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A folk festival as a field test –

The low voltage distribution network under the microscope

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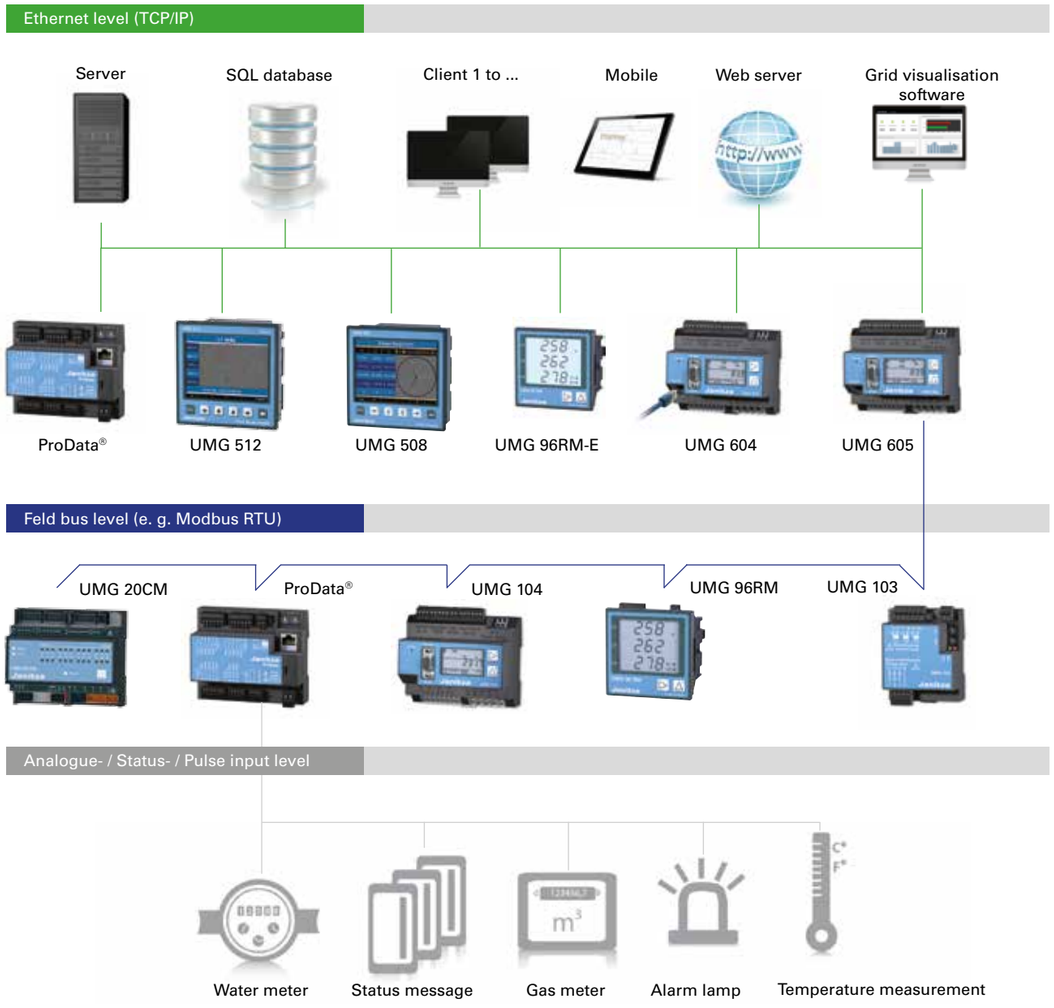

UMG 508 / UMG 604 = Janitza power analyser

UMG 512 / UMG 605 = Janitza power quality analyser

UMG 96RM / UMG 96RM-E / UMG 103 / UMG 104 = Janitza multifunctional measurement devices for energy measrument technology

UMG 20CM = Janitza Residual current monitoring (RCM) and energy data acquisition

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A folk festival as a field test: The low voltage distribution network under the microscope

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A folk festival as a field test: The low voltage distribution network under the microscope

Stuttgart's folk festival on the "Wasen" is one of the largest folk festivals in Europe, and proves a challenge for the grid operator in Stuttgart every year. In 2015, it also served as a field test. Mobile measuring boxes captured all load flows in the ten local secondary substations on the festival site precisely to the second. The measurements not only increase the supply assurance of a folk festival. In the mid-term it is also intended that such measures will toughen up the entire distribution network for the future energy supply to the region covered by the Stuttgart grid.

But first, a few figures from the Cannstatt folk festival on the Wasen, in the heart of Stuttgart-Bad Cannstatt: 37 hectares, over 330 operations, 35,000 seats, four million visitors – and 1,760,000 kWh of electricity consumed! Making sure that this event runs reliably is a major task for the grid operator "Stuttgart Netze Betrieb GmbH", a joint venture of Netze BW and Stuttgart's public utility company.

Ralf Schwollius, one of the team leaders for operations and maintenance, sums up the supply situation: "The Wasen is supplied by two different substations, in order to almost entirely compensate for a failure by way of redundancy. Furthermore, all stations on the site exhibit an intelligent design, i.e. they are remotely monitored and remotely controlled from a central network control centre of Netze BW. It is therefore possible for the control centre to remedy any faults and failures directly." Despite this, Ralf Schwollius is on-site every day during the set-up phase and for the two weeks of the festival. The ten secondary substations (Image 1) and around 100 cable distribution cabinets with up to ten connections keep him on tenterhooks. "The first week after the festival starts is very interesting for us", explains Ralf Schwollius. "That is when it becomes clear whether the reported power reflects the reality." With the first stampede of visitors, bottlenecks arise time and again despite the extensive planning. The load centres change from year to year, even some of the major rides change their location. Ralf Schwollius therefore depends on the assistance of

Image 1: The transformer stations are integrated in the folk festival backdrop.

the registered fitters, who in turn rely on the festival tent and ride operators. However, a precise forecast is not possible due to too many unknown factors - in particular the weather.

More action, more beer, more energy

Critical consumers are the major rides, which not only require extensive power but also load the network with reactive power, harmonics and return feeding (Image 2 and Image 3). However, even the large festival tents, which always stand in the same locations and are almost constantly full of visitors, cause difficulties for Ralf Schwollius and the operators: Their power consumption is increasing constantly. There are a number of reasons for this. For example, the main tents have expanded their capacity from around 3,500 to almost 6,000 seats. This requires increased refrigeration, more chicken roasters, etc. Each of the main tents has a connected load of approx. 600 kW. Furthermore, for fire safety reasons gas-operated heating and cooking appliances are banned in all areas of the festival site including the caravan parking spaces, and the supplies have all been replaced with electrical equivalents.

And the modern lighting equipment brings no relief either. Ralf Schwollius: “There is no discernible reduction in consumption due to modern lighting technology. The basic lighting load has fallen, but this is more than offset by the new possibilities afforded by LED technology.”
For a long time the energy supply was safeguarded by high power reserves. However, such assurances are meeting their limits in times of rising costs and increasingly demanding consumers (Image 4). The loads arising due to power electronics are increasing; direct influence on the operators is difficult. A ride does not have the technical and financial options open to an industrial operation. “We need to deal with the circumstances, which means dimensioning the connections accordingly”, says Ralf Schwollius. “However, our customers - in particular the beer tent suppliers, who take over the power supply from the transfer point - are also reaching their limits. They are required not only to safeguard the entire supply, but also the supply to the individual stations inside the tent. They require information for this, although they have relatively little knowledge of the load distribution. They have therefore requested our support.” When it came to keeping unnecessary reserves available, all parties involved were unanimous - that was not a sustainable option. Instead, an accurate real-time analysis of the energy flows was required, in order to optimally utilise the available capacities. This is not possible with the traditional drag pointer instruments, particularly because reactive currents and harmonic interferences should also be captured. The measurement technology specialist Janitza electronics GmbH was therefore commissioned with developing a suitable solution.

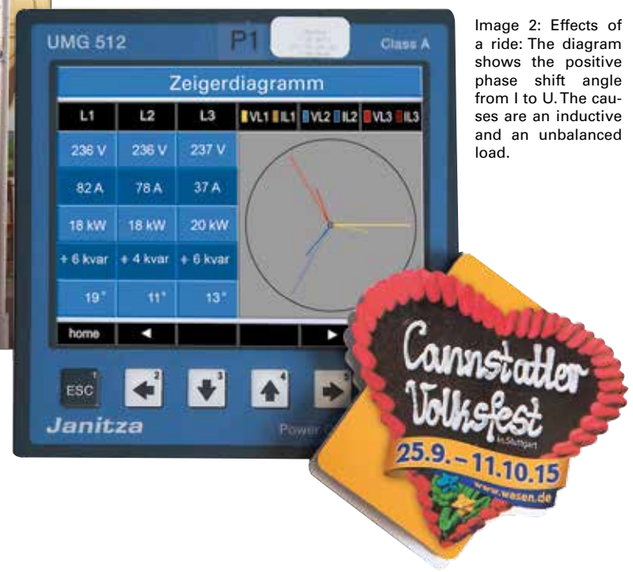

Image 2: Effects of a ride: The diagram shows the positive phase shift angle from I to U. The causes are an inductive and an unbalanced load.

Image 3: A wide range of consumers are present on the Wasen: Rides with rapid load changes and non-linear characteristics, as well as giant beer tents with connected loads of up to 600 MW.

Energy acquisition to go: Mobile measuring boxes

Load flow measurement and power quality analysis on the distribution level are gaining in importance for all grid operators and energy suppliers. Stuttgart Netze therefore considered the Wasen not as an isolated measure, but as a field test for a comprehensive future solution. Measurement technology that prevails in this extreme situation will also prove itself in everyday practice. Because the site is only used on an intermittent basis, it was decided that the instruments should remain mobile. Stuttgart Netze and Janitza therefore worked together to develop the mobile measuring boxes (Image 5). Kilian Eckert, Business Development for Power Utilities at Janitza, describes the system: “We capture the supply from the transformer to the busbar on the one side, and the low voltage outputs on the other side - the latter on a four-pole basis (Image 6). That is important, because it is only with the measurement on the PEN phase that the reactive currents and return feeding can be captured.” (Image 7) Ralf Schwollius also emphasizes the significance of the four-pole measurement: “The

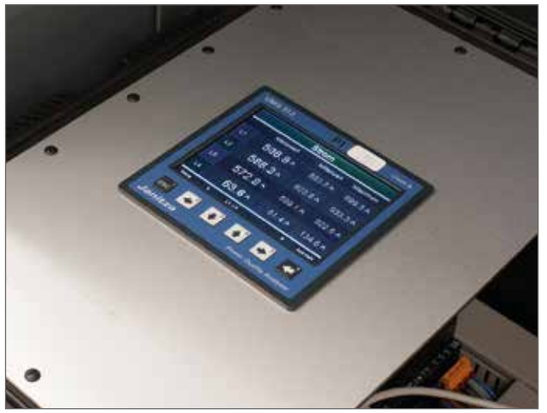

Image 4: As the measured value memory shows, the monitored outlet is well utilised. The nominal current is 1000A, phase L2 was partially loaded with 933 A.

Image 5: Ralf Schwollius from Netze BW GmbH and Kilian Eckert from Janitza at the measuring box.

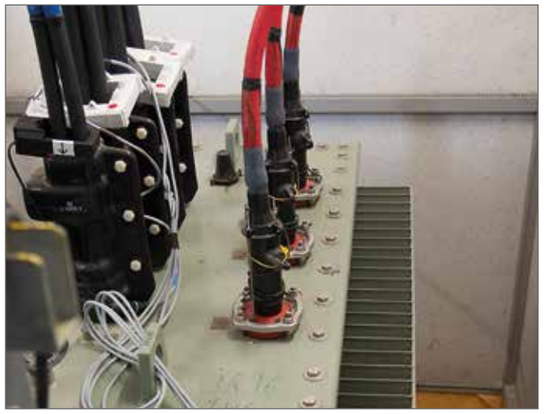

Image 6: The measurements also include the supply cable at the transformer.

Image 7: The converters are installed at the outlets and at the supply lines from the transformer. This provides a complete picture of the overall situation.

interharmonics range is very interesting. The PEN phase often has a smaller cross-section, although it carries more and more current. We need to gather empirical values for the loads and recognise trends." All measurements take place via split-core current transformers, which can be safely fitted and removed during ongoing operation without an interruption of the phase (Image 8). The heart of every measuring box is a class A measurement device UMG 512. With this, it is possible to capture the power quality in the network and document all data. Two measurement devices of type UMG 20CM are installed below the main device, each of which has 20 current inputs. As such, both devices can capture a total of ten LV outputs on a four-pole basis (Image 9). "With the measuring boxes it is possible to capture load profiles in meshed low voltage networks and networks in general. Furthermore, it is also possible to make return feeding and interference, such as harmonics, visible"; Kilian Eckert sums up the possibilities in brief, adding: "The open interfaces also constitute a highlight. Here on the Wasen, we have equipped the boxes with mobile telephony modems. This means that the low voltage grid management office at Stuttgart Netze has access to the data at all times. The same systems can also be adapted to the interfaces and control lines of existing equipment with very little effort. In this way, we avoid redundancies and keep investments to a minimum." (Image 10)

Stuttgart Netze is profiting in a number of ways from the measured data: It is increasing the supply assurance, easing planning, improving the interference analyses and opening up new commercial fields in the service division.

Measured data for greater supply assurance

As previously described, the weekend after the folk festival opens brings with it the first major stress test for the supply. In principle, the preconditions are good: The stations are heavily meshed with each other via low voltage lines. Additional power can be made available through network changeover measures. However, this would require those responsible to plan greater reserves, due to the lack of comprehensive load profile acquisition. With the mobile communicating measuring boxes, it is now possible to access the data in real-time, and even locate interference, network failures, etc. The technicians can specifically intervene in order to facilitate rapid re-establishment of the supply. Ralf Schwollius goes a step further: "We can even anticipate whether bottlenecks are a risk and implement precautions before failures arise. Additionally, we are able to better analyse a problem, and

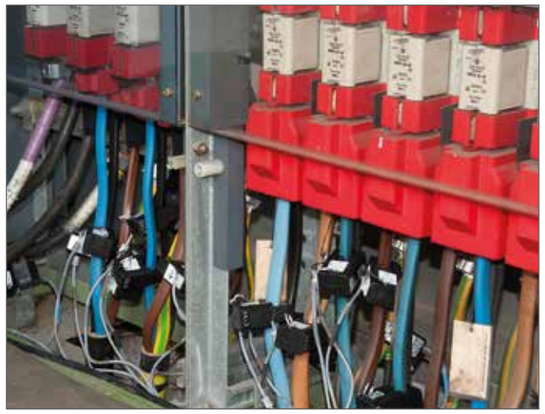

Image 8: The split-core current transformers can be fitted and disassembled at the line connection without intervention. That makes mobile use possible in the first place.

Image 9: The mobile measuring box next to an outgoing section. The split-core current transformers can be fitted and disassembled at the line connection without intervention. That makes mobile use possible in the first place.

Image 10: Thanks to the open interfaces, the mobile measuring box offers numerous possibilities for evaluation and documentation. Here, a load curve is visible directly on the Notebook.

determine whether the cause is to be found with us or the customer." (Image 11)

On the topic of precautions, Kilian Eckert adds: "Our measurement devices offer parametrisable threshold value monitoring. The customer can determine when a warning message is issued, and therefore avoid failures." Ralf Schwollius points out a further aspect of the supply assurance: "What happens if a tent supply drops out? There is naturally an emergency lighting supply, but the entire operation comes to a standstill. And now we are dealing not only with 6000 visitors, but with 6000 presumably fairly drunken visitors. How do they react when the supplies stop coming? Today the dynamics are different to how they were 10-20 years ago. And it is necessary to consider this behaviour when dimensioning the supply assurance."

Measured data with added value

Measured data is opening up a new commercial field to Stuttgart Netze, because detailed load profiles constitute real added value for major consumers. Ralf Schwollius is already able to report on the first successes: "The beer tent operators have commissioned us with the data acquisition and are paying for this too." Because the tents and major rides anyway require their own cable distributions and therefore their own outlet in the substation, Stuttgart Netze is able to offer them this service. Furthermore, the measured data helps the parties involved to analyse critical situations (Image 12). In this way it is possible to develop strategies together, in order to deliver an assured supply to major consumers in the future too.

Ralf Schwollius points out another financial aspect: "The Federal Network Agency has introduced a ranking system for network operators, to evaluate failure times. If network sections and equipment (calculated by the average availability of all equipment) are not available then penalties, in other words fines, are issued." Another good reason to invest in the measurement technology.

Surprising findings

Several weeks were required to comprehensively evaluate the data. However, even the first profiles delivered surprising findings. Christian Seiz, an employee at the order centre of Stuttgart Netze, comments on the load profile of a beer tent (Image 13): "Due to the drag pointer instruments, we only anticipated short peaks. The precise history revealed a different picture. The load peaks lasted significantly longer." The recording originates from a Saturday. For the purpose of interpretation, a look back at the day's routine is required. At the weekend, the Wasen opens at 11:00 hrs. The tent fills up quickly. Between 16:00 and 17:00 hrs, the tent is completely closed and cleaned. In the evening, it opens from 17:00 to 23:00 hrs. The screenshot clearly shows that the load arises suddenly at 07:00 hrs when work starts, and then rises constantly.

A further flank at 11:00 hrs signals the tent opening. The severe and lengthy gradient is due to the beer chilling. Once the guests have been served the first round of beers, consumption stabilises at a high level. The "beer chilling peak" reappears at 17:00 hrs. Also noteworthy is how the consumption decreases significantly during the evening, although the tent was certainly well attended on a Saturday.

Image 11: Non-linear loads lead to harmonics and return feeding. The measurement shows how these add up on the neutral conductor (green).

Image 12: The UMG 512 can capture and present harmonics in detail: here harmonics 5, 7, 11 and 13.

Additionally interesting is the recording for one of the larger rides, the "Top Spin", which combines pendulum and rotating movements. The screenshot (Image 14) clearly shows the rapid load change during a ride, as well as the reactive currents (blue curve). The stampede of visitors is also clearly visible. Only at lunchtime does the rush diminish somewhat.

Christian Seiz continues: "Stuttgart Netze and the operators of the rides and beer tents benefit in equal measure from the data. A risk of bottlenecks can be detected, as can possible technical problems. Even gradual changes are apparent at an early stage." This allows Stuttgart Netze to provide an additional service. The target groups are customers who shy away from the outlay required for their own measurements. They can obtain not only the data but also a qualified interpretation of it from Stuttgart Netze.

From the Wasen to real life

On a mid-term basis, Stuttgart Netze and Netze BW are planning to employ the measurement technology on a comprehensive basis. Ralf Schwollius on the topic: "What we are testing here, and the findings we are gaining, can be comprehensively applied later on. The technology brings extensive added value, both for the stability of the medium and low voltage network, and for the re-establishment of the supply. This applies in particular in light of recent developments." Ralf Schwollius is speaking here of the growing number of decentralised suppliers. The loads on the distribution level can no longer be sufficiently captured with Ferraris meters and drag pointer instruments. Only precise load profiles can determine where capacities suffice and where expansion measures are required. Clear figures are not only indispensable here for costs reasons, but also as grounds for public construction measures: Solar cells on one's own roof are popular, although a substation in the neighbourhood is less so.

Added to this comes the availability of manpower. With a failure, technicians are required to travel from their place of work or home. During the rush hour this has a major impact on the time required to re-establish the supply - in particular in Stuttgart. With detailed data, journeys for diagnostic purposes become superfluous.

A further problem is of a social nature. Ralf Schwollius: "Society's acceptance of interruptions to the energy supply is diminishing, in particular at major events for which consumers have paid a high entrance price, or where alcohol is involved. Also in the private sector problems arise quickly, for example due to computers or controllers that react sensitively to failures. In rural areas, acceptance still tends to exist. However, in towns and cities even minor interruptions lead quickly to compensation claims." Yet another reason in favour of precise load analysis. With compensation claims, it is possible to precisely determine when an interruption occurred and exactly which area was affected. The next aim now is to expand the measurement technology, step-by-step. Ralf Schwollius: "The good thing about the concept is the mobile technology. Due to the high investment volume, the equipment of all plants is not always financially viable. However, we are at an early stage and Janitza is acting with extensive flexibility and innovation. This opens up diverse possibilities for further development."

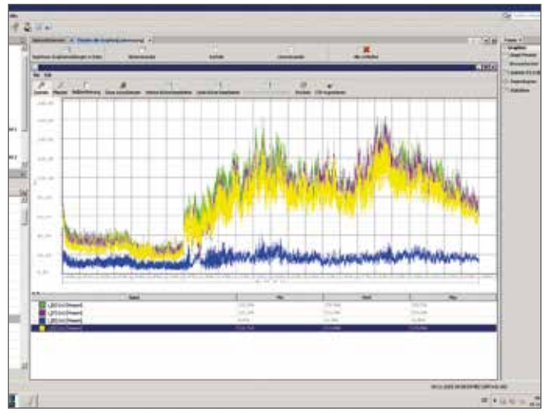

Image 13: The load profile of a beer tent. Clearly visible are the opening hours and the cleaning break in the afternoon

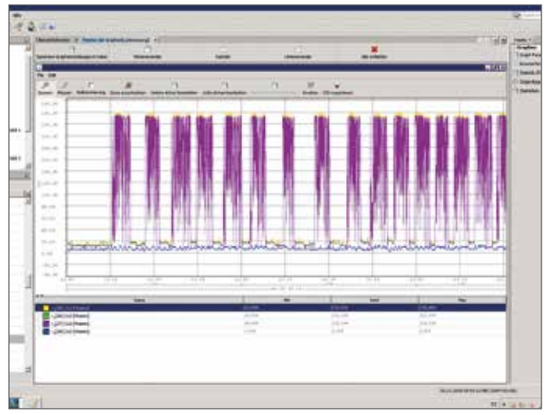

Image 14: The load profile of a ride shows not only the embarking and riding phases, but also the rapid load change during a ride.

((Image source)) Janitza electronics GmbH

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