

# Application of Hybrid Real-Time Power System Simulator for Designing and Researching of Relay Protection and Automation

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**Abstract.** Development, research and operation of smart grids (SG) with active-adaptive networks (AAS) are actual tasks for today. Planned integration of high-speed FACTS devices greatly complicates complex dynamic properties of power systems. As a result the operating conditions of equipment of power systems are significantly changing. Such situation creates the new actual problem of development and research of relay protection and automation (RPA) which will be able to adequately operate in the SGs and adapt to its regimes. Effectiveness of solution of the problem depends on using tools – different simulators of electric power systems. Analysis of the most famous and widely exploited simulators led to the conclusion about the impossibility of using them for solution of the mentioned problem. In Tomsk Polytechnic University developed the prototype of hybrid multiprocessor software and hardware system – Hybrid Real-Time Power System Simulator (HRTSim). Because of its unique features this simulator can be used for solution of mentioned tasks. This article introduces the concept of development and research of relay protection and automation with usage of HRTSim.

## 1. Introduction

Currently, task of development, research and exploitation of smart grids (SG) is one of the highest priorities task in power engineering. The development of SG associated with the solution of sophisticated problems focused on radical increasing of controllability and observability of electrical networks and power systems by usage of FACTS (Flexible Alternating Current Transmission Systems).

Planned large-scale integration of high-speed FACTS devices which are used for voltage regulation, power flows and etc. in quasi-steady-state and transient normal and abnormal operating regimes is greatly complicates are dynamic properties of power systems. As result the operating conditions of equipment of power systems are significantly changing.

Such situation creates the new actual problem of development and research of relay protection and automation (RPA) which will be able to adequately operate in the SGs and adapt to its regimes.

Effectiveness of solution of the designated problem depends on using tools. The development and research of RPA requires a large amount of information about the regimes and processes in power systems. Because of it simulators are main tools for such task. Alternative for mathematical simulation in this case is absent because of commonly understood reasons.

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The "ideal" simulation system must meet the following requirements:

- ensure satisfactory simulation's accuracy;
- usage of high-adequate three-phase mathematical models of all primary and auxiliary equipment of SG;
- lack of decomposition of regimes and processes in primary and auxiliary equipment of SG;
- lack of limit of simulation time-interval;
- flexibility of simulated power system scheme;
- availability of integration of RPAs algorithms;
- possibility of physical RPA connection for closed-loop testing;
- possibility of simulation of big (real dimension) power systems.

The complex of these requirements allows removing from the list of "suitable" tools all software simulators. Among hardware and software simulators the most famous and widely exploited are digital simulators – RTDS [1, 2] and eMEGASim [3, 4]. But these devices cannot provide the key requirement – guarantee satisfactory simulation's accuracy, because of usage of numerical integration methods [5, 6]. Moreover, due to the presence of restrictive conditions [5-8]: solutions of the differential equation must satisfy the Lipchitz's condition, the length of the interval solutions is limited by Dahlquist's theorem and others; in most cases we have compromise: to limit the order of differential equations system or the interval of integration, or the total simulation time. The increasing of dimension of the simulated SG necessarily leads to simplification of the power equipment models. Because of it the adequacy and accuracy of the simulation's results are reduced. The simplification (equivalenting) of simulated power system significantly reduces the adequacy of testing and researching of RPA.

Analysis of numerous works devoted to the numerical simulation of power systems and the numerical integration methods shows that achieved results generally remains within the existing theory of discretization methods for ordinary differential equations. Any prospects of fundamental positive changes and deformations of these bounds are absent.

In Tomsk Polytechnic University developed the prototype of hybrid multiprocessor software and hardware system – Hybrid Real-Time Power System Simulator (HRTSim) (Figure 1) [9-13]. Inherent in HRTSim principles allows eliminating methodological error of solving of the elements and SG models, regardless of the differential order, stiffness and time-interval. Therefore, the accuracy of the solution is guaranteed and is determined only by instrumental error of simulator's hardware part. This error is can be minimized by usage of integral precision components.

## **2. Application of HRTSim for designing and researching of relay protection and automation**

However, current version of this simulator not allows implementing the requirement of flexibility of simulated SG scheme. Also there is problem with requirement # 6: user cannot integrate any algorithms or models in HRTSim without source code of its software. These shortcomings, however, are not insurmountable.

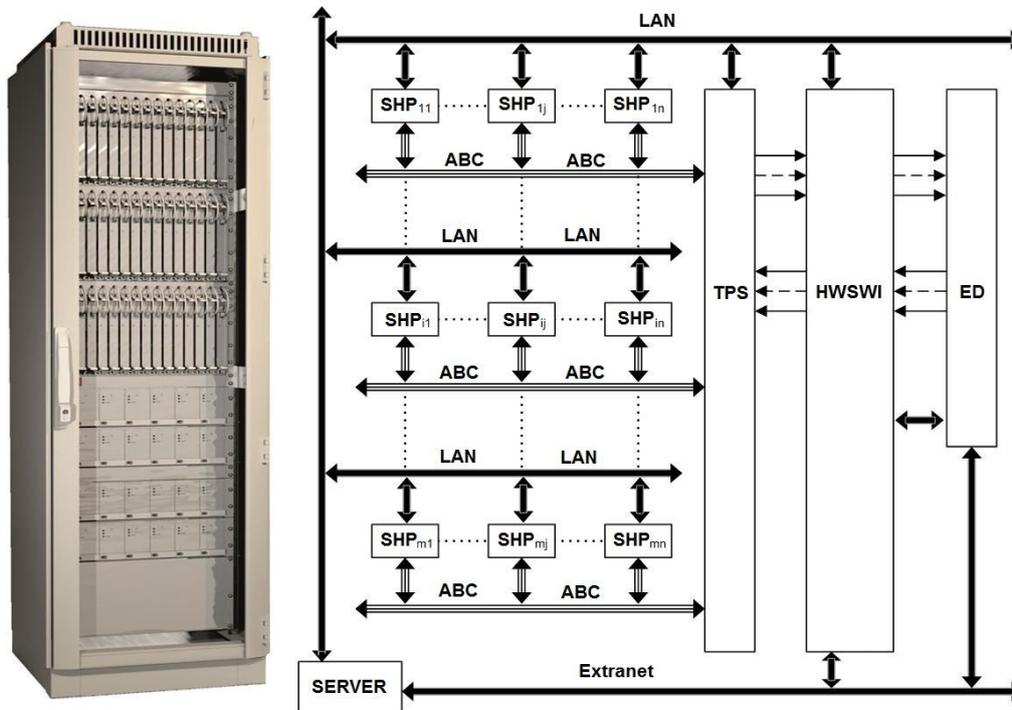
In case of elimination of designated shortcomings HRTSim can serve as the universal platform for RPA developing (Figure 2), including wide-area protection systems (WAPS), as well as for its testing and researching, including closed-loop testing (Figure 3).

The presence of steps 1 and 2 (Figure 2) do not require, according to the authors, any comments.

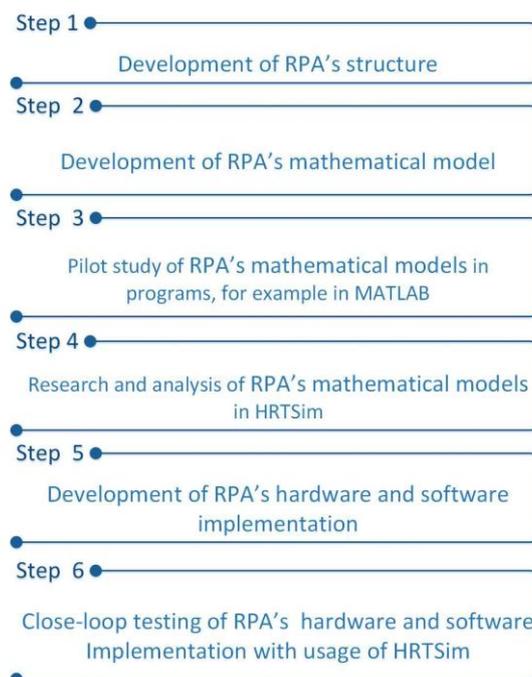
The step 3 involves the initial verification of developed RPA's algorithms. Usage of HRTSim is possible here, however, this stage of development, usually accompanied by a large number of tests and adjustments, which requires frequent usage of the SG model. In the presence of a plurality of parallel developments and only one HRTSim obvious difficulties may arise. And although the simulator allows multi-user mode, this requires concerted actions. If such problem is absent, the apparent barriers for HRTSim using on the stage of pilot studies are absent too. But for this designated shortcomings must be eliminated.

The step 4 allows checking of the developed and debugged RPA's algorithms in operating conditions close to reality for elimination of any errors which was not resolved on step 3.

The step 6 is the last stage which involves usage of the HRTSim. Physical currents and voltages generated in the simulator during a simulation process are sent to the analog outputs of HRTSim and from there, by means of external amplifiers, can be transmitted to the analog inputs of tested RPA.

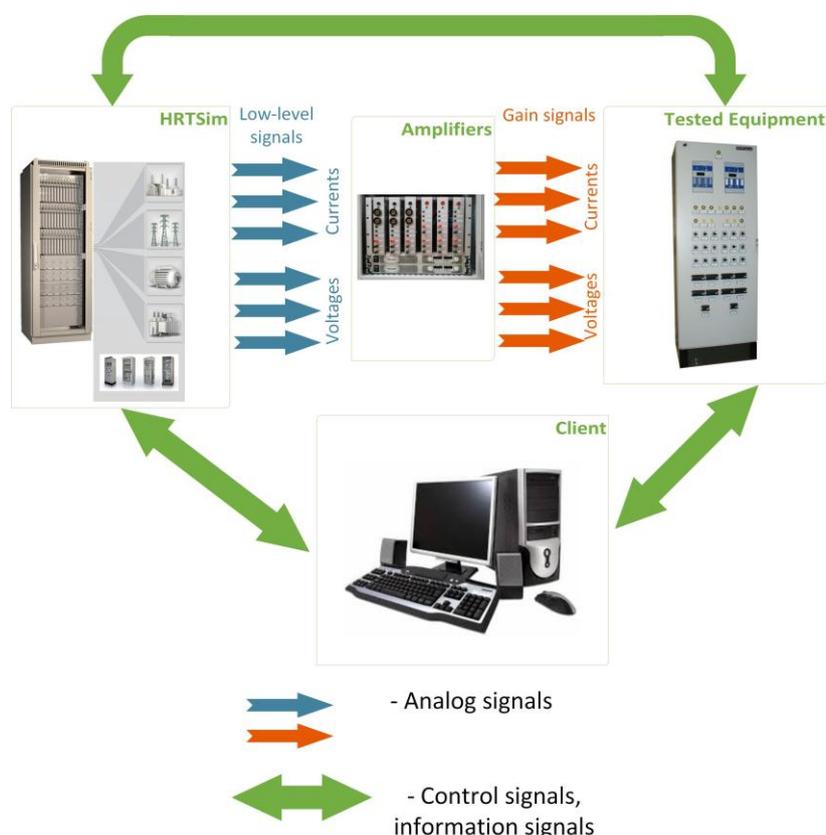


**Figure 1.** HRTSim external view and structural scheme: SHP - specialized hybrid processors; LAN – local area network; TPS – three-phase switch; HWSWI – hardware/software interface; ED – external device; ABC – three-phase input/output of SHP.



**Figure 2.** The proposed scheme of RPA's development with usage of HRTSim.

I want to emphasize once again that the efficiency of research on the steps 4 and 6 will be maximized by using of real-dimension SGs model and accordingly the minimum amount of simplifications and restrictions.



**Figure 3.** Close-loop testing scheme.

It should be noted that the HRTSim allows integrating mathematical models of RPA devices, adequately and reliably reproducing processes in their specific implementations and measuring current and voltage transformers – detailed models [14]. Usage of such models increasing the effectiveness of testing of RPA devices, including the close-loop testing. It is possible because of a detailed analysis of the key functional units of RPA, as well as tracking the reaction of a real device and the model to changes in SG and reliably identifies the causes of inconsistencies in the case of its occurrence.

### 3. Conclusion

In conclusion, I want to emphasize that the "foundation" laid in HRTSim has a unique potential and after additional work the simulator may be used as the universal platform for research and development of any RPA devices, including wide-area protection systems (WAPS).

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