Increasing Test Efficiency at a Large Manufacturer of Protection and Process Control Equipment

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Abstract

Manufacturers of protection and process control equipment who also build complete plants must be capable of conducting reliable testing in order to avoid the costs of modifications and consequential losses. The various test phases are presented here in brief. Modern test sets are certainly an investment but one which pays for itself particularly quickly if testing is organized and standardized, and the opportunities presented by automated testing are fully exploited.

At the request of a major, anonymous, supplier, its entire worldwide test set pool was examined for its automation potential using OMICRON Control Center. An estimate of the savings which could be achieved in testing time and associated costs was generated. Regional differences and a timeline for how the "degree of automation" has developed are also part of the project's remit, while the sensible use of the saved testing time to ensure innovative future growth will be examined. A brief glance is also cast over other methods of organized and automated testing, such as testing with IEC 61850, system-based testing with RelaySimTest, or test data management with ADMO.

The figures given for costs and profits are, of course, examples only and can vary greatly from region to region. The conditions at any particular location must, therefore, be thoroughly scrutinized before arriving at any conclusions regarding one's own business. These examples should, however, greatly increase motivation.

1 Introduction

Before we broach the complex analysis of test set pools of major manufacturers of protection and process control equipment, let us start with a simple example:

Imagine that a manufacturer who regularly carries out a variety of protection tests and, therefore, has scope for automation (several relays of the same type or comparable functionality, or repeated tests in different project phases or maintenance cycles) decides to buy an automated test set.

To be on the safe side with our rough estimate, let us also assume that this investment would cost something roughly between €30,000 and €60,000, depending on their choice of product and application.

Let us further assume that this manufacturer usually sells a working day in his project or service business for some €1000 and that the daily staff costs and overheads are at least €600, which corresponds to an hourly cost of about €75 over an eight-hour day.

Let us be pessimistic and also assume that they only use their equipment effectively for 20% of the working day, and for the rest of the time it is either standing about in the stores, is in transit, or is held up in customs somewhere. Customer statements to us, however, often attest to a totally optimized use of the equipment, sometimes with significantly greater degrees of utilization but let us stay with a worst-case scenario. If this customer carries out automated testing, using freely available Protection Testing Libraries (PTL) [4,5,6,7] or customized test plans for some of it, they can easily reduce the time taken for testing and drawing up test reports to one-thirds. This figure is still on the safe side, since a number of customers have told us "*We can do it in one-fifth of the time*" [10].

If we disregard the usual weekend on-site work in the project business and assume a completely normal working year of 50 weeks, each of 5 days, this comes to 250 days per year.

And now the simple calculation:

- **1 CMC** used for 20% of the time:
  ➔ 0.2 x 250 days = 50 days/year
- **Time**: Automated = ⅓ of manual:
  ➔ 50 days instead of 150 days manually
  ➔ 100 days of testing saved
- **Cost savings** (€600/day; €75/hour):
  ➔ 100 days/year x €600 day
  = **€60,000 per year**
- Test set investment approximately €30k - €60K
- **ROI** (Return On Investment):
  ➔ CMC amortized after **½** to **1 year**
- **Profit after amortization**:
  ➔ This CMC would save 100 days per year, or €60K per year, for another 10-20 years.

Figure 1: Simplified amortization calculation for an automated CMC test set.

One can of course spend a long time discussing the pros and cons of whether this calculation would actually work out in real life; what its logical consequences would be; what could sensibly be done with the time and costs saved and to what extent a manufacturer would have to pass some of them on to the end customer as a result of the competitive pressures in the product, project, and service business; or to what extent the manufacturer could use these savings to address other important tasks that would give them a technological and sustainable economic advantage. More on this in Section 4. The fact remains that a manufacturer who does not make use of the advantages of automation, or looks for savings in the wrong place when selecting test sets and opts for solutions that do not offer such possibilities or entail more quality problems than benefits, will, compared to other manufacturers, suffer disadvantages, be more expensive, earn lower profits, or even lose market share.

In order to carry out a more detailed examination of the profitability of organized automated testing for manufacturers of protection equipment and complete plants, it is important firstly to know and understand the manufacturer's process and the individual test phases.

One thing is important in the project business in particular, but also in development and production:

Testing is worthwhile in order to discover system errors at an early stage. The later a fault is discovered and has to be corrected, the higher the costs incurred by this modification will be for the manufacturer.

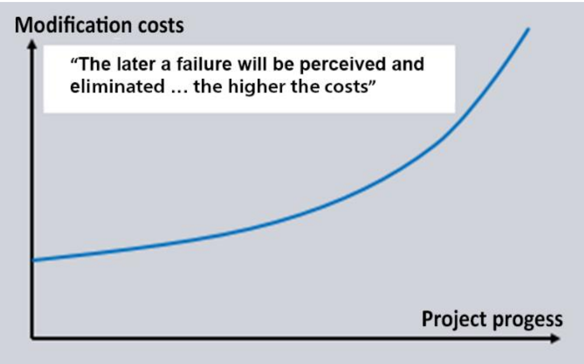

Figure 2: Symbolic curve of modification costs

2 Typical Test Phases

Manufacturers of protection and process control equipment, who also manufacture plant components such as medium-and high-voltage components, or build, commission, and maintain complete plants, must carry out testing over the widest range of situations. The following typical test phases can be broadly distinguished:

2.1 Testing During Research and Development

When new protection relays are designed, or existing equipment is refined and improved, this generally goes hand-in-hand with new technological advances, and their functionality must then be tested accordingly. Relay and test set manufacturers often encounter new challenges here.

This applies to new algorithms, communication, for example, as per IEC 61850, integration of innovative transducers, new grid solution concepts such as Smart Grids, or completely new applications.

R&D departments must subject new equipment to a large number of tests during type testing to ensure that the new equipment operates correctly in all circumstances. Extensive use of automation is already made here to facilitate the handling of large numbers of different test situations and uncovering any problems that may still exist. On occasion, large numbers of manual tests are also carried out for examining quite specific phenomena in detail.

2.2 Testing in Series Production

In the series production of new or existing models, the aim is to ensure that every unit "off the line" complies exactly with the manufacturer's specifications. In these routine tests, large numbers of accuracy tests are carried out one after the other, as are special function tests. It is self-evident that this is highly automated and that automatic test reports are vital.

2.3 Testing in the Project Business

In the project business, equipment and components manufactured in-house or third-party equipment that has been bought-in, are assembled into systems or complete plants which are then supplied to the end customer in accordance with the specifications. The plant is installed and, following acceptance by the customer, is put into service.

A detailed description of the project business can be found in the joint publications of a major switchgear manufacturer and OMICRON [1,2].

The main project phases are as shown below in a simplified project plan (Figure 3).

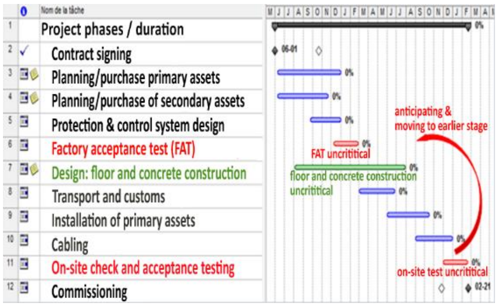

Figure 3: Simplified project plan and main project phases

All sub-units (for example, cubicles, digital control systems, high- and medium-voltage equipment, etc.), and finally the complete plant, must be subjected to absolutely reliable testing. Since the "man-hours" test here is planned in advance and included in the project contract price, it is enormously important in this very competitive business to optimize hours worked and cost savings. On the other hand, quality must be a top priority (for safety reasons and because of the enormous material and downtime costs in the event of a failure). Poor quality in this business quickly moves a vendor on to the blacklist of the dissatisfied customer, so that follow-up orders are highly unlikely.
The secondary testing has a significant influence on the entire project. It takes up the largest part of the overall project testing time and consists of two main sections:

- Factory testing, followed by the factory acceptance test (FAT)
- On-site testing, followed by the site acceptance test (SAT)

Figure 4: Factory test of a provisionally complete interconnected protection and digital control system

To optimize time and costs while assuring maximum quality, it is important to do as much testing as possible in the factory in advance, in order to keep the on-site testing as short and efficient as possible. The man-hour costs for the latter are significantly higher. Furthermore, the on-site testing is part of the project's "critical path" (a delay in this phase will delay the entire project). Factory testing, however, which runs parallel to the civil engineering earthworks and concreting, is not.
The protection and control system components are often provisionally connected together in the factory and the operation of the complete system tested in advance.
Bay panels and protection functions are often highly standardized, so automated testing is widely used here as well. The same test sequences can be used later on site.

2.4 Testing During Maintenance and Servicing

If regular maintenance has to be carried out at the customer's plant after commissioning, this is often undertaken by the manufacturer's service department. Some customers perform the maintenance checks themselves or contract them out to an external service provider.
Whatever the situation, the manufacturing test sequences can be re-used for maintenance so that any changes over time in the performance of the equipment can be identified by comparing the test results. A well-organized library of test data and plants is necessary for this (see also Section 5) [9].

2.5 Testing for Fault Analysis

Trouble-shooting or grid failure analysis generally no longer belong to the actual project, but are typical tasks for a plant after delivery in the warranty phase or for a later service or maintenance contract. The ability to evaluate faults and record events allows questions such as why a protection relay has tripped or not to be explained. Test sets allow the recorded data to be "played back" and fed into an identical relay, which makes the analysis of specific failure cases much easier.
A well-organized library of data and documentation of the failure case is also of great importance here (see also Section 5) [9].

3 Examination of the CMC Test Set Pool of an International Manufacturer

We have undertaken a close examination of the CMC equipment pool and associated OMICRON Control Center (OCC) licenses of one of our customers of many years standing. This customer is a leading international manufacturer of protection and process control equipment. They also offer complete solutions and customized switchgear in the project business, as well as commissioning and maintenance services. The following data were gathered by OMICRON at the end of 2015 at the request of the manufacturer as part of a Quality Value Engineering (QVE) exercise.

Important preliminary remarks:

We have intentionally not given the name of the manufacturer, as the following contains very detailed information about its international equipment pool.

However, for clarification we would like to make it clear at this point that the figures used in this article do not necessarily have anything to do with this manufacturer, but have been deliberately selected from different manufacturers in order to preserve the anonymity of the data. The figures are intended to give a general understanding of the test process and do not in any way indicate the origin of the data.

*We have simply called the company **"ELECTROCOMPANY"** without intending to refer to any firm which may have a similar name.*

3.1 CMC Equipment Pool of the Manufacturer

The manufacturer "ELECTROCOMPANY" has a total of 449 CMC protection test sets in use worldwide. The first devices were bought as early as 1995. All of these devices are still in operation today and are used around the world in research and development, production processes, and the project and service businesses. Figure 5 shows the worldwide purchase of CMC equipment per year. The devices are shown by date of factory delivery of all units which at the time of the survey (2015) belonged to the manufacturer "ELECTROCOMPANY". Devices that have been acquired through takeovers of other companies between 1995 and 2015 are included by their factory delivery date. Devices belonging to companies that may have been disposed of and which no longer belong to "ELECTROCOMPANY" were eliminated retroactively by their factory delivery date.

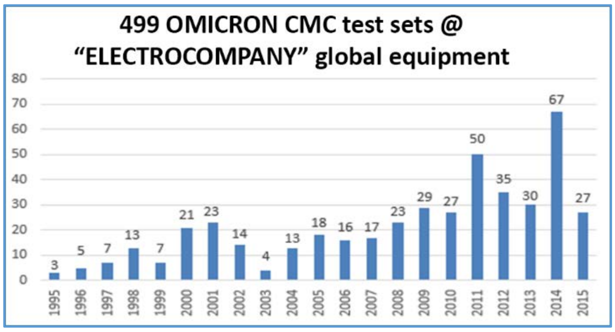

Figure 5: CMC equipment pool of "ELECTROCOMPANY" (by year of delivery)

3.2 Use of the <u>O</u>MICRON <u>C</u>ONTROL <u>C</u>ENTER (OCC)

Use of the OCC allows a very high “degree of automation” to be achieved. Even though separate test modules, such as STATE SEQUENCER, RAMPING, OVERCURRENT, ADVANCED DISTANCE, and many others, already offer a wide range of automation possibilities, OCC allows a further major step forwards to be taken. Different test modules can be put together in any order in OCC to form a test sequence. This can be performed either step-by-step or completely automatically, and all the results are obtained in a full test report. If e<u>X</u>tended <u>R</u>elay <u>I</u>nterface by <u>O</u>MICRON (XRIO) is also used, the test functions in question can be adapted automatically to the individual setting parameters of the relay. This means that relays with the same function, but with different settings depending on the outgoing feeder, are tested automatically with the same sequence without the need for any functional adaptation. Many relays also allow their setting parameters to be exported, which can then be loaded into the OCC completely automatically. Consequently, it makes sense to predefine such OCC test sequences once for each relay type or function, and then always to work with the same sequence, which saves an enormous amount of time and also allows for interesting comparisons during the evaluation (for example, changes in the relay behavior in the time during maintenance tests or also tests for discrepancies during production). OMICRON provides its users with a large number of such sequences as a PTL for most relay types, free of charge. These can be adopted directly as they are, or adapted by the customer to match their testing requirements. In the project business, customers often create OCC sequences for complete standardized cubicles with several relays in order to make enormous time savings during the functional test of the complete cubicle, firstly in the factory test, and then again later during commissioning at the construction site.

Our manufacturer, "ELECTROCOMPANY", makes extensive use of the OCC, depending on the field of application and the factory. In other areas we have seen an increasing potential for improvement, particularly in recent years. Figure 6 shows a comparison, this time cumulative per year, of the quantities of CMC test sets and the associated OCC licenses in which "ELECTROCOMPANY" has invested in over the last 20 years.

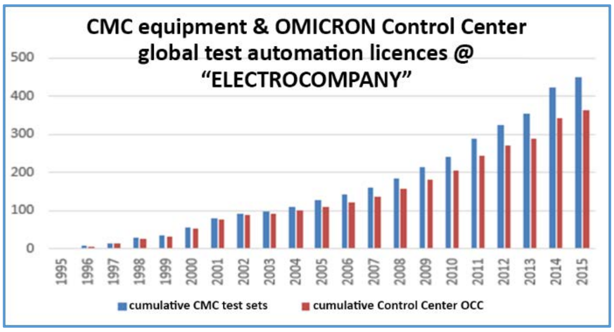

Figure 6: CMC equipment pool and OCC of "ELECTROCOMPANY" (cumulative)

3.3 Definition: "Degree of Automation"

We have established the term "degree of automation" for the following study of the equipment pool of "ELECTROCOMPANY" and defined it as follows:

$$\text{"degree of automation"} = \frac{\text{number of OCC}}{\text{number of CMC}} \quad (1)$$

This definition does not clearly state the extent to which the work at "ELECTROCOMPANY" is actually automated, since manual work can naturally continue even if an OCC license is held. However, it does give an interesting insight into the potential for automating the equipment pool and how this has developed over the past 20 years. We know from customer feedback and enquiries to our technical support that the existing OCC licenses at "ELECTROCOMPANY" are used extensively. There is undoubtedly a permanent requirement for training in order to familiarize new colleagues with the possibilities and advantages of OCC and thereby increase the effective degree of utilization still further.

It should also be noted at this point that not only does the OCC contribute to automation, but that "ELECTROCOMPANY" has developed its own external user interface in its own protection equipment production facilities, and controls its CMC units using the CMEngine automation interface supplied by OMICRON. In fixed test installations, where test specimens are subjected not only to electrical but also to thermal or mechanical tests, the test technician in series production has the advantage of having the same user interface for all applications. Since CMEngine is also included in the OCC package and "ELECTROCOMPANY" usually acquires it as a joint package in order to use the equipment elsewhere for pure automation with OCC, our figures are not falsified by that. The "degree of automation" in this case includes external control via CMEngine.

3.4 Development of the “Degree of Automation” Worldwide

If we look at the "degree of automation", as defined above, for the worldwide equipment pool of "ELECTROCOMPANY", two surprising things immediately become apparent:

- The average "degree of automation" at "ELECTROCOMPANY" worldwide is very high, at approximately 85%.
- In the first 10 years, the "degree of automation" rose rapidly to 100%. From 2004 it fell slowly, but continuously, to about 80% today. The trend is a slight decline.

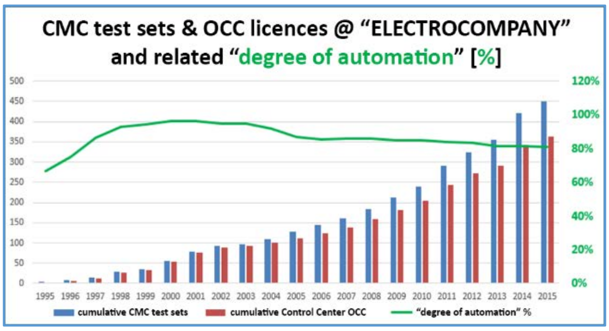

Figure 7: "ELECTROCOMPANY" CMC equipment pool and OCC and "degree of automation" worldwide (cumulative)

The slight drop in the "degree of automation" over the last 10 years at "ELECTROCOMPANY" was of particular interest to us, and we have held meetings with test technicians and commissioning managers from this sector to find an explanation. We were able to identify three possible main causes:

Main causes:

- Until about 10 years ago, the position of "technician" was still very important in large companies. This was the person who defined the exact requirements for test technology. Since then, the purchasing department has exerted greatly increased influence in decision-making. Technical advantages no longer count as much, and instead often only the purchase price matters. Many buyers were given clear directions a few years ago to save money and were instructed to no longer buy everything the technician asked for. Personal bonus payments are often an additional factor, and depend simply on the reduction in the purchase price without taking the overall efficiency into account (Quality Value Engineering or Total Cost of Ownership). These latter points have assumed more importance again in recent years, but the approach used is long and difficult.

- Competition has become increasingly strong, especially in the international project business, and project prices have dropped while margins are becoming narrower. In recent years attempts have, therefore, been made to work more with cheaper local units and to delineate financial project responsibilities clearly, including within the Group. Increasing reliance is being placed on business-oriented project management, in which professional project managers with a commercial rather than a technical background are employed, sometimes supported by business administrators who only monitor the costs in their area. This statement by an experienced commissioning manager brings home the point: "*The number of people with a holistic view and who can see* *the overall success of the firm or a project split between onshore and offshore, is decreasing all the time. It has become very difficult today to find a project manager who is ready to invest more time in intensive factory tests, so that somebody else down the line saves time at the construction site, if the costs saved there are no longer within the PM's responsibility."*

- Similarly, external temporary staff have been increasingly used in recent years as part of cost-cutting exercises and workload optimization, often in countries where continued technical education and training is neglected. Frequent internal personnel changes and inadequately trained staff mean that existing automation possibilities for testing are sometimes insufficiently utilized, which inevitably leads to more time being spent on manual testing. The lack of awareness of the advantages of automated testing is reflected in the declining "degree of automation".

3.5 Development of the "Degree of Automation" by Region

Examination of the development of the "degree of automation" by region leads to further interesting conclusions, some of which greatly support the above remarks, but in addition reveal local phenomena.

Figure 9 shows a comparative overview of the average "degree of automation" by region. The six individual evaluations in Figure 10 show the development over time of the "degree of automation" in these six regions.

Figure 8: Overview of different regions

The largest region in terms of CMC equipment usage at "ELECTROCOMPANY" is the Europe and Africa (EA) region which extends from Vladivostok to Cape Town, but excludes the Central Europe (CEU) region with the main markets of Germany, Austria, and Switzerland. Together with Latin America (LA), CEU is the region with the greatest "degree of automation". The level here is almost 100%, while in the EA and Middle East and South Asia (MESA) it is only around 70%. Asia Pacific (AP) and North America (NA) are in the middle, with about 85%.

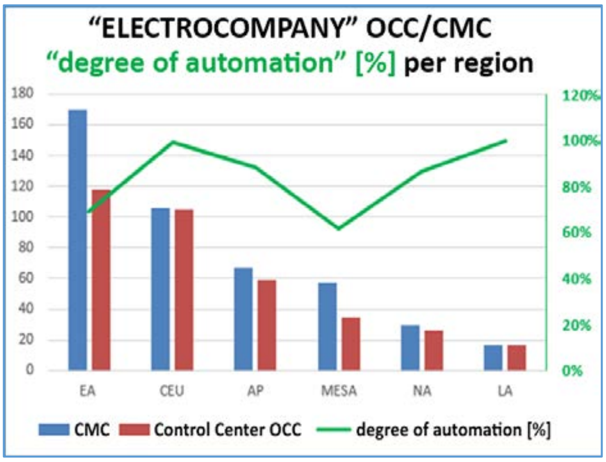

Figure 9: CMC equipment pool and OCC "ELECTROCOMPANY" with corresponding "degree of automation" (by region)

If one looks at the changes over time in the "degree of automation" by region, some very interesting developments can be seen:

In Central Europe, the "degree of automation" over the last 20 years has remained constant at almost 100%. In the main markets of Germany, Austria, and Switzerland, the advantages of automation are recognized and utilized in full by "ELECTROCOMPANY". This is the consequence on the one hand of great economic success, an understanding of quality, and highly organized working methods, coupled with relatively high wage costs if viewed from a global perspective. On the other hand, a high level of regular good training and continuing education of the technical personnel, or participation in industry-specific technical seminars, such as the OMICRON user conferences, for example, contributes to employees of different companies exchanging ideas and learning from each other.

In Europe & Africa, we can clearly see the decline at a worldwide level in automation at "ELECTROCOMPANY" as described above. Over the last 15 years it has dropped slowly but constantly, from 100% in 2001 to just under 70% today. The reasons for this have already been set out in Section 3.4.

In Asia Pacific, we observe precisely the opposite phenomenon. The "degree of automation" at "ELECTROCOMPANY" in this region is steadily increasing, and has now reached almost 90% after starting at about 40%. This is a major success, for which there are

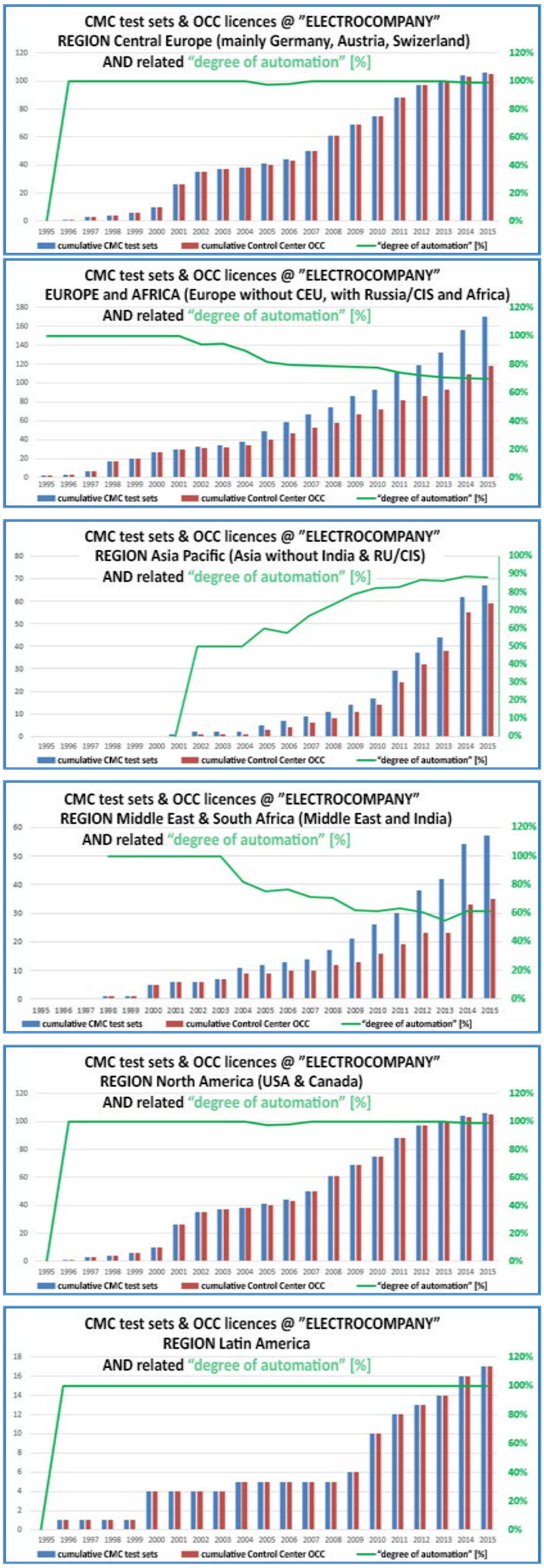

Figure 10: "ELECTROCOMPANY" CMC equipment pool and OCC and "degree of automation" (cumulative)

two main reasons. Firstly, in Asian countries, OMICRON stands out very clearly from the simple price-cutting cheap products from the local competition due to its high quality and inimitable high capacity for automation, and is particularly competitive with OCC. Secondly, if using IEC 61850, OCC represents an enormous simplification when working with GOOSE and Sampled Values (SV), which are very widely used in this region.

In Middle East & South Asia, a sharp drop in the "degree of automation" at "ELECTROCOMPANY" can be seen, which is presumably connected with the economic situation, the price level, and also the low wage costs in India. Test technicians from low-cost home countries are also predominantly employed in the wealthy Middle East. In addition, automation can be easily replaced if one test technician is simply replaced by three low-cost test technicians who carry out the testing manually.

In North America & Latin America, the "degree of automation" has remained constant over the years at almost 100%. This is presumably due, among other things, to the very early use of digital American relays in the market, which already offered a large number of sophisticated protection functions at a very early stage, and where automated testing was particularly worthwhile. The local technicians from "ELECTROCOMPANY" are, therefore, used to this kind of testing due to their work environment.

The minor drop in the "degree of automation" in NA in the last three years is presumably directly connected with the strong growth of OMICRON at "ELECTROCOMPANY" in this market. As a result of increased co-operation with "ELECTROCOMPANY", new additional areas of application outside relay technology have been discovered here for CMCs, for which there is no initial demand for automation.

3.6 Division into Two Representative Test and Automation Profiles

In order to estimate as accurately as possible the time and cost savings that have been achieved from the complete CMC equipment pool at "ELECTROCOMPANY" since its inception, we have roughly divided the typical application cases into two simplified main use profiles. We have defined three scenarios (MAX, MIDDLE, and MIN) for each of these two profiles. MIN is the worst and MAX the best realistic case. These are, of course, approximations and simplifications, but on average these two application groups and three scenarios give a realistic picture.

We have put research, development, laboratory tests, and production tests in **application group 1**.

Project business in the factory and at the construction site, together with service and maintenance testing, have been put together in **application group 2**.

The significant difference between these two groups is that there is a higher degree of usage of the test devices in the laboratory and production, since the equipment there has no downtime time due to shipping, customs, etc. The time saved with the OCC is also slightly higher here, since devices of the same type are often tested in series. In the project business, the periphery around the equipment must also be included, which reduces the possible time savings. However, the personnel costs in production are lower, since no travel costs, foreign service allowances, hazard working allowances, etc., are incurred, contrary to the situation on the construction site.

For the sake of simplicity, we have left the number of working days in the year at 250 in both cases, although weekends are often worked when commissioning. This is allowed for in the degree of usage, however.

Since test modules also allow a certain amount of automation without using OCC, we have taken this into account by using a smaller time saving only for those devices not yet fitted with OCC (module/manual). For all the others, we have only used the (OCC/manual) data, and not counted the time savings twice.

Electrocompany application	R&D / lab / production			Project / site / service		
Scenario	MIN	MEDIUM	MAX	MIN	MEDIUM	MAX
Utilization ratio / year (%)	60	70	80	20	40	60
Saved time OCC/manual (%)	50	70	90	40	60	80
Saved time modules/manual (%)	20	30	40	20	30	40
Working days /year (days)	250	250	250	250	250	250
Staff costs/day (€)	600	600	600	800	900	1000

Table 1: Estimation parameters per application group and scenario for "ELECTROCOMPANY"

3.7 Global Savings in Testing Time and Costs

The calculation of the time savings and costs over all the years for the worldwide equipment pool of "ELECTROCOMPANY" is similar to the above, very simplified, example (Table 1). Since we wish to consider all the units, we have assumed for the sake of simplicity that the two application groups are represented roughly equally strongly in the Group worldwide. This would have to be examined in correspondingly greater detail if considering savings by region, country, or even facility. The differences average themselves out on a worldwide basis.

Figure 11 shows the development of the cumulative testing time saved in days for the entire equipment pool.

Depending on the scenario, between 20,000 and almost 70,000 days have been saved over the past 20 years (Figure 12). The realistic MIDDLE scenario gives a **saving of 40,000 days**.

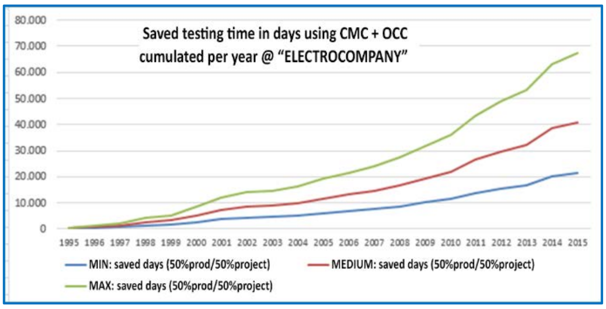

Figure 11: Testing time saved worldwide (cumulative) at "ELECTROCOMPANY"; MIN, MIDDLE, MAX scenarios

If we convert these time savings for testing into the corresponding personnel costs, again taking both application groups and their daily cost rates as the same, this gives cost savings from automated testing for "ELECTROCOMPANY" of between €13 million and €46 million. The realistic MIDDLE scenario gives a **saving of some €26 million**.

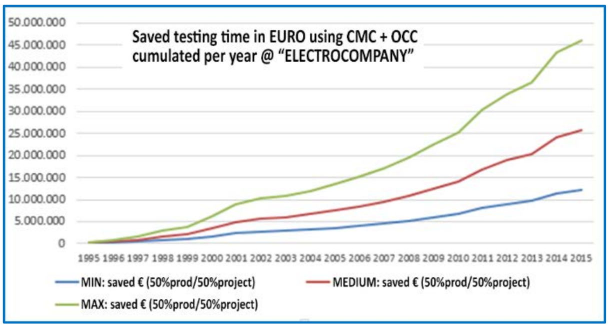

Figure 12: Test costs saved worldwide (cumulative) at "ELECTROCOMPANY"; MIN, MIDDLE, MAX scenarios

The fact that the above savings have a non-linear upwards slope despite the "degree of automation" being slightly downwards (Figure 7) is due to the strong equipment pool growth accompanying the growth of the "ELECTROCOMPANY" Group.

3.8 Potential Estimation: Efficiency Increase due to OCC Upgrade

One of the tasks of the QVE study at "ELECTROCOMPANY" was to determine the potential for improving the equipment pool. Eighty-six CMC devices, approximately 17% of the pool, are currently operated without OCC. An immediate retrofitting of these devices with OCC would, if they were also used for automation purposes, result in further cost savings of €2.3 to €5.2 million every year, depending on the scenario. In the MIDDLE scenario, the **additional potential savings are €3.7 million per annum**. And all for a negligible investment cost.

However, it would have to be ensured that optimal use was being made of the OCC licenses for all the devices. Training and sharing of experiences are the key here (see Section 4.2).

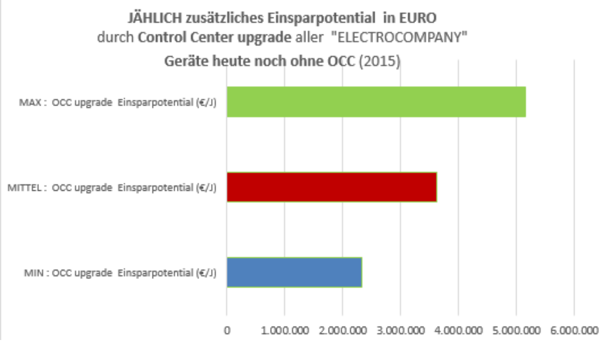

Figure 13: Additional potential worldwide savings at "ELECTROCOMPANY" from an OCC upgrade, in Euro

3.9 Further Steps in the Case Study

In the "ELECTROCOMPANY" case study, we presented the results to the central purchasing department as part of a QVE study. As a manufacturer of test sets, OMICRON is in a purchase group for external tools and materials, which are not physically built into the products and systems of "ELECTROCOMPANY" (in common with manufacturers of fork lift trucks or wrenches, up to shipping service providers). It was very important to explain exactly what our systems do and that the major benefit arises when one just starts to think in cross-project and cross-company terms, instead of making savings in the wrong area.

The results were very positively accepted. The purchasing department at "ELECTROCOMPANY" is very interested in long-term co-operation with strategic vendors who participate in long-term value creation for its Group.

Subsequent efforts will then be taken to ensure that these possibilities are better known within the Group. The existing co-operation in research and development, which is already very good, will be expanded and efforts made in the operational business to broaden the great success of the CMC equipment pool to other products in the growing OMICRON product range. Internal, continuing education and sharing of experiences was identified as a major point that we want to strengthen, particularly in those countries where the "degree of automation", as defined by us, is low or even declining.

4 Sensible Use of the Saved Time

We now come to perhaps the most important point of the entire article: **What does "savings" mean?**

We have estimated the testing time saved and converted it into an equivalent sum of financial savings in euro, using a "man-hour" cost rate. We have done this to show the order of magnitude and potential savings more clearly.

A CMC can do many things; it can save much time and effort, reliably check system safety, and help develop new innovative solutions, but unfortunately it cannot print money.

The financial savings, therefore, remain fictitious, although the time savings are real. It is up to the tester and their employer how they allocate this time in a fair way, and what they sensibly do with it.

4.1 False Conclusion for Innovative Manufacturers: "CMC Replaces Test Technicians"

Absolutely the biggest and most irresponsible false conclusion that the management of a company could make if they are interested in a successful continuation of their enterprise, would be to say: "*X times 1500 hours saved, which means we no longer need X test technicians*".

Anyone who has tried to recruit a well-trained protection technician knows how difficult it is to find a suitable candidate, and how immensely valuable an internal protection technician or protection engineer is for their company.

Protection and test technicians not only know the complicated protection equipment, test sets and test procedures, but also have to understand the operation of the entire secondary periphery, the connected high-voltage equipment, and the entire grid system, since the protection contains an overview of the complete system and must respond correctly to it. Protection technicians often have extensive experience, particularly in the project business, and a good general understanding of the overall process of a project, as they intervene at different important times and are well able to judge where things need to be improved.

Furthermore, in recent years digital protection has been increasingly merging with digital process control, and in future will do so even with non-conventional transducers, merging units (MU), or digital switchgear controllers, so that new challenges will constantly arise in the field of communications with IEC 61850.

4.2 Investment in Continuing Education, Training, and Lasting Competitiveness

The question of what to do with the saved time in order to re-invest it in a way that brings maximum profits for the company can, therefore, be easily answered:

It should be invested in protection technicians, in their training and continuing education, and, if necessary, in further developments in other technical fields in the company, where they can make a decisive contribution with their experience. This can be, for example, in the development of new and innovative products, improving project efficiency and quality, or developing new additional profitable business in the service field.

In any case, their experience should also be used to train new young test technicians in good time, who in many countries unfortunately are increasingly joining companies that offer ever-sparser training in basic electrical engineering.

In our case study with "ELECTROCOMPANY" – a modern, highly competitive and future-oriented Group – this is exactly what has been done. When we report middle-range savings of €26 million, it has saved this sum by using automated testing in the entire production and project process in recent years to avoid having highly qualified test technicians spending their time on point-to-point tests on copper wiring and other repetitive tasks, as shown symbolically in Figure 14. The time made available for these specialists was used to develop innovations and services, and also lucrative additional business, at a comparable cost.

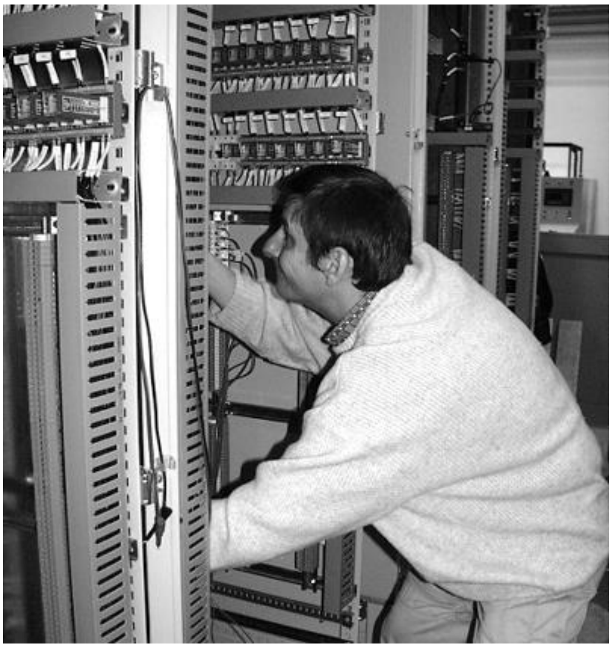

Figure 14: Time-consuming point-to-point testing in the copper-wiring era, before fiber glass

5 Outlook

In the previous sections we have dealt almost exclusively with the efficiency of working with the OMICRON Control Center, as this was the main objective of the study.

However, for the sake of completeness we would like at this point to mention that a number of other possibilities exist in the field of testing, which can increase the efficiency of a tester or entire team of testers.

5.1 Optimized Utilization of the CMC Equipment Pool with the Addition of CMControl with Mixed Teams of Protection Experts and Occasional Users.

At customer visits and product presentations attended by entire technical departments, we constantly encounter the following observation: In a team that shares one or more CMC test sets, there are almost always a few test technicians who use the equipment regularly, and some of whom are very familiar with automation technology. The use of a PC does not present any problems for them either. However, there are almost always some team members who are very polyvalent and deployed in primary and secondary engineering as part of service functions or on the construction site. These technicians often only need to carry out very simple secondary tests a few times each year and frequently do not have the time to learn the TEST UNIVERSE and the OCC. Moreover, use of a PC for their easy task is often regarded as superfluous, or even represents a hindrance.

For these employees, perfect automation is not the efficient solution; instead it is far more efficient for them simply to perform the test manually, without a PC.

If it is desired to substantially increase the degree of usage of a CMC device in such a mixed team, the additional use of CMControl, a tactile control unit for simple manual tests, is the ideal solution. These CMControl units can also be retrofitted in an existing equipment pool and, therefore, offer the chance of utilizing the CMC capacity better, either automated with a PC or manually without a PC.

It is, therefore, worth their while for test team leaders to think through the team composition carefully and reflect on such an additional option. Care should be taken, however: there are good technicians who nonetheless find using a PC unpleasant. They often do not like to admit it, but are very happy when they have a simple alternative which makes their work easier, and thereby overcomes their accumulated reticence towards the protection tests.

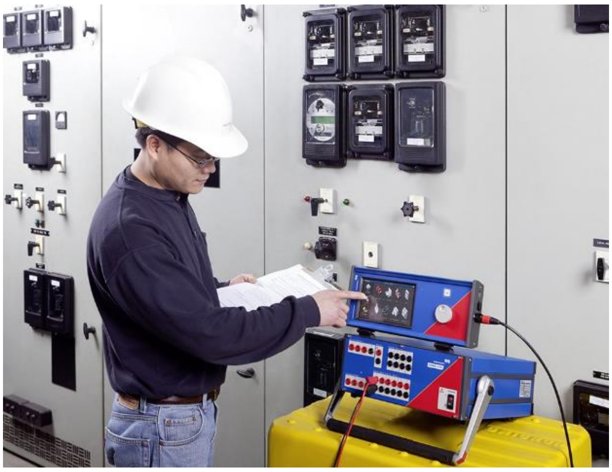

Figure 15: Quick manual testing with CMControl for simple test tasks

5.2 System-Based Testing with RelaySimTest

Classic automated testing with OCC tests the correct operation of a protection relay, using the protection parameters set in this relay. This is, therefore, often called "parameter testing".

However, what if the parameters are wrong? Either incorrectly calculated, or wrongly input, or transferred from one typical switchgear to another of the same kind in the course of copying during the general factory test, without setting the necessary final adjustment for the particular outgoing feeder afterwards. This does happen – and not infrequently.

The device is then found to be operating correctly with "parameter-oriented testing". However, under some circumstances it may be completely wrongly set for real operational use.

The software RelaySimTest [8] offers excellent capability here, also automated, of testing not just whether the protection function is correct, but also whether the protection parameters are the right ones for the application in question. In other words, they test not just the relay, but also the people who have calculated the protection parameters or "typed" them into the protection device.

A test of this kind is known as "system-based testing" and is based on a power line and grid simulation, best done with measured grid parameters. RelaySimTest then automatically runs through a series of freely selectable fault conditions and checks whether in reality the relay actually trips correctly with its current settings, and refrains from tripping when there is no need.

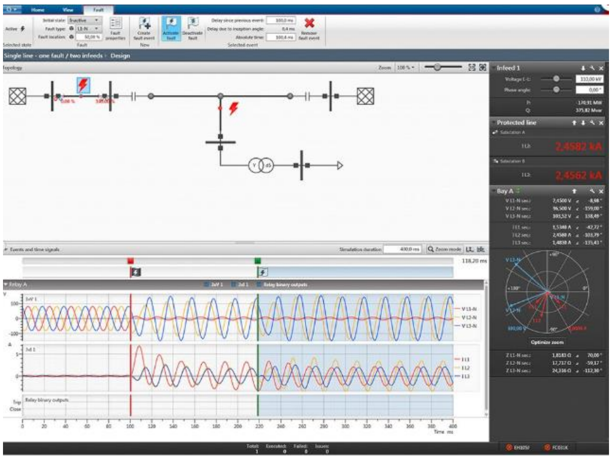

Figure 16: System-based testing with RelaySimTest

5.3 OCC Automation for Protection Testing with IEC 61850

Any test technician who wants to know all about protection equipment and grid behavior, but at the same time has to deal with testing using communications and data designations in GOOSE or Sampled Values (SV), has their work cut out. They would be well-advised to make this as easy as possible by means of automation, so that they can concentrate on the important matters. Relays can of course be tested with IEC 61850 without using OCC, but then every time the test set is switched on, the GOOSE signals and SV streams must be declared again - "digital cabling", like re-wiring the test set in the past if someone had unplugged it and put it away during the lunch break. OCC is just as helpful in the world of IEC 61850 as combined plugs and special "test plugs" are for traditional testing. The GOOSE or SV module is loaded and the settings entered just once at the start of the OCC sequence, after which everything always happens automatically when the sequence is restarted. This saves time and avoids unnecessary errors.

5.4 Simple Automatic Management of Protection Test Data with ADMO

Much has been said so far about quality and potential time savings regarding the test process itself, and in producing the test report.

However, the management of test data, test reports, and associated documentation also offers substantial scope for improving quality (this is sometimes demanded and checked in quality audits anyway), saving time, and even adding considerable value in the service field, in order to generate new profitable business.

A lot of test data and files are still simply filed away somewhere when a project has been completed or a maintenance inspection carried out. Important data is either left to gather dust in paper folders somewhere, or else disappears into the depths of

Windows Explorer, or even worse, into a huge company database where all sorts of stuff is stored.

So when all the old data from a test is required (audit, relay failure examination in the event of incorrect tripping, or just for more regular maintenance), nothing can be found, or what is found is incomplete, or else much time has to be spent until everything is together.

ADMO offers a very simple solution for this for storing all data at once and finding it again immediately. ADMO also allows an overview of a relay pool or projects to be created easily and maintenance cycles to be programmed, which automatically give reminders as to when and where the next measurement has to be taken. The potential for power utilities, but also for project firms and service providers, is considerable. Particularly in combination with the OCC, the option is available for regular maintenance operations of comparing the results of tests on a relay with those of previous tests, and drawing sensible conclusions from this about any changes. All that is required is to have all the old data available with the precise OCC sequence for it in order to compare like with like by feeding in exactly the same input. The calibration certificates of the two test sets (then and now) may also be available so that the discrepancy in the results over time can be clearly ascribed to a change in the relay or its connection to the periphery.

Figure 17: Organized test data management with the ADMO maintenance management solution

6 Summary

Due to the increasing digitization in protection equipment, process control systems, and plant construction, the demands on tests are becoming increasingly diverse. Functions that used to be hard-wired are integrated digitally today. On the one hand this makes testing and the demands on test technicians more complex, while on the other hand, new possibilities for increasing the efficiency of a test while simultaneously reducing the test time are arising all the time.

This concerns above all a suitable testing strategy in which complete systems are almost fully tested in advance at an early stage in the factory. The use of fiber optic data buses instead of classic copper wiring encourages this.

By contrast, the possibilities for carrying out efficient automated testing and saving valuable testing time, for example with the OMICRON Control Center, are becoming ever-greater.

The case study of a manufacturer of protection devices, process control equipment, and complete plants, shows how impressively high such time savings can be. Even though this is only a rough estimate supported by several customer statements, it is clear that the investment in good, reliable automated test sets bears no relation to the immense cost savings.

Automated and organized testing is worthwhile, as is the investment in training and continuing education seminars for test technicians, whose competence will become an increasingly important capital asset in a successful and innovative business.

Glossary of Abbreviations

ADMO – OMICRON maintenance management solution
AP – Asia-Pacific region
CEU – Central Europe region
CMC – OMICRON secondary test set
CMControl – OMICRON manual user interface
CMEngine - automation interface
EA – Europe and Africa region
IED – Intelligent Electronic Device
FAT – Factory Acceptance Test
GOOSE – Generic Object Oriented Substation Event
GPS – Global Positioning System
LA – Latin America region
MAX – optimistic scenario
MESA – Middle East and South Asia region
MIN – pessimistic scenario
MIDDLE – middle, realistic scenario
MU – Merging Unit
NA – North America region
OCC – OMICRON Control Center
PTL – Protection Testing Library of OMICRON
RelaySimTest –software for system-based testing
SAT – Site Acceptance Test
SV – Sampled Values
QVE – Quality Value Engineering
XRIO - eXtended Relay Interface by OMICRON

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Key Words

Protection relay, automated testing, OCC, efficiency, project business, production, type test, series test, factory test, FAT, site test, SAT, man-hour costs, time savings, quality value engineering, QVE, total cost of ownership, system-based testing, data management, IEC 61850, continuing education, training.

About the author

Till Welfonder, who holds a doctorate in power engineering, was born in 1967 in Stuttgart, Germany. He was awarded his degree in electrical engineering at the University of Stuttgart in 1994. In 1995 he moved to France and obtained his doctorate in "Fault location in neutral compensated MV Grids of EDF" in 1998 at the Institut National Polytechnique in Grenoble. He began his career as a protection engineer in 1998. From 2000 to 2007 he was responsible for protection and substation control activity at an international HV/MV turnkey project substation manufacturer before becoming their head of the medium-voltage division in 2007. At the end of 2009 he moved to OMICRON France as Area Sales Manager for France and Italy, with a particular focus on protection testing. Since 2013, Till Welfonder has been the OMICRON Regional Sales Manager for the Europe and Africa region, including the coordination of key account management tasks for a small number of selected major international customers.