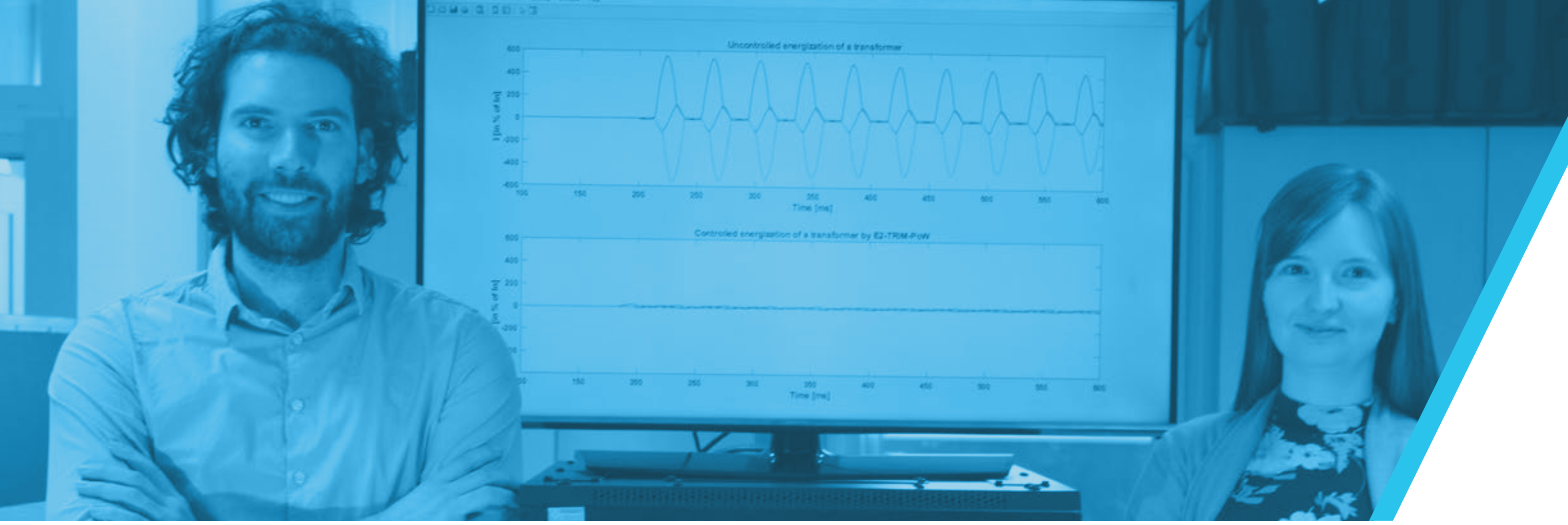


STATE-OF-THE-ART PROTOTYPE TESTING OF PAC DEVICES FOR THE POWER INDUSTRY

Application

- Protection, Automation and Control (PAC)

Related Products

- OP4510, RT-LAB, ARTEMiS

Type of Simulation

- Hardware-in-the-Loop (HIL)

SUCCESS STORY

INTRODUCTION

Protecta Electronics Ltd. is a leading manufacturer of digital protection relays and automation products for the power industry. Headquartered in Budapest, Hungary, Protecta has over 60 years of experience in developing and producing advanced protection and control devices.

Protecta offers a comprehensive range of protection solutions for high- and medium-voltage networks, including power stations and industrial applications. Its product lineup includes high-performance protection systems for feeders, transformers, generators, motors, lines, and busbars.

Beyond protective devices, Protecta manufactures substation automation controllers and specialized equipments such as transformer voltage and tap changer controllers, transformer inrush current minimizers, Petersen coil controllers, and high-speed transfer devices for transformers and incoming feeders.

Many industrial standards require automated testing of protection systems, mandating thousands of simulation-based test cases for validation. The conventional approach involves generated test waveforms using power system simulators and injecting them to intelligent electronic devices (IEDs) via relay testers. While effective, this offline method has limitations.

To enhance its protection system testing capabilities, Protecta Electronics Ltd. acquired an OP4510 real-time simulator. Coupled with OPAL-RT specialized software, this device runs MATLAB Simulink® models in real-time, enabling extensive electrical power system simulation. The solution not only automates testing of individual protection functions but also allows validation of complex protection and automation devices under near-real operating and fault conditions. Additionally, it facilitates coordination testing of multiple protection devices within a system, improving reliability and performance.

DEVELOPMENT

Protecta's Challenges

Protecta has encountered numerous challenges in testing protection functions and systems. As with any critical infrastructure, uncleared faults in the network can lead to severe damage and costly outages. Ensuring product quality and reliability at the highest standards is essential, and this is only achievable with a state-of-the-art testing environment—where a real-time simulator plays a crucial role.

Additionally, some customers require verification that the IEDs they purchase will function as intended. They request or conduct tests applied to their specific use cases and the unique characteristics of their power systems. One key reason for acquiring a simulator was to better meet these specialized customer requirements.

Another significant advantage of real-time simulation is its ability to test protection and control functions more comprehensively than ever before. Previously, testing multiple IEDs on the same network was impossible, as the effect of faulty device could not properly be reflected on the system using pre-generated waveforms. Moreover, certain controller functions—such as transformer tap changer controllers and arc suppression coil controllers—can only be effectively tested in real-time, where network conditions directly influences the behavior of the controller.

SOLUTION

For power system modeling, Simulink® was used alongside OPAL-RT's RT-LAB software, enabling Protecta's R&D team to seamlessly convert existing simulation models into a real-time environment. The simulator generates analog output signals which feed an amplifier, which then injects voltages and currents into the protection devices. The analog and digital outputs from these devices are connected back into the simulator, allowing it to process the signals and dynamically adjust the simulation in real-time.

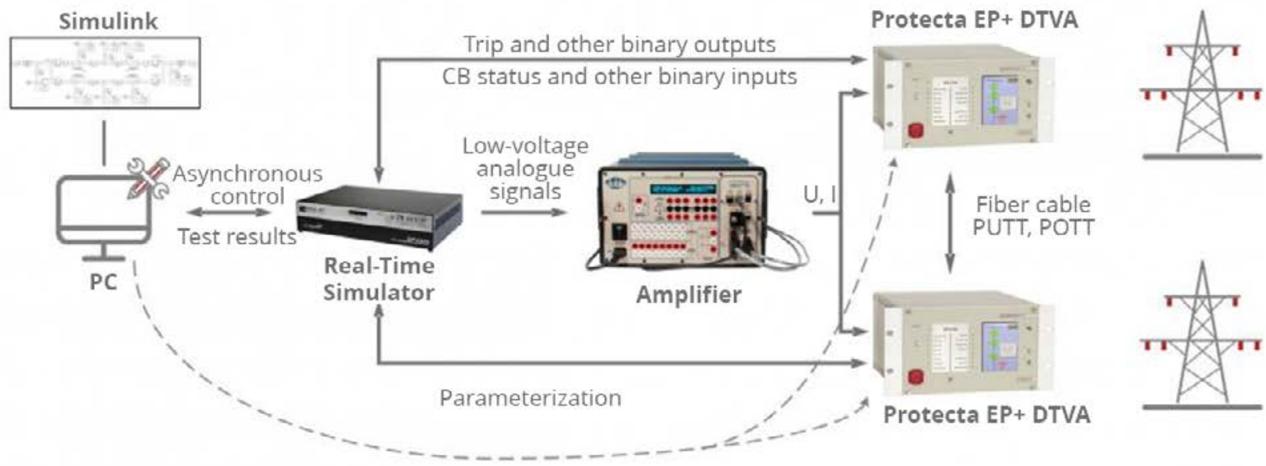


Figure 1 Schematic of a distance protection test

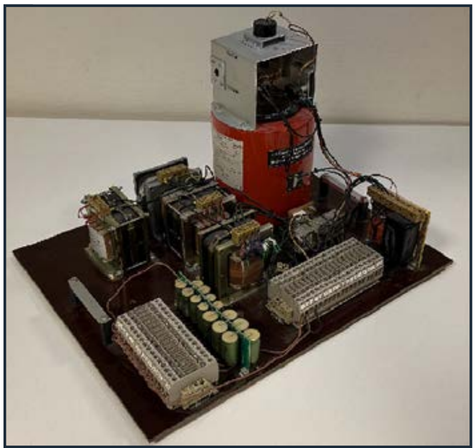
Some models were developed to simulate complex power system phenomena, including evolving faults, magnetizing inrush current during energization, CT saturation, VT failure, power swings, and automatic reclosing. These models support both manual real-time testing—where parameters can be adjusted on the fly—and automated batch testing using Python to run large sets of pre-programmed test cases. Additional models were created using Simulink® and RT-LAB to enhance the testing and development of protection and controller algorithms. One such model focused on the **Point-on-Wave (PoW) switching function** with an integrated **Transformer Inrush Current Minimizer (TRIM)**. This function optimizes switching for transformers, large inductors, and capacitors, preventing high voltage or current peaks due to switching transients. Since switching errors as small as a tenth of a millisecond can significantly amplify these transients, testing of this required the RTS to operate with high speed and precision. Another functional test using the simulator was the **arc suppression (Petersen) coil controller**, designed for compensated networks. This device fine-tunes the arc suppression coil by adjusting its iron core in response to the network's capacitive zero-sequence current.

"The OP4510 Real-Time Simulator from OPAL-RT has revolutionized our R&D and testing processes at Protecta Electronics.

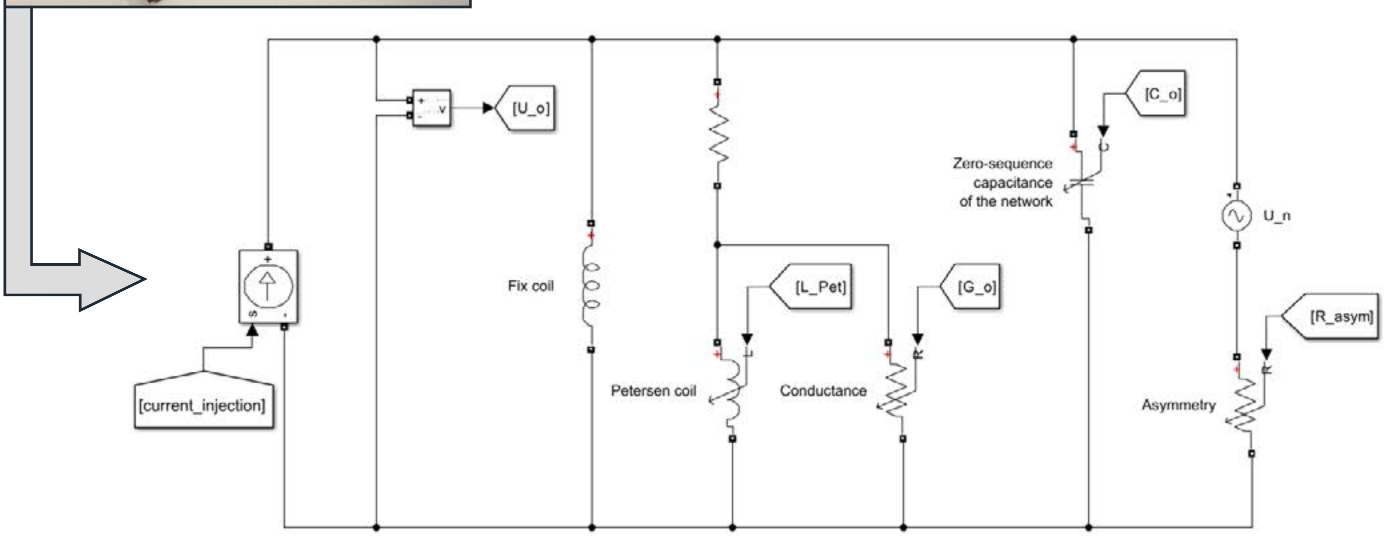
Its Simulink-based operation allowed seamless integration of our existing Simulink models, making it easy to transition to real-time environment.

The simulator enables automated testing of a large number of test cases in a very simple way, saves time and ensures compliance with international standards and customer-specific requirements."

Kristóf Hackel, Chief R&D Officer



The Electric Model to Test the Arc Suppression Coil Controller and the Simulated Network



Accurate tuning minimizes the fault current during single-phase-to-earth faults, often preventing outages. The controller continuously measures the network's zero-sequence parameters and adjusts the coil position accordingly. Since coil movement directly impacts residual voltage, real-time simulation was essential—both parameters had to be changed simultaneously for valid measurements. Previously, tests relied on a physical electrical model with real capacitors, inductors, and a small motor drive, but this setup lacked flexibility. With the simulator, a broader range of network parameters could be tested, eliminating inaccuracies inherent to the physical model.

CONCLUSION

The integration of the OP4510 real-time simulator has proven highly effective in the research and development of digital protection relays, significantly expanding the range of tests that can be conducted. Beyond R&D, the real-time simulation system has been instrumental in demonstrating the performance of Protecta's protection devices during **accreditation and homologation processes** required for entering into new international markets.

Looking ahead, Protecta aims to further expand its library of real-time test scenarios, including tests for busbar protection and line differential protection. Additionally, the company plans to develop new simulation models to streamline the design and validation of protection and controller functions. The simulator will also play a key role in establishing the necessary hardware environment for testing applications related to the **IEC 61850-9-2 Process Bus** standard.

"Real-time simulation has simplified the testing of controller functions, eliminating the need for complicated physical electrical models while improving precision.

Additionally, the RTS allows us to test the coordination of multiple devices, their behaviour and impact on each other."

Annamária Tóbiás-Bíró, S&A Development Engineer