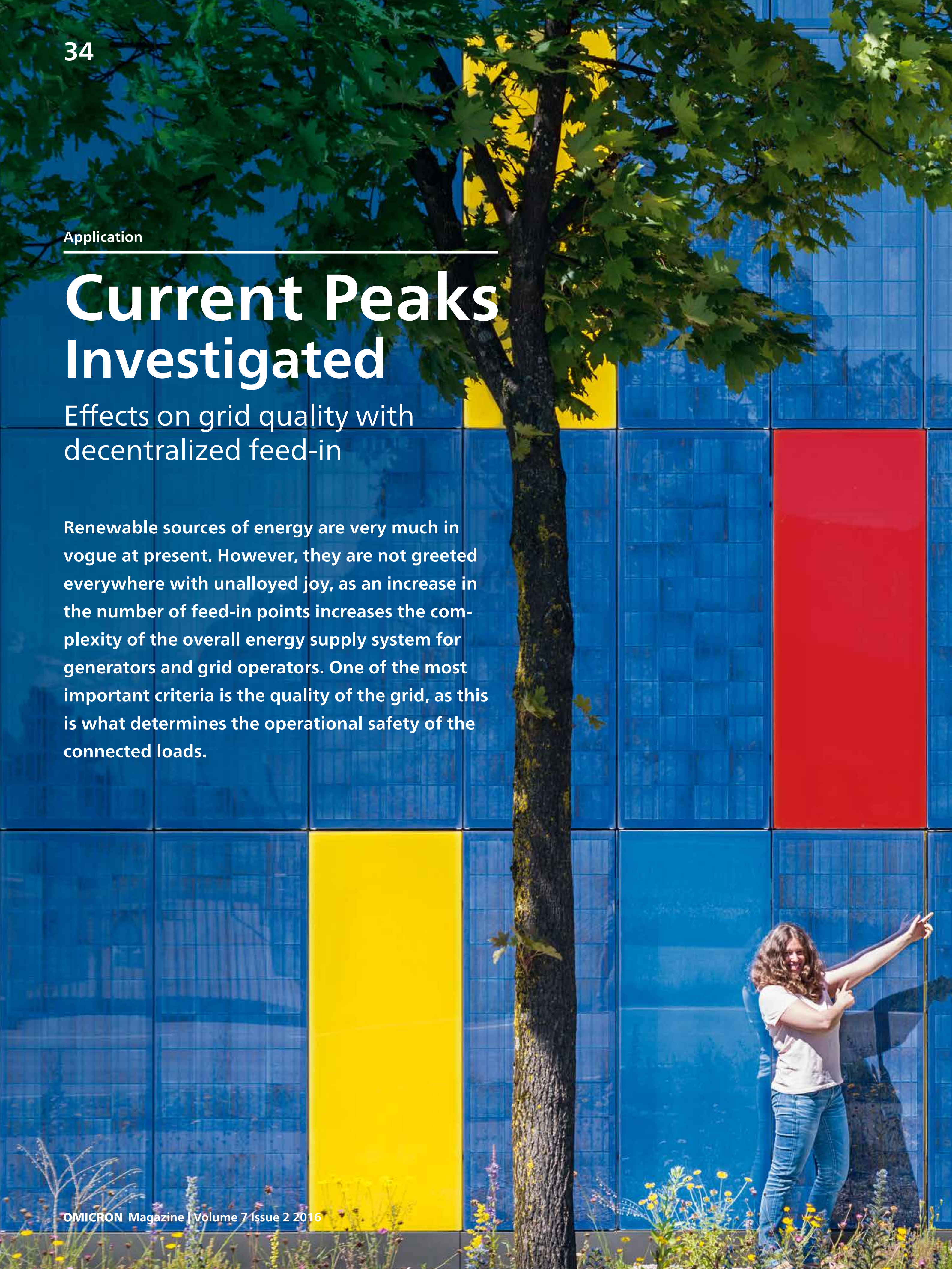

Application

Current Peaks Investigated

Effects on grid quality with decentralized feed-in

Renewable sources of energy are very much in vogue at present. However, they are not greeted everywhere with unalloyed joy, as an increase in the number of feed-in points increases the complexity of the overall energy supply system for generators and grid operators. One of the most important criteria is the quality of the grid, as this is what determines the operational safety of the connected loads.

780 m² / 8,396 ft² of photovoltaic panels are installed at the frontside of OMICRON's office in Klaus.

May 2015, the perfect time to take a closer look at the operation of OMICRON's own photovoltaic (PV) installation. Rather than the energy output of the system, Ines Halbritter, Software Project Manager in the Power Utility Communication division, was more interested in the effect the installation had on the internal and external energy distribution network. It is a well-known fact that renewable energy generation facilities deliver widely varying amounts of energy according to the prevailing weather conditions and time of day.

What makes high quality so important?

The consequences of poor grid quality are manifold: Increased energy consumption, higher grid losses, interruptions to power supplies and hence failure of, or damage to, equipment. Information technology equipment and sensitive measuring instruments are the most susceptible, but even large machines can be affected.

Many factors can influence grid quality, with voltage and line frequency being the most common. These have already been examined in some detail, and nowadays have little impact on the overall operation of PV installations.

Current harmonics – the poor relation

Ines suspected something else lay behind the reason why faults still occur: "For me, the current harmonics were central to my investigation. So far, very little attention has been paid to them in this regard."

A distorted sine wave is a typical feature indicating the presence of the harmonics that often trigger inexplicable phenomena such as computer crashes or loss of data. Current peaks concealed by the harmonics are particularly insidious, as their constant presence can lead to thermal overloading of the connected equipment. As part of her master's thesis, Ines therefore studied the current harmonics in our internal grid, which is connected to the medium-voltage grid and is also supplied by our PV installation.

The installation has a maximum output of 92 kW, and any surplus energy is fed into the grid. The internal low-voltage network is connected directly to the public medium-voltage grid (11 kV) via a transformer with a nominal output of 1 MVA. ▸

«For me, the current harmonics were central to my investigation. So far, very little attention has been paid to them in this regard.»

Ines Halbritter
Software Project Manager, OMICRON

For her measuring setup, Ines used three DANEO 400 units, as these provide a high sampling rate (up to 40) and offer high levels of precision when recording voltages, currents and their harmonics. To ensure the results were correctly time-aligned, she synchronized all the devices via GPS using OTMC 100 PTP Grandmaster Clocks. In addition, a roof-mounted weather station with a radiation sensor was used to record weather data.

Ines chose three locations for her measurements:

- Directly at the point that the PV installation feeds into the internal network. This is where she logged power and currents in addition to voltages, an ideal way of keeping an eye on the inverters.
- Within the downstream distribution network to note the effects on it.
- Directly at the transformer and the supply terminals of the energy supplier in order to detect disturbances from and into the medium-voltage grid.

She controlled all the systems involved from a single laptop via the internal network using the DANEO Control software package. After the initial configuration, no further manual intervention was required for recording the measurements.

Preparatory analysis steps

At all three measuring locations, the devices logged the required data for one minute every full hour – around 470 individual readings per device and recording time. The results were then analyzed using time-series charts, phase diagrams, bar charts and correlation diagrams.

As expected, power and current corresponded to the level of solar radiation. The power factor demonstrated that while it is generating power, the PV installation is always striving to supply pure active power.

"On days with little radiation, the grid drew more reactive power from the PV installation," noted Ines in her analysis. "This means that the PV installation is having a positive effect on reactive power."

Sinusoidal currents with flat roof

There were some days, however, when the current waveform was more distorted. The disturbances were clearly visible, even at high levels of radiation and a total output of about 40 kW, in other words just under half nominal output (Figure 1). At low levels of power output, the waveform deviated more strongly from its ideal sinusoidal shape; this was most pronounced when operating in the lower partial load range. This was also apparent from the total harmonic distortion (THD_i) values.

Current harmonics the culprit

The THD_i generally exhibited an exponential increase during the morning and evening, as well as when total output was less than 5 kW, and reacted inversely proportional to the output (Figure 2). Ines identified the 5th, 7th, 11th and 13th order harmonics as the culprits.

In the case of the 5th harmonic, both the PV installation (up to 25%) and the connected load were significant factors, irrespective of the level of solar radiation. However, these values were considerably lower on days when there was little interference from industrial power systems. Ines was therefore able to conclude that the PV installation exacerbated the disturbances in the grid.

The 7th harmonic acted in a similar manner, but did not fall back as much on non-working days. The higher-level harmonics showed only a limited correlation with

Testing with DANEO 400:
One of the measuring points was located directly at the transformer and the supply terminals of the energy supplier in order to detect disturbances from and into the medium-voltage grid.

the level of radiation. The inverters are the cause of these harmonics. They may well produce an outstanding voltage curve, but the currents distort as soon as the working point drifts out of the optimum operating range.

A question of location

In our distribution network and the medium-voltage grid, these disturbances are barely noticeable because the feed-in point is ideally situated with a rigid coupling close to the transformer, resulting in low levels of impedance. However, Ines does have one final thought: "The situation is different in a local grid with a large number of distributed PV installations. In this scenario, permanent grid monitoring with flexible compensation can prevent potentially negative impacts for consumers and loads."

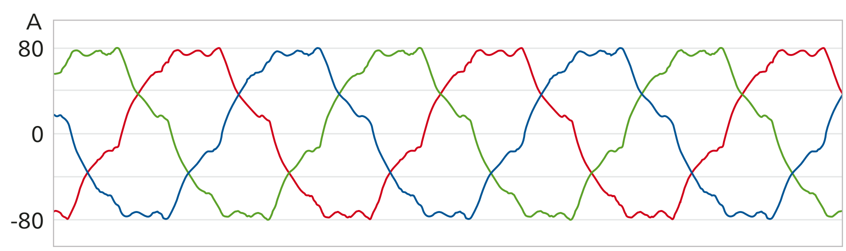

Figure 1: The acquired current waveforms show significant distortion, even at normal levels of solar radiation.

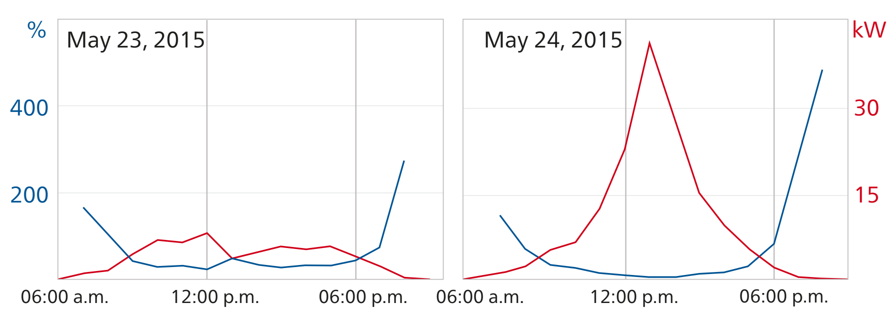

Figure 2: The THD_i reacted inversely proportional to the output.

DANEO 400

DANEO 400 is a hybrid measuring system that records and analyzes all conventional signals (voltages, currents, hard-wired binary status signals) and messages on the communications network in a substation. It processes both digital and analog signals and provides information to assess their proper co-ordination.