verify the novel technological devices before manufacturing.
- To test and validate the new-built electrical equipment before physical connections with the real grid.
- To identify all facilities and equipment needed for this research lab.
- To design an optimal layout for this lab.
- To find out all opportunities and challenges ahead.