EFFICIENT GRID OPERATION AND MAINTENANCE WITH SIMULATION APPS

Engineers at NARI Group developed a customized Cable Condition Analysis Expert System App based on their multiphysics model to accurately predict cable faults and improve troubleshooting efficiency.

By **ZHANG QIQI**

ELECTRIC CABLES AND WIRES are hailed as the "blood vessels" and "nerves" of China's national economy, providing the foundation for electric power infrastructure construction, the smart grid, and new energy industries.

The demand for cable lines increases as China's economy continues to grow. Increased power load can cause parameter fluctuations of electrical systems or momentary interruptions. This may lead to grid equipment malfunction, or, in extreme cases, fires and explosions. Routine maintenance of cable systems helps to keep the economy growing and customers happy, while failure protocols allow for speedy electrical recovery.

Electrical equipment needs regular assessment to prevent sudden power outages, where testing equipment such as infrared, ultraviolet, and partial discharge are used. However, these routine "health tests" are not able to fully reflect a cable's condition or determine failure types in many situations. Additionally, cables are installed in different environments, such as underground, within tunnels, or up in the air, adding unique challenges to detection work.

ACCURATE CABLE HEALTH ASSESSMENT REQUIRES SIMULATION

TO KEEP POWER RUNNING, in addition to relying on traditional testing equipment, engineers must take other factors into consideration, for example, cable structure and material, impurities in the cable,

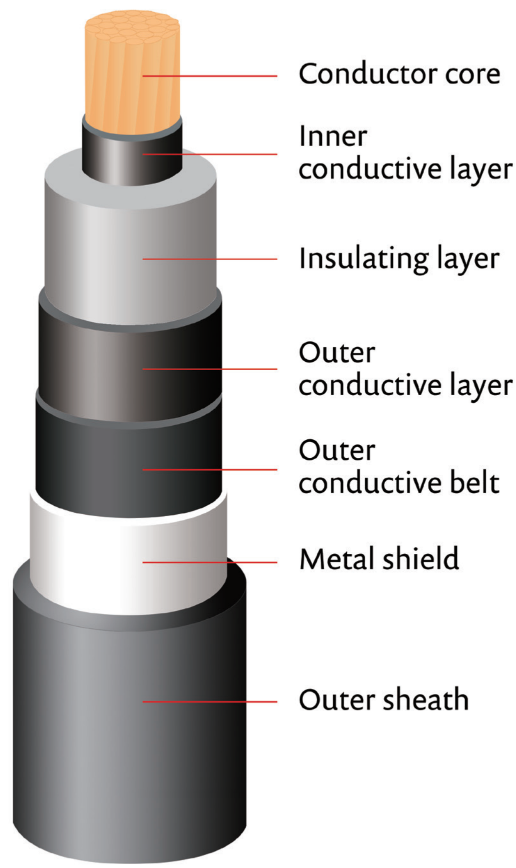

Figure 1. Schematic of a standard cable structure.

Figure 2. Left: Water tree caused by the interaction between the electric field and moisture. Right: Close-up of the mechanical damage to the insulation layer.

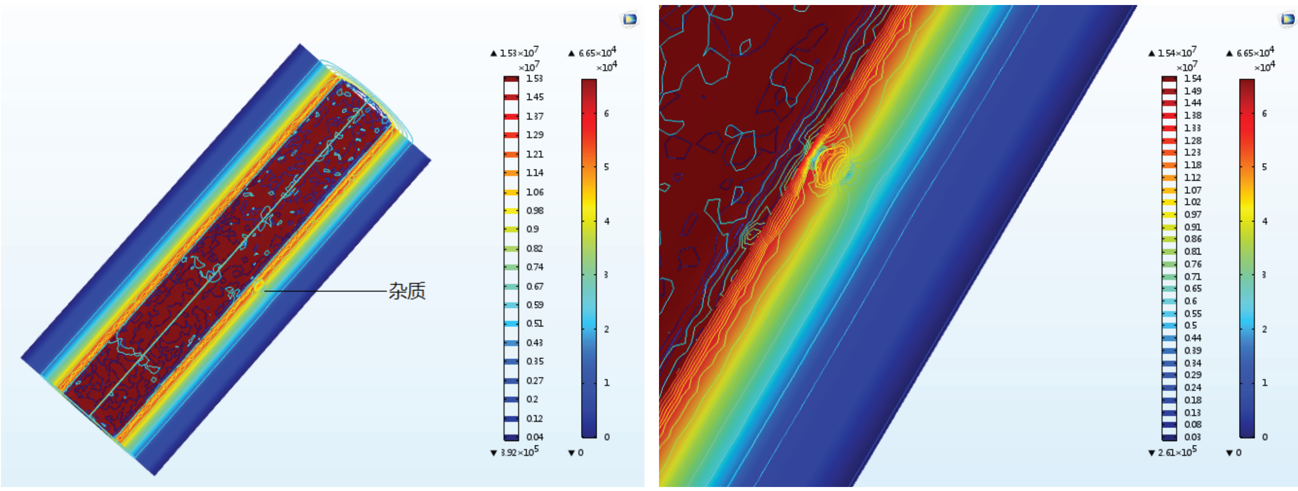

Figure 3. Left: Simulation results of a cable with impurities included, showing potential distribution and electric field norm contours. Right: Detailed view of the electric field.

voltage fluctuation, and operating conditions and environments.

Wuhan NARI Group Corporation (NARI) of the State Grid Electric Power Research Institute is affiliated with State Grid Corporation of China. NARI focuses on research and development, design, manufacturing, and engineering services for power transmission and transformation products. NARI also works with local power companies on equipment maintenance and failure analysis. Given the many parameters and physical phenomena involved, a team of engineers led by Jing at NARI used simulation to investigate changes in electrical fields due to factors, such as health of the cable system, and failure causes.

HOW WATER TREES AFFECT CABLE HEALTH

CABLES ARE MADE UP of a complex multilayer structure. The wire core consists of one or several sets of mutually insulated stranded wires, wrapped in a highly insulating layer (Figure 1). When inducing factors such as moisture, impurities, protrusions, or space charge, occur in the insulating layer, part of the insulation material will develop tree-like microchannels as a result of the combined action of moisture and an electric field. In operating cables, the electric field forces moisture to displace in such a way that it continuously accumulates at the fault spots. This results in mechanical damage to the insulating layer and expanded damage to the insulator. This phenomenon, known as "water tree" is regarded as the main cause of damage in high-voltage cables used for power transmission (Figure 2).

To understand the impact on cable health, NARI's engineers used multiphysics simulation to create a cable model. "COMSOL Multiphysics® features a user-friendly interface and predefined physics interfaces that make modeling easy to adopt organizationally" said Jing Zhang, engineer at NARI.

Simulating the cable fault required two steps. First, they set the radius and electrical properties of the materials in each layer of the cable and calculated the normal electric field when a high voltage is applied. The next step was to introduce parameters representing impurity and the presence of a water tree layer. "Assessment of cable health entails analyzing its behavior when deteriorating material properties and the formation of water trees are considered, and the COMSOL® software makes this easy to do," Zhang explained.

In comparing the results of the electric fields under normal and abnormal conditions, the engineers were able to reach an accurate understanding of the impact of the impurities and water trees on the cable's performance. The electric field of standard cables only involves lines of electric force that point to the shielding layer along the radius of wire; therefore, the electric field distribution is uniform. Once impurities are added, as shown in Figure 3, the uniform electric field is disturbed. Once a local electric potential difference exceeds the maximum allowable voltage in the insulating layer, the

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layer is compromised and will break down in a relatively short time.

BRINGING A DIGITAL TWIN TO THE FIELD

SIMULATION OFFERS a vast landscape of knowledge of cables to engineers at NARI. However, when cable failure occurs in the real world, troubleshooting personnel are not trained to use the digital twin provided by a multiphysics model to analyze failure causes based on real-time data. In remote areas, it may take days or even weeks to invoke an expert to conduct a site survey and remove the fault. If on-site troubleshooting personnel are able to understand what condition led to the failure through simulation, the troubleshooting work is greatly simplified. To enable maintenance personnel to respond in real time, Zhang developed a simulation app featuring relevant parameters that the troubleshooting personnel can modify. A simulation app can be created from any multiphysics model using the Application Builder in COMSOL Multiphysics.

The Cable Condition Analysis Expert System app (Figure 4) allows the field technicians to directly enter data from the cables and select the type of fault, thus modifying the underlying multiphysics model on the fly, to calculate and output the data necessary to understand what caused the fault. The app quickly yields a reported potential and electric field, which guides the technicians to determine whether it is necessary to replace or repair the cable. “The simulation app plays a key role in cable maintenance. It makes the work of our field technicians more efficient by empowering them to confidently assess and repair faults,” Zhang said.

The Cable Condition Analysis Expert System App developed by NARI is adopted by a subordinate unit of Guangxi Power Grid Co., Ltd. Repair personnel, who use it to predict cable faults and maintain the normal operation of the power grid system in southwest China. ◎

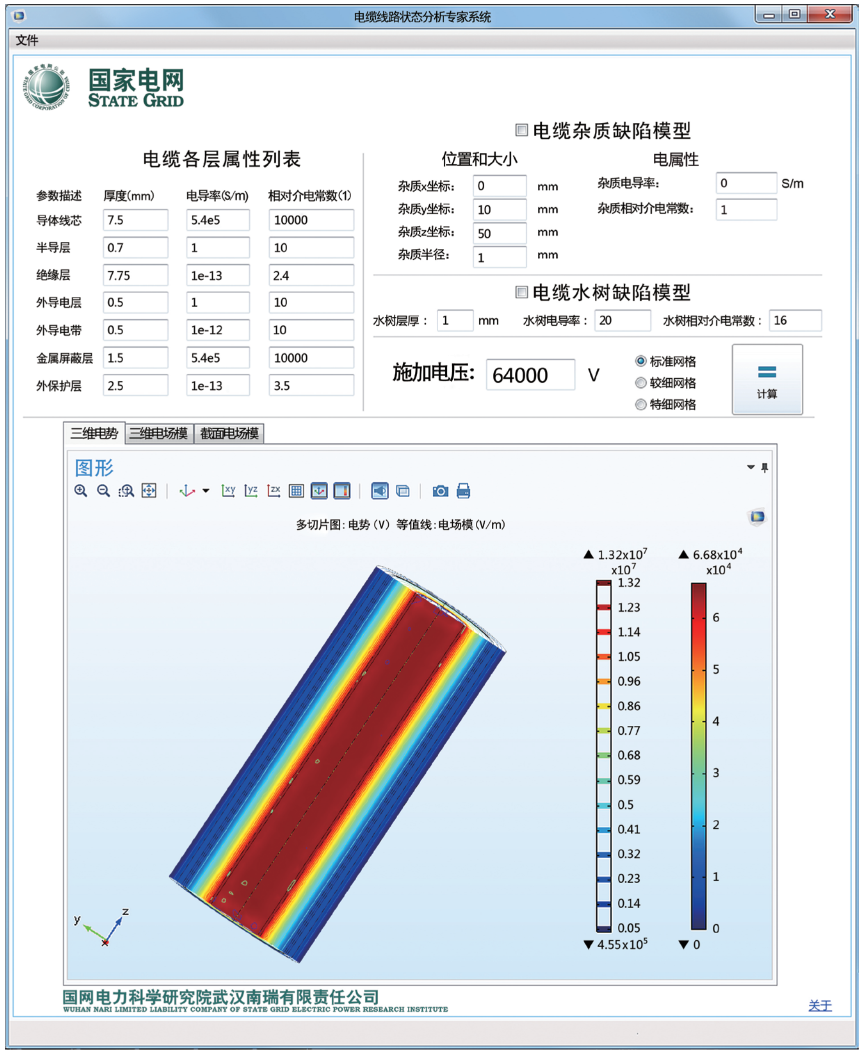
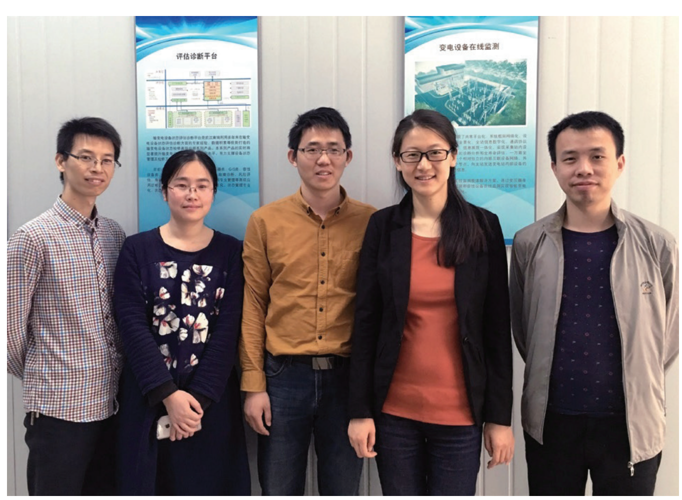


Figure 4. The Cable Condition Analysis Expert System app.



Members of the simulation research team, part of the Shipment Inspection Services Division at NARI Group Corporation. Left to right: Zhao Chen, Ting Hu, Tiyou Fang, Jing Zhang, and Hao Wang