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NEW DESIGN AND ADVANCES IN TECHNOLOGY

Digital Twins: **Revolutionizing Testing of Protection Relays**
Power Cable Systems Reliability and Longevity: Past, Present, and the Future
Cost Effective **Methods for Repairing Oil and Gas Leaks**

Digital Twins: Revolutionizing Testing of Protection Relays

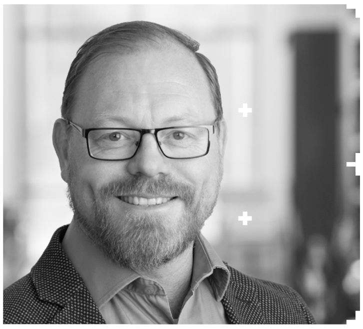
by **Niclas Wetterstrand**
and **Andrea Bonetti**

Simulating an asset's physical or functional performance in a computer – a digital twin – has delivered benefits in engineering for decades.

There are now companies who have developed and are enabling this technology in the relay protection engineering and testing world.

This has allowed companies to continue carrying out a range of tasks despite the travel bans and social distancing measures that have arisen during the COVID-19 pandemic.

Beyond that, benefits like cost savings, work force utilization, comfortable working hours, and trained personnel, are being achieved.



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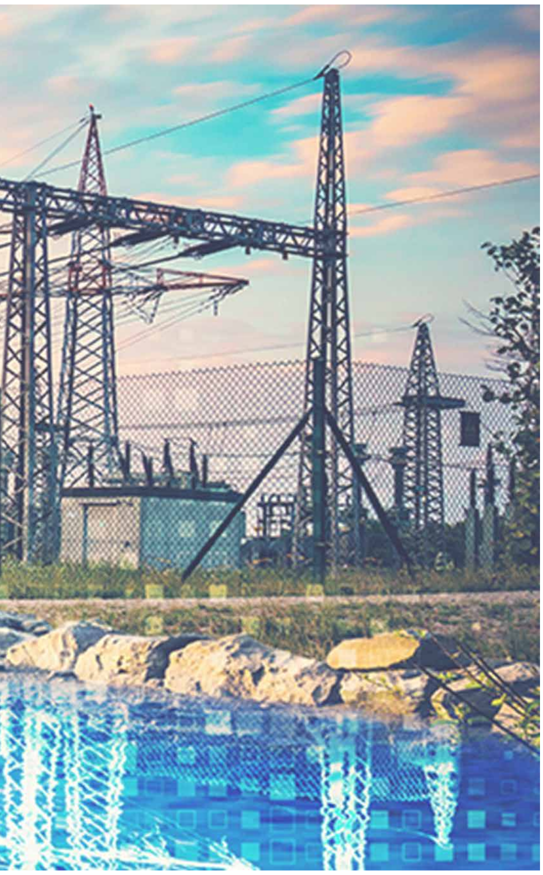


Andrea Bonetti is Senior Specialist in power system protection and IEC 61850 applications at MEGGER SWEDEN AB. Prior to that he worked as product manager and technical specialist for relay test equipment and IEC 61850 test set and tools at Megger for 7 years, and has 18 years of experience as HV power system protection specialist at HV relay protection manufacturer ABB Grid Automation Products. Andrea is member of the IEC TC 95/MT 4 and TC 95/WG 2 committees, and he received the IEC 1906 Award in 2013. He holds a patent in the area of IEC 61850 testing tools and algorithms. Andrea obtained a master of science degree in electrical engineering from Sapienza University of Rome, Italy.

A digital twin is a digital copy of a physical asset. This concept has been used for a long time within the power industry, for instance, when designing the physical layout of a substation. If the digital copy is well made and the creation tool enables the drawings to be generated automatically, the physical build of the substation and its components should fit perfectly together and within the defined footprint, without rework. Simulation of power networks functionality is frequently used to justify designs and calculate relay protection settings. Even functional simulation down to asset level happens today, but that is a generic simulation of a function. The benefit is that the system is proven to work in the digital world, and if the setup in the virtual world is well designed, it is highly likely to work in the real word.

DIGITAL TWIN TECHNOLOGY SIMULATES AN ASSET'S PHYSICAL OR FUNCTIONAL PERFORMANCE.

Today, this concept has been taken one step further with the development of a cloud-based digital twin of protection devices. The relay protection functions in the digital twin have been cloned from the physical asset so the behaviour is identical. User interfaces like the front panel buttons and display are the same and the configuration software is used as one would do with a physical relay. The environment also allows a system of digital twin IEDs to be connected so a larger installation can be set up virtually.
This opens new possibilities since the relay setup can be tested in every degree; but to do that, a way to simulate the electrical properties of the power network virtually is needed.

A digital twin of a test equipment is doing exactly that. Instead of generating voltages and currents as the physical product would do, its digital twin is providing these signals digitally. With this test setup, when the digital twins of both the protection relay and test set interoperate, it is possible to evaluate the virtual protection relay functions with so called "virtual testing".
This unlocks enormous potential to perform a lot of test activities virtually instead of relying on the traditional way with physical assets.

Remote FAT

Factory acceptance testing (FAT) is normally performed at the supplier's or contractor's site to ensure that the selected components both are configured properly and work together in the way that the system was designed. This means that all equipment needs to be sent to the same location and installed and wired temporarily, which is both costly and time consuming. This is still viewed as a time saving and important step since it proves that the system works as designed. Plus, when problems arise, and they always do, the project team can troubleshoot in a controlled environment and during a less stressful project phase than that of the actual commissioning. Furthermore, the technical experts are either involved to support this activity or at least physically nearby, so it is easier to get their support than when being out in the field.

The digital twin environment creates notable advantages in the context of FAT. The process of setting up the system with digital twins, the so-called "digital twin ecosystem", requires a small effort but saves time and a notable net cost over the use of real assets. These savings are achieved because the need for transportation and temporary wiring are eliminated.

THE CONCEPT OF THE DIGITAL TWIN HAS BEEN TAKEN A STEP FURTHER WITH THE DEVELOPMENT OF A CLOUD-BASED DIGITAL TWIN OF PROTECTION DEVICES, OPENING UP NEW POSSIBILITIES IN THE RELAY PROTECTION ENGINEERING AND TESTING WORLD.

To create the digital twin ecosystem, simply select the required assets in the digital twin system and

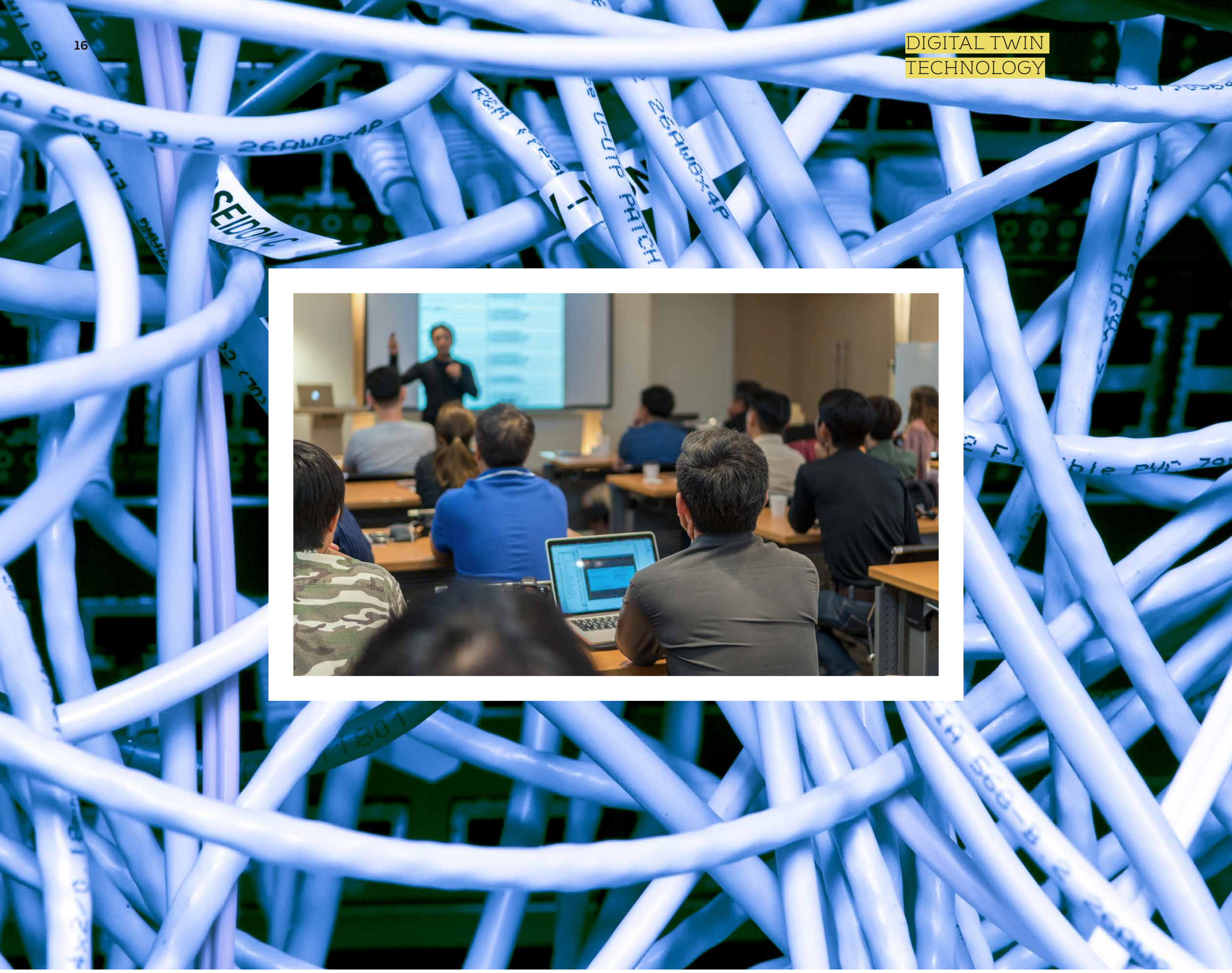


Photo: Megger

digitally connect them with a few clicks. Once it is set up, this system can be accessed and worked upon by many engineers in parallel, which gives opportunities to reduce the lead time.

In addition, these engineers can comfortably work from their desk during their normal work hours instead of travelling to the FAT site. If they need to be at a different location, engineers can access the digital twin wherever they are in the world, if they have access to internet. Virtual FAT with digital twins has been extremely valuable during the pandemic where travel bans, and social distancing have been imposed.

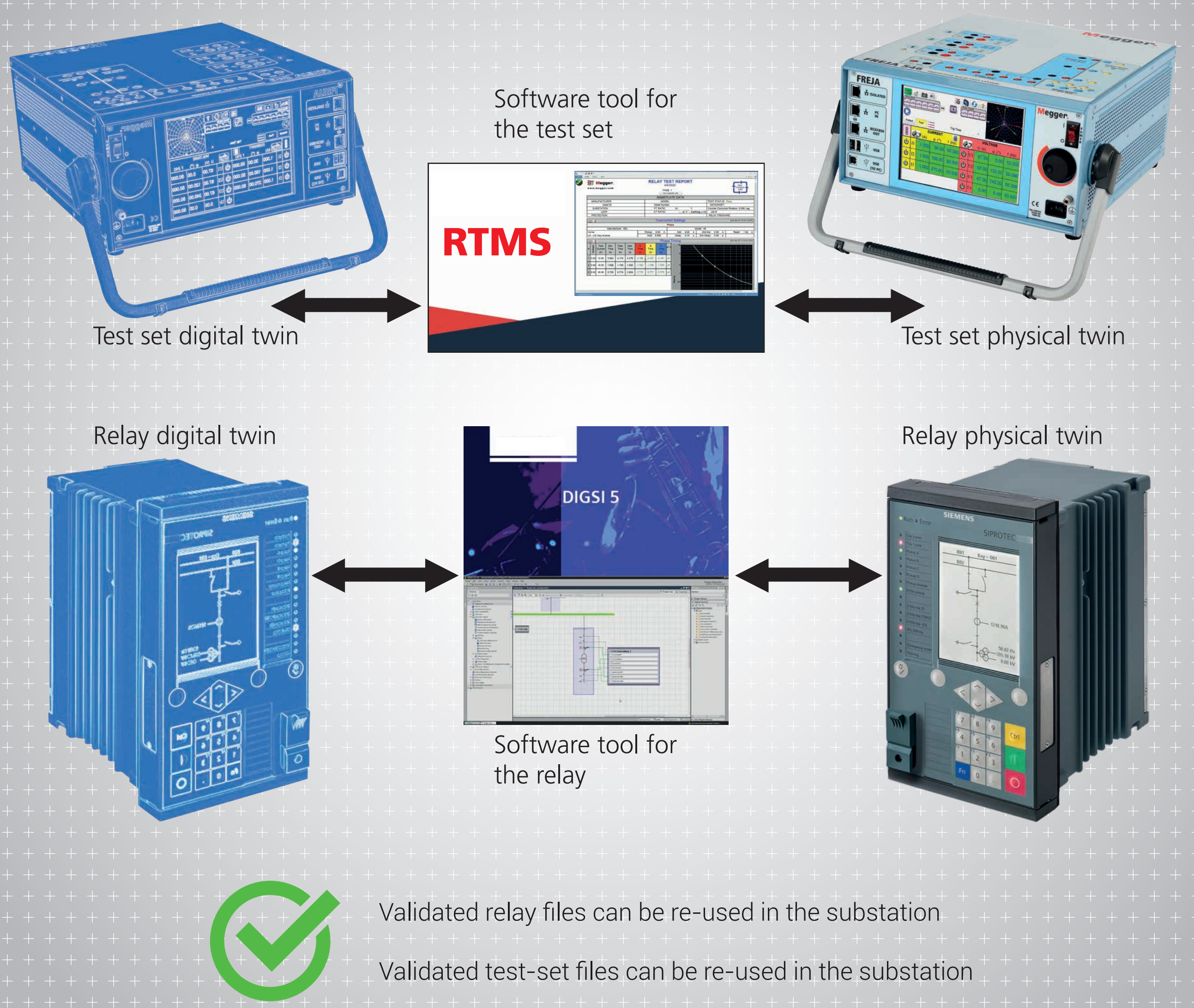
Commissioning

The benefits don't end with the validation of the protection system design. A subset of the tests that were created in the digital twin for the test system can be reused later when arriving at the site. This saves time in the time critical commissioning phase. This also gives the commission engineer confidence that the system has worked before so the troubleshooting of problems that arise in this stage can be focused on hardware and connection issues. Furthermore, the digital twin system should be saved for future use in training, remote support, or when validating ensuing upgrades.

"But wait a minute", say the professionals, "we didn't capture any tests of the hardware and the physical connections?"

WHEN THE DIGITAL TWINS OF BOTH THE PROTECTION RELAY AND TEST SET INTEROPERATE, IT IS POSSIBLE TO EVALUATE THE VIRTUAL PROTECTION RELAY FUNCTIONS WITH SO CALLED "VIRTUAL TESTING". THIS UNLOCKS ENORMOUS POTENTIAL TO PERFORM A LOT OF TEST ACTIVITIES VIRTUALLY INSTEAD OF RELYING ON THE TRADITIONAL WAY WITH PHYSICAL ASSETS.

Yes, this is true, and this cannot be skipped before the system is put in service. Then the question becomes: How many times do we need to test the hardware before it is placed into service? It is already done in the factory when the asset passes its final quality assurance test; can we rely on that? To fully benefit the virtual FAT, the answer is yes. The hardware tests performed in the FAT are then moved



t o the site and taken care of in the commissioning phase.

The key factor for a successful virtual commissioning, and a subsequent site commissioning, is the reusability of the data between the digital twins and the physical twins. Put differently, the digital twin and its physical twin must be able to share the same data.

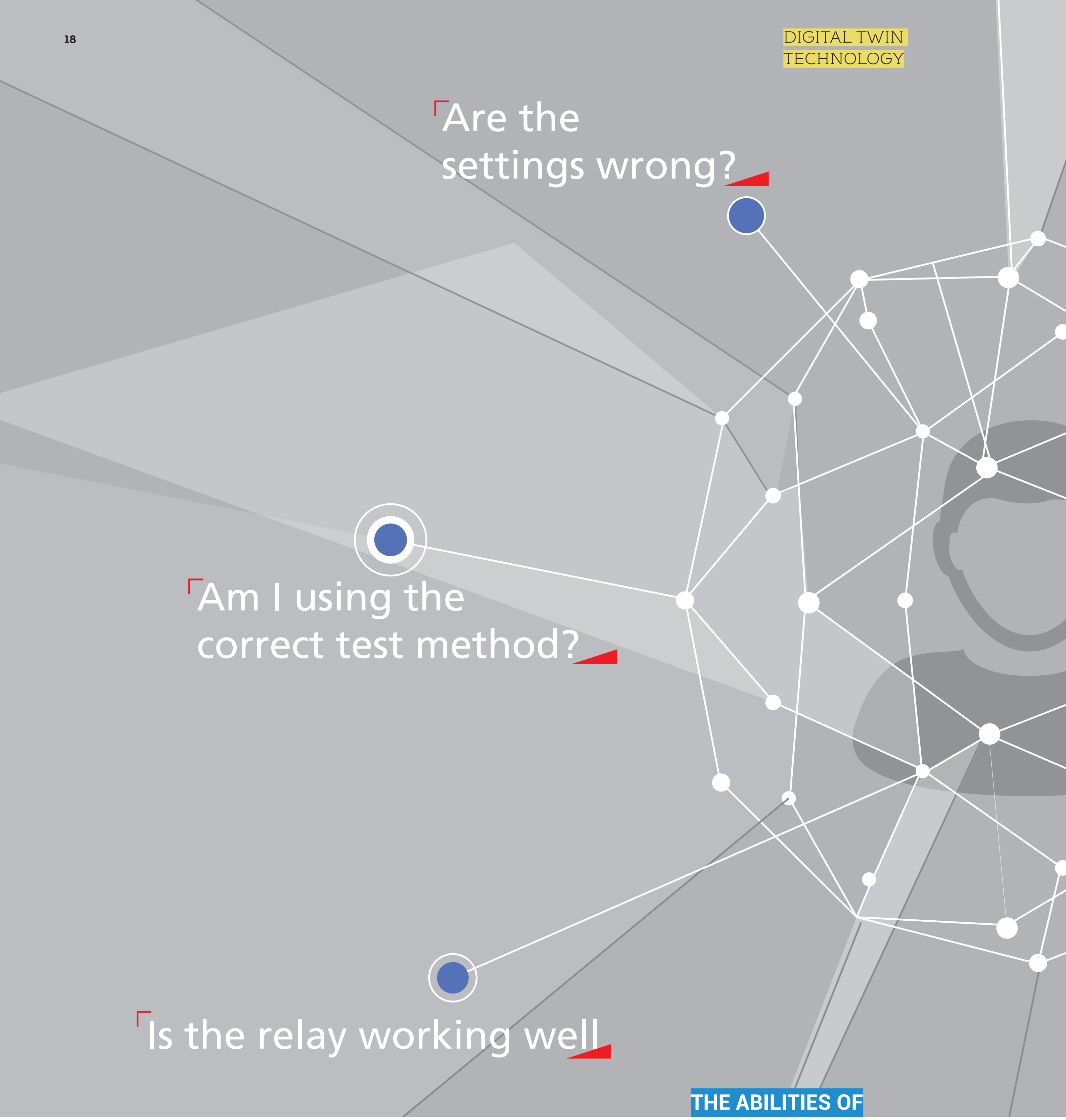
With this data sharing approach, the test files that were validated during the virtual tests, where digital twins were used, can be reused by the physical twin test set. The same is true of the relay protection data (settings, configuration etc...): the setting file validated during the virtual tests can be transferred to the physical twin, minimising the risk of mistakes, increasing the quality of the delivered protection system, and contributing to great time savings.

THE DIGITAL TWIN TECHNOLOGY CAN PLAY AN IMPORTANT ROLE IN THE SUBSTATION LIFE CYCLE IN THE EVENT OF AN UPGRADE – FOR THE CONFIRMATION OF HOW THE REPLACED IEDS WILL OPERATE IN THE OLD ENVIRONMENT, FOR TESTING THE SUBSTATION EXPANSION DESIGN, AND FOR HOW THE NEW SECTION WILL WORK WITH THE OLD.

Training

Wouldn't it be wonderful if there was a possibility to get familiarised with the substation that's going to be commissioned beforehand? Well, you guessed it, with the digital twin this is possible. Personnel can get training not only on the actual IEDs used in this project but also on the system where the IEDs are working together. Training after completion of the virtual FAT is possible as the test equipment and the prepared test files used for this FAT are available. This preparation gives greater confidence that the commissioning will go according to plan and minimises the risk of being caught off-guard by something unexpected.

For junior engineers, this is even more valuable since experience can be built in a comfortable home environment where mistakes aren't hazardous or costly, as they don't involve live voltages and hardware that can be damaged. Plus, expert guidance and support is nearby. As with the FAT, the training can also be performed in parallel, where all students have



access to all parts of the system at the same time, and they all have their own digital twin of the test equipment to work with. This is very different from how training with physical assets is performed, wherein a group typically has access to a limited number of relays and test equipment.

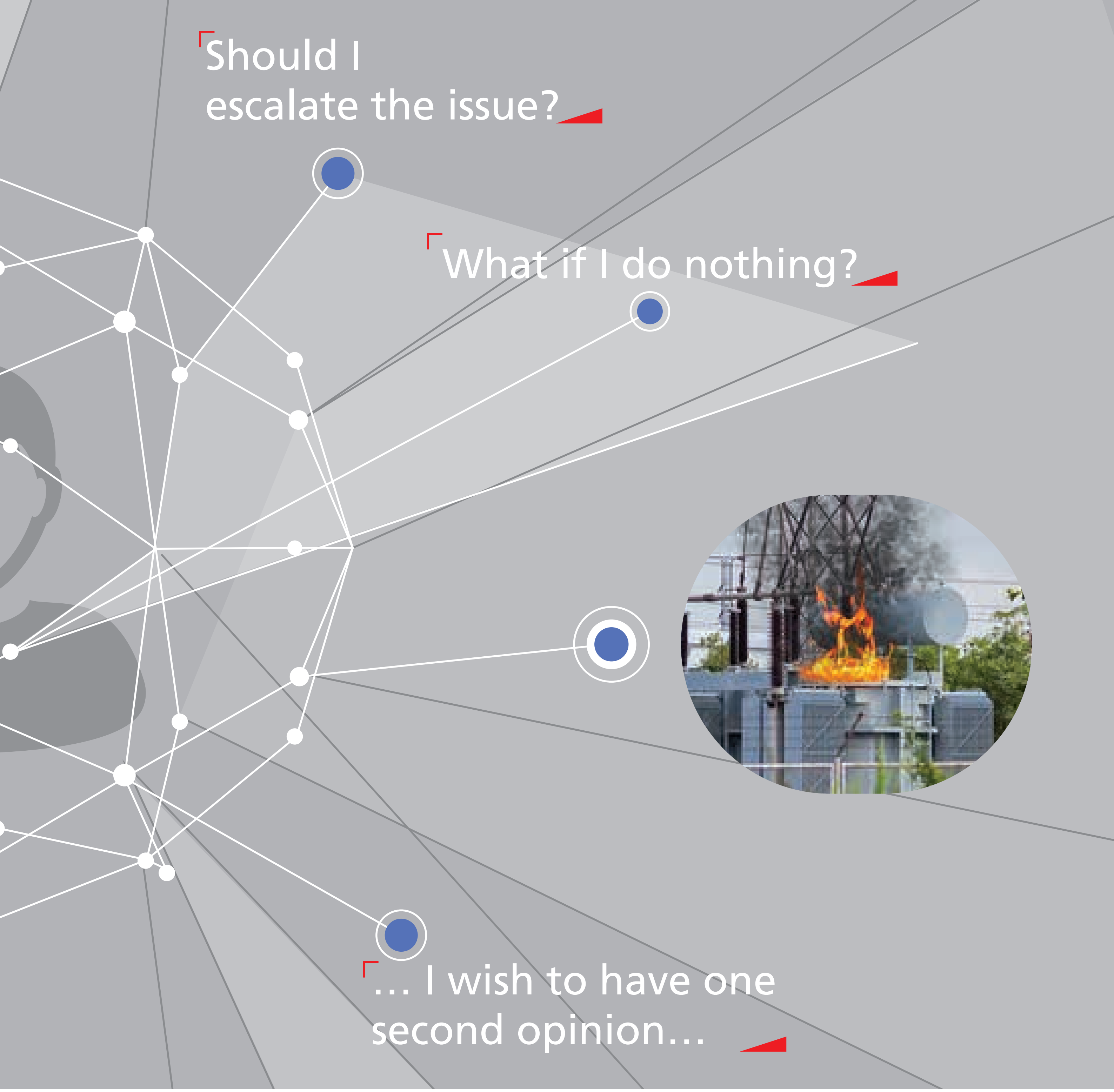
Remote support during commissioning

Commissioning is normally the last phase before the substation is put in service to start generating revenue. Therefore, there is normally high pressure to deliver the project on time. Mistakes and problems get high visibility and might affect the delivery date, and solving problems, under pressured time, is in many cases notably inefficient. To enter this phase with a system that

THE ABILITIES OF DIGITAL TWINS CAN OFFER SIGNIFICANT HELP WITH RESEARCH AND DEVELOPMENT, CHALLENGING TEST TASKS WITH GREAT DISTANCES BETWEEN IEDS, OR SITUATIONS WHERE A SUPER-TEST SET WOULD BE NEEDED.

has already been tested virtually, with the test files already created, and the engineers trained, is a great step forward. However, all who have been part of a commission-

Photo: Megger



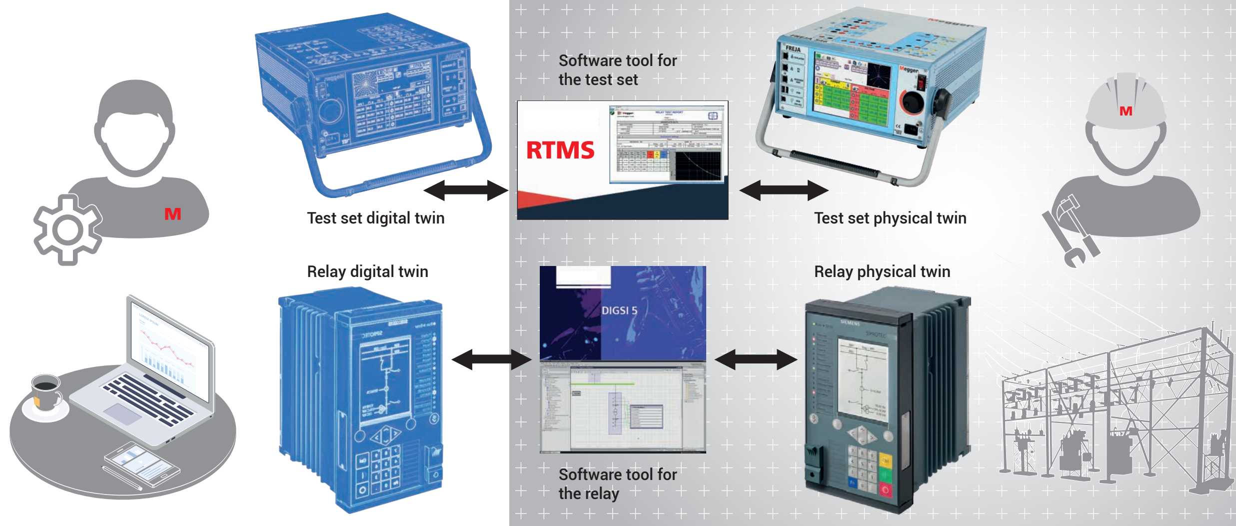
ing job know that there are always some uncertainties, which may lead to problems that need to be solved on the fly. Typical questions from commissioning engineers, experiencing doubts, are:

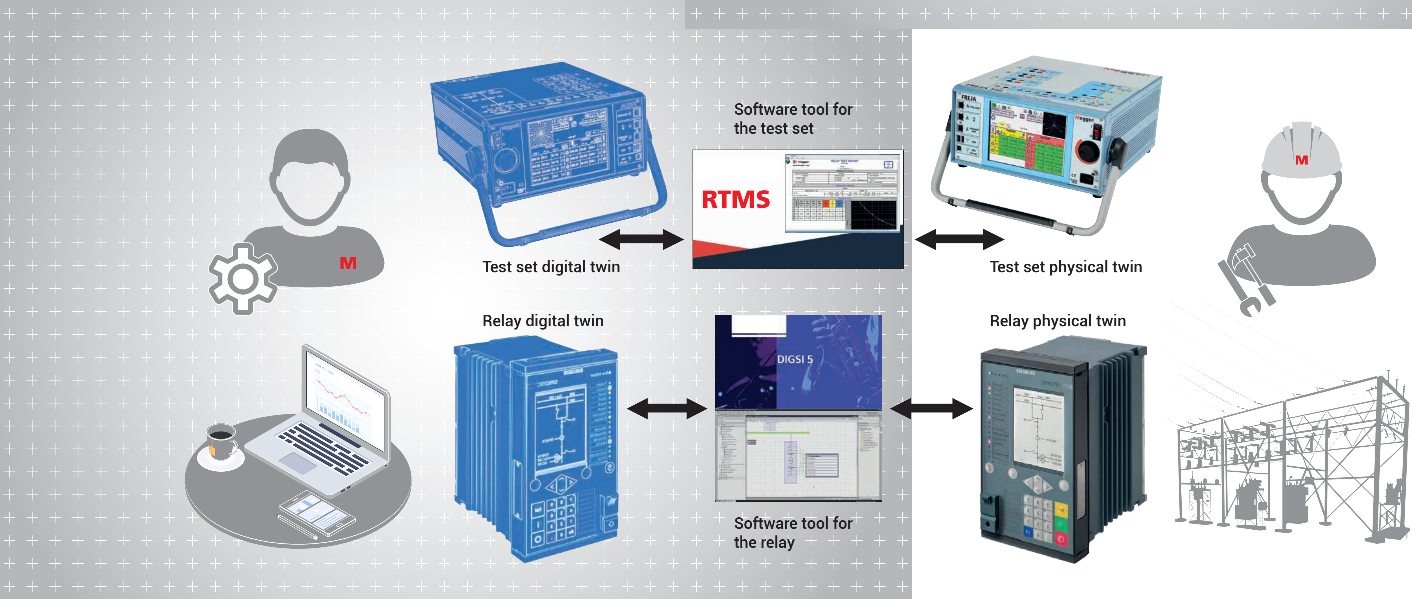
- Is the relay performing correctly?
- Am I using the correct testing method?
- Should I escalate this issue?
- What happens if I do not escalate it?
- Who can help me with a good 'second opinion'?

Navigating these nagging concerns is all in a day's work for commissioning engineers, and they do it very well. However, sometimes even these talented people get stuck, or at least like to get a second opinion to ensure their proposed solution is appropriate. This is where the digital twin again provides a huge benefit.

A problem discovered during commis-sioning can easily be replicated so that more experienced experts back in the factory both, can see the problem for themselves, and propose a definitive working solution. The actual setting files and testing files from the field are read from the physical devices and are sent to the expert who loads the received data into the digital twins and can start troubleshooting.

When the problem is found and corrected, an updated settings file with corresponding updated tests are returned to the commissioning engineer. These files are now reused





and tested in the field to make sure the problem is solved, even though the likelihood is high that the problem is solved, since it has already been confirmed with the digital twin. The digital twin technology enables the technical expert to be present when needed, without travel or disruption to normal working hours. The technology also allows high level specialists to be present on test activities that are too demanding for average technicians. This way the specialists can contribute to decreased mistakes during on-site commissioning testing.

Firmware or hardware updates

Finally, the digital twin technology can play an important role in the substation life cycle in the event of an upgrade. This may range from a small firmware upgrade to something lager, such as an upgrade of several IEDs or extending the substation capability. In the example of a firmware upgrade, the substation owner wants to make sure that this upgrade will not affect the IED protection capabilities. By making a few successful tests in the digital twin environment, the substation owner confirms that the firmware upgrade will not cause an unexpected interruption, or worse, insufficient protection of the network assets. This will ease the minds of both the one responsible from the supplier and the substation owner.

Major upgrades to an existing system, such as multiple IED replacements or a substation expansion, are rather commonplace since many power grids were built a long time ago, and have capabilities that are reaching their limits with today's increased demands for electrical supply. These projects are like new installations, but the new parts need to work with the old installation, therefore the digital twin is beneficial for the confirmation of how the replaced IEDs will operate in the old environment, for testing the substation expansion design, and for how the new section will work with the old.

Conclusion

The digital twin technology exceeds what standard simulation tools can perform today. To have an exact functional digital copy of the IEDs and the test equipment that also can interact with each other has proven to provide benefits in the areas highlighted in this article – FAT, Training, Commissioning, and Upgrading – and it doesn't stop there! The abilities of digital twins can offer significant help with research and development, challenging test tasks with great distances between IEDs, or situations where a super-test set would be needed. The digital twin marks a new era of substation verification and will drive increased quality and reduced costs for the delivered protection systems.

Photo: Megger