ELECTRICAL TESTER SPECIAL

VIRTUAL TESTING OF PROTECTION RELAYS IS *REAL*!

ISSUE 003 / 2021

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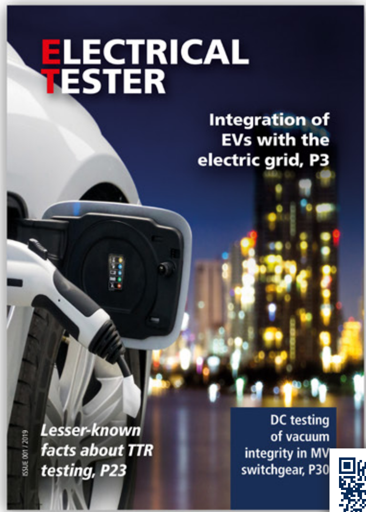
Issue 1



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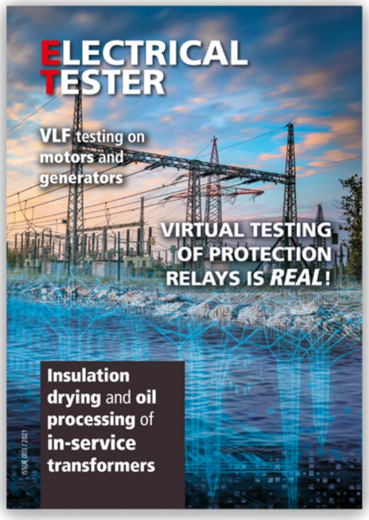

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Letter from the Editor

Jill Duplessis

Dear readers,

I am very excited to bring you this latest issue of Electrical Tester magazine!

Before we begin, I'd like to recognise the excellent contributions from our esteemed, non-Megger colleagues: Cedric Harispuru, Greg Steeves, Xicai Zhao, Ersan Kabalci, Murty Yalla, Thierry Bardou, and Volker Leitloff. Thank you all! Our ET readers are avid consumers of electrical testing content and are well-served by having such varied voices discussing so many topics. Many years ago, as a young engineer, I was tasked with leading the development of a transformer field processing guide. What I would have given to have had Greg's article on this subject to aid me in sorting all of the approaches!

I also extend praises to my many Megger colleagues for their exceptional articles. The process of producing such high quality content can be arduous and is nothing short of a labour of love and care for our readers, who we hope will be helped by their contributions.

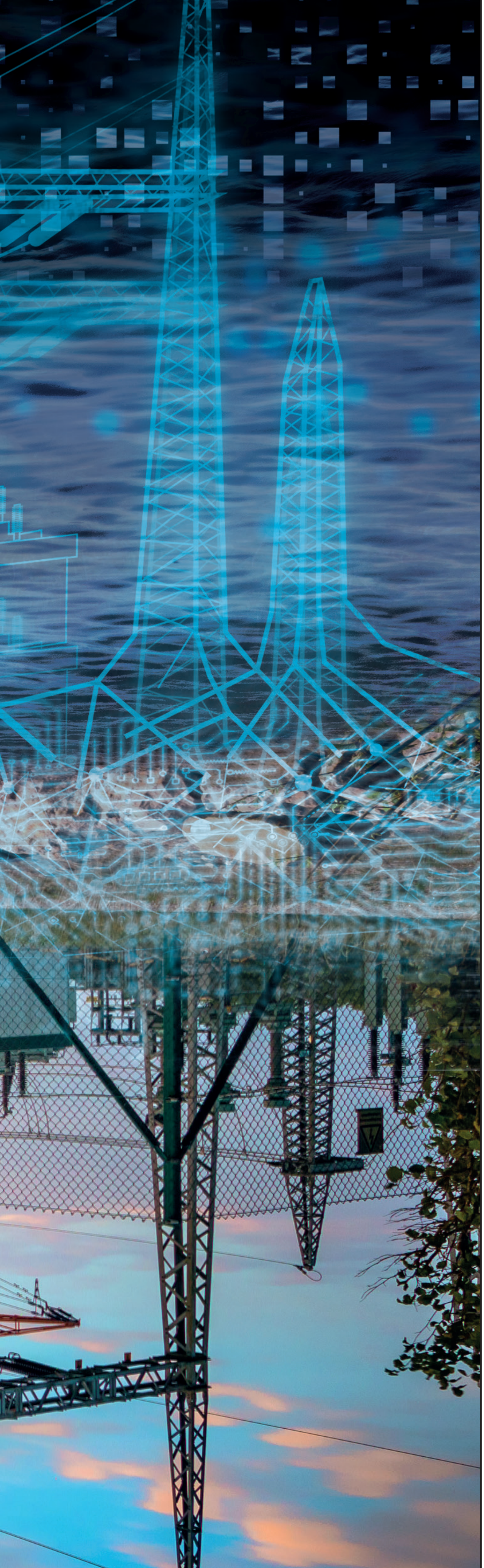
As for such aforementioned topics, I'd like to highlight the article by Stan Zurek and Dave Milner titled "What is a Knee Point?". I commissioned this piece as a dedication to my newly retired line manager, Jeremy Hewlett, and Stan and Dave produced it beautifully. Jeremy was always one to emphasise the importance of paying attention to 'fundamental knowledge' and I wanted to honour that legacy in this article. Indeed, "what is a knee point?" was one of his favourite examples! So whichever corner of the world this issue finds you, Jeremy, this article is for you!

ET magazine is evolving and expanding, and to that end this issue features our own Assistant Editor and Designer, Izzy Fraser-Underhill talking about her work and life in our "Powered By" article. This is a great way to find out more about her, and why she has my vote for President of the World! Furthermore, I'd like to introduce you to my newest Assistant Editor for Copy, Léonie Alvey, who has helped me proof and edit the articles in this issue and will continue to do so going forward.

And finally, I am honoured to deliver a welcome message from Megger's Group Director, Andrew Dodds, which you can read on the next page. Andrew's extensive knowledge about the world of electrical testing is truly inspiring to me and hopefully you'll get a feel as to why.

My warmest regards to you all and enjoy this issue!

Jill



Virtual testing of protection relays is real!

By Cedric Harispuru,
Andrea Bonetti,
Marius Pitzer
and Niclas Wetterstrand

Virtual reality has been around for more than two decades. What started as a feature of computer games has become the norm in many industries, delivering benefits that include reduced costs, increased reliability, and better efficiency. In the power industry, early adopters of virtual reality are not only enjoying these benefits; they are also finding that it helps them continue carrying out a whole range of tasks despite the travel bans and social distancing imposed by the ongoing pandemic.

Virtual testing of protection relays raises many questions. How closely does a virtual relay match a real relay? How closely does the virtual relay test instrument match the physical test instrument? And how much of real-life relay testing is mirrored in virtual testing? This article aims to provide at least some of the answers.

The trend to move from analogue signals to digital data is growing in the substation world. IEC 61850, digital substation, smart grid – they are all concepts that point to the future. Although network owners are increasingly accepting digital technology, commissioning procedures for substations have hardly changed, except for the adoption of virtual interconnections via IEC 61850 GOOSE or SMV messages. However, opening the door to digital technology has made possible more radical advancements, such as the implementation of the Digital Twins that are being developed by Megger and Siemens and paving the way for virtual testing.

Digital Twins and virtual testing

The Digital Twin is a concept that has been around for some time in the industrial sector. It is simply the name given to a virtual replica of an asset. It could be a physical copy of the real asset, but, more importantly, when it comes to relay testing, it is a functional copy that includes interfaces, functions, and algorithms. This means that today's substation designers can verify the substation's physical design and layout using Digital Twins and evaluate the substation assets' performances individually and as a system [1].

A relay protection Digital Twin can be used to carry out all the tests needed to validate a protection and control application without having the hardware, without being at a specific location, and without waiting time between the different stages of the project. Engineers can even work on the same assets in parallel without any conflict. Examples of what can be validated are applications with single or multiple devices, including protection functions, interlocking, bay communication, etc. The validation is not limited to relay protection functionality towards local breakers or other protection devices (commonly referred to as horizontal communication); it is also possible to validate the integration with the substation automation system (commonly known as vertical communication) and substation cybersecurity. For this purpose, Siemens introduced a cloud-based service that holds SIPROTEC DigitalTwin, their SIPROTEC 5 devices' digital replicas.

Performing virtual tests involves not only the relay's IED behaviour but also the process simulation to provide test inputs. This includes the virtual injection of currents and voltages, the virtual energisation of the IED's binary inputs, and transducers for 0 to 20 mA signals. This process simulation may provide static inputs or dynamic inputs such as a COMTRADE replay. If these tests are generated from relay test software, the commissioning tests can be prepared and evaluated before the actual commissioning starts.

The outputs from the IED of the Digital Twin relay match the real IED outputs. They include the status of the binary outputs, the telegrams sent via communication protocols, the data recorded in the event/disturbance recorder, the HMI functionality with measurements, the indications to the user, and so on. With this approach, many tests can be prepared without a secondary injection test set and without any wiring. A direct benefit is that most of the configuration issues that normally have to be handled on-site are eliminated.

As the commissioning stage happens near the end of the project, time pressures are often high, which may lead to mistakes and the adoption of undesirable shortcuts. Virtual testing helps alleviate these time pressures. Furthermore, since all tests have been prepared in advance and validated virtually, possible faults caused by errors in the test configuration (e.g. IED's logics, protection functions settings, etc.) are removed before they turn up in the real world. All these factors lead to time savings and a more precise estimate of when the substation will enter service and start contributing to revenue.

Open loop test

A key concept in virtual relay testing is open loop testing, which means that the test sequence is performed without considering the relay reaction. In a virtual test, instead of applying real voltages, currents, and binary contact signals, these are provided digitally to the virtual relay analogue inputs and the virtual relay binary inputs (for testing teleprotection scheme carrier receive signals or breaker failure start signals, etc.). The digital values of these signals are stored in a COMTRADE file. There are several reasons for choosing the COMTRADE standard: first, it is the format that has been used for several decades by most power system tools like RTDS, CAPE, and ETAP; second, IEC 61850 has standardised COMTRADE as the file format for disturbance recorders; and third, COMTRADE is a dual-logo standard supported by the IEC and the IEEE [2].

For a COMTRADE file to be used in virtual testing, it must be possible to acquire the data from the file and process it as if it was real time, but in the virtual time associated with the virtual relay. This means that the tests can be faster or slower than real time, but the file processor needs to interact with the virtual relay so that the response time reflects that of the real relay. When the file is processed, the relay response is analysed using the relay event recorder, disturbance recorder, or by simply monitoring the virtual relay HMI, depending on the test's complexity. As already stated, with open loop testing, there is no interaction between the virtual relay and the virtual test set. Still, there are many aspects of relay performance and operation that can be evaluated and verified.

Creating COMTRADE files with RTMS software

The Megger RTMS (Relay Test Management Software) package is relay software that has been developed for use with Megger automated relay test instruments in the SMRT and FREJA ranges. These test sets can generate the COMTRADE files based on the test sequences necessary to perform the virtual tests. RTMS is connected to a virtual test device instead of a real test instrument, and, in this way, the user can create the tests required and then produce the equivalent COMTRADE test files (Figure 1). The virtual tester configuration reflects real SMRT and FREJA test sets, so it becomes the Digital Twin of the commissioning engineer's test equipment.

If an application requires more currents and voltages than are available from a single test set, there is an option to allow for this in the COMTRADE setting file. Even though it no longer corresponds to a single piece of test equipment, this arrangement could be replicated in the real commissioning test with two or more test sets daisy-chained together to achieve the required number of inputs and outputs. Figure 2 shows how several Megger test sets can be daisy-chained to form a unique larger test set for testing applications where a large number of synchronised current and voltage generators are needed ([3] and [4]).

COMTRADE files for testing purposes can be generated in other ways. Still, the advantage of creating them using the RTMS software (Figure 3) is that the prepared test cases are then ready to be used when the real commissioning

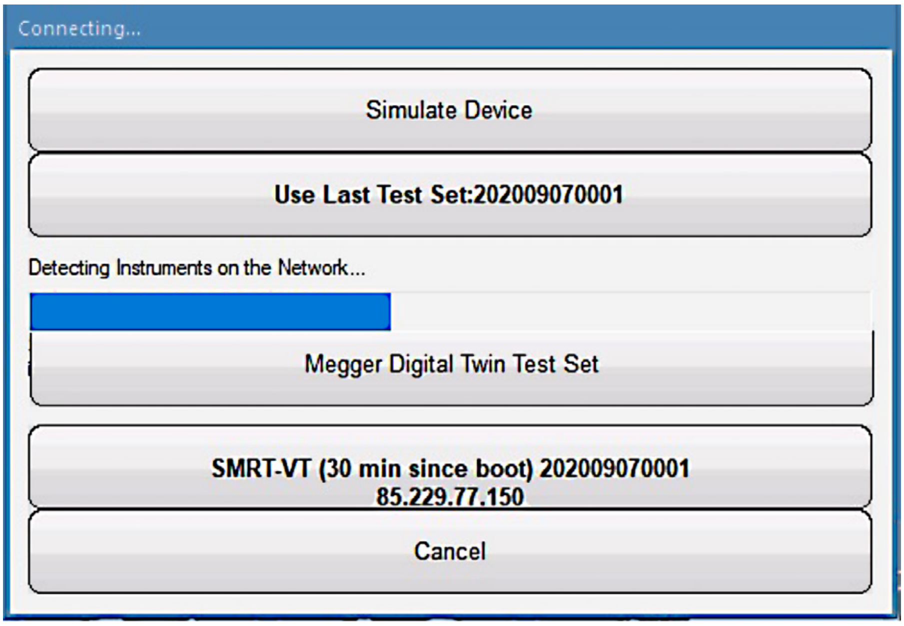


Figure 1: Open loop testing with COMTRADE files; the user runs a Digital Twin version of the Megger test set. The door for open loop testing is open!

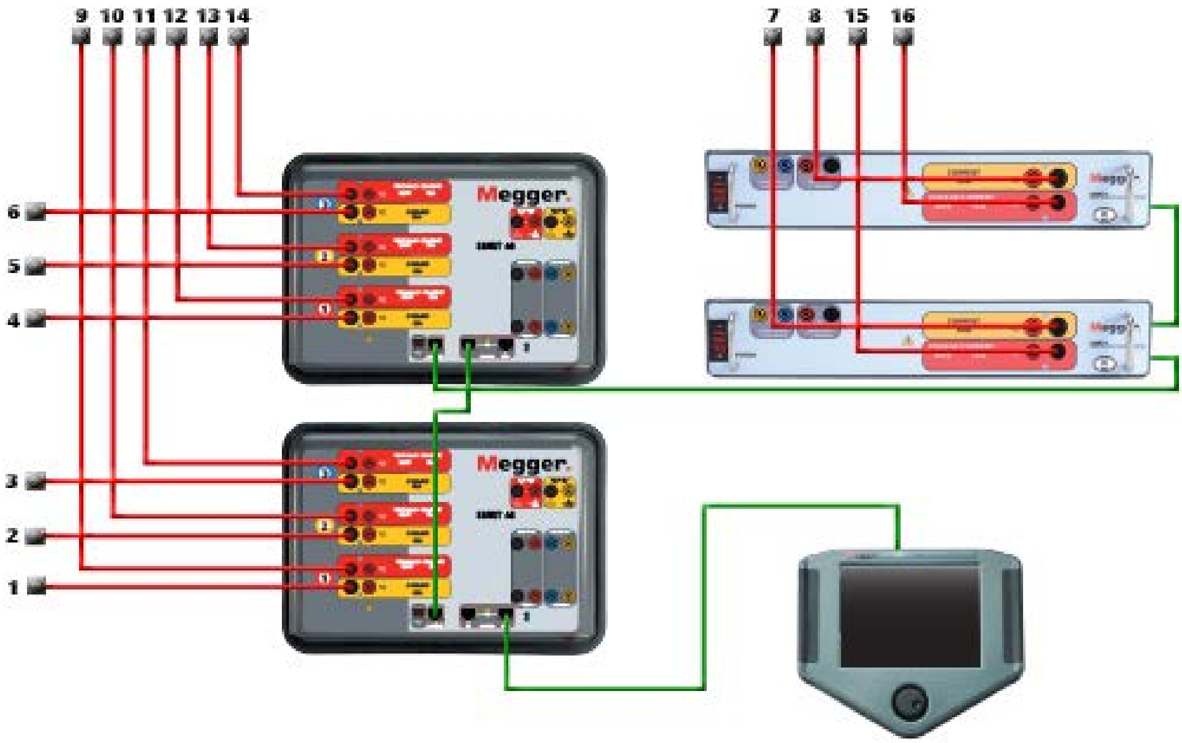


Figure 2: Two SMRT46s and two SMRT1s interconnected

takes place. And not only are they prepared, but they are also tested and fine-tuned since they have been proven in the virtual tests to give satisfactory results. Additionally, once the user has gained experience in virtual testing, the number of tests that will be repeated during the real commissioning will likely decrease significantly. This is thanks to growing confidence that if the results of the Digital Twin tests are satisfactory, the real test results will also be good. Nevertheless, the need for real tests will never be completely eliminated. Some factors, such as physical connections, correct settings, and so on, can only be verified by real-world testing.

Virtual testing with a simulated IED in IEC 61850

Digital Twin relay testing should not be confused with simulation models for IEC 61850 devices. In the case of IEC 61850 simulation, the distance protection function is only represented by its IEC 61850 description, for example, by its logical device (LD), the PDIS logical node (LN), and data attributes (signals) such as start and trip (PDIS.St, PDIS.Op). The distance protection algorithm running into the PDIS logical node is not simulated, but it is when virtual testing is carried out with a Digital Twin. Other limitations of IEC 61850 simulation are that, at present, interfaces to the outer BI and BO are not modelled, internal interactions between several LNs are not visible, and the settings are poorly modelled.

With an IEC 61850 simulation of an IED, the test engineer simply 'raises' the appropriate bit of the data attribute to simulate a distance protection trip. This test is important, for example, to verify the correct data information sent by the relay (MMS server) to the station SCADA or station RTU. Still, it should

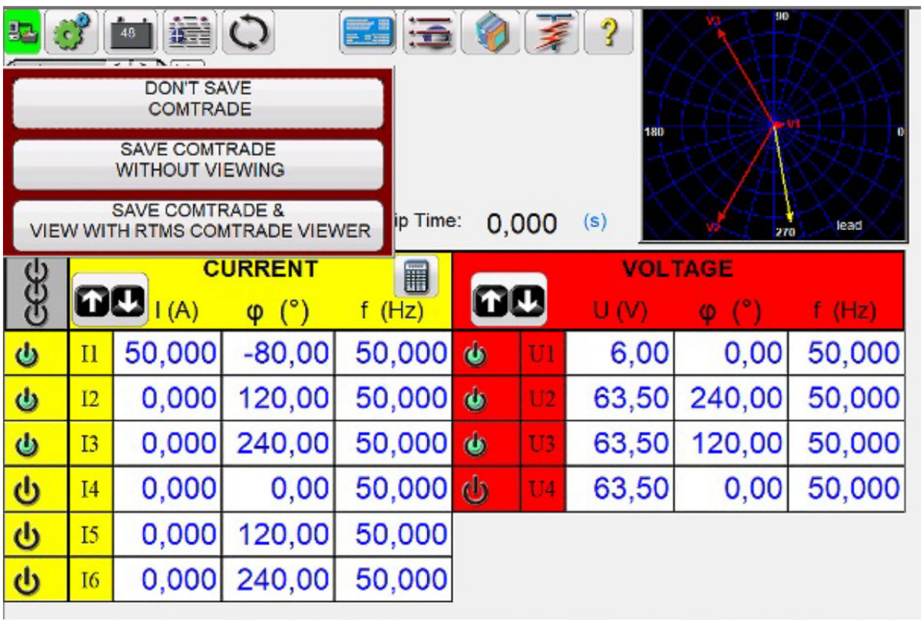


Figure 3: A view from the RTMS software showing how the COMTRADE file can be exported

not be confused with a relay protection test. Relay testing with a Digital Twin will, of course, also be able to perform IEC 61850 communication, so in a few words, it is more powerful than IED simulation in IEC 61850. Both testing methodologies have a role to play, but it is important to understand that their applications are different.

Covid-19 changes the future

The global pandemic has, unsurprisingly, accelerated the search for alternative methods of working that cut costs, minimise travel, and support social distancing for network owners. Electricity is one of the cornerstones of our modern world. It cannot be allowed to fail, particularly in these difficult times when hospitals have approached maximum capacity with patients requiring life support. During the pandemic, energy demand and revenues have decreased, so keeping the power networks running during lockdown has become an even more challenging task. Furthermore, in the longer term, it is projected that carbon-free electricity is the energy source that will need to grow to support the predicted growth in demand while moving toward an environmentally sustainable future. Digital Twins can help address many of the contradictory demands raised by these issues, both in the short and long terms.

The pandemic has shown, and is showing, one very important reaction to digitalisation, in the broadest sense: it can be done! Even those who, for whatever reason, were resistant to the use of digital solutions have rapidly abandoned their doubts and embraced the new methods. Significantly, we have all very quickly become experts in using videoconferencing tools like Zoom, Teams, or Skype. Many of us working globally have meetings early in the morning or late in the evening. These habits are arguably here to stay, even if in the future a better compromise between virtual and physical meetings becomes possible. And, like videoconferencing, virtual testing of relay protection is one of the digital activities that is undoubtedly here to stay.

Step-by-step virtual relay protection testing

The steps needed to prepare for virtual testing are not very different from those needed for testing in the real world. The main difference is that everything is done with software, which significantly speeds up and simplifies things that can be time-consuming and complicated in the real world. For instance, rewiring or loading settings at different locations now requires only a few mouse clicks. A step-by-step overview of the virtual testing process is:

- Build the virtual substation, including connections, reflecting all or part of the real substation
- Calculate and load the settings into the virtual relay protection IEDs
- Configure all tests that need to be performed (various protection functions or schemes)
- Virtually wire the test devices to the relays
- Perform the tests by mass COMTRADE import and replay in a virtual device
- Analyse the tests through the relay event recorder, disturbance recorder, or simply by monitoring the virtual relay HMI

What can be tested with the open loop method?

1. Measurement of relay operate time (trip time)

A simple pre-fault and fault sequence, with the fault well inside the operating characteristic, results in a trip command recorded by the disturbance recorder of the protection device. From the disturbance recorder, it is possible to measure the internal time difference from when the fault started to when the operate (trip) signal was issued. The reaction time of the output contact and the time needed by the analogue and A/D conversion card to process the data are not simulated in the Digital Twin. Therefore, adding 3 ms[1] to the internal time for the former and approximately 5 ms for the latter will give a good idea of the relay operate time that will be measured in the substation [5].

Figures 4 and 5 illustrate step 3 above. In this example, tests have been configured to measure the operate time of the distance protection after a pre-fault condition (according to IEC 60255-121:2014) with zero load current and healthy voltages (Figure 4):

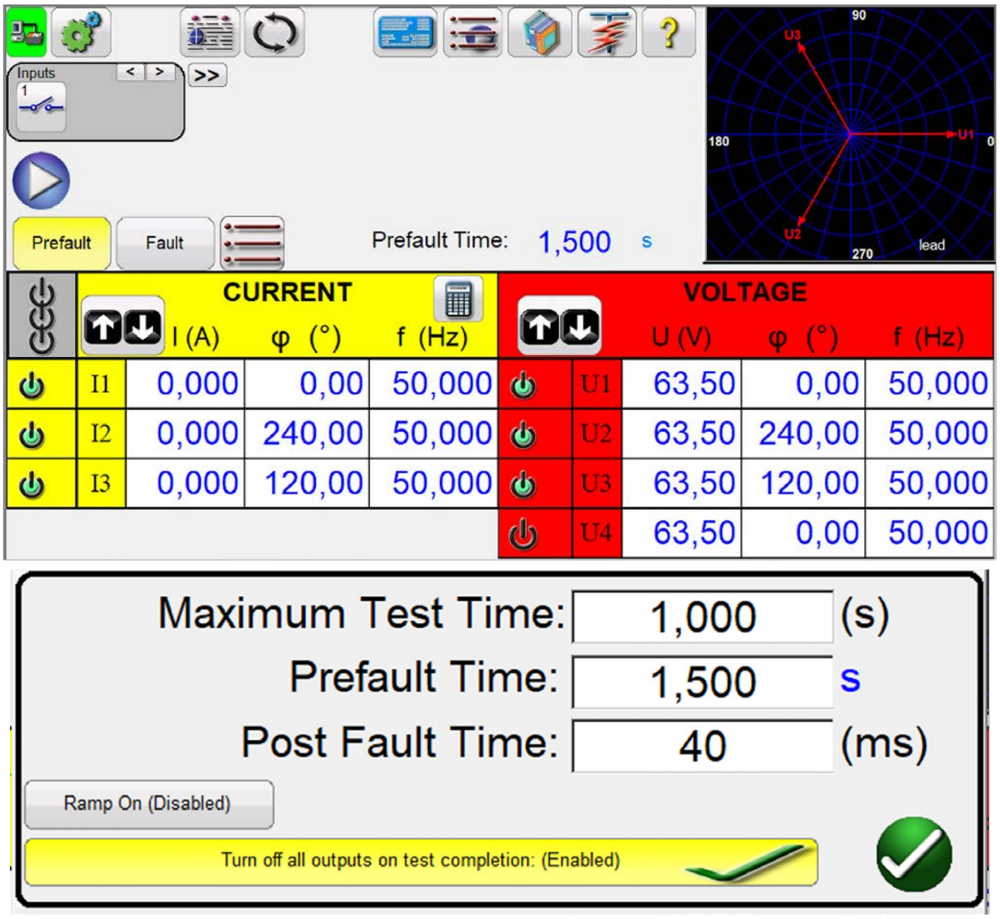


Figure 4: Configuring tests to measure the virtual relay operate time

1 This is a reasonable average time. Typical reaction time of relay binary output contacts can vary from 3 ms to 10 ms, depending on the binary output card used. If static outputs are used, the time could be less than 1 ms.

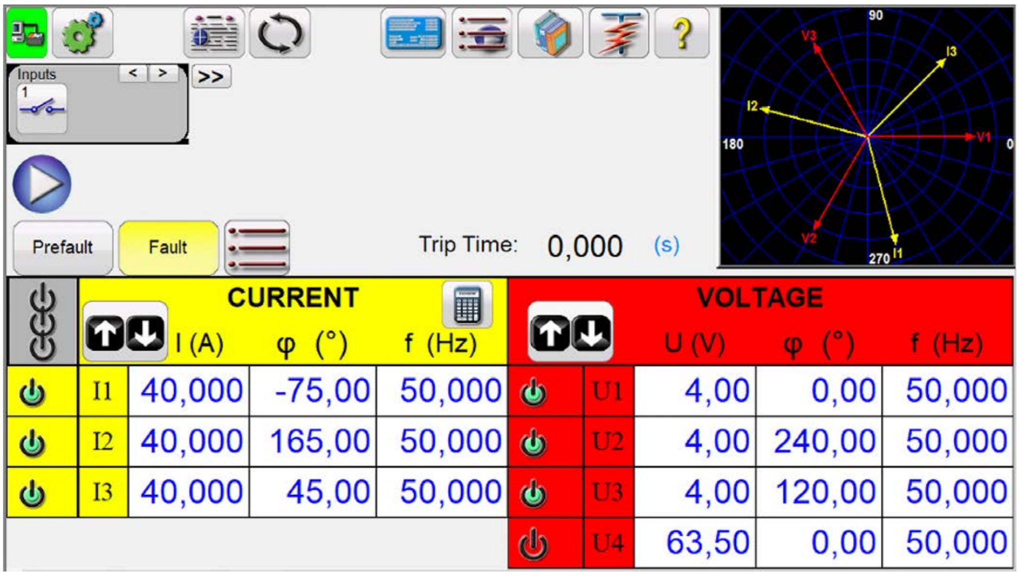


Figure 5: Configuring tests (the fault characteristics) to measure the virtual relay operate time

A three-phase fault in the forward direction with the secondary quantities given in Figure 5, with a fault level of 8 times the rated current for a 5 A relay rated current, will represent a fault in the forward direction in Zone 1 if the CTs are earthed towards the protected line:

The COMTRADE file can be previewed by the RTMS software before exporting (Figure 6).

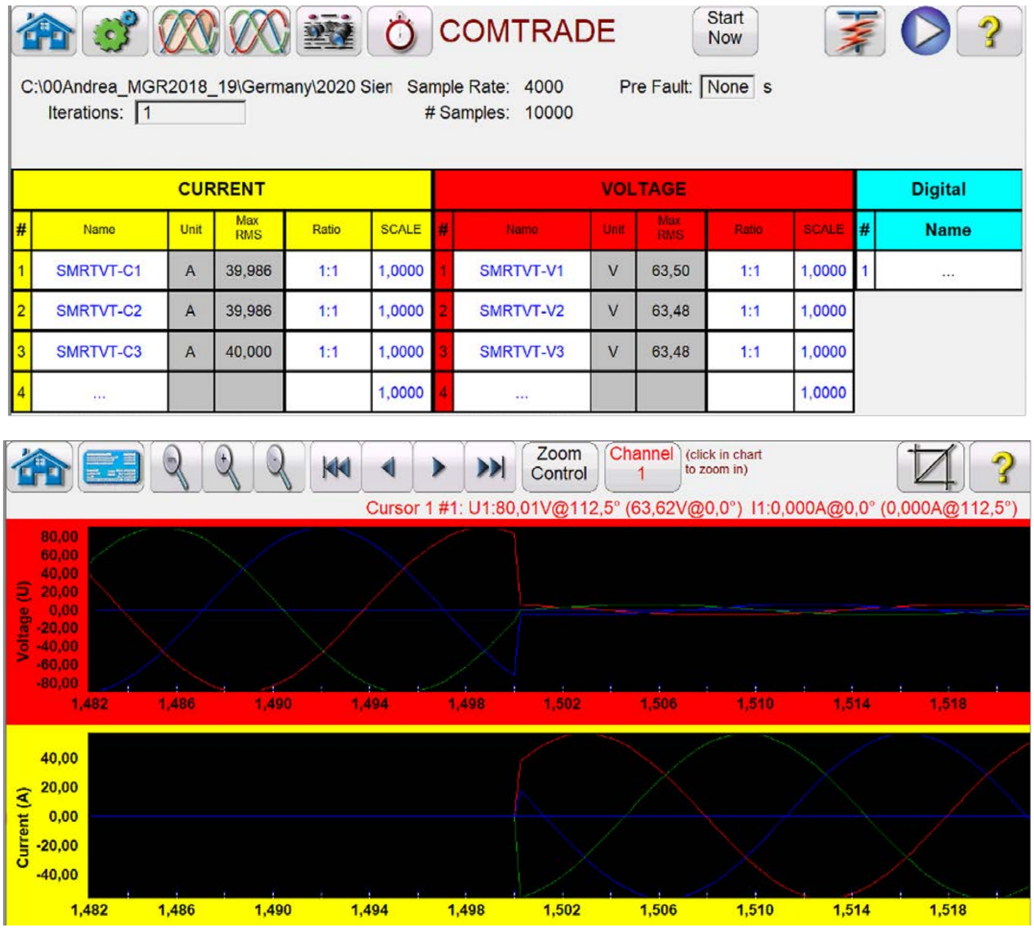


Figure 6: COMTRADE file created in RTMS

The file can also be analysed using other COMTRADE tools (Figure 7).

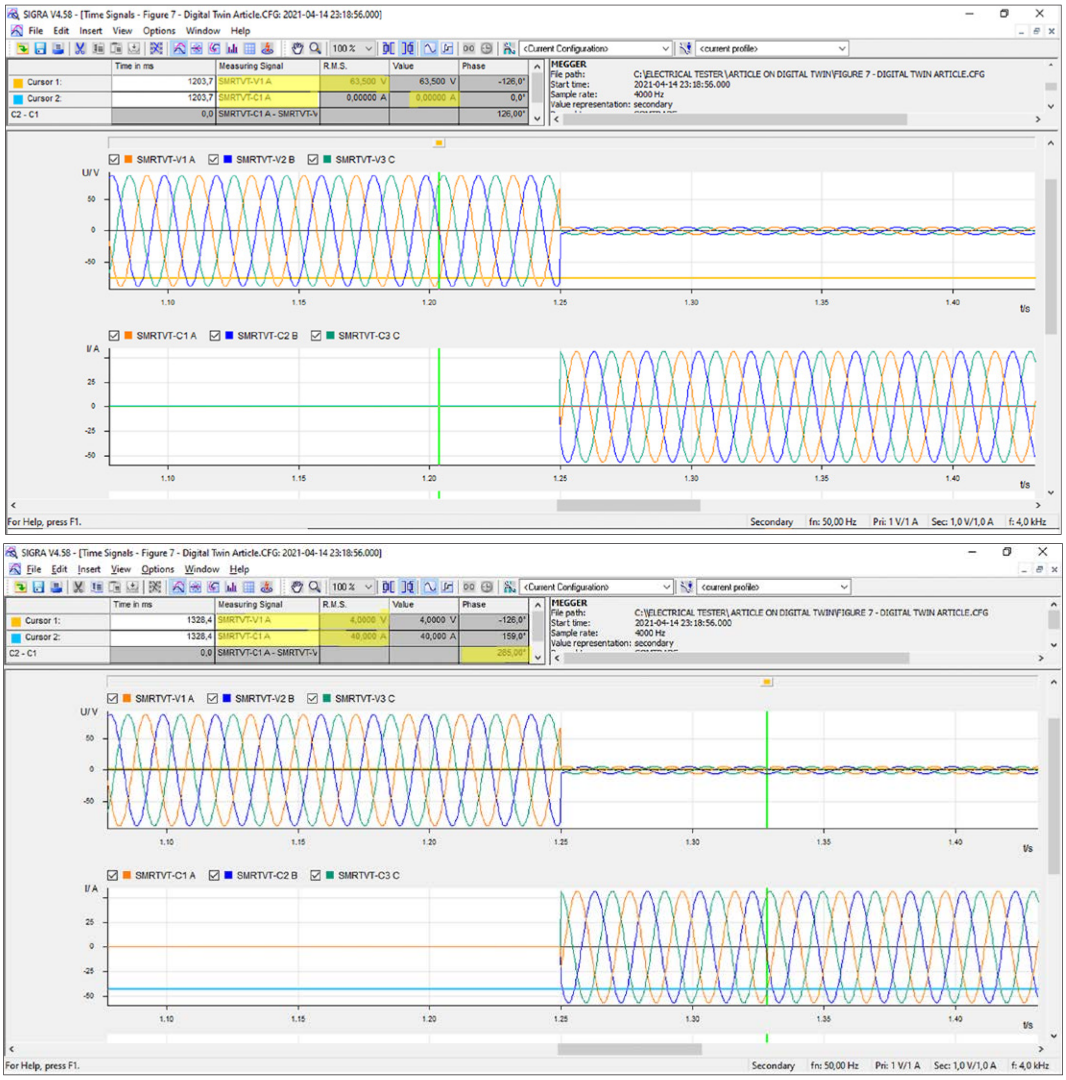


Figure 7: Opening the COMTRADE file from Siemens' DIGSI/SIGRA tool

The COMTRADE file is uploaded into Siemens' cloud based SIPROTEC DigitalTwin, as shown in Figure 8.

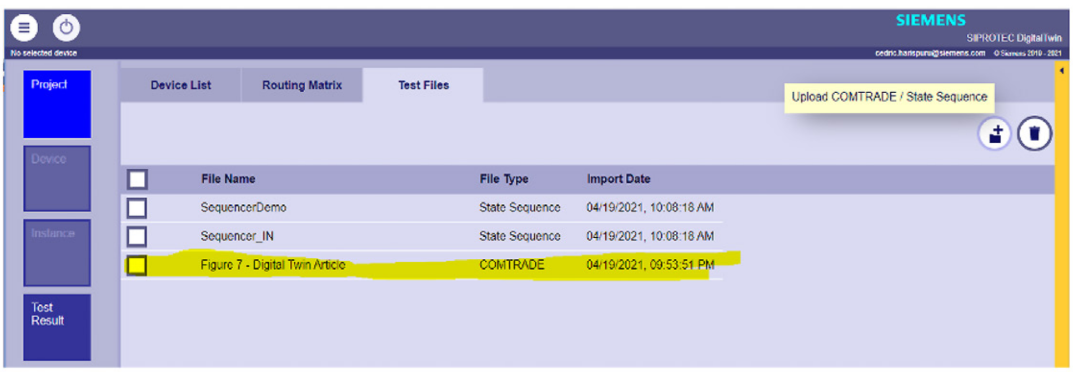


Figure 8: COMTRADE file generated by the Megger Digital Twin is available for use in the Siemens' cloud SIPROTEC DigitalTwin, https://siprotec-digitaltwin.siemens.com/

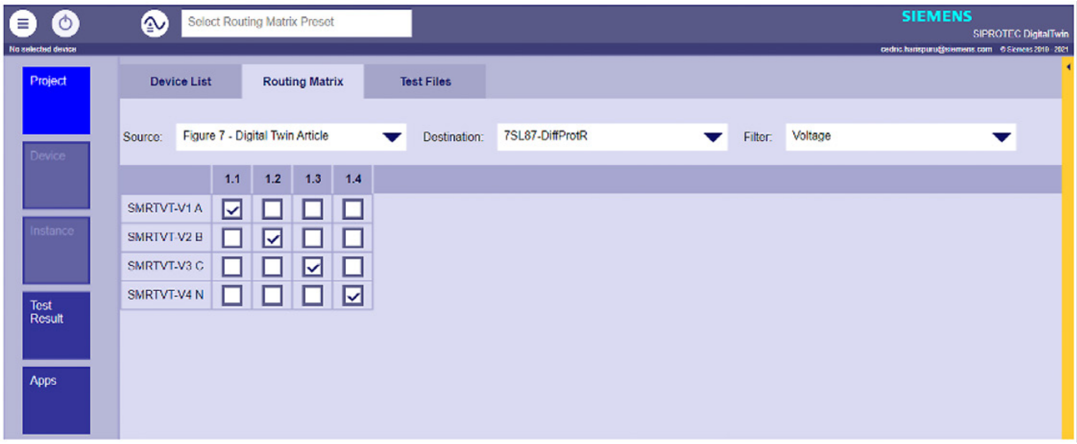


Figure 9: The COMTRADE analogue signals are associated (mapped) to the analogue inputs of the SIPROTEC relay. In this example, the mapping is done for the voltage channels

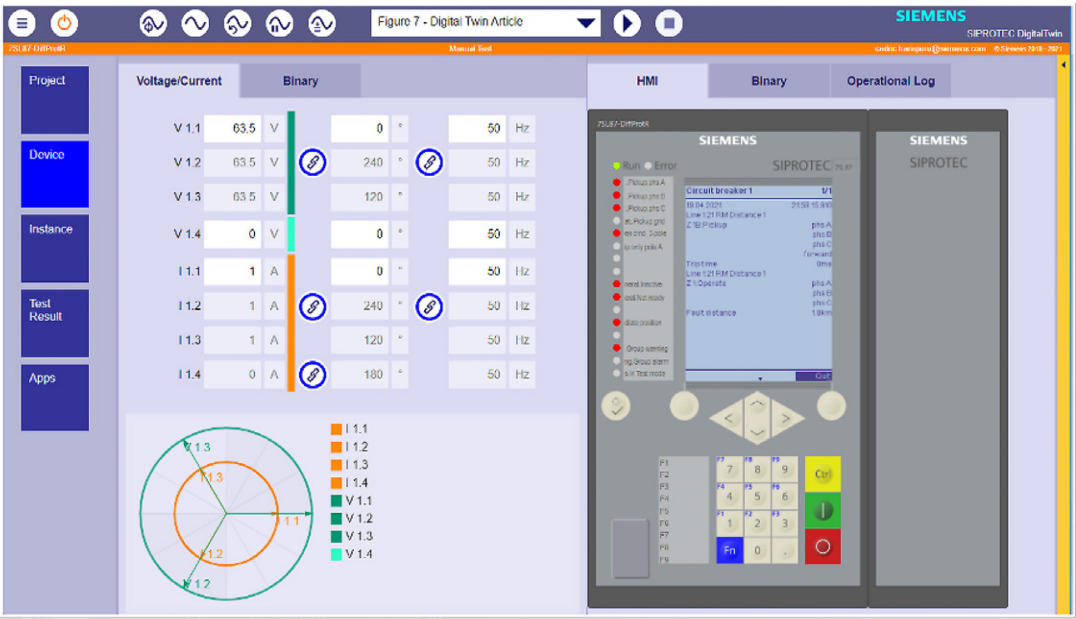


Figure 10: The COMTRADE file has been virtually injected into the Digital Twin relay, and the result is available at the virtual HMI for a first analysis

The necessary mapping of the test set signals (COMTRADE analogue signals) to the relay virtual analogue inputs is also done in the cloud (Figure 9).

The test is run. The relay operates and the resulting COMTRADE file from the relay disturbance recorder can be retrieved. From the COMTRADE file, it is possible to measure the relay operate time, excluding the time delays for the relay contact operation (3 ms) and analogue data acquisition (5 ms). Adding 8 ms to the measured operate time gives a reasonable value of 15 ms + 8 ms = 23 ms for the operate time. At a later stage during commissioning, the actual protection relay operation time can be verified with the same test sequence based on the same test file, using an SMRT or FREJA 500 series test set. As a first approach, it is convenient to verify the test results from the virtual HMI of the Digital Twin relay before entering in the deeper analysis of the event or disturbance recorder (Figure 10).

What can be tested with the open loop method?

2. Measurement of 'non-trip' for a fault in the reverse direction

The test sequence used in Example 1 can be slightly modified for simulating a fault in the reverse direction. Assuming that the relay is not supposed to trip under these conditions, it will be sufficient to reverse all the fault currents by 180 degrees and set the maximum fault time to, say, 3 seconds.

- Export the COMTRADE file from RTMS.
- Import the COMTRADE file to SIPROTEC DigitalTwin.
- Perform the mappings between COMTRADE signals (test set signals) and the virtual analogue inputs of the virtual relay.
- Run the test.

Here the result can be checked easily, either by observing the virtual HMI or virtual trip indicator LED to verify that the relay has not tripped or by checking the event recorder to confirm that no trip has been recorded. There is no need to upload the disturbance recorder file (if indeed any new event is available, which will depend on the triggering strategy), except when troubleshooting after an incorrect relay operation, which may, for example, be the result of wrong settings or wrong configuration in the signal logic (CFC in Siemens DIGSI).

The last statement already begins to demonstrate the power of open loop testing. If the relay settings are wrong or the relay logic is incorrectly configured, these problems will be revealed. And, let's be honest, most of the time, we are not testing the relay or the test set, or even the connections – we are testing ourselves. This is as it should be because the engineer is a fundamental part of the protection system.

3. Verify simple overcurrent inverse time curves

You will have an idea of what the operating curve looks like in the I-t plane and the RTMS software can easily plot this curve for you. Select some points at particular current levels and note the associated operate time.

- Run separate tests, one for each of the selected current levels. Set the fault time in the test set at 10 % or 200 ms higher than the theoretical value.
- Export the COMTRADE file, transfer the COMTRADE file to the Digital Twin, perform the necessary mappings, and run the test. Verify operation (trip) from the relay, HMI/LED indications, or the event list.
- Perform the same test, with a maximum fault time set to 10 % or 200 ms less than the theoretical operate time. Run the test and verify that the relay does not trip.

With well-chosen test points, it is possible to test a two-stage overcurrent (inverse time and definite time) characteristic with three or four test points (six or eight COMTRADE files).

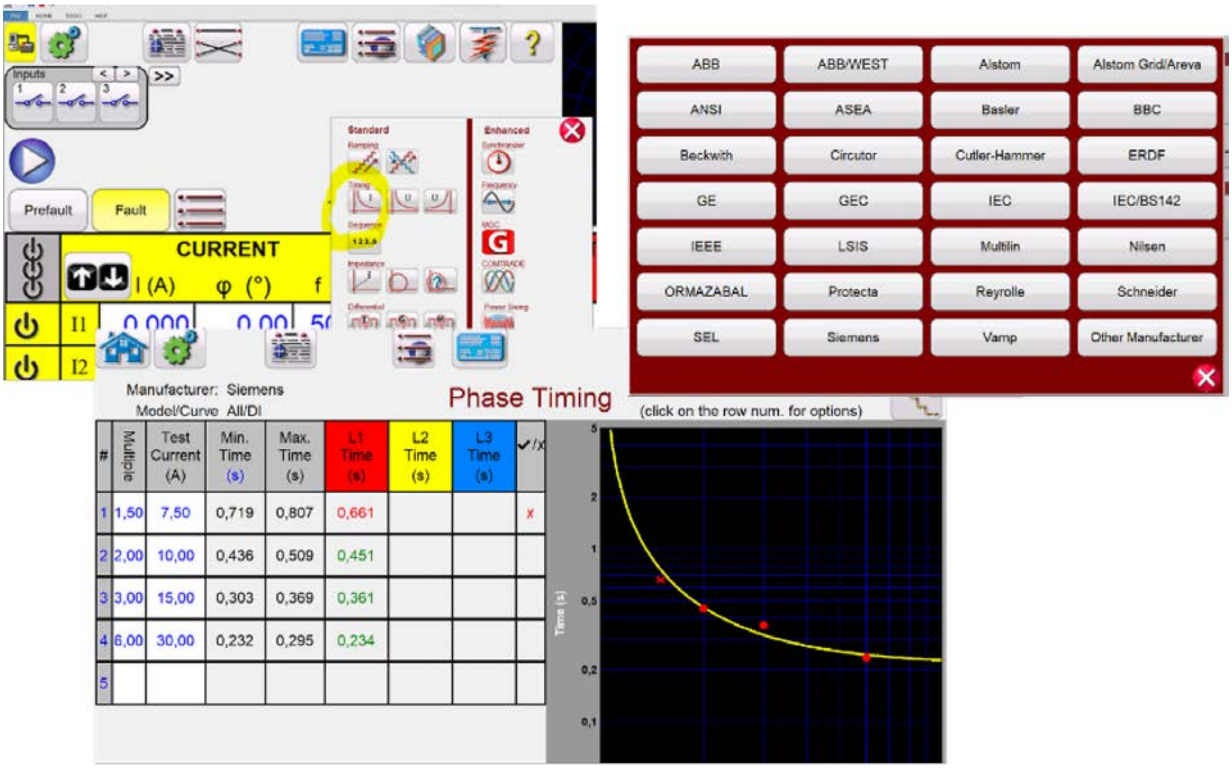


Figure 11: Example of test plans/templates for protection relays, with automatic import of settings from setting files

4. Verifying the correctness of setting groups.

Each setting group activated in the relay needs to be tested during commissioning, which is time-consuming. When the tests are performed with the virtual open loop method, they are more time-efficient and there is no need to be in front of the relay at the substation – the tests can be performed from the office or home, even before the relay is physically installed.

The examples above can be extrapolated to manage tests for different setting groups in the Digital Twin. Later, at the commissioning stage, it will be necessary to repeat only some of these tests to verify the connections to the binary outputs. Furthermore, the virtual tests will have already been performed successfully, so provided the connections are correct, there is a high degree of certainty that the real tests will proceed smoothly.

We are approaching the idea that at commissioning, a sort of 'maintenance test' procedure is applied, and the main reference is the pre-commissioning virtual tests. In other words, the commissioning tests will be a subset of the virtual tests, as today the maintenance tests are a subset of the commissioning tests (see [6] and [7]).

5. Verifying teleprotection schemes

Let us consider the practical example of a permissive underreaching teleprotection scheme for distance protection – a PUTT. Testing this protection scheme requires activation of the relay binary input associated with the 'carrier receive' signal. The carrier receive signal is produced by the relay test set by activation of a binary output which, in the real test, is connected to the relay binary input. Depending on how realistic it needs to be, there are two main methods of performing a virtual test:

a. The simple approach using the pre-fault and fault test method

From RTMS, prepare a simple pre-fault and fault sequence where the fault is a solid fault in relay Zone 2. The distance protection test tool in RTMS can be used to plot the relay characteristic and get the voltages and currents as a function of one solid fault in Zone 2. The maximum fault time must be higher than the expected operate time for Zone 2, say at least 1 second.

- Save the COMTRADE file, transfer it to the cloud, perform the test and verify operation of the distance protection relay in Zone 2 (which will probably be close to 400 ms).
- You can use the relay event list for this verification or verify the approximate timing in the recorded disturbance file.
- Prepare another test based on the previous one, but this time keep the binary output of the test set steadily activated (closed).
- Run the pre-fault and fault sequence, with a fault in Zone 2 and the test set binary output activated (closed). Save the COMTRADE file.
- This time, the COMTRADE file will contain information about the binary output position (activated) and the voltages and currents waveforms.
- Transfer the COMTRADE file to the cloud, map the analogue signals, as usual, map the carrier-send signal (binary output position in the COMTRADE file) to the correct binary input signal of the virtual relay.
- Perform the test and verify instantaneous operation of the distance protection relay with the help of the recorded COMTRADE file.

This test is not completely realistic because the carrier is received by the relay before the fault starts, but in many cases, it is good enough.

b. A more realistic test using the sequencer in RTMS

- Prepare the following sequence in RTMS:
- STEP 1: Pre-fault values, as in a). Duration, 1 second.
- STEP 2: Fault in Zone 2, for 30 ms.
- STEP 3: Same fault in Zone 2, with activation of Binary Output 1. This simulates that the relay at the other line end has started/ picked-up (20 ms), has sent a carrier, and the carrier has taken 10 ms to reach the relay under test. These figures are more than reasonable. Step 3 will have a duration of 1 second.
- Save the COMTRADE file and upload it to the cloud. Map the analogue inputs and digital signals as in a).
- Perform the test.
- Verify instantaneous operation as soon as the carrier was received by the relay. This should be around 30 to 40 ms from the fault injection, depending on the debounce time of the relay binary input. Use the internal disturbance recorder to verify the correct behaviour.

- Repeat the same sequence as above, but do not activate the test set's binary output – keep it open (inactive) for the whole time.
- Export and upload the COMTRADE file, map the analogue and binary signals, run the test.
- Verify relay operation in Zone 2.

The list of tests that can be carried out using the open loop method is very long and, hopefully, the reader can see by now the value of this approach. With this method, it is possible to perform at least 75 % of the tests that would be performed during commissioning, making it possible to carry out troubleshooting and changes to the relay configuration and settings before commencing real-world tests. During commissioning, the final 25 % (or less) of the tests will be performed with a test set in the usual way. Some of the key tests performed virtually will be repeated during commissioning to confirm the correctness of the virtual tests.

Quick tests with a vector generator

A simple vector generator is an integral part of Siemens' cloud service. For some of the simpler test cases, it is arguably faster to use this to validate functionality. Still, the disadvantage is that no test file is generated that can be reused during commissioning with the physical test set. It is necessary to set up this test on the fly, but at least the function will have been tested virtually, so there should be minimal risk of any issues.

Beyond virtual protection testing

There are numerous other areas that can benefit from virtual testing using the Digital Twin. In many applications, interoperability problems are a concern as they are difficult to foresee and frequently time-consuming to troubleshoot. Being able to use virtual testing to validate interlocking and tripping via IEC 61850 GOOSE communication on the station bus and correct all issues before real testing commences is a considerable benefit. The substation automation system, including gateways, local HMI, fault record collector and communication via IEC 61850 MMS, DNP3 or Modbus TCP can also be validated to ensure smooth commissioning. The Digital Twin also allows multiple protection and automation engineers to access a test circuit simultaneously. These may be engineers within the same company or engineers working for different companies, and this is a handy feature when coordinating the integration of equipment from multiple suppliers.

Since distances between sites in the real world can be an issue, virtual testing of protection data interfaces for teleprotection or differential protection

applications in distributed systems can bring immense benefits. Devices located at a distance from each other can easily be tested using the Digital Twin, and adjustments made, where necessary, to optimise performance. This is particularly useful in applications where incorrect or suboptimal configuration may have an enormous negative impact.

With the emergence of the digital substation, cyber security is another key issue where the capability and configuration can be verified using Syslog, RADIUS, or RBAC to give confidence that the implementation complies with mandatory security regulations.

Beyond virtual commissioning

Even though commissioning is the stage when virtual methods deliver the most obvious savings, there is a place for these methods throughout the whole life cycle of a substation. An example is that they facilitate efficient and scalable on-the-job training for the commissioning and operational teams. Employees can be easily trained, based on their exact needs, either remotely or on-site, without the need for a dedicated training room equipped with a full range of test devices. Ultimately, better training will significantly reduce human errors and misunderstandings.

Another area where virtual methods bring benefits is the investigation of real power faults by virtually replaying COMTRADE files. The protection behaviour can be analysed in the virtual world. If needed, configuration parameters can be adapted, and test result improvements can be documented and then deployed more quickly on the substation site. An associated activity is the management of software patches used to implement security enhancements and functional upgrades. These can be verified virtually so that their functionality and performance can be confirmed before they are securely deployed on-site.

Next steps for virtual testing

A final example applies to cases where standardised engineering and configuration are used for a range of projects. In these cases, validation testing is performed for the first project. Acceptable results can then be ascribed to all following projects without requiring more validation tests.

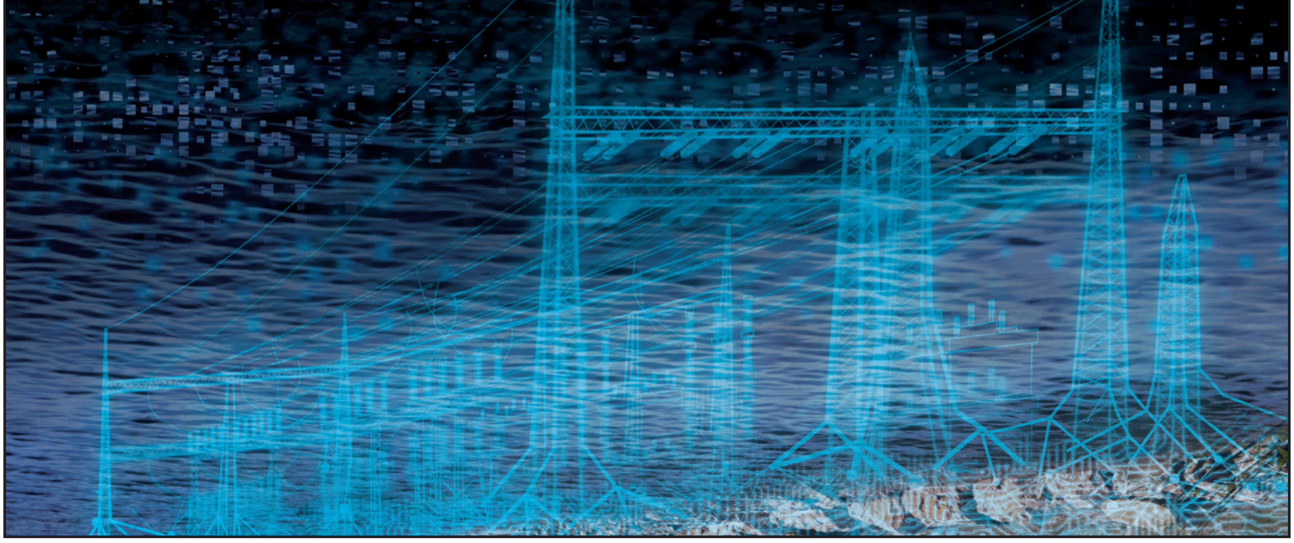
The next step for virtual testing with Digital Twins is to enable direct interaction between the Digital Twin of the protection device and the Digital Twin of the test set. This means that data flows from the test set to the relay and from the relay to the test set to indicate, for example, operate (trip) conditions. Interaction between the relay and the test set occurs just at it

would in the real world. This approach is called closed loop testing and, with it, test sets will be able to validate test results and produce results as they would in the real world. Experience gained from open loop tests, including feedback from users, will drive the development of closed loop solutions. Megger and Siemens are working together closely in this area. Several Digital Twins are already in place, and some exciting announcements will be made in the near future!

Conclusion

Virtual testing of Digital Twins is a significant step forward in enabling power network owners to economically and functionally optimise their systems. It is not uncommon to prepare settings and test procedures prior to the commissioning phase. Still, without validating them in a realistic environment, there is often a need for time-consuming troubleshooting and setting adjustments during commissioning when time pressures are high. Virtual testing eliminates these problems. Moreover, it supports remote working and social distancing, both crucial responses to the ongoing pandemic.

Virtual testing of virtual relays will increase accessibility for project participants and provide the opportunity to troubleshoot and adapt settings in a less stressful project phase, thereby significantly reducing test time and the requirements for expertise on site during commissioning. This is because many of the complex issues will have already been solved in the virtual environment. This also eases problems relating to the sharing of test equipment on site, which sometimes becomes a nightmare when actual testing takes longer than the time allocated. In a nutshell: virtual testing with Digital Twins is an excellent way of ensuring that commissioning goes smoothly and the substation can go live on time. Not to mention, many of the features described in this article will already be available in the first release of the Megger Digital Twin!



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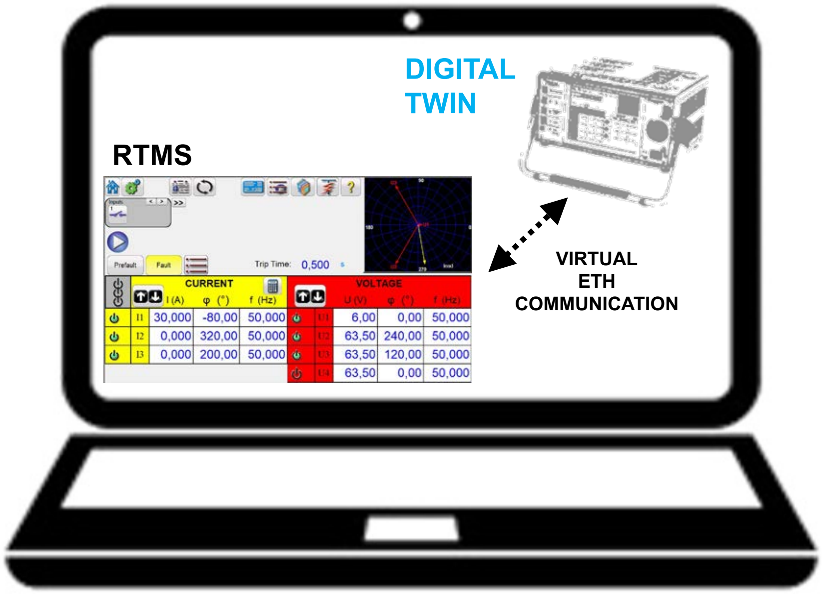
How can I try this technique?

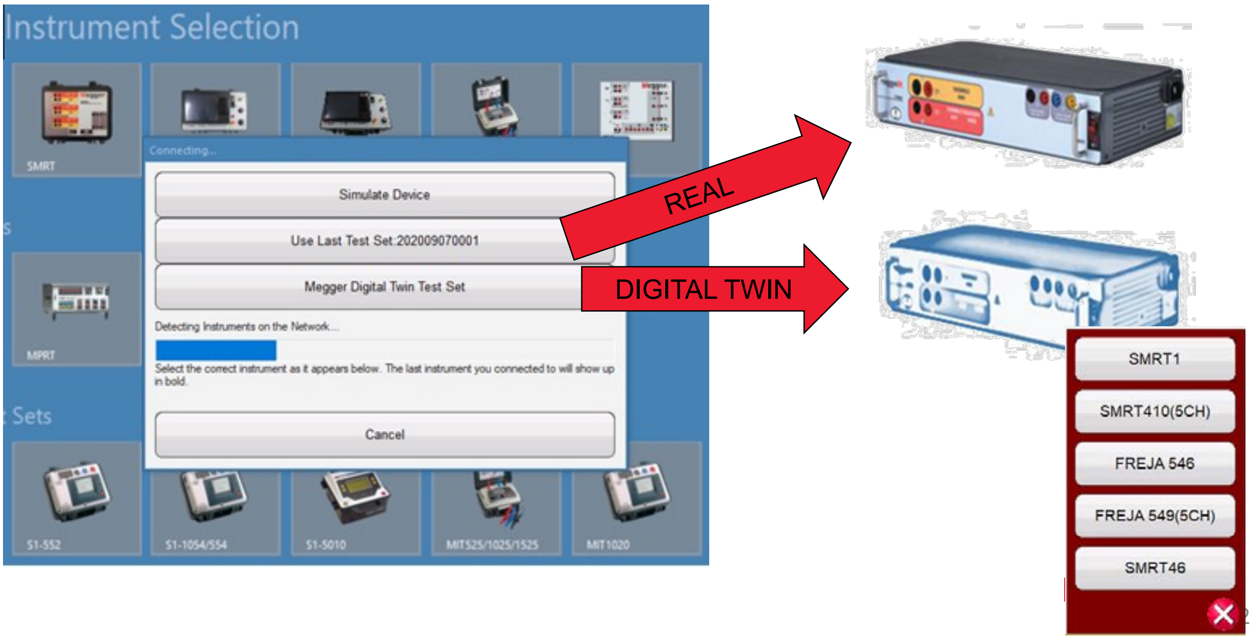
If you are interested in trying this technique, you first need to get a special version of the RTMS software from Megger. This special version contains the 'Digital Twins of Megger' test sets, as you can see in the picture below:

Then, to get started with the technique, contact Megger using the details at the end of this page.



You then need to use the Digital Twin for protection relays, which is SIPROTEC 5 Digital Twin. For this you will need to contact Siemens using the details at the end of this page.

To re-use your test files created during virtual testing, you will need a physical relay test set, such as SMRT1, SMRT410, FREJA 546 or SMRT46. While you can use other Megger relay test sets, please note that they do not yet have a digital twin.



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SMRT 1 - SINGLE PHASE Relay Test System

- Small, rugged, lightweight and powerful
- Operate with or without a computer
- Intuitive manual operation with Smart Touch View Interface
- High current, high power (75 amps/400 VA rms)
- Network interface provides IEC 61850 test capabilities

SMRT 46 - THREE PHASE Relay Test System

- Small, rugged, lightweight and powerful
- Operate with or without a computer
- Intuitive manual operation with Smart Touch View Interface
- vHigh current, high power output
- (60 Amps/300 VA rms) per phase
- 4 Voltage channels, 3 Current channels, with convertible voltage
- channels provides 1 voltage and 6 currents
- Dynamic, Transient and GPS Satellite Synchronized End-to-End
- Testing Capabilityv
- IEC 61850 Testing Capability

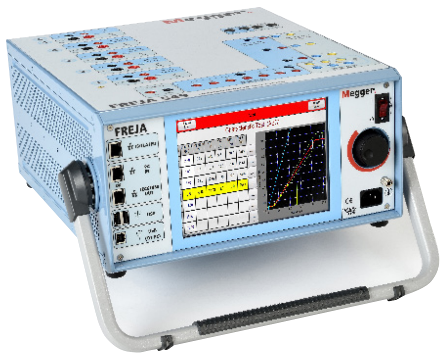
SMRT 410 Relay Test System

- Small, rugged, lightweight and powerful
- Operates with or without a computer
- High current, high power output (60 amps/300 VA rms) per phase
- Flexible output design provides up to four-phase voltage, up to ten-phase current
- Network interface provides IEC 61850 test capabilities

FREJA 546 - Relay Test System

- Fully automated testing using FREJA Win software
- Stand-alone operation using intuitive high resolution graphic touchscreen, no PC required to operate
- High current, high power output – up to 60 Amps / 300 VA rms per phase
- 4 Voltage channels, 3 Current channels, with convertible voltage channels provides 1 voltage and 6 currents
- Dynamic GPS Satellite Synchronized End-to-End Testing Capability
- IEC 61850 Testing Capability

FREJA 549 - Relay Test System



- Fully automated testing using FREJA Win software
- Stand-alone operation using intuitive high resolution graphic touchscreen, no PC required to operate
- High current, high power output – up to 60 Amps / 300 VA rms per phase
- Provides up to 9 currents for testing transformer and bus differential relay
- Dynamic GPS Satellite Synchronized End-to-End Testing Capability
- IEC 61850 Testing Capability

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Jill Duplessis is the Global Technical Marketing Manager for Megger. Her focus is on content strategy and content development for marketing and business segment initiatives. Jill is editor of Megger's Electrical Tester magazine. She is the primary author of Megger's Transformer Life Management (TLM) bulletin series and author of many articles, papers and a book titled Electrical Field Tests for the Life Management of Transformers. Prior to her move to Megger, Jill was Director of Power Programs for a start-up company in Washington D.C., where she was responsible for developing, testing and deploying new applications of (intensity modulated) optical monitoring systems for transmission and distribution utilities. Before this, she gained over 17 years of experience in the condition assessment of substation assets, first as a Principal Engineer at Doble Engineering Company and following as a Primary Manager and Regional Application Specialist, Transformers, for OMICRON electronics USA. She has prior electric utility work experience (with Florida Power Corporation, now part of Duke Energy, and Georgia Power Company), where she enjoyed an exposure to a wide breadth of engineering functions. Jill received a BSEE degree from Georgia Institute of Technology in 1991 and completed extensive master studies in electrical power engineering at Rensselaer Polytechnic Institute, Troy, NY.

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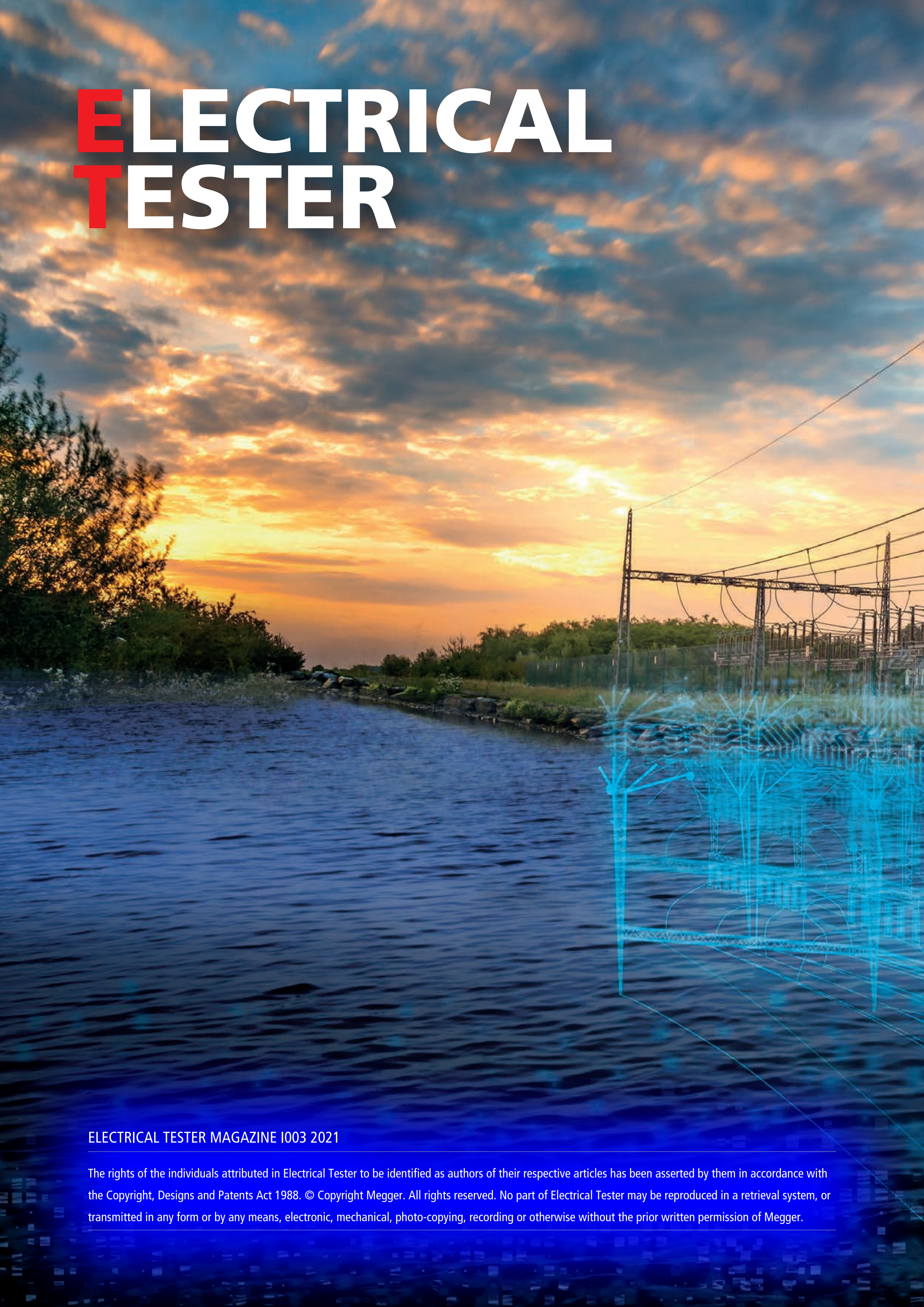

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