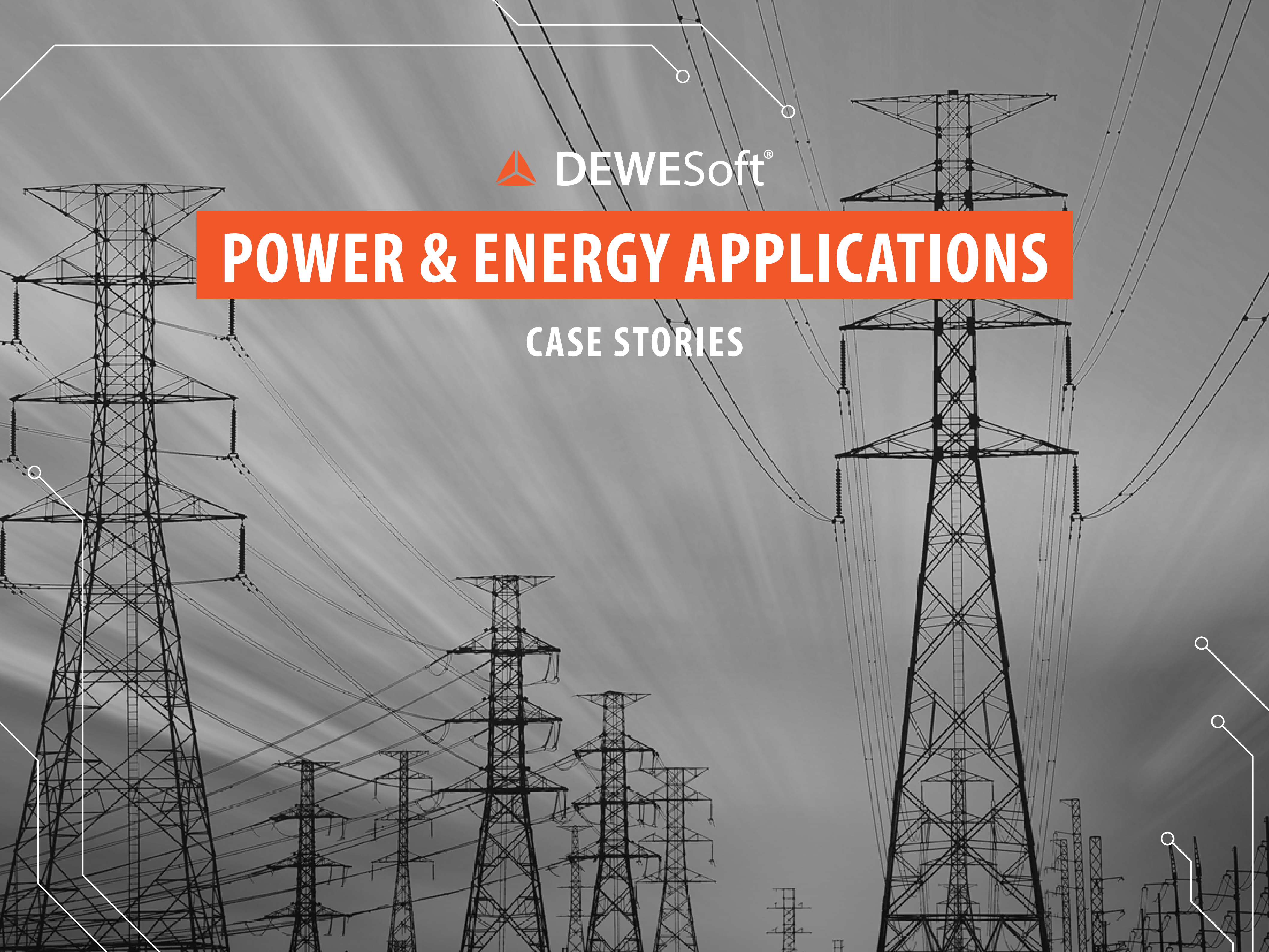
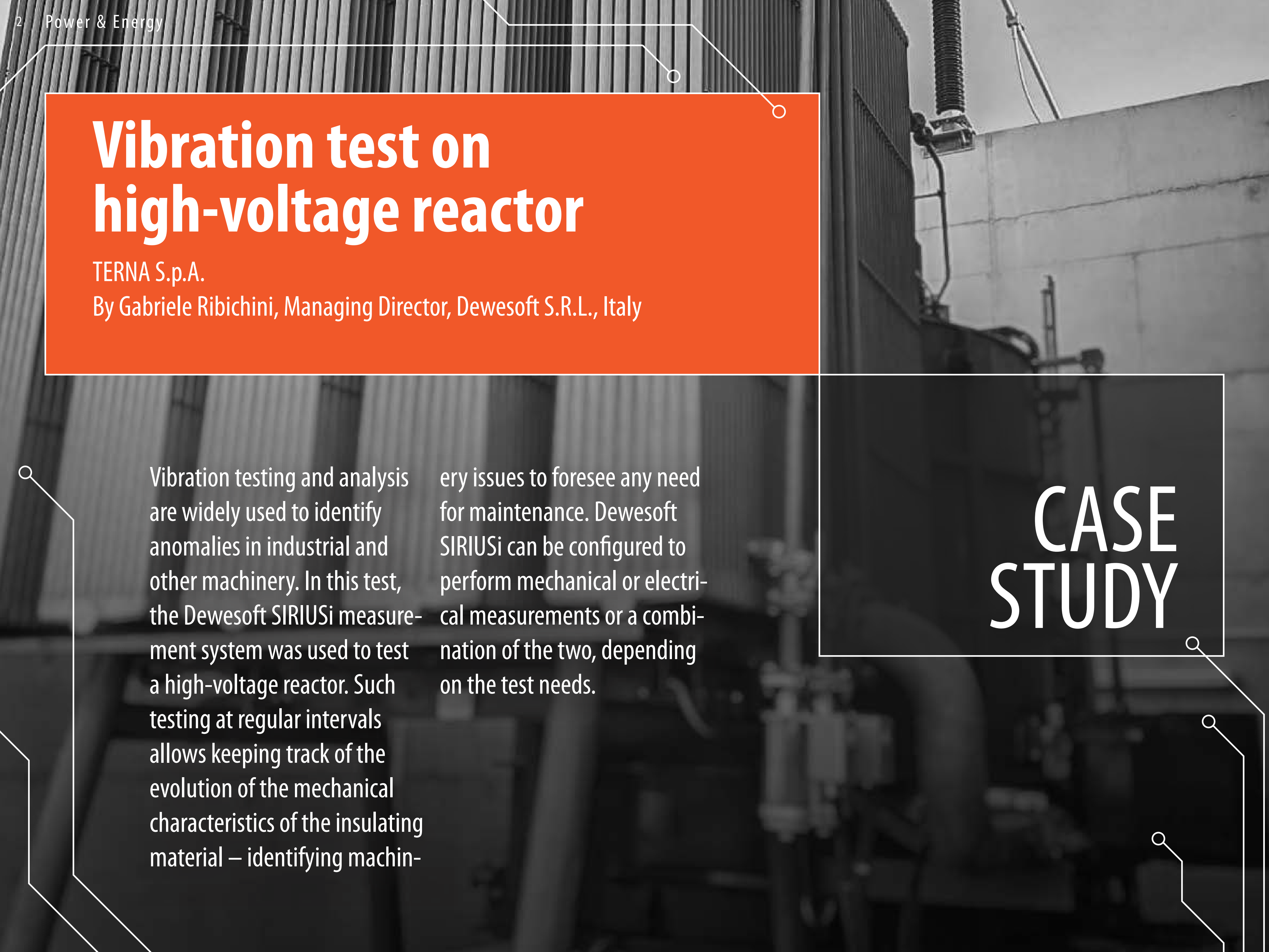
DEWESoft®

POWER & ENERGY APPLICATIONS

CASE STORIES





Vibration test on high-voltage reactor

TERNA S.p.A.

By Gabriele Ribichini, Managing Director, Dewesoft S.R.L., Italy

CASE STUDY

Vibration testing and analysis are widely used to identify anomalies in industrial and other machinery. In this test, the Dewesoft SIRIUSi measurement system was used to test a high-voltage reactor. Such testing at regular intervals allows keeping track of the evolution of the mechanical characteristics of the insulating material – identifying machinery issues to foresee any need for maintenance. Dewesoft SIRIUSi can be configured to perform mechanical or electrical measurements or a combination of the two, depending on the test needs.

Terna S.p.A. is a transmission system operator (TSO) based in Rome, Italy. It operates through Terna Rete Italia, which manages the Italian high-voltage transmission grid. A network of 74,669 Km of lines with 888 electrical substations, and 4 control centers managing 320 billion kWh every year. Such grids distribute high-voltage electricity many times greater than consumer voltages, in Italy typically up to 380 kV (AC).

Shunt reactors are used in high voltage energy transmission systems to stabilize the voltage during load variations. A traditional shunt reactor has a fixed rating and is either connected to the power line all the time or switched in and out depending on the load.

The main power system parameters are system voltages and frequency which normally indicate the level of generated active and reactive powers against the load power requirement.

Increased active and reactive power load tends to decrease the system frequency and voltage levels respectively. It then becomes essential to generate additional active and reactive power. The function of the reactors is to stabilize the grid voltage by consuming the reactive power of overhead lines in low load conditions.

The high quality and long-term stability of these components are crucial for a reliable transmission network. However, low noise and vibration levels are required by customers. Noise from reactors and large power transformers has a tonal character, which is perceived as more annoying than broadband noise at the same sound levels.

Purpose of the test

The purpose of the test was to verify the differences in the level of vibrations between a particularly noisy reactor and a less noisy one (a normal one) as the applied load varies. This comparison is aimed at evaluating the possible variations over time of any mechanical-structural drifts of the reactors, to predict and prevent their failures.

The measurement equipment used

- One Dewesoft SIRIUS signal conditioning and data acquisition system, model SIRIUSi-HS 4xHV, 4xLV
- One Dewesoft AC current clamp, model DS-CLAMP-15AC
- Two IEPE 10mV/g uniaxial accelerometers
- G.R.A.S. 46AE 1/2" microphone
- Interface accessories
- DewesoftX data acquisition software
- Power Analysis package

Current Transformers (CTs) are used to measure alternating current (AC). They are inductive sensors that consist of a primary winding, a magnetic core, and a secondary winding.

Essentially, a high current is transformed to a lower one using a magnetic carrier, thus very high currents can be measured safely and efficiently. In most current transformers, the primary winding has very few turns, while the secondary winding has many more turns. This ratio of turns between the primary and secondary determines how much the magnitude of the current load is stepped down.

The AC detected by the primary winding produces a magnetic field in the core, which induces a current in the secondary winding. This current is converted to the output of the sensor.

Current transformers are available as split-core configurations from Dewesoft, which allows convenient hook-up possibilities since the circuit does not need to be altered in any way.

The module integrates a high-end signal conditioning circuit with all the necessary features, such as:

- selection of AC or DC coupling,
- programmable gains,
- offset compensation (deriving from transducers),
- programmable low-pass filters,
- excitation of the current probes,
- the possibility of IEPE measurement,
- self-recognition of the current probes and the sensitivity to be used and self-recognition of adapters.

Among the various features, the galvanic isolation at 1600V channel-channel and channel-GND is noteworthy.

Noisy reactor

The vibration monitoring test of the mechanical structure of the noisy phase 4 reactor - see measurement in figure 3 - involved two configurations:

Accelerometer 1 is positioned behind the pressure indicator and Accelerometer 2 is positioned on the exchanger side; Accelerometer 1 is positioned behind the pressure indicator and Accelerometer 2 is positioned on the HV output side.

Reactor	Acc. 1 (pressure indicator)	Acc. 2 (exchanger side)	Acc. 2 (HV side)
Noisy reactor Phase 4	0.363 g	0.606 g	0.779 g
Standard noise reactor PHase 12	0.142 g	0.430 g	0.430 g

Measurement setup

One channel of the SIRIUSi isolated data acquisition system was dedicated to the voltage measurement, detected downstream of the VT (1:3850). The other channel was used for the current measurement downstream of the reactor (CT 1:400).

For this test, two accelerometers were used on the external structure of the reactor - see figure 2. One was kept in a fixed position near the temperature indicator and the other moved into two positions during the test. One on the exchanger side and one on the HV output side.

Normal noise reactor

The vibration monitoring test of the mechanical structure of a reactor with a normal noise level, the phase 12 reactor - see measurement in figure 4 - involved two configurations:

Accelerometer 1 is positioned behind the pressure indicator and Accelerometer 2 positioned on the exchanger side Accelerometer 1 is positioned behind the pressure indicator and Accelerometer 2 is positioned on the HV output side.

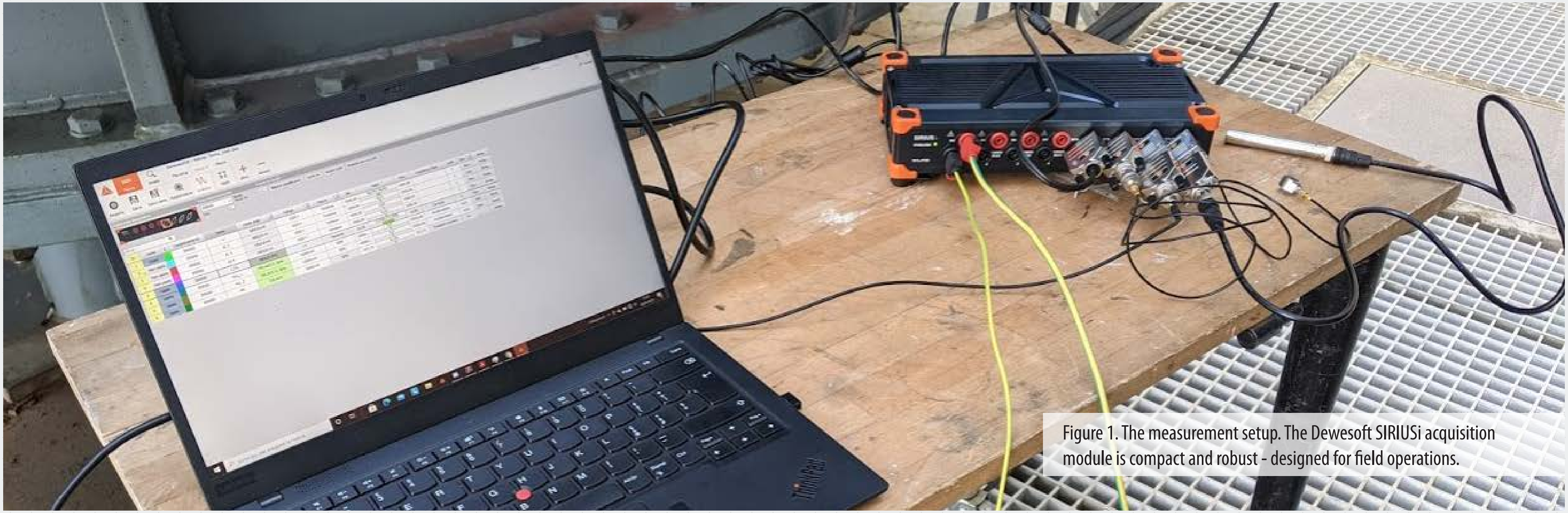


Figure 1. The measurement setup. The Dewesoft SIRIUSi acquisition module is compact and robust - designed for field operations.

Comparative mechanical analysis

We did a comparative mechanical analysis between the phase 4 reactor and the phase 12 reactor - see table 1 and figure 6.

For both measurement configurations, the mechanical behavior of the Phase 4 reactor shows higher acceleration RMS values when compared with the acceleration RMS values acquired on the Phase 12 reactor.

The extracted data show that a reactor with a normal noise level shows a uniform vibration level on both sides (exchanger side and HV side), equal to 0.430 g. The accelerometer near the pressure indicator - see figure 5 - measures an acceleration equal to about one-third of the other. This is a phenomenon that is explained by the presence of a reinforcement of the metal carpentry not far from the first accelerometer.

The analysis carried out on the noisy reactor, on the other hand, shows a clear

Figure 2. An accelerometer was used at two different positions on the reactor during the test – on the exchanger side and the HV output side.

discrepancy in the vibration values on the two sides measured by accelerometer 2 (0.606 and 0.779 g RMS).

Also, in this case, accelerometer 1 detects a lower vibration level but with a ratio of about ½ instead of ⅓ as in the case of a noisy reactor. The phenomenon is clearly visible in Figure 6.

A frequency analysis of the signals from the accelerometers shows the clear presence of harmonics up to 1,500Hz - see figure 7.

The spectral content is different but present at the same frequencies.

By adding the line voltage to the graph (in green), the correlation of the frequency of mechanical vibrations with that of the reactor energization becomes clear - see figure 8. The line voltage is at 50Hz, while the harmonics of the vibrations are multiples of 100Hz.

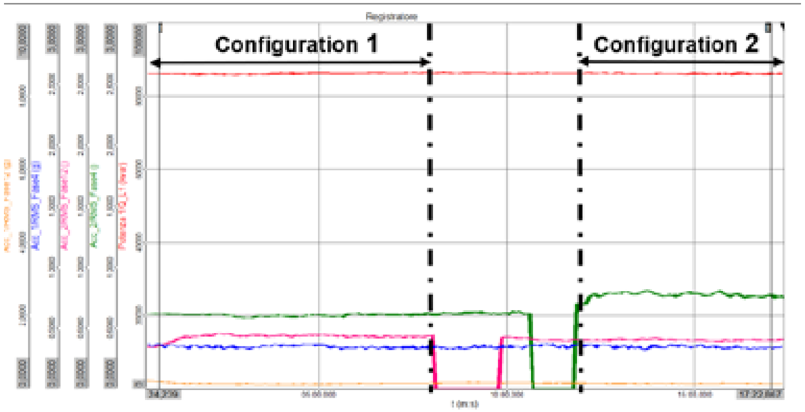


Figure 3. Measurement on the reactor showed a high noise level, in both test configurations.

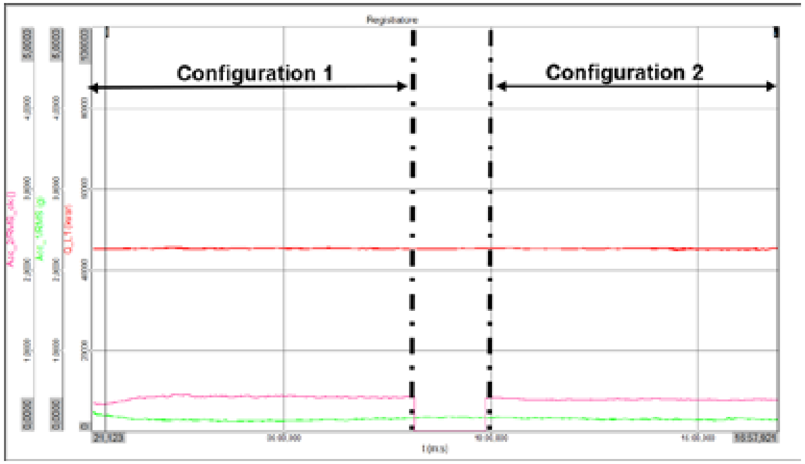
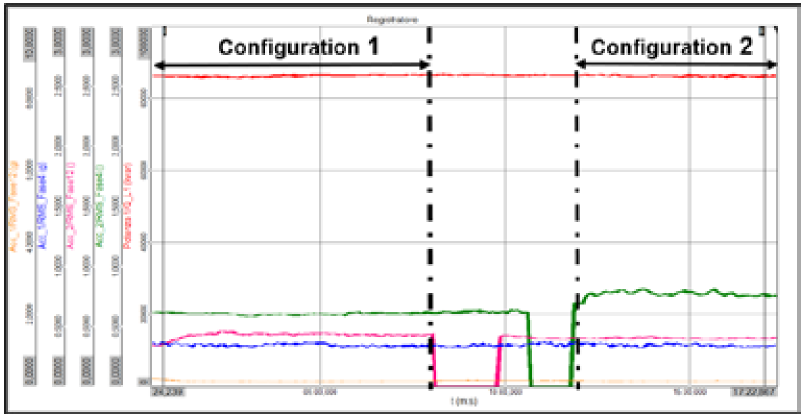


Figure 4. Measurement on the reactor showing normal noise level, in both test configurations.



(left) Figure 6. Comparison of measurements in the two configurations. The green curve shows a different RMS level of vibrations on the noisy reactor (Phase 4), passing from configuration 1 on the exchanger side to configuration 2 on the HV side. The two levels, on the other hand, are almost identical for the pink curve which represents the measurement on the normal noise reactor (Phase 12).


Figure 5. The measurement position behind the reactor pressure indicator.

Power analysis

We performed a power analysis on the voltage and current signals acquired downstream of the VTs and CTs to calculate the typical parameters of a network analyzer.

Line frequency
The line frequency was calculated by the PLL algorithm integrated with DewesoftX which guarantees an accuracy of 1 MilliHertz.

In the 20 minutes of recording, the system detected frequency variations with a peak-to-peak variation of 0.07 Hz - see figure 9.

Phasor analysis
A display of voltage and current phasors highlights the phase shift of 90°, which is typical of the almost pure inductance of the reactor - see figure 10.

Harmonics analysis
The very low Power Factor (0.0255) is almost totally caused by the phase shift close to 90 degrees, while the distorting power is practically negligible (almost perfect sinusoidal regime).

For reactive power Q, is measured in "var" (volt-ampere-reactive) – VA added the letter "r". The multiples of "var" are kvar (kilovar) and Mvar (megavar).

The distorting power D is 1,059 kvar out of a total reactive power Q of 86,347 kvar and an apparent power S of 86,375 kvar.

Conclusion

The tests carried out have clearly shown a high level of vibrations of the noisy reactor (Phase 4) compared to the normal noise reactor (Phase 12). It also showed a non-uniform distribution of intensities on the two measured sides.

The measured vibration shows a perfect correlation with the 50Hz mains frequency, a clear sign that it derives from reactor energization phenomena.

An analysis at regular intervals of the reactors with the Dewesoft system undoubtedly allows to keep track of the evolution of the mechanical characteristics of the insulating material and to foresee any need for maintenance.

The Dewesoft SIRIUSi system can be configured to perform mechanical or electrical measurements or a combination of the two, depending on the test needs.

The power analysis, in parallel with the mechanical measurements, allows you to keep all the electrical characteristics of the system under control and adds important information to detect any anomalies.

The same tool could be used for modal analysis (Modal Test) when the reactor is not energized, to identify the frequencies and modal shapes - see figure 13.

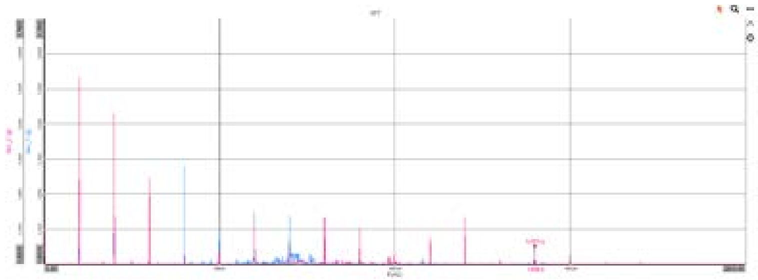


Figure 7. The acquisition on the noisy reactor, in blue the accelerometer near the temperature sensor, the exchanger side in red.

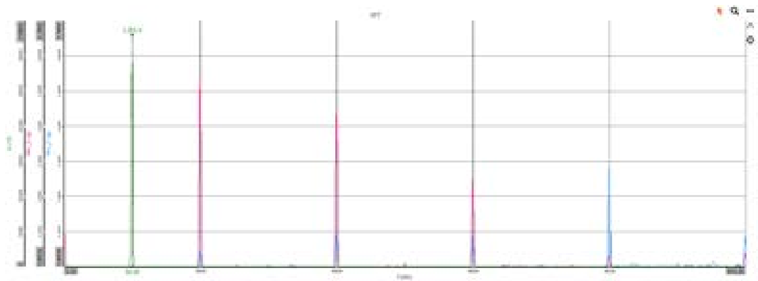


Figure 8. The correlation of the reactor energization and the frequency of mechanical vibrations. The harmonics of the vibrations are 100Hz multiples of the line voltage - here shown up to the frequency of 500Hz.

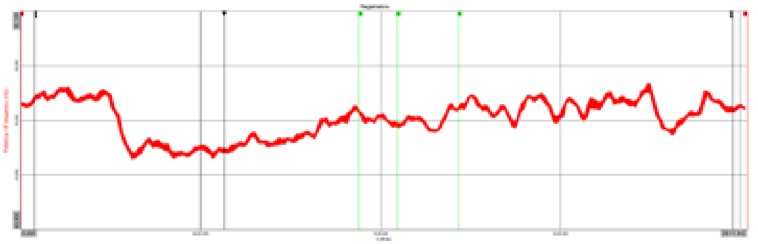


Figure 9. The frequency variations – the scale of the graph ranges from 49.9 to 50.1 Hz.

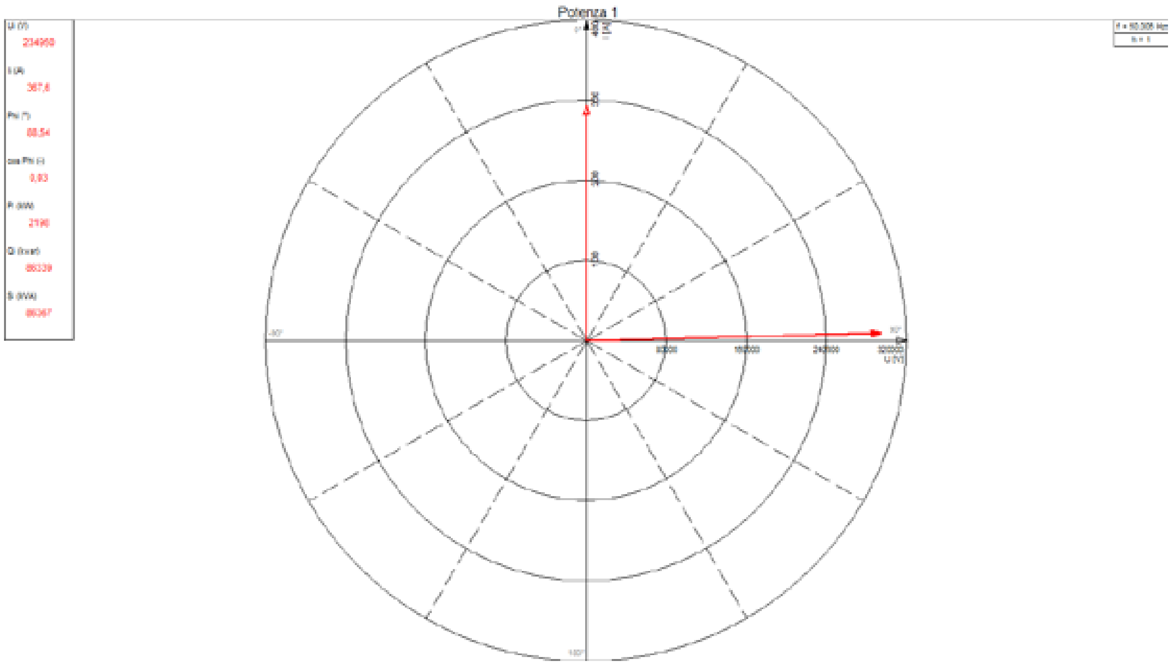


Figure 10. The trend of the first harmonic voltages and currents. The measurement system allows the analysis of the phasors for all harmonics (up to 100 °).

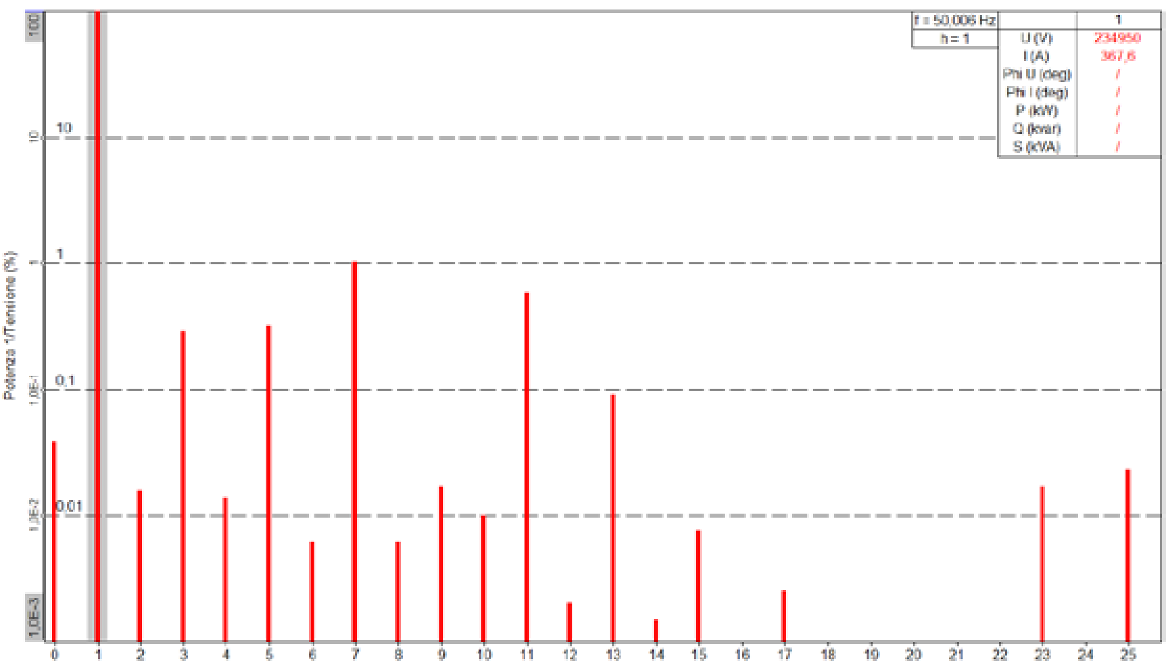


Figure 11. A detailed harmonic analysis highlights the presence of small harmonics that is practically only visible on a logarithmic scale.

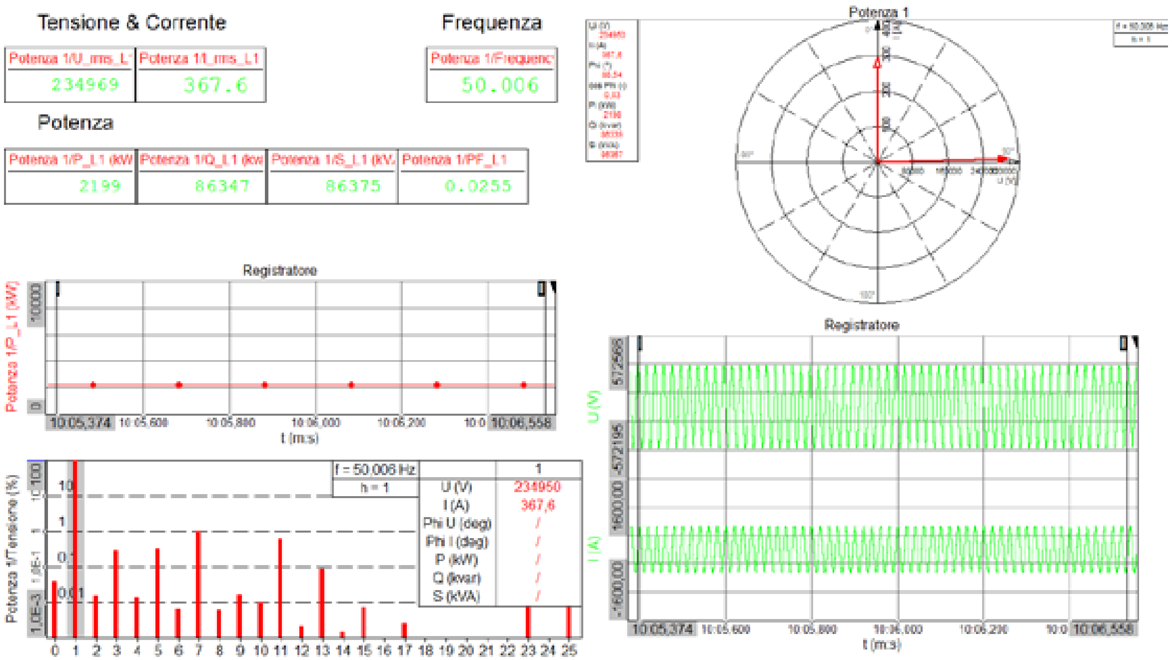


Figure 12. The standard (customizable) power analysis screen of the DewesoftX Power Module. A wide range of parameters is calculated.

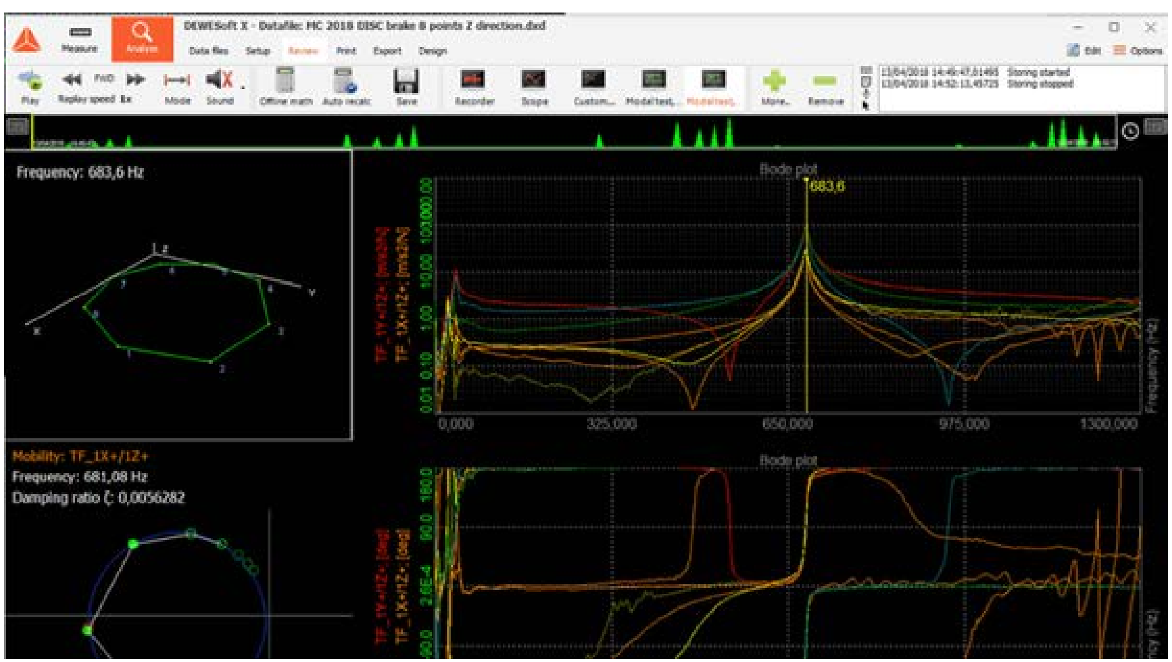


Figure 13. Modal analysis identifying the frequencies and modal shapes of the reactor.

More information

How to measure current using current sensors and transducers
AC and DC Voltage Measurement
Power Measurement and Power Analysis
Power quality measurement and analysis
Dewesoft Power Analyzer solution
How to measure vibration
Dewesoft vibration measurement and analysis solutions

High-voltage switch testing with synchronizer

TERNA S.p.A.

By Gabriele Ribichini, Managing Director, Dewesoft S.R.L., Italy

Circuit breakers are critical components of power delivery systems. They prevent damage to the system's components and wiring when the current in the electrical circuit supersedes design limits. The Italian transmission system operator Terna S.p.A. wanted to check the switching function of an old synchronous high-voltage circuit breaker. Dewesoft data acquisition systems and Power Analysis software did the job.

CASE STUDY

Terna S.p.A. is a transmission system operator (TSO) based in Rome, Italy. It operates through Terna Rete Italia, which manages the Italian high-voltage transmission grid. A network of 74,669 Km of lines with 888 electrical substations, and 4 control centers managing 320 billion kWh every year. Such grids distribute high-voltage electricity many times greater than consumer voltages, in Italy typically up to 380 kV (AC).

The synchronizer

Circuit breakers are mechanical switching devices capable of making, carrying, and breaking our grid current in normal and abnormal conditions. During abnormal conditions such as when lightning strikes a transmission tower, circuit breakers isolate the faulty components of the system to prevent additional damage. Ideally, in the closed condition, a circuit breaker should function as a perfect conductor to ensure optimal current flow.

A synchronizer is widely used in high voltage (HV) circuit breakers to avoid that the contact is being opened or closed when the current flow is high. Opening a high current flow would lead to electric arcs and reduce contact lifetime.

The synchronizer, knowing the actuator delays, observes the sinewave timing and gives a command to the breaker in a magic instant, calculated to have a null instantaneous current when the contact moves.

The same actuation is performed on all three phases, with different timing since the three sine waves are shifted by 120 degrees.

Figure 1. The Dewesoft SIRIUSi-HS acquisition module is extremely compact and robust, designed for field operations.

A brand-new installer is calibrated to work perfectly and preserve contacts during operations, but unfortunately, during years it happens that contact opening/closing time varies and may result in actuation at the wrong time.

Purpose of the test

The purpose of this functional test was to analyze an older synchronous HV circuit breaker to check for possible deviations from the initial setup.

The Measurement Equipment Used

- Dewesoft SIRIUS signal conditioning and acquisition module, model SIRIUSi-HS 4xHV, 4xLV
- Three Dewesoft AC current clamps type model DS-CLAMP-15AC
- DewesoftX data acquisition software
- DewesoftX Power Analysis module

The SIRIUSi-HS module integrates signal conditioning functions, such as AC or DC coupling selection, programmable gains, offset compensation (deriving from transducers), programmable LP filters, excitation of current probes, and much more, including self-recognition of the probes current and sensitivity to use - see figure 1.

Among the various features, the galvanic isolation at 1600V channel to channel and channel to the ground (GND) is noteworthy.

Connecting the instrument to the system

The three voltages were connected on the secondaries of the voltage transformers - see figure 2 - with a conversion ratio of 1:3800, while the three currents were intercepted downstream of the current transformers with a conversion ratio of 1:800.

The two command signals - opening and closing signals at 110Vdc - sent by the synchronizer to the switch were also connected.

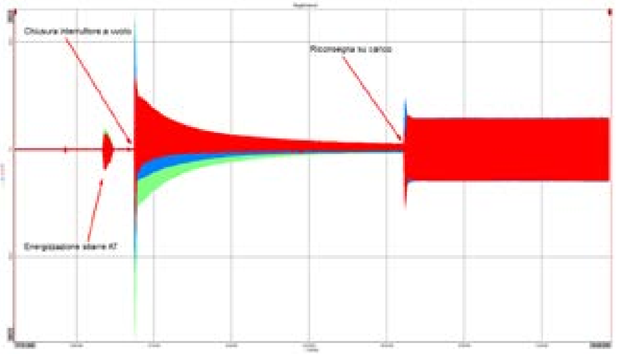


Figure 3. The circuit breaker - three distinct moments: 1) the energization of the HV busbars, 2) the closing of the no-load circuit breaker, and 3) delivery on load.

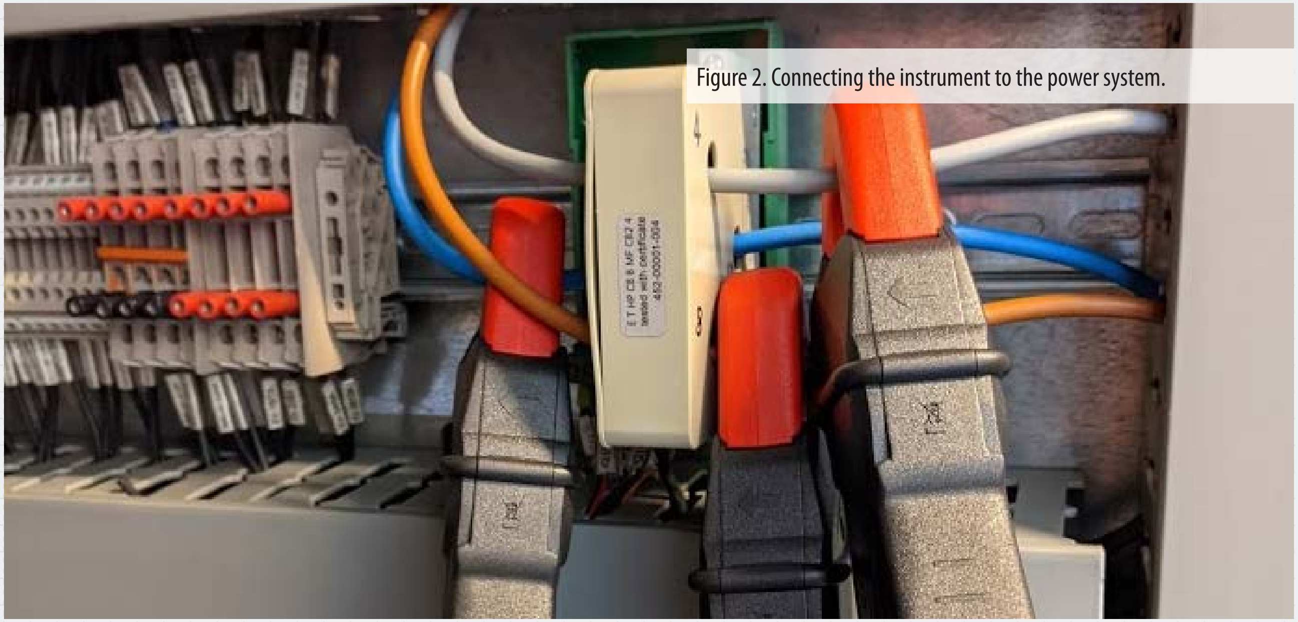


Figure 2. Connecting the instrument to the power system.

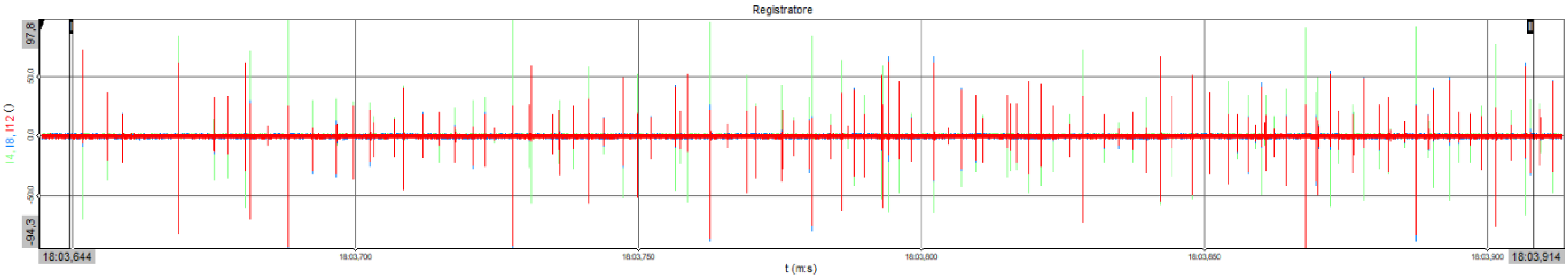


Figure 4. A sequence of high-frequency discharges with a time history measures the energization of the HV bars.

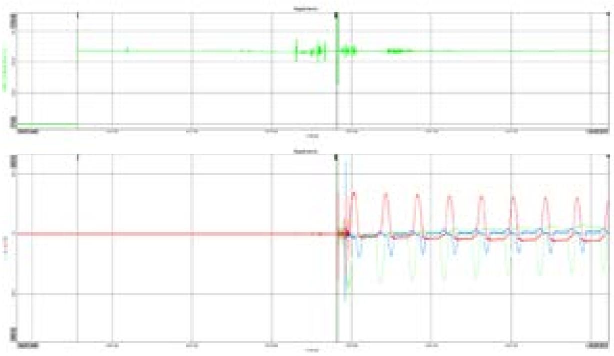


Figure 5. The switch closure test - the command signal is the green signal at the top.

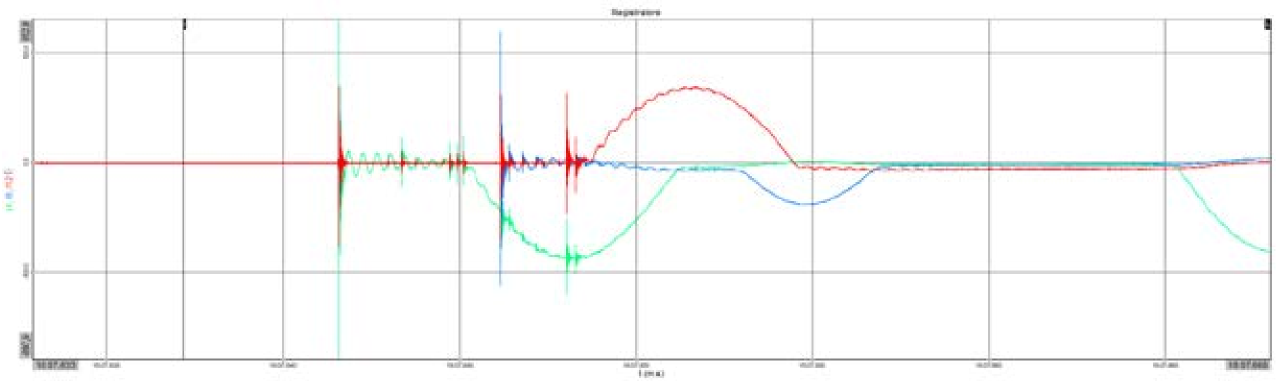


Figure 6. A detail of the current signals in the instant of closure highlights a nervous trend.

Carrying out the test

A typical circuit breaker closure test can be divided into three distinct moments: the energization of the HV busbars, the closing of the no-load circuit breaker, and delivery on load - see figure 3.

Energization of the HV busbars

The energization of the high-voltage bars is measured by a sequence of high-frequency discharges with time history - see figure 4.

Closing the switch

Analysis of Closing Times

The execution of the switch closure test shows the command signal that rises to 117V at a certain instant - see figure 5.

From the trend of the current signals, we can measure the activation delay equal to 163ms.

The detail of the current signals in the instant of closure highlights a very nervous trend, probably due to the triggering of discharges with current peaks up to 900A - see figure 6.

The absence of a load downstream of the switch is probably the cause of the important distortions of the current signals following closure - see figure 7.

Behavior analysis of the synchronizer
A detailed analysis of the switch switching instant highlights that the closure of the three phases does not occur at regular intervals and in incorrect instants - see figure 8.

The analysis shows that phase 12 (red) is closed when the instantaneous voltage V12 is about 24kV, followed by phase 4 (after 4.33ms) when the instantaneous voltage V4 is about 234k €, and finally, phase 8 (after 1,89ms) when the instantaneous voltage V8 is -317kV.

This behavior causes electric arcs, clearly shown as peaks on the currents graph above.

Phasor analysis

A phasor analysis highlights the mismatches and imbalances in the three phases. Figure 10 shows the trend of the first harmonic voltages and currents (h = 1, f = 50.011Hz) with the switch closed and without load.

Harmonics analysis

While a harmonic analysis highlights the presence of important distortions, which contributed to the achievement of PF 0.534 - see figure 11.

Other
Many other parameters are calculated by the DewesoftX Power Module, the standard, customizable power analysis screen is shown in figure 12.

Conclusion

Following the tests carried out, it is clear that the synchronizer under test is not working correctly; the closing of the contacts does not take place at the right moment causing important discharges with currents up to 900A.

Furthermore, the closure of the three contacts does not occur at regular intervals, the closing interval between phase 12 and 4 is 4.33ms while between phase 4 and 8 the interval is 1.89ms, a clear symptom of malfunction in case of steady-state periodic three-phase.

The analysis of phenomena with Dewesoft data acquisition systems allows easy verification of operation correctness. It is possible to automate this verification with integrated sequences in DewesoftX that guide the operator in the field who does not necessarily have to be competent in the technology used.

A regular synchronizers verification is easy and enough to identify those with aging problems that require some maintenance to come back to normal operation. Correctly working synchronizers are important to preserve expensive contacts of HV circuit breakers.

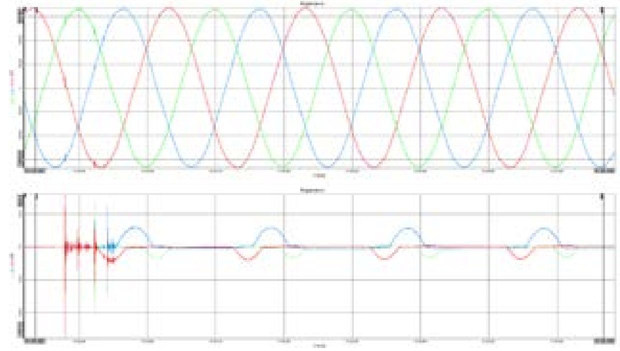


Figure 7. Distortions of the current signals following closure - comparing the three voltages and the three currents.

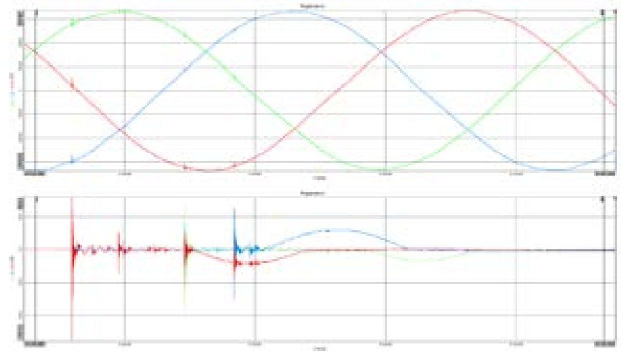


Figure 8. Analysis of the switch switching instant highlights - the closure of the three phases does not occur at regular intervals and appears in incorrect instants.

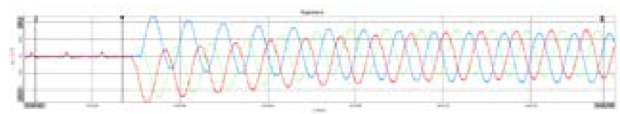


Figure 9. Upon delivery, the current signals assume a regular shape.

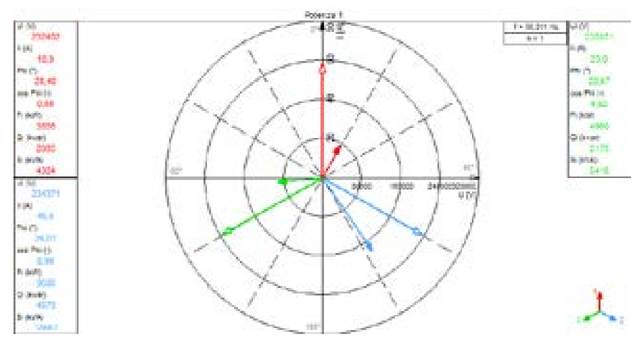


Figure 10. Phasor analysis – this can be repeated for any harmonic.

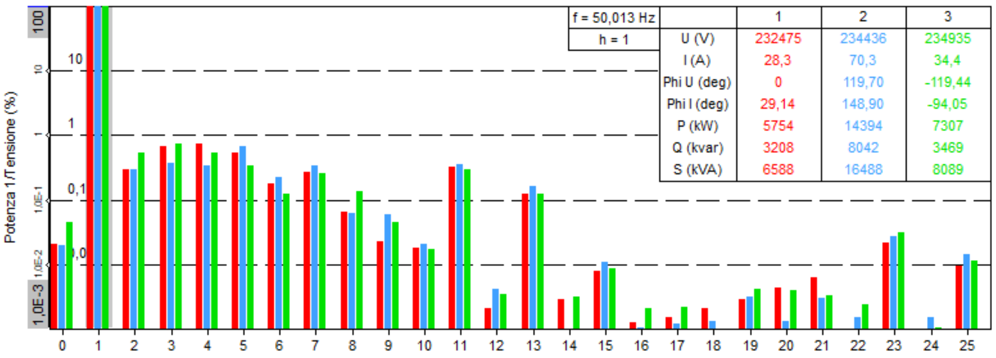


Figure 11. Harmonic analysis reveals distortions.

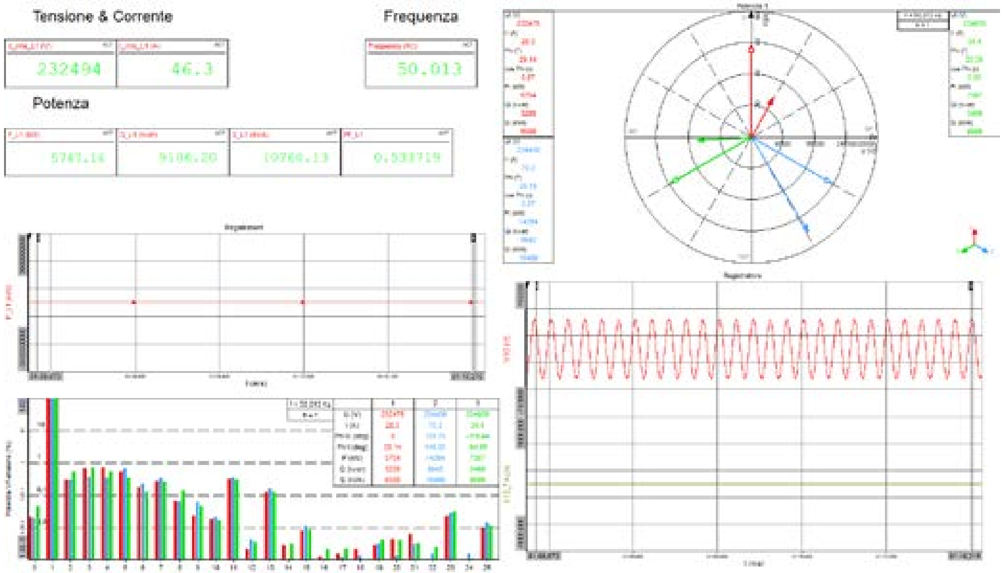
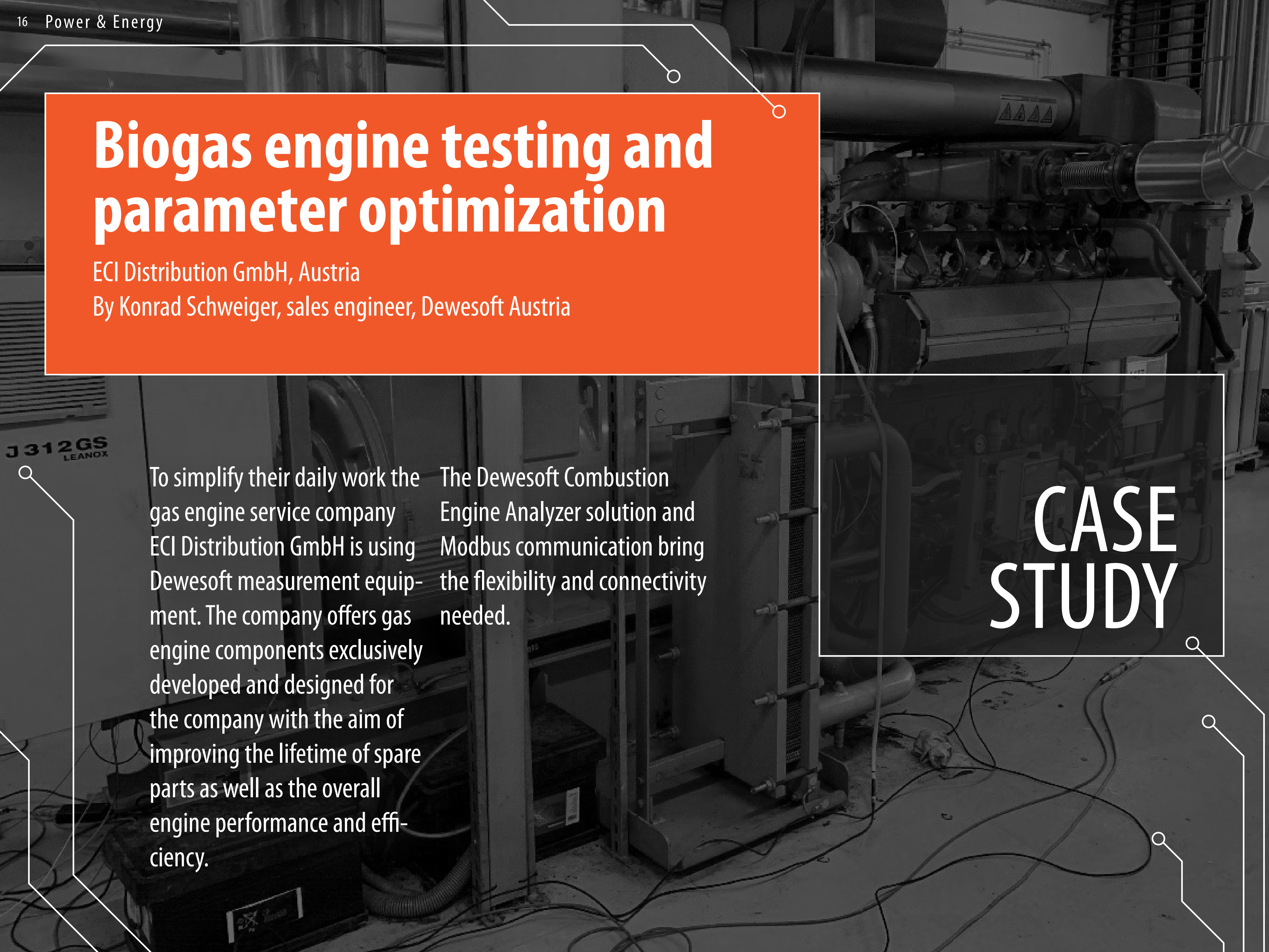


Figure 12. The DewesoftX standard power analysis screen.

References

[How to measure current using current sensors and transducers]
[AC and DC Voltage Measurement]
[Power Measurement and Power Analysis]
[Dewesoft Power Analyzer solution]



Biogas engine testing and parameter optimization

ECI Distribution GmbH, Austria
By Konrad Schweiger, sales engineer, Dewesoft Austria

CASE STUDY

To simplify their daily work the gas engine service company ECI Distribution GmbH is using Dewesoft measurement equipment. The company offers gas engine components exclusively developed and designed for the company with the aim of improving the lifetime of spare parts as well as the overall engine performance and efficiency.

The Dewesoft Combustion Engine Analyzer solution and Modbus communication bring the flexibility and connectivity needed.

Engine Competence International-Distribution (ECI Distribution) is an energy engineering company that specializes in high-tech products and solutions for gas engines with customers in more than 40 countries. ECI provides its own special-designed gas engine components. This service prolongs the lifetime of customer spare parts and improves engine performance and efficiency. The customers benefit from reduced maintenance costs, engine efficiency, and reliability.

ECI-Distribution´s key product components such as cylinder heads, connecting rods, pre-chambers, spark plug sleeves are produced by ECI-Manufacturing. By optimizing existing technologies and developing new concepts, ECI-Distribution maximizes generation output while complying with the low emission guidelines. The company also offers consulting services in gas engine solutions using alternative and efficient concepts of technology, engineering, and elaborating solutions to different markets and application requirements that will meet specific customer expectations.

The ECI-Distribution engineers continuously strive to extend the lifetime of spare parts to lower the cost of overall maintenance. The skilled sales and product support team recognize all aspects of the gas engine business. Whatever the application, they have the experience to provide solutions for commercial as well as technical challenges.

Figure 1. The Jenbacher biogas motor/generator unit is under inspection.

Combustion analyzer solution

With the Dewesoft Combustion Engine Analyzer solution – a combination of Dewesoft X software with a plugin and a SIRIUS data acquisition device (see figure 2) - data collection and visualization is just a matter of minutes.

Measurement setup

ECI Distribution GmbH uses this data acquisition system and sensors testing setup:

- SIRIUSi-8xSTG+ measurement instrument
- 3 x DSI-CHG-50 adapters
- 3 x AVL cylinder pressure sensor GH14D with M5 screw
- 1 x Ignition voltage per voltage divider
- 1 x Crank angle sensor installed on the engine with 164 pulses and zero pulses; connected to SIRIUS SuperCounter® input
- Dewesoft X3 software
- Combustion Engine analyzer Plugin (Base + Advanced)
  - Pressure
  - Online calculation
  - Adjustable cylinders
  - Heat Release
  - Knocking
  - Filter
  - Additional analog inputs

- Modbus Master Plugin TCP/IP
- Remote network connection per VNC client

SIRIUSi Combustion Engine Analyzer systems are used for engine research, development, and optimization, and even for component development and testing – such as ignition systems, exhaust systems, and valve control gear. The system consists of isolated SIRIUSi hardware and the Dewesoft X software package for measurement and analysis with a specially designed plugin for combustion engine analysis.

Such a system supports angle and time-based measurement results and uses highly sophisticated algorithms for online or offline mathematics and statistics – calculating heat release and other thermodynamic parameters. The Combustion Engine Analyzer can be fully integrated within a testbed and also supports data from other sources: e.g. Video, CAN, Ethernet, . . . Data can be exported to several different file formats.

In addition to combustion analysis, the system can be expanded to handle other measurement applications such as hybrid testing on the powertrain, noise, and vibration measurement together with synchronized video or GPS data.
Pressure sensors are used to measure the cylinder pressure of the engine. Depending on the sensor type, these can be directly connected to the SIRIUSi amplifier like any other input channel or through external signal conditioning amplifiers. Additionally, an angle sensor is needed for getting angle domain measurement results.

Measurements

For this measurement, a sampling rate of 200kS/s was used. Three of the 12 cylinders have been applied with cylinder pressure sensors - see figure 3. In the additional channels the ignition voltage has been specified, to get the signal in the angle-domain and overlay to the compression curve.

The customer was impressed by the high angular resolution of down to 0,025 degrees and the easy integration of the ECI Engine control's Modbus TCP interface.

As the biogas motor/generator unit generates also heat and noise next to electricity, the customer connected per network and VNC Client remotely from the control room.

Analysis results

The Dewesoft instrument provides a helpful tool for the service company ECI Distribution GmbH to adapt and optimize the motor parameters over the operational range after the engine upgrades - see figure 4.

Conclusion

Since the daily work of the customer requires flexibility to fit the various types of machines, the SIRIUS universal STG input module and the possibility for a future extension by DSI-adapters, and other software plugins (Siemens S7, OPC UA, . . .) provides the best interconnectivity.

The galvanic isolation of the channels guarantees safety and better signal quality for the different environments.

The flexibility of the instrument and software helps the ECI-Distribution to make daily work more effective and to focus on its core know-how - parameter optimization.

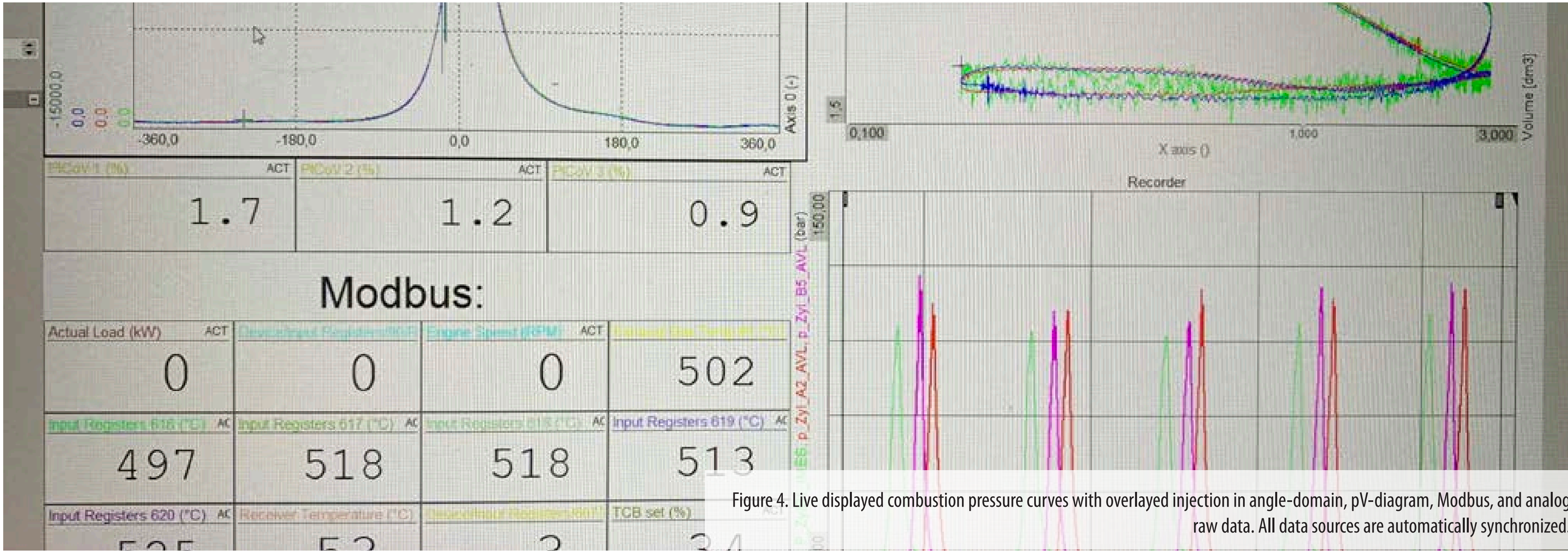


Figure 4. Live displayed combustion pressure curves with overlayed injection in angle-domain, pV-diagram, Modbus, and analog raw data. All data sources are automatically synchronized.

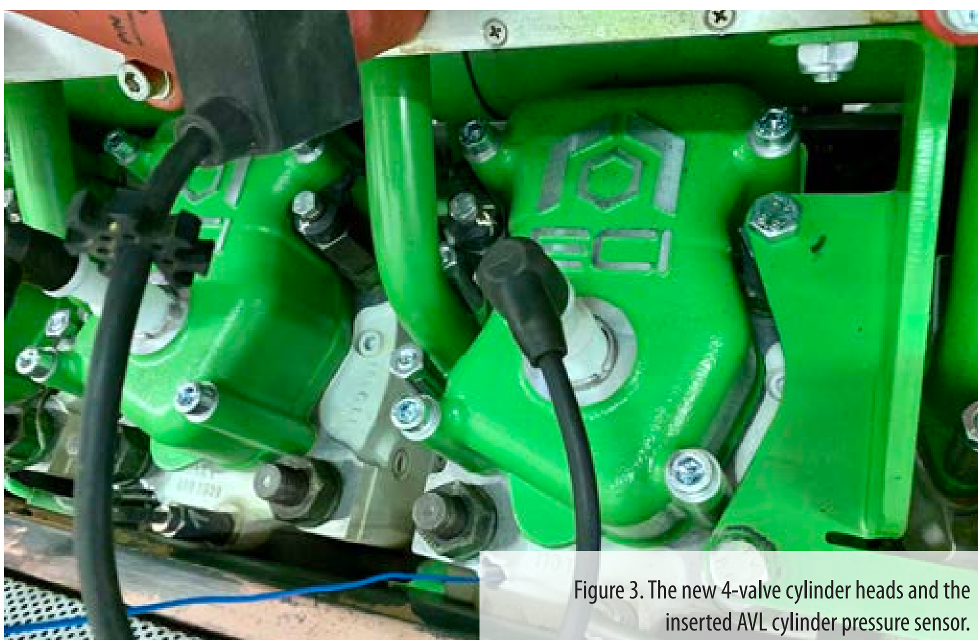


Figure 3. The new 4-valve cylinder heads and the inserted AVL cylinder pressure sensor.

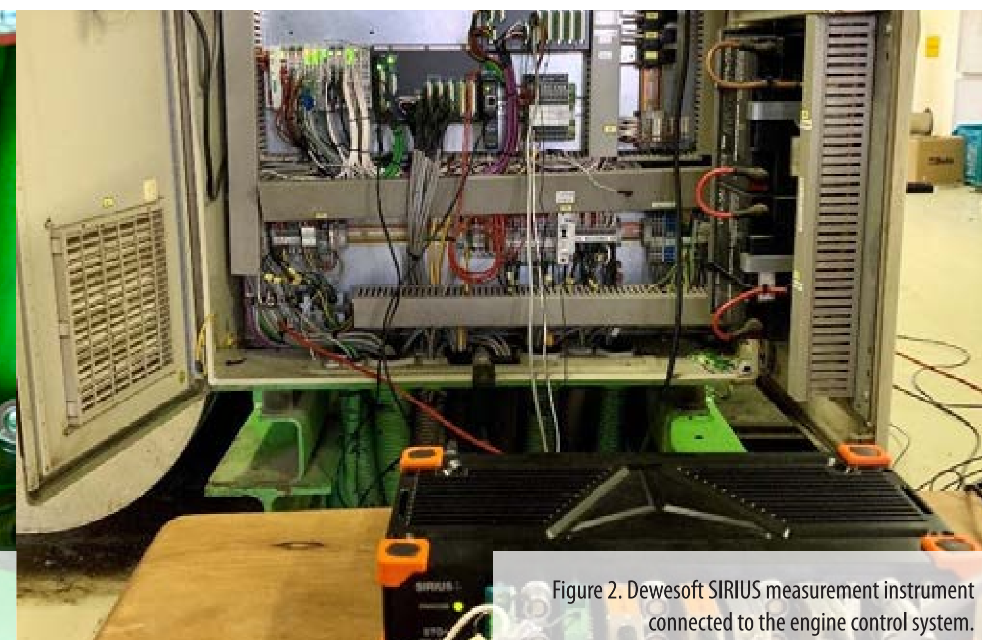


Figure 2. Dewesoft SIRIUS measurement instrument connected to the engine control system.

Dewesoft data acquisition (DAQ) integration with KS Tornado testbed

ELIN Motoren GmbH
By Konrad Schweiger, Regional Sales, Dewesoft GmbH, Austria

CASE STUDY

The Austrian company ELIN Motoren GmbH has fully integrated a mandatory vibration measurement of each produced machine – motor or generator – as part of the final inspection procedure. When searching for a suitable DAQ system, the requirements were to keep it portable, measure vibration and electrical power with just one system (raw data), and that the delivery of the data during the test should flow flawlessly to the KS Tornado testbed. Dewesoft provided the right solution.

A few years ago, ELIN Motoren decided as part of their digitization strategy, to obtain a vibration profile of each motor and generator at the time of delivery. The goal was to verify product quality and to have reference data for evidence in case trouble appears at a later stage at the customer.

ELIN Motoren, headquartered in Austria, is a high-tech company manufacturing rotating electrical machines - motors and generators - that are used worldwide. The company has 125 years of experience, a total of 1000 employees and an annual turnover of 120 million euros. Since the end of 2019, ELIN Motoren is 70% owned by the global technology company Voith Group.

The company focuses on electric machines, motors in the low- and medium- but also in the high-voltage range. It develops and produces customized solutions for industrial applications in the markets of:

- Wind,
- Mining,
- Plastics,
- Power plants,
- Marine, and
- Oil and gas.

Its generators are particularly used for wind energy and decentralized energy generation.

The testbeds at Elin Motoren are supplied by KS Engineers, a leading provider of test benches for the automotive and engine industries. The KS product line includes test and simulation systems for the development and testing of batteries and fuel cells. KS also provides solutions for the coordination of drive systems in the field of electromobility.

Watch the ELIN introduction video

Figure 1. Test setup at the in-house test field of ELIN Motoren.

KS Engineers or Kristl, Seibt & Co. GmbH is an owner-managed company with headquarters in Graz working in the fields of automotive testing, industrial automation, and technical building equipment. KS Engineers supplies knowledge in the fields of mechanical engineering, electrical engineering, control engineering, electronics, and IT.

The testbeds are run by the automation software named Tornado. This software package with a graphic interface provides measurement, control, and report functions for test benches. It is optimized for engine and chassis dynamometer test stands, powertrain test benches, and vehicle component test rigs.

Test bench – DAQ integration

The KS testbed software Tornado controls the device under test (DUT), e.g., starts an engine runup or coast down, sets the RPM, etc. - see figure 1. The DUT sends back information, such as temperatures or operational status.

The requirement from ELIN Motoren was during measurement to continuously get the vibration data from Dewesoft hardware and software into the Tornado software. This communication is handled via TCP/IP by a Dewesoft plugin, the Testbed module.

The Dewesoft testbed module is an interface between DewesoftX data acquisition software and testbed control systems. It uses the Request/Response working principle and can be pre-set and used independently of DewesoftX. In this way, it is controlled only by the master system requesting certain data from the TestBed module, which gives the response back to the master system.

In the case of ELIN Motoren, the Tornado software requests the measured orbit and order analysis data in real-time from the Dewesoft channels during measurement. Simply, through the AK protocol, which offers a very compact command set.

The plugin supports four specific so-called master-slave protocols:

- AK Protocol,
- Puma Open,
- D2T, and
- Tornado.

The solution

DAQ Hardware and DAQ Products

- Two SIRIUS R2DB data acquisition systems
- SIRIUSi-CUSTOM DualCoreADC signal conditioner slice with 8 analog channels: 1xACC+, 5xACC, 2xSTG - for Noise, Vibration, and Harshness testing (NVH)
- SIRIUSi-HS high-speed signal conditioning slice with 8 analog inputs: 2x STG, 3xHV, 3xLV - for power
- SIRIUSi-HS-4xHV-4xLV high-speed data acquisition system for power measurements
- SIRIUS-CUSTOM data acquisition system
- KRYPTONi-8xRTD for RTD temperature measurement
- DSI-ACC adapters for direct IEPE sensor connection
- DS-TACHO2
- DS-SHUNT-05
- DAQ Software

DewesoftX data acquisition software

- Dewesoft Dynamic Signal Analysis (DSA) software option: FFT Analyzer, Order Tracking, Modal Test, Human vibration, Shock Response Spectrum, Sound Level, Torsional Vibration, and Rotor Balancing
- Dewesoft Power option
- Dewesoft Testbed plugin

For all of these protocols, the RS232 or TCP/IP connection is possible.

It can be used with the Combustion Engine Analyzer (CEA) module where engine cycles are used for storing and calculation conditions. Alternatively, it can also be used in time mode where any channel or value can be sent from DewesoftX, and measurement time is used for triggering and calculation interval.

Measurement modules

The measurement instruments and data loggers are portable. The same DAQ devices can be used for the testbed but also for on-site service and installation. That's why the ELIN Motoren decided for a mix of SIRIUS R2DB as an all-in-one data acquisition and single SIRIUS modules for easy expansion to a higher channel count.

The decision to purchase Dewesoft was also made because there are no further software license costs, updates are free forever, and the data files are accessible to anyone without a license. Electrical power and vibration data are measured with the same system, raw data are stored, and can be recalculated.

Dewesoft SIRIUS R1DB and R2DB all-in-one portable data acquisition systems

Figure 2. Measuring housing and bearing vibrations in the in-house test field.

Dewesoft DSI adapters

With DSI-adapters they can adjust to any measurement requirements of today. DSI adapters are TEDS IEEE 1451.4 equipped sensor adapters that turn any of our universal analog input amplifiers with DSUB9 connectors into direct IEPE, charge, thermocouple, shunt, voltage, LVDT, or RTD input.

IEEE 1451.4 is a set of smart transducer interface standards developed by the Institute of Electrical and Electronics Engineers (IEEE), while TEDS indicates that they include a Transducer Electronic Data Sheet.

Eddy current sensors

Eddy current sensors are used for measuring shaft displacement - orbit, shaft centerline, and shaft orbit plot. Eddy current sensors are designed for non-contact displacement, distance, position, oscillation, and vibrations measurements. Their robust sensor design is suitable for industrial measuring, particularly suitable when high precision is required in harsh environments with pressure, dirt, or extreme temperatures.

At ELIN the engineers are especially interested in particular parameters like:

- S_0 peak-peak
- S_90 peak-peak, and
- Smax.

The eddy current sensors are already integrated with the D.U.T. They must be precisely mounted since they need to have a very high sensitivity - 7.87 V/mm - to be able to measure displacements in the micrometer (um) range. Furthermore, they require a special supply of -19V, however, the SIRIUS-STG module can supply a programmable sensor supply in this range.

Orbit analysis with Dewesoft Orbit analyzer

The Dewesoft Orbit Analysis module is tailored for turbomachinery applications and designed for precise rotor movement measurements and advanced analysis - see figure 5. It is an analysis tool for rotor movements examination and assessment of any movement restrictions causing vibration, as well as a diagnostic tool enabling the detection and prevention of many types of potential faults and machinery downtime.

IEPE accelerometers

Integrated Electronic Piezo-Electric (IEPE) accelerometers have become the most commonly used accelerometer type. IEPE accelerometers are basically accelerometers with a built-in charge or voltage amplifier. Because of this, IEPE accelerometers require no special cabling and are very easy to integrate with a system.

IEPE accelerometers require a constant DC power source, however, many data acquisition systems include this. The microelectronic circuit inside a voltage mode IEPE accelerometer limits its ability to tolerate hostile environments when compared to charge mode accelerometers. Still, these accelerometers often have a temperature range of at least -40° to +125°C which is enough for most applications.

ELIN Motoren uses voltage mode IEPE accelerometers for measuring housing and bearing vibration for Dewesoft Order Tracking Analysis within the optional Dewesoft software module - see figure 6. They can define an overall vibration profile, a Campbell plot, and also use the data to check for abnormalities, e.g., detecting if any harmonics are dominant over the RPM range.

Conclusion

Dewesoft offers a solution to extend KS Tornado test beds already in operation. They can easily be complemented with a range of Dewesoft application solutions, such as:

- High Precision Power Measurement
- Combustion engine analysis (CEA)
- Any other DewesoftX software option/plugin like OPC UA, Modbus, . . .

Any such combination offers great benefits for all existing Kristl Seibt users, for example, when it comes to engine development. No matter if it is conventional combustion, electric, or hybrid since all modules can be combined within DewesoftX software.

The users benefit from software updates with no annual license costs, high quality hardware with great flexibility, and a strong local support team.

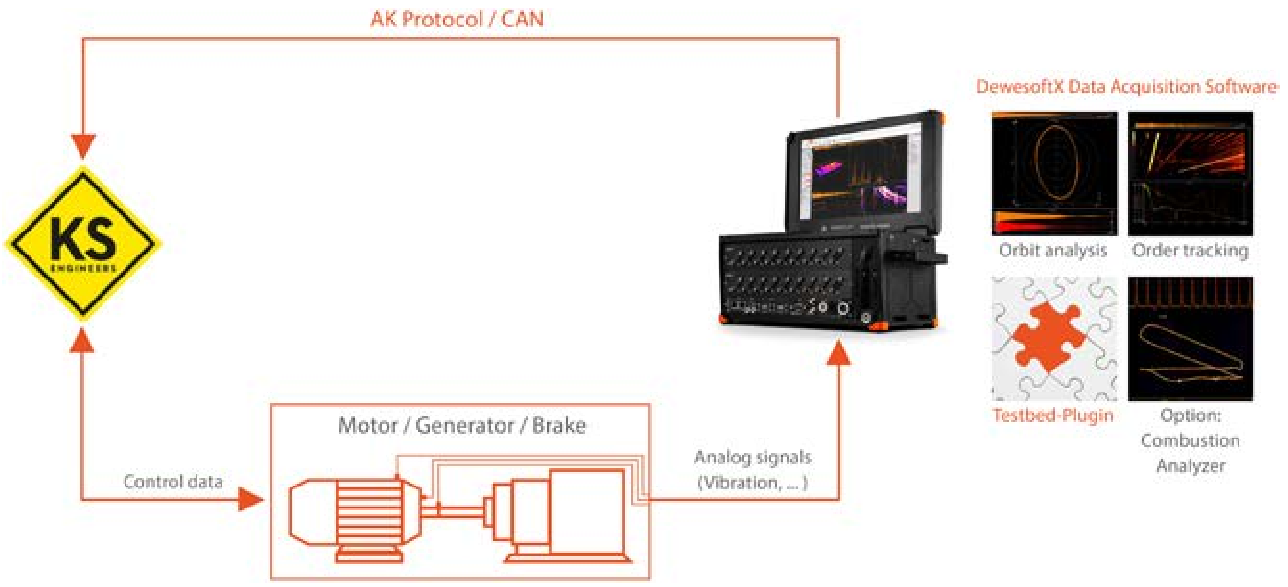
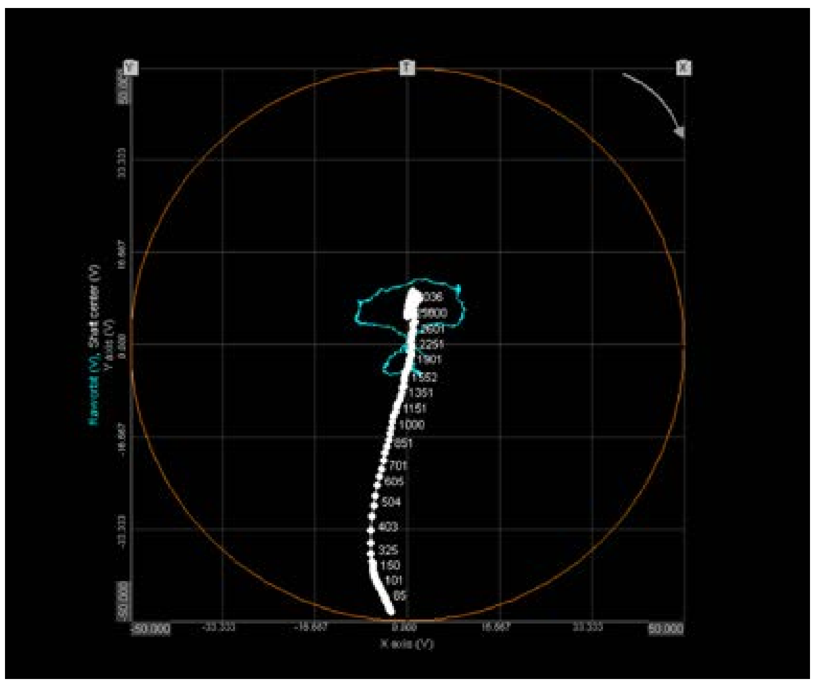


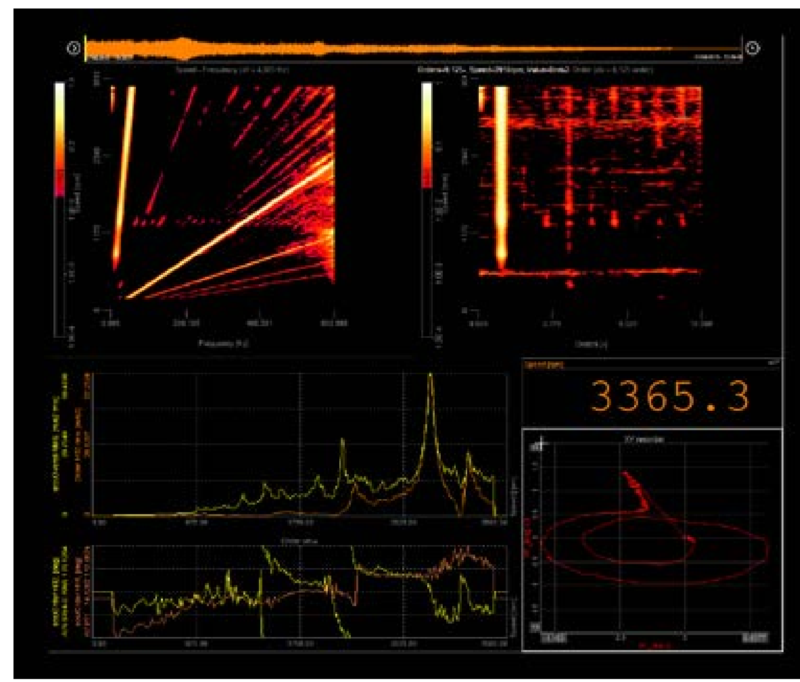
Figure 3. The Dewesoft data acquisition system delivers vibration analysis results to the Tornado software

(right) Figure 4. Measurement setup - an R2DB with SIRIUS modules is remotely accessed from the control center.

(left) Figure 5. Example of an Orbit analysis measurement display.

(right) Figure 6. Example of an order analysis measurement display.





Testing power inverters and motor terminal issues

Talete SpA, Italy

By Gabriele Ribichini, managing director, Dewesoft Srl, Italy

CASE STUDY

After the installation of power inverters, our customer started to experience frequent motor failures in one of their production plants. Inverters were introducing some hidden phenomena causing the issue, but what to do in this situation? They were almost on the way to revert to a standard 50 Hz power supply to limit damages when thanks to the Dewesoft technology they realized that the issue was triggered by a simple brass nut in the motor terminal block.

Are inverters the cause of burned motor terminal blocks at a water supply site?

Have you ever had an issue after installing inverters in your electrical system?

PWM (Pulse Width Modulation) inverters are capable of running asynchronous AC power motors at a variable motor speed than the standard 50Hz power source from the grid. Inverters convert AC motor power from the grid to DC power and provide an inverter output as **PWM** (pulse width modulation) power signal used to power induction motor woundings.

In contrast with pure sine wave inverters, they can bring good power savings but since they introduce a **high number of harmonics** they can also cause tricky issues like **temperature increases, bearing faults, vibrations**, and noise due to all the effects of high frequencies phenomena in the network (bad power quality).

It is proven that traditional instruments are often blind to inverter output frequencies, if you deal with inverters you need to wear good glasses!

Figure 1. Lake Bolsena, the largest volcanic lake in Europe, supplies drinking and irrigation water.

The customer issue - motor burn-down

At a Talete SpA water supply site, the terminal blocks of asynchronous motors driving pumps started to burn frequently after the installation of inverters. Technicians began to blame the new power system based on the PWM power supply and wanted to revert to direct the 50Hz power source from the grid.

The chief technical officer wanted to understand the reason for this electric failure. Bypassing inverters would have wasted the investment completely and reverted to a constant power consumption even at low flow rates. Not a very good idea!

Talete SpA is a wholly public company formed by local authorities, the municipalities, and the province of Viterbo in Italy. The company is handling the freshwater life cycle, from the supply of drinking water to the management of purifiers and sewers. It also carries out research, consultancy, and assistance as well as protection, monitoring, and enhancement of water bodies.

Their facilities are full of any kind of electric motors, starters, inverters, and pumps, where Dewesoft finds all sorts of applications from rotating machinery analysis to power quality measurement.

One of their water lifting systems uses two twin 315kW electric motors to lift freshwater from Lake Bolsena to the town of Montefiascone, about 400 meters above the lake level - see figure 2.

These pumps used to be powered directly from the 3-phase grid at 50Hz until a recent system upgrade introduced PWM inverter-based control systems to allow more efficient control of the water flow.

After this modification motor terminal blocks started to fail often (at least once or twice per year) due to excessive temperature, resulting in big damages with the need of substitution of the complete cabling from the motor to the respective inverter.

Since this issue was not observed before, all the attention was directed to inverters and high-frequency motor control (PWM) effects - see figure 3.

This kind of system introduces a high number of harmonics bringing sometimes some unexpected phenomena.

Figure 3. The inverters at the Talete pumping site are designed for a wide range of power ratings and voltages.

Figure 2. One of the two electric motors driving a water pump.

Figure 7. The 3-phase Delta connection of the motor.

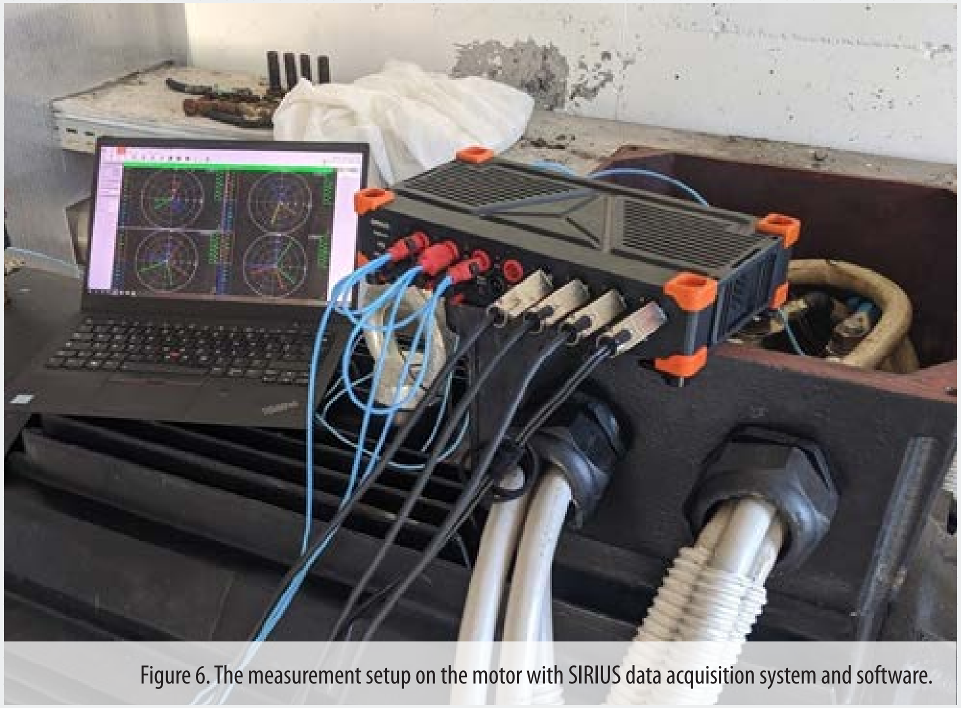


Figure 6. The measurement setup on the motor with SIRIUS data acquisition system and software.

Accurate power measurement in a range of frequencies

Standard **electrical measurement systems** are not designed to understand all power phenomena having an inverter and motor coupled due to their limited capability to **analyze high-frequency signals**. Technicians were not able to find any issue on this system, they were groping in the dark.

High-end test systems, on the other hand, are mostly designed for laboratory tests and they were not happy to use them in the field due to their fragility and complexity of use.

Some of them are known as power analyzers and provide results of power calculations averaged in cycles (typically 10) without giving the possibility of recording raw waveforms that are very important to understand transient phenomena, review the measurements, and eventually re-calculate power parameters if any adjustments are needed during the data analysis.

Even accuracy in measurements and calculations is often an issue. Systems in the market often claim very good measurement accuracy, but they are designed to give their best at 50Hz.

When dealing with inverters you have to remember that a big number of high-frequency harmonics are generated, so the instrument has to be designed to give good measurement performance in a wide range of frequencies, not only at 50Hz.

A normal industrial inverter, like the one used by Talete in this system, may be based on a **switching frequency of 20kHz** or more; this means that to analyze only 10 harmonics you need an instrument having an analog bandwidth of at least 200kHz, achievable with a sampling frequency of about 500kHz or more.

The Dewesoft measurement solution

Likely, Dewesoft has great hardware and software solutions for these kinds of measurements.

The Dewesoft SIRIUS DAQ family includes the HS version (High Speed) that uses a high-performing sample and holds 16-bit ADC able to read signals as fast as 1 MS/s. This brings an **analog bandwidth** of about 460 kHz, enough to **analyze 20 harmonics** of a typical industrial inverter - see figure 4 and 5.

The combination of hardware and software allows accuracy like no others. Even the best-known system in the market does not perform like Dewesoft when analyzing a wide frequency spectrum power supply...

Having inverters, there's not only a 50Hz sinusoidal signal to analyze as in the standard AC power.

These high-performance characteristics are built in a compact, rugged and portable system designed to be transported and easily and safely used in the field. Characteristics like full isolation and current probes auto-configuration could be crucial when performing measurements in the field with uncomfortable setups and limited testing time if compared to a testing laboratory.

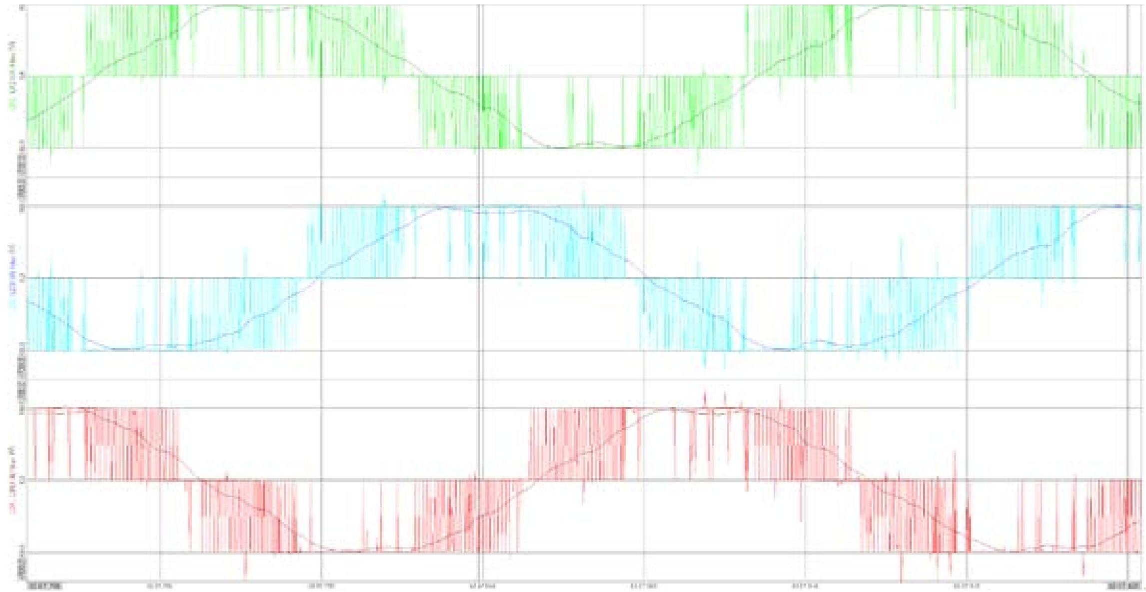


Figure 9. Graph showing the three line voltages overlapped with their respective currents.

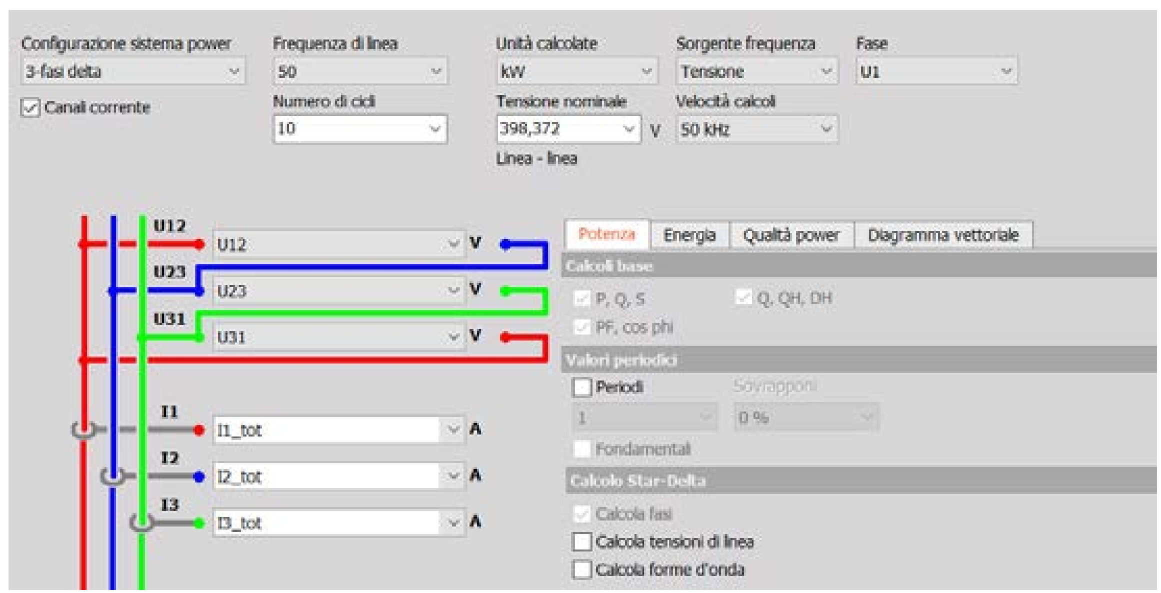


Figure 8. The measurement setup in DewesoftX data acquisition software provides a visual selection of the different wiring schematics - in this case, 3-phase Delta.

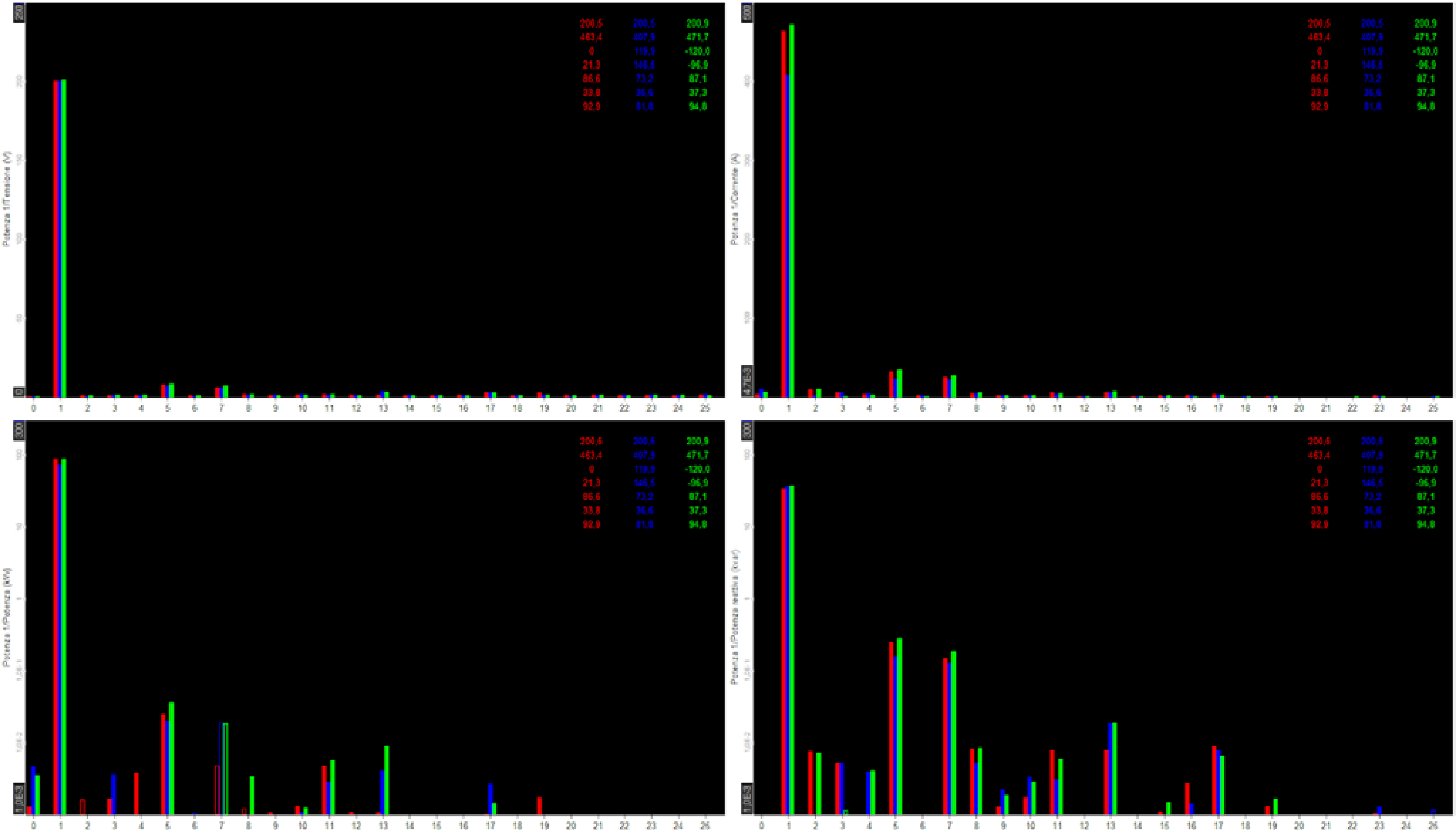


Figure 10. Dewesoft harmonics displays.

Measurement results

We analyzed the motor power source in all its working scenarios trying to reveal problems. Waveforms and power parameters were calculated and stored for later deep analysis.
The motor had a 3-phases delta connection - see figure 7 - and the software has been configured accordingly to calculate all typical power parameters and power quality parameters as requested by EN50160 and IEC61000.

Measurements showed the three line voltages overlapped with their respective currents - see figure 9. Using an inverter it is normal to observe highly distorted voltage signals since sinusoidal waves are built using PWM (Pulse Width Modulation) from the DC power.

Dewesoft is also able to represent this phenomenon using harmonics displays, where the actual line fundamental frequency is measured and it's multiple (harmonics) contributions are drowned - see figure 10.

Total calculated values were reported as P: 250 kW, Q: 184 kVAr, D: 147 kVAr, S: 310 kVA

Starting from an apparent power of 310 kVA, only 250 kW (active power) are converted to mechanical power, due to an important presence of reactive power (Q=184 kVAr).

A careful observer could notice that most of the reactive power is due to distortion (Distortion Power D=147kVAr) and not a cosPhi effect - see figure 11.

Two prevalent harmonics (5th and 7th) cause overheat of stator windings and torsional vibrations that could be further investigated but for sure not the cause of the terminal block failure.

Even though the motor is not working efficiently, the apparent measured power is lower than the nominal power (S=310 kVA < 315 kVA), moreover the effect of the harmonic distortion is known to heavily reduce the motor life but not to cause any burned terminal block.

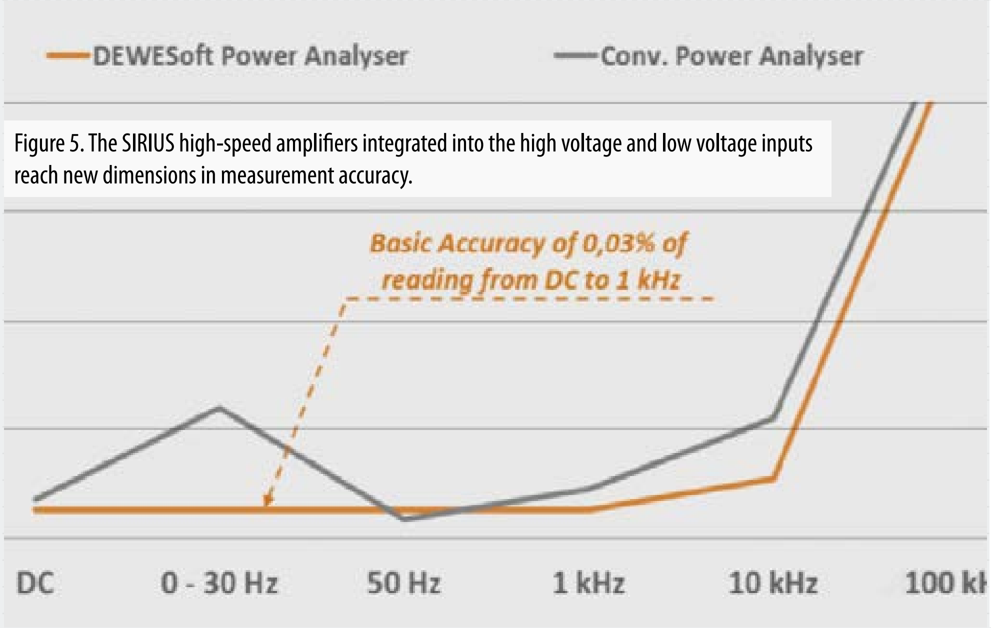


Figure 5. The SIRIUS high-speed amplifiers integrated into the high voltage and low voltage inputs reach new dimensions in measurement accuracy.

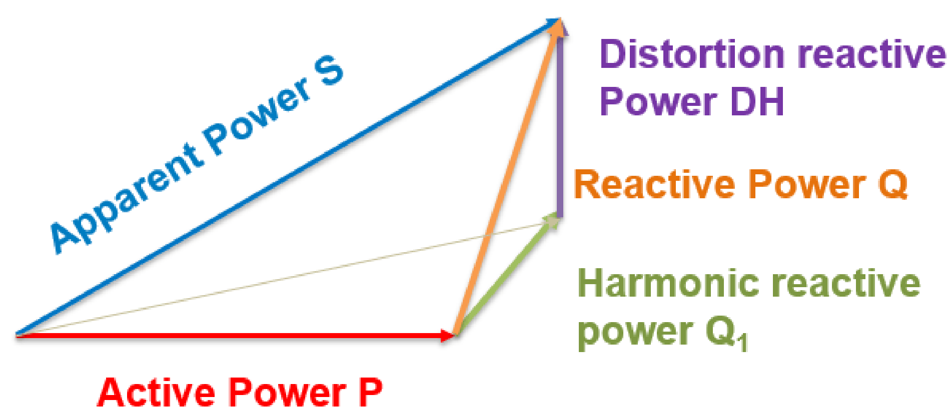


Figure 11. Losses in conduction due to reactive power.

The root causes

Using the Dewesoft technology we could easily prove that the burned terminal block root cause was for sure not related to the effect of inverters on the motor.

So we started to analyze the system to find any other possible root causes - see figure 12.

We noticed that motor windings end lugs were NOT in direct contact with the inverter cable end lugs, a brass nut was installed between them.

With the motor working at full power, we measured a voltage drop on the brass nut of about 6Vrms considering all the harmonics - having an analog bandwidth of about 460kHz.

With a current flow of 450 Arms in each phase, we could calculate a total power loss of about 8 kW in the terminal block box of each motor.

This phenomenon could easily explain why the terminal blocks burned regularly.

Conclusion

"Let's remove these damn nuts!" shouted Luigi, the technical manager. With this simple change, the problem was solved immediately, with no cost and keeping the inverters in operation for efficient flow control - see figure 13.

From this application, it was clear to everyone how important it is to use the right measurement instrument when dealing with inverters.

PWM Inverter-powered drives are becoming very popular in modern industrial plants and traditional measurement systems, designed for AC power, give no more reliable measurement so that several simple phenomena cannot be easily understood.

High bandwidth, high accuracy measurement reliability far from 50Hz, waveform storage, and system portability are the most important features in these applications.

Dewesoft has good experience in these high-frequency electric phenomena and a comprehensive set of ready-to-use solutions that helped this customer to understand and solve a tricky problem.

Testing of electric household appliances

BSH Home Appliances Holding, Nanjing, China

By Leslie Wang, Support Engineer, Dewesoft China

CASE STUDY

Today more and more household electrical appliances use microcomputers. Common household electrical appliances are now capable of doing some complex working procedures. BSH, a world-renowned manufacturer of household appliances needed a new test system to measure voltage, current, power, temperature and more, to verify whether the work procedure household appliance is consistent with the design or not.

The Dewesoft solution - a SIRIUS DAQ system, with a custom test box, flexible DSI sensor interface, and powerful Dewesoft X data acquisition software - helped the customer get the test results needed with a simple and efficient test setup.

Introduction

With more microcomputers used, more and more electrical household appliances can perform more accurately control, which means the appliances can do more complex working procedures. Manufacturers of household appliances now need more advanced measuring devices to test and verify these. The device under test, in this case, is an induction multi cooker – capable of roasting, baking, boiling, braising, steaming, frying, and sous-vide cooking - all combined in one appliance with memory function, pre-set timer, and 50 preset programs for various dishes. The cooker even comes with a mobile app adding functions such as a shopping list, preparation videos, and new recipes added regularly.

The customer in this case is a world-famous manufacturer of household appliances in China, BSH Home Appliances Group (BSH Hausgeräte GmbH), founded in 1967 as a joint venture of Robert Bosch GmbH (Stuttgart) and Siemens AG (Munich). BSH has been exclusively owned by Bosch Group since January 2015. In its over 50 years of history, BSH has grown from a German exporter into one of the world's leading home appliance manufacturers.

Since BSH entered the China market in 1994, and over decades of fast growth, China has become one of the most important global markets for the Group worldwide. Headquartered in Nanjing, BSH China holds five branch companies, operates three production bases in Chuzhou, Wuxi, and Nanjing, and has a research and development center in Nanjing.

The wide range of white appliance products manufactured in China includes refrigerators and freezers, washing machines, laundry dryers, water heaters, cooking appliances, and other home small appliances. In addition, the company imports some appliances like dishwashers and ovens from BSH production bases in Europe.

Issue and application

This is a case of general testing as well as testing the quality and safety (electrical safety). The customer wants to verify whether the heating process and complex working procedures of their household appliances, such as an electric kettle or electric cooker, are consistent with the design or not. Multiple signals, such as voltage, current, and temperature need to be measured, but with as few channels as possible.

Previously the customer used traditional multimeters and dynamometers to measure and test, but now they use a Dewesoft SIRIUS - a flexible USB and EtherCAT data acquisition system - and Dewesoft X3 software with a Power analyzer module, an advanced math module for power analysis and power quality analysis.

In addition, through the European headquarters, the customer already knows Dewesoft and uses a custom Dewesoft product, TEST-BOX-HV-10A. BSH in China wished to use the same product and the same specific custom-made system as the company group headquarters.

TEST-BOX-HV-10A allows the measurement of voltage and current, and can at the same time supply the power to the test household appliance. This custom module and flexible DSI adapters can help the customer perform the test and acquire the results needed.

Solution - setup and configuration

The actual testing took place in the customer's testing laboratory with a Dewesoft SIRIUS data acquisition module, the custom test box module, a thermocouple sensor, and the device under test – the electric multicooker - see figure 1.

Hardware:

- Data acquisition system: SIRIUSi-2xHV-2xLV-Ban-2xLV-2xLV+
- Current and Voltage adapter box: TEST-BOX-HV-10A
- Thermocouple Type K Sensor Adapter: DSI-TH-K

Software:

- Dewesoft X3 Data Acquisition Software with Power module option

In this case, SIRIUS with high galvanic channel-to-channel isolation is used. It includes 2 HV (High-voltage) channels, 2 LV (Low-voltage) banana plug channels, 2 LV DSUB9 channels, and 2 LV+ channels with additional digital counter/encoder inputs.

In addition, another custom-made product, TEST-BOX-HV-10A, is also used. It's a test box with a 10A current shunt, which can convert the current signal to a low voltage signal for measurement.

This TEST-BOX is supplied with a measuring cable with banana connectors. For voltage measurements, the supplied cable is connected to the SIRIUS HV amplifier and for current measurements to the SIRIUS LV-BAN amplifier. It includes a main switch for activating the measurement housing, a measuring socket supply to the test household appliance, and a tube fuse 10A - see figure 2 and 3.

The Dewesoft DSI® adapters convert any analog input amplifier with DSUB9 connector into a universal analog input that can accept everything from strain gage, IEPE/ICP, LVDT, RTD, current to voltage signals with up to ±200V - and in this case a thermocouple.

The adapters are automatically recognized by the TEDS sensor chip and all settings are configured automatically inside Dewesoft X DAQ software.

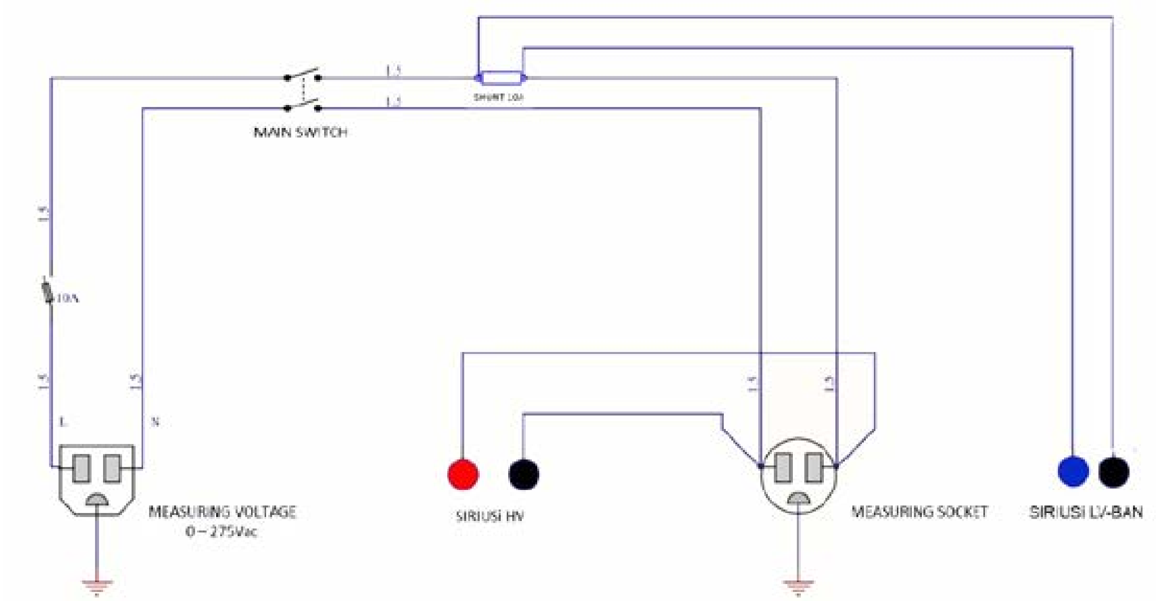


Figure 2. The wiring of the TEST-BOX-HV-10A

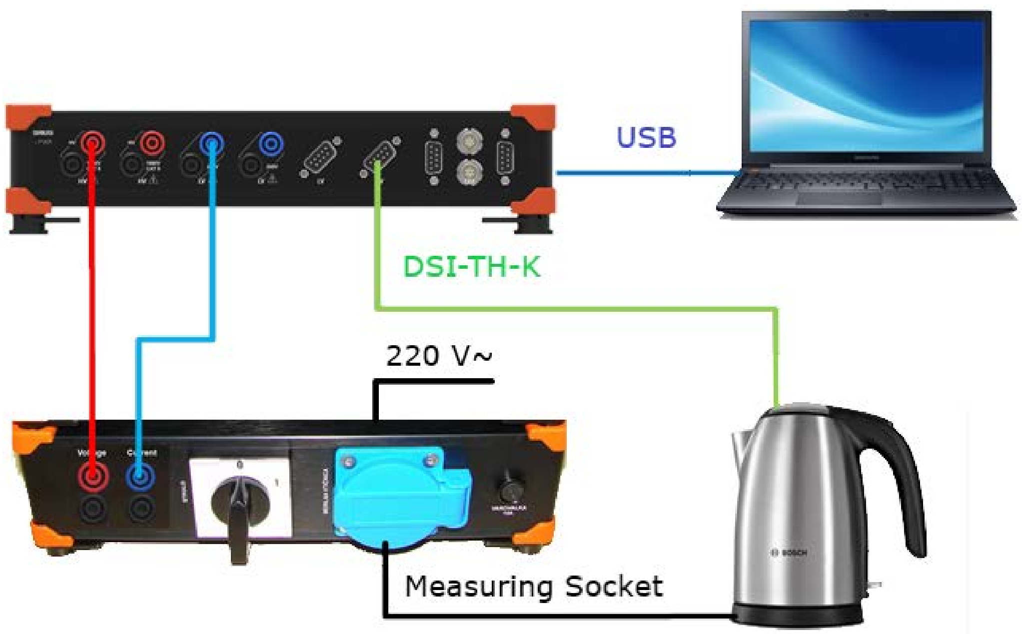


Figure 3. Measuring and test connection diagram.

Measurements

To test the multicooker the measuring cable was simply connected to the SIRIUS data acquisition system and TEST-BOX-HV-10A. The socket of the test household electrical appliances was plugged into the measuring socket of the TEST-BOX-HV-10A, as shown in the connection diagram above.

Water was heated by the electric cooker under test – the same procedure would apply for other appliances, e.g. an electric kettle. The voltage and current were measured by the TEST-BOX. The temperature was measured through the thermocouple sensor. The power consumption (energy efficiency) calculation, the voltage, and the current is calculated and visualized by curves of power and temperature.

TEST-BOX-HV-10A is supplied with power from the overall electric supply, while the device under test - the electric cooker - receives 220V AC from the measuring socket of custom product TEST-BOX.

The measuring voltage signal from the measuring socket is connected to the banana connectors directly to the SIRIUS data acquisition system, through the HV amplifier. The current signal is converted into a low voltage signal by the 10A shunt, and also connected to the banana connectors of the SIRIUS LV-BAN amplifier.

At the same time, the SIRIUS can **measure the temperature** with the DSI-TH-K thermocouple adapter from the water in the test electric kettle or electric cooker.

Considering that any instability of the electric supply could impact the final power calculations and the test result, the customer used the power supply from the stabilized voltage supply to minimize the potential sources of test faults of this nature.

More and more modern household electrical appliances use microcomputer boards, and the working procedures of such household products become more and more complex.

For instance, the electric cooker in this case, according to the design of the customer, does not always keep the power of the cooker at its high during all of the heating procedures. In fact, the power will go down when the temperature reaches a certain point and then go up and down again - interchanging until the water in the cooker reaches the boiling point.

It's a complex process and the manufacturer needs to control it, record the curves of power consumption and temperature, and analyze the results.

Measurement results and analysis

DewesoftX Power Analysis module was used for the calculation of the power parameters.

Almost all household electrical appliances are based on a single-phase power system - see figure 4.

The power and the temperature curve visualize the complete work procedure of an electric cooker - see figure 5. Zooming in on the heating part, the blue box part, we can see in figure 6 that at the beginning of the heating, the power value is to keep the heating power. But when the water temperature is over about 100 degrees Celsius, the power value of the cooker starts to change down and up, between the heating power and low value.

And then in figure 7, zooming in on the brown box, indicating the keep-warm function status, the result shows that the cooker is doing some work when this function is active, and the working power transfer is in the range of about 4W to 11W.

Having recorded such a curve of the data, the customer can verify the product according to the design, the power rating, the timing of the work procedures, the work time, and more – finally, gain the knowledge supporting the further improvement of the products.

Conclusion

The testing demonstrated the flexibility and ease of use of the Dewesoft data acquisition systems, and the power of the custom-made SIRIUS module, and the custom-made product, TEST-BOX-HV-10A.

In comparison with the test device previously used by the customer, the Dewesoft SIRIUS DAQ device is much smaller in size, more flexible, and the included Dewesoft DAQ software easier to use. The Dewesoft solution measures all signals in just one time axis, facilitating and thus simplifying the customer analysis of the data.

The customer also benefited from the Dewesoft flexibility and in case more channels are needed in the future, the ease of expansion. Overall connectivity is strengthened as BSH China already has other Dewesoft data acquisition systems in use, and as the headquarters of BSH in Europe is using Dewesoft, test data can now be easily shared and compared.

Even more, the flexibility of Dewesoft software licensing allows customers to read and analyze recorded data files on any computer(s) without any additional software license.

The potential to help facilitate and qualify the development of household appliances is even larger. Dewesoft can measure much more, for example, appliance working noise, the vibration of vacuum cleaners, or the speed of revolution of high-speed blenders - almost everything a customer may need.

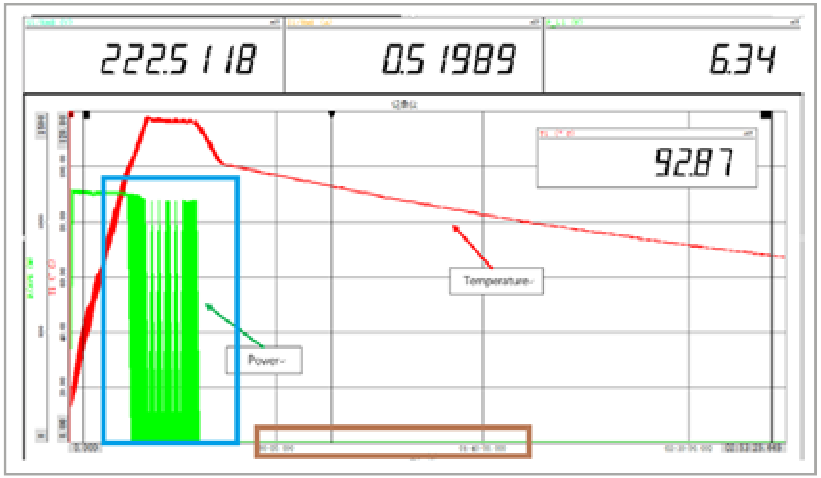


Figure 5. The work procedure of an electric cooker is visualized by power and the temperature curves. The cooker heating is marked in green in the blue box, while the keep warm function is marked in the brown box.

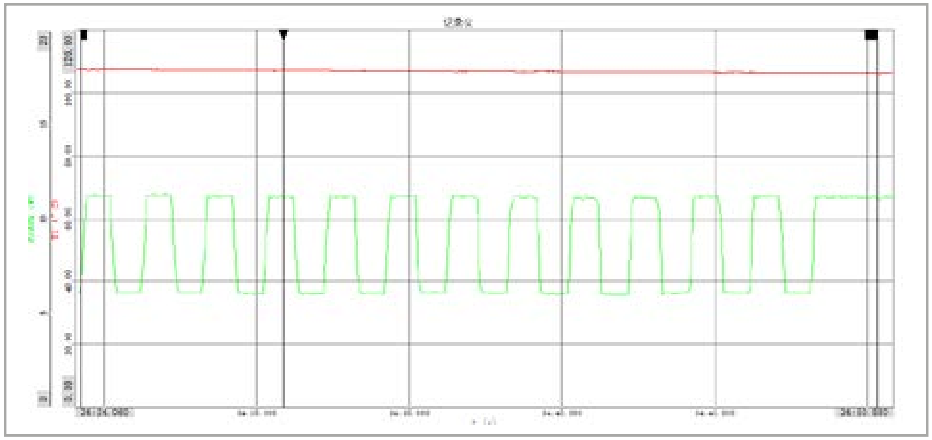


Figure 6. Zoom of the heating part of figure 6

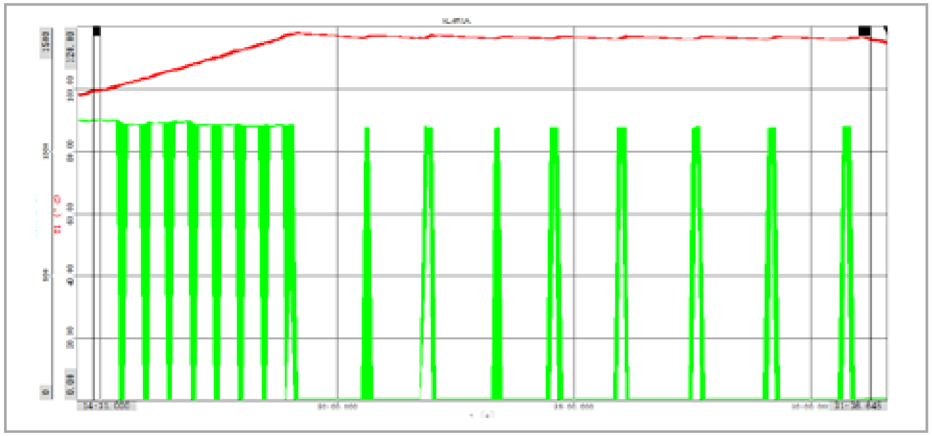
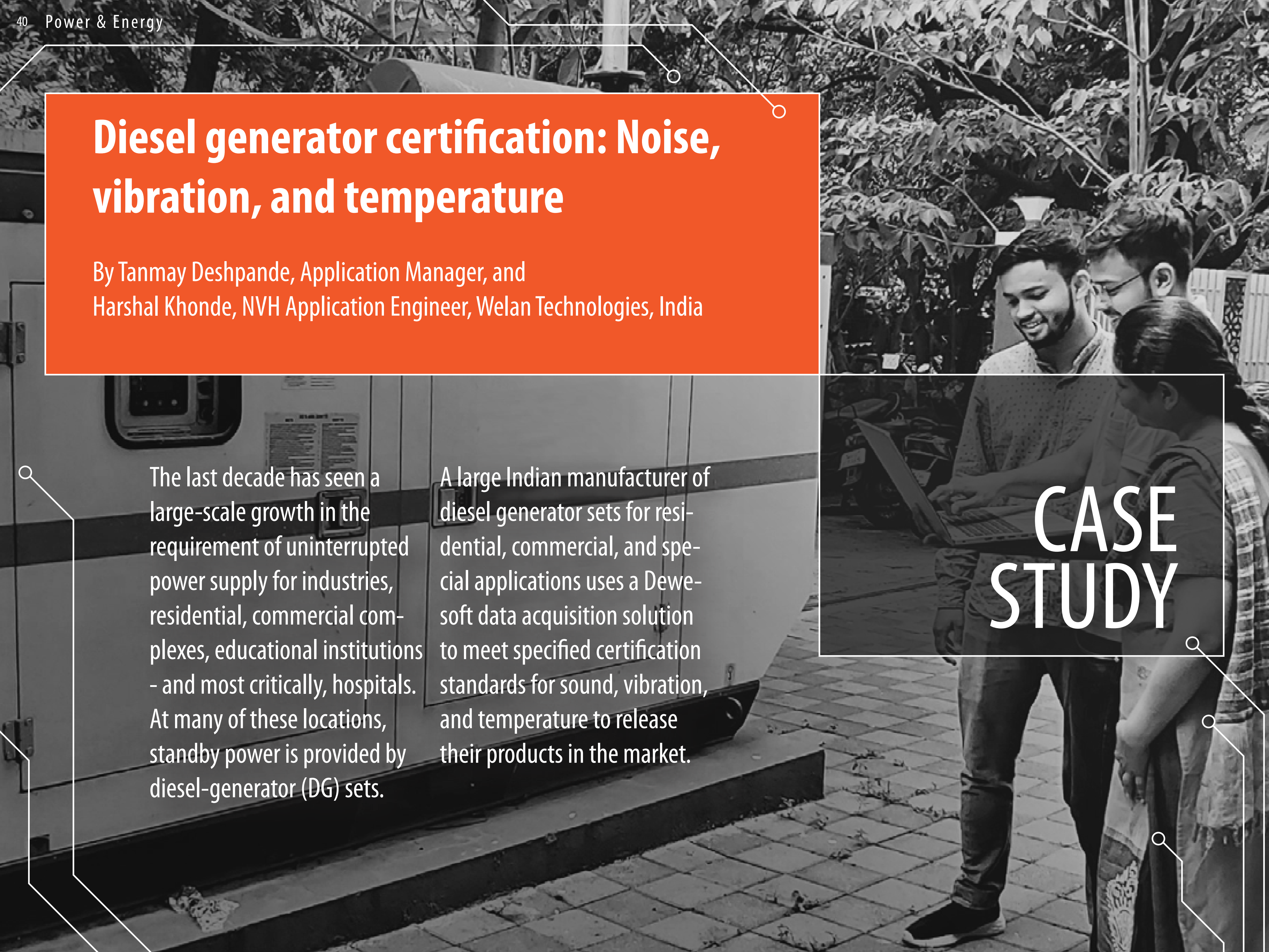


Figure 7. Zoom of keep-warm function in figure 6.



Diesel generator certification: Noise, vibration, and temperature

By Tanmay Deshpande, Application Manager, and
Harshal Khonde, NVH Application Engineer, Welan Technologies, India

CASE STUDY

The last decade has seen a large-scale growth in the requirement of uninterrupted power supply for industries, residential, commercial complexes, educational institutions - and most critically, hospitals. At many of these locations, standby power is provided by diesel-generator (DG) sets.

A large Indian manufacturer of diesel generator sets for residential, commercial, and special applications uses a Dewesoft data acquisition solution to meet specified certification standards for sound, vibration, and temperature to release their products in the market.

As per the norms of the Indian Central Pollution Control Board (CPCB) diesel generator sets (DG) shall comply with noise standards of less than 75 dBA and has to be tested following the ISO 8528 standard for noise level. These generators are manufactured with acoustic enclosures to get optimum performance of noise level and power.

International rating standard

The standard regulation for any diesel generator sets to be approved for sound, vibration, and temperature measurement is ISO 8528. This standard defines various classifications for the application, rating, and performance of generating sets consisting of a Reciprocating Internal Combustion (RIC) engine, an Alternating Current (AC) generator, and any associated control gear, switchgear, and auxiliary equipment.

ISO 8528-6:2005 is defining test methods for engine-driven generating sets, the general test requirements as well as a functional test and an acceptance test. Functional tests must always be done and usually occur at the manufacturer's factory.

The standard defines six types of ratings:

- Emergency Standby Power (ESP)
- Prime Power (PRP)
- Limited-Time Running Power (LTP)
- Continuous Power (COP)
- Data Center Power (DCP)
- Maximum Power for Low-Power Generating Sets (MAX) (Less than 12kWe)

Figure 1. instrument setup on the site.

The criteria determined are the annual run-time expectation, load variability, and load factor.

The classifications in ISO 8528-1:2005 are intended to help align the generator set manufacturer and customer by providing customers a common basis on which to compare generator set ratings from different manufacturers.

Therefore, the canopy enclosure is the main component of the industrial diesel generator set and engine performance is dependent on the canopy. To get optimum performance of the canopy, designers mainly need to juggle between the diesel generator sound levels and temperature.

The efficiency of the diesel generator set is directly dependent on the acoustic enclosure and various parameters like inlet temperature, ambient temperature, canopy in/out temperature, radiator, water in/out temperature, vibration, and sound levels.

Product certification of diesel generators

Headquartered in Pune, the Detroit of India, the industrial engineering company, Welan Technologies was founded by a group of technical experts with solid industry experience. They are at the forefront of providing technological solutions to the industry in the field of sound, vibration, static and dynamic transducers, test and measurement equipment, and analysis systems.

Our client is one of the largest manufacturers of diesel generator sets in residential, commercial, and special applications.

The company adheres to international standards by acquiring and adapting the latest technologies along with in-house R&D. It manufactures diesel generator sets ranging from 3 KVA to 1000 KVA. With any capacity of diesel generator sets specified certification standards are met. Only after certification, the generator sets are viable to be sold in the market.

Dewesoft data acquisition products provide an operative solution for a quick measurement of diesel generator set parameters. In this case, we used the DEWE-43A and KRYPTON data acquisition systems - see figure 1.

DEWE-43A 8-channel data logging system was used for microphone and accelerometer inputs and KRYPTON 8-channel for thermocouple inputs.

The included DewesoftX software is easy to set up and very interactive. There are various design options to set the communicative monitor screen.

The defined parameters of interest are:

- Sound Power,
- Temperature measurement,
- Engine Inlet temperature,
- Canopy In temperature,
- Ambient temperature,
- Alternator In/Out,
- Radiator Water In/Out temperature,
- Canopy Out temperature,
- Delta T - the difference of temperature between two measuring points in time and/or position, and
- Vibration above and below AVM (Anti Vibration Mounting).

The main application is to measure these parameters simultaneously and only at a particular interval of time and different loads. The regulations for the measurement of the diesel generator set parameters suggest continuous monitoring of the temperature, the vibration at the engine mounting, and noise measurement.

Measurement setup

For measurement, in this case, 17 sensors were used; including eight thermocouples, one vibration sensor, and six free-field microphones for noise measurement. As per the requirement of the client, continuous monitoring of sound, vibration, and temperature data was needed. So, the measurement of all the above parameters has to be done after 1 minute. The instruments and sensors used for this particular measurement are listed below:

- Data acquisition system setup
- DEWE-43A - 8 Channel Data Logging System
- KRYPTON 8×TH - 8 Channel temperature inputs

DEWE-43A is a versatile USB data acquisition system with universal analog inputs, digital counter inputs, and a dual CAN bus interface. It is suitable for various dynamic data acquisition applications.

KRYPTON is a rugged and distributed data acquisition module with an EtherCAT interface for analog and digital I/O and IP67 degrees of protection. KRYPTON DAQ modules come in various configurations spanning from small single channel units up to bigger 16-channel units for temperature, voltage, current, IEPE/ICP, and strain gauge signals.

- Sensors and transducers
- 6x Free field microphone

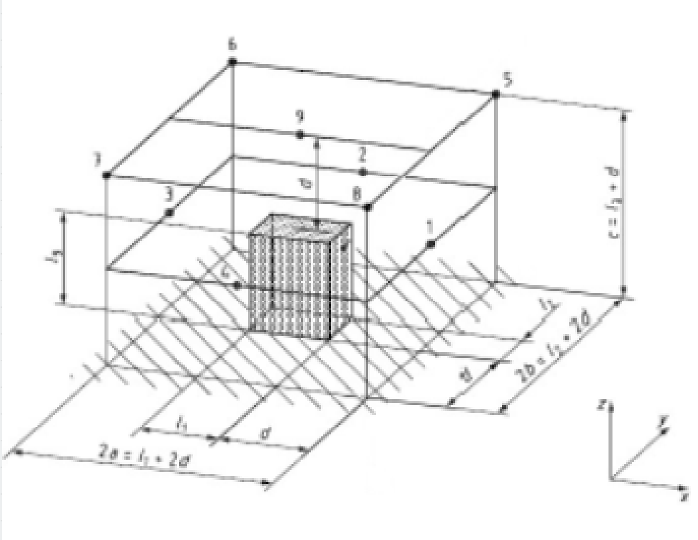
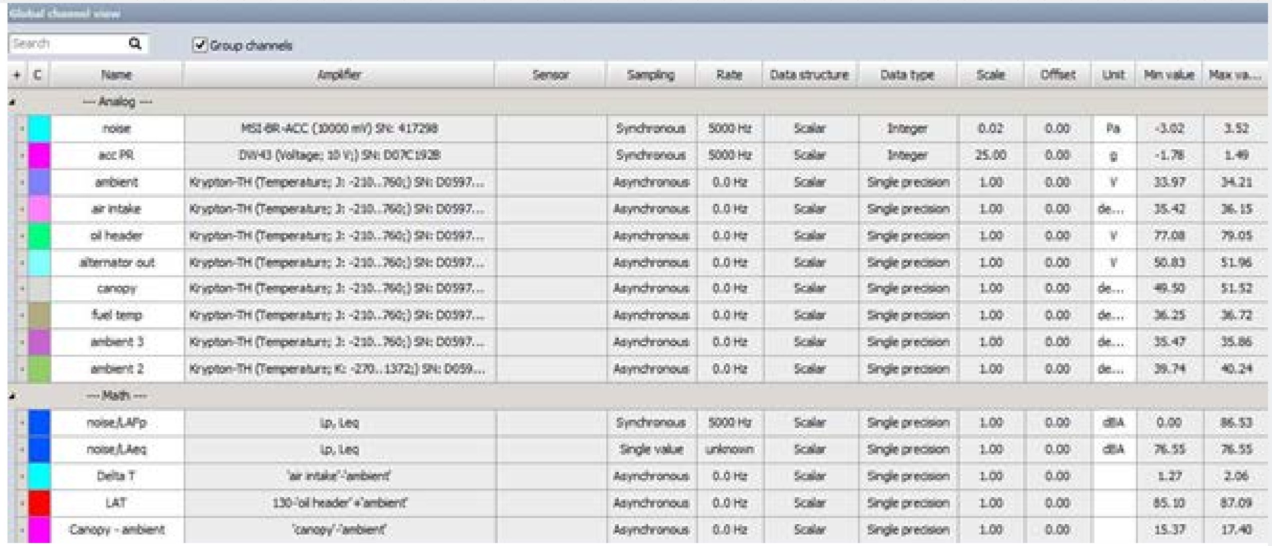


Figure 2. Sound source placed over an acoustically reflective plane.



Global channel view

Search | Group channels

+	C	Name	Amplifier	Sensor	Sampling	Rate	Data structure	Data type	Scale	Offset	Unit	Min value	Max va...
		--- Analog ---											
		noise	MSI-BR-ACC (10000 mV) SN: 417298		Synchronous	5000 Hz	Scalar	Integer	0.02	0.00	Pa	-3.02	3.52
		acc PR	DW43 (Voltage; 10 V;) SN: D07C1928		Synchronous	5000 Hz	Scalar	Integer	25.00	0.00	g	-1.78	1.49
		ambient	Krypton-TH (Temperature; J: -210..760;) SN: D0597...		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00	V	33.97	34.21
		air intake	Krypton-TH (Temperature; J: -210..760;) SN: D0597...		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00	de...	35.42	36.15
		oil header	Krypton-TH (Temperature; J: -210..760;) SN: D0597...		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00	V	77.08	79.05
		alternator out	Krypton-TH (Temperature; J: -210..760;) SN: D0597...		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00	V	50.83	51.96
		canopy	Krypton-TH (Temperature; J: -210..760;) SN: D0597...		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00	de...	49.50	51.52
		fuel temp	Krypton-TH (Temperature; J: -210..760;) SN: D0597...		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00	de...	36.25	36.72
		ambient 3	Krypton-TH (Temperature; J: -210..760;) SN: D0597...		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00	de...	35.47	35.86
		ambient 2	Krypton-TH (Temperature; K: -270..1372;) SN: D059...		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00	de...	39.74	40.24
		--- Math ---											
		noise/LAFp	Lp, Leq		Synchronous	5000 Hz	Scalar	Single precision	1.00	0.00	dBA	0.00	86.53
		noise/LAeq	Lp, Leq		Single value	unknown	Scalar	Single precision	1.00	0.00	dBA	76.55	76.55
		Delta T	'air intake'-'ambient'		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00		1.27	2.06
		LAT	130-'oil header'+'ambient'		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00		85.10	87.09
		Canopy - ambient	'canopy'-'ambient'		Asynchronous	0.0 Hz	Scalar	Single precision	1.00	0.00		15.37	17.40

Figure 3. Channel setup and the channel view.

- 1x Piezo-resistive vibration sensor
- 1x K type thermocouple
- 7x J type thermocouple
- Measurement and analysis software
- DewesoftX data acquisition software
- DSA (Digital Signal Analyzer) software option
- Sound Power software option

DewesoftX software can acquire, store, visualize and analyze data from analog, digital, CAN, GPS, video, serial, and many other data sources. The latest version of the software is named DewesoftX.

Measurement parameters

Channel setup in the software

The following recording parameters were set in the Dewesoft software channel set up:

- Triggered condition: Fast on triggered
- Sampling rate: 5000 S/channel
- Reduced Rate: 0.2 s
- Number of channels: 15

Temperature measurement

Apart from basic temperature measurements, we have added simple Math in the DewesoftX software. We wanted to measure the Leaving Air Temperature (LAT) and Delta T, the difference between the two temperatures: Canopy temperature and ambient temperature.

As per standard, the Delta T value should be less than 7 degrees Celsius. Using DewesoftX software during the measurement, we have set the alarm indicator from a design.

Noise measurement

In the standard, different numbers of noise measurement points are defined concerning the canopy size of the generator set - see figure 2. These points are measured in dB(A) value with equivalent continuous sound level (Leq) mode and the final result is calculated with a logarithmic average of all points. This we have set up with arithmetic functions for calculating final averaged results.

Vibration measurement

In the diesel generator set, the engine and alternator assembly are set up with Anti Vibration Mounting (AVM) to avoid the transfer of vibration to the floor. Transmissibility of vibration is calculated to check the isolation of the mounting by measuring the vibrations below and above AVM. This is calculated by using the Dewesoft 'Math' function.

Measurement and analysis

The measurement screen is set up to see all the standard measured parameters like temperature, vibration, noise, and customized parameters which were added from the math function - see figure 4.

Sound power measurement

Noise Emissions standards from Outdoor Equipment (2000/14/EC), the EU Noise Emissions Directive is a CE Marking Directive that applies to the list of 57 types of equipment mentioned in articles 12 & 13 of the directive, including generator sets.

As per CE standard, if an Indian manufacturer wants to export generator sets to any EU country, they need to comply with sound power as per ISO 3744 standard. We have utilized the Dewesoft Sound Power solution to set up the microphone positions as per standard - se figure 5. The sound power setup is less time-consuming and incorporated with all standards of sound power.

ISO 3744:2010 specifies methods for determining the sound power level or sound energy level of a noise source. This is done from sound pressure levels measured on a surface enveloping the noise source.

The machinery or equipment under test is placed in an environment that approximates an acoustic free field near one or more reflecting planes. The sound power level - or, in the case of noise bursts or transient noise emission, the sound energy level - produced by the noise source, in frequency bands or with **frequency A-weighting applied**, is calculated using those measurements.

Figure 4. Measurement screen with the customized display.

Figure 5. Instrument setup for sound power measurement.

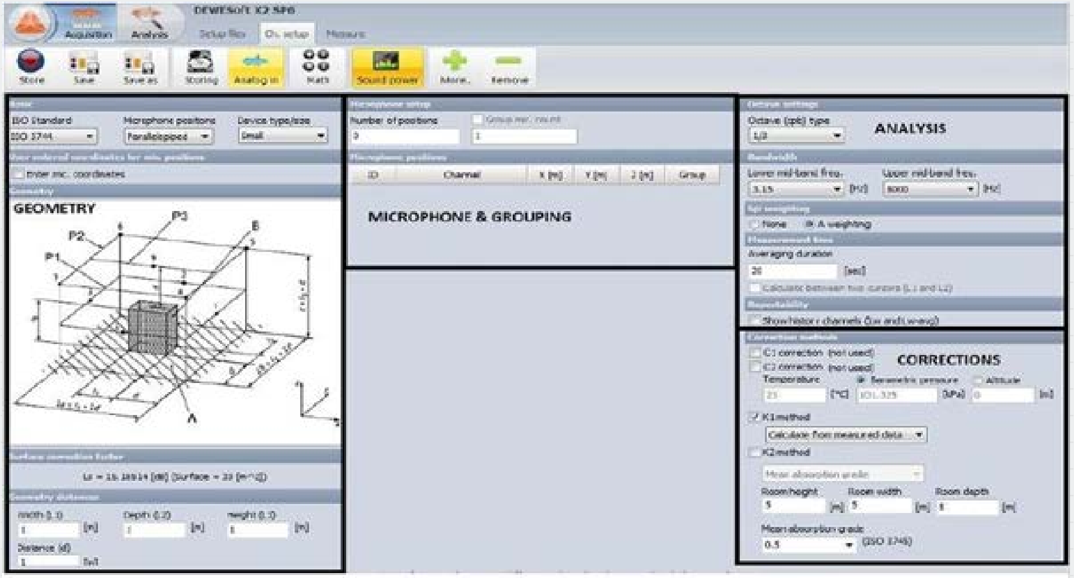


Figure 6. Sound Power module and setup in Dewesoft software.

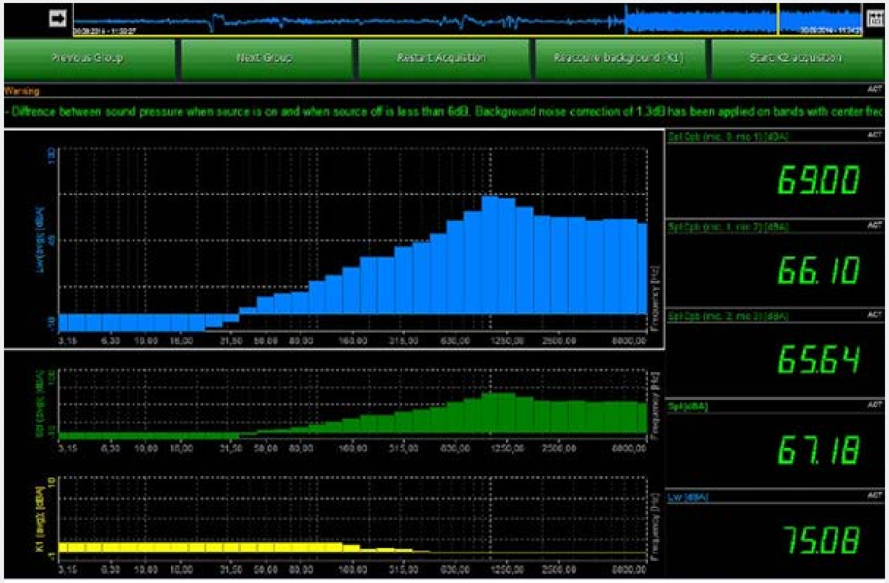


Figure 7. Sound Power measurement in Dewesoft software.

There is a predefined measurement setup for the sound power measurement, where we have to select the ISO standard, geometry, numbers of microphones, and their positions and correction factor according to ISO standard - see figure 6.

The **Sound Power Level (Lw)** of the diesel generator and related **Sound Pressure Level (SPL)** was measured - see figure 7. As per standard, we can also add a background noise correction factor and a metrological correction factor by the easy-to-use guided interface.

Conclusion

The real-time measurement and signal conditioning, as well as data storing at triggered events, was successful for this particular 15 KVA diesel generator set. It seems the equivalent noise level in dBA is on the higher side with a small margin. The expected value is less than 75 dBA. The averaged value is matching with the calculated results. Temperature measurement and LAT value were below an acceptable limit.

Including setup time, sensor mounting, and measurement with the particular triggered conditions, everything was completed in one hour. The overall experience to use Dewesoft hardware and software is quite less time-consuming, easy to set up, easy to measure, and most importantly very sophisticated analysis options were provided by DewesoftX software with the customizable displays.

A report was readily generated for the particular triggered time intervals as per measurement requirements and with respect to loading conditions.

In the generator industry, following the performance, the most important product feature is the quality of the generated energy. This can be assessed by several energy analysis parameters and easily tested with the Dewesoft power analysis software.

Performance measurement on electric boat

Case Study by Nika Pockaj, Marketing Manager, Alfastreet Marine,
and Bernard Jerman, Regional Sales Manager SEE, Dewesoft

CASE STUDY

The Slovenian boutique boat builder, Alfastreet Marine, has introduced a brand-new boat model – the 28 Cabin Electric. To evaluate the performance of a fully electric version of this model, equipped with twin electric Piktronik 10 kW engines, Alfastreet needed to test its stability and performance and also to compare data from simulations with actual measurements. The Dewesoft Power Analyzer was applied to measure the electrical power of the two electric motors and the boat speed in real-life situations.

The company Alfastreet Marine is a producer of boutique boats, small and intimate vessels for leisure, that at this moment come in three different sizes – 18ft, 23ft, and 28ft. With 10 years of experience Alfastreet boats, today are sold in 20 countries worldwide, 75% of these boats sold are electric.

In design and development, Alfastreet pays attention to every single detail to ensure an optimal combination between functionality, timeless design, and high usability - all this to create the best experience on the water.

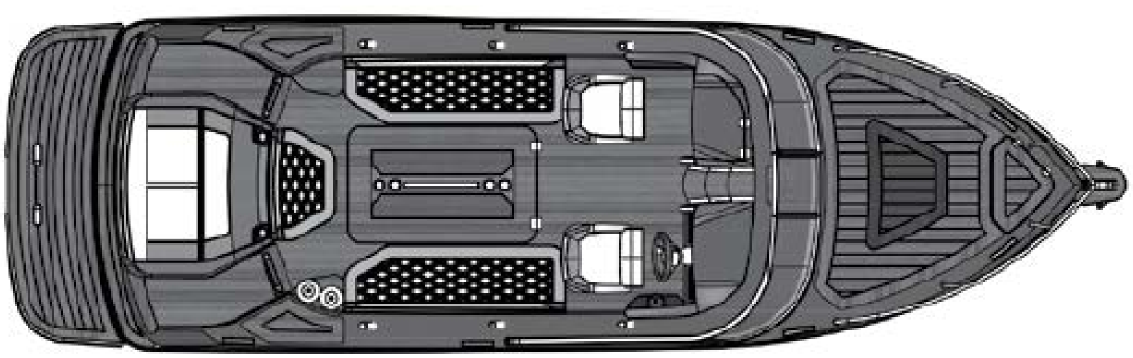
Alfastreet Marine offers a wide range of boats with customized options. Buying a boat, each of the customers has to customize their boat by the design, but also, by the propulsion system and type. Selecting either electric, diesel, petrol, or semi-hybrid propulsion - each has different performance results.

Depending on the selected propulsion system, Alfastreet uses displacement or planing hulls. The displacement hull has a convex, bottom contour or planing surface and does not ride high on the water like a planing hull, but is plowing through and parting the water, while a planing hull has a flat or concave bottom contour and plane up on top of the water.

Figure 1. The ergonomics cockpit of type 28 offers comfortable seating for 12 persons.

Electric Range	Motor Range
Length: 8,6 m / 28′ 3″	Length: 8,6 m / 28′ 3″
Length over all: 9,8 m / 32′ 2″	Length over all: 9,8 m / 32′ 2″
Beam: 2,9 m / 9′ 6″	Beam: 2,9 m / 9′ 6″
Empty weight: 4300 kg / 9480 lbs.	Empty weight: 4300 kg / 9480 lbs.
Draft: 0,8 m / 2′ 7″	Draft: 0,8 m / 2′ 7″
Max persons: 12 adults	Max persons: 12 adults
CE certificate: C	CE certificate: C
Engine: Up to 50 kW	Engine: Up to 450 kW

Table 1. The type 28 Cabin specifications include both types of propulsion.



The challenge

The 28 Cabin models come with a variety of customization options but the main advantage of the boat is the use of two types of hulls. Using two varieties of hulls enables better performance, stability, and maximum efficiency on the water. Whatever engine is chosen, the 28 Cabin Sport should be a safe and comfortable cruiser that exudes quality and enjoyment even when reaching higher speeds - see figure 1.

The electric version of the 28ft Cabin Electric model is designed for the luxurious leisure experience on board and with her unique displacement hull design offers optimized performance, as well a low electricity consumption.

Knowing the performance capability of the boat is important since each customer has different demands for the speed, range, engine power, and lithium ion battery pack.

The goal is to have data that can be presented to the customers with the intention of a better and even more understandable presentation of the boat and its features. Results should show the advantages of the boat and its navigability.

Figure 2. SIRIUSi HS 4x HV, 4x LV with DS-BP2i.

The solution

The Dewesoft power meters provide the most flexible solution for all power analysis calculations as well as electrical power and mechanical power measurements. It is a combination of multiple products in a single device:

- Power Analyzer,
- Combustion Analyzer,
- Oscilloscope,
- RAW Data Logger,
- Spectrum Analyzer,
- CAN logger,
- etc.

and delivers synchronous acquisition of all data - electrical data, mechanical data, vehicle bus data, positioning data, video, etc.

Dewesoft Power Analyzer is used in a variety of different applications in several industries. In this case, a SIRIUSi single slice data acquisition system with High Voltage and Low Voltage amplifiers with AC and DC current clamps was used.

Dewesoft Power Analyzer allows the use of different current transducers and sensors, depending on the required measurement accuracy or the available space for sensor installation.

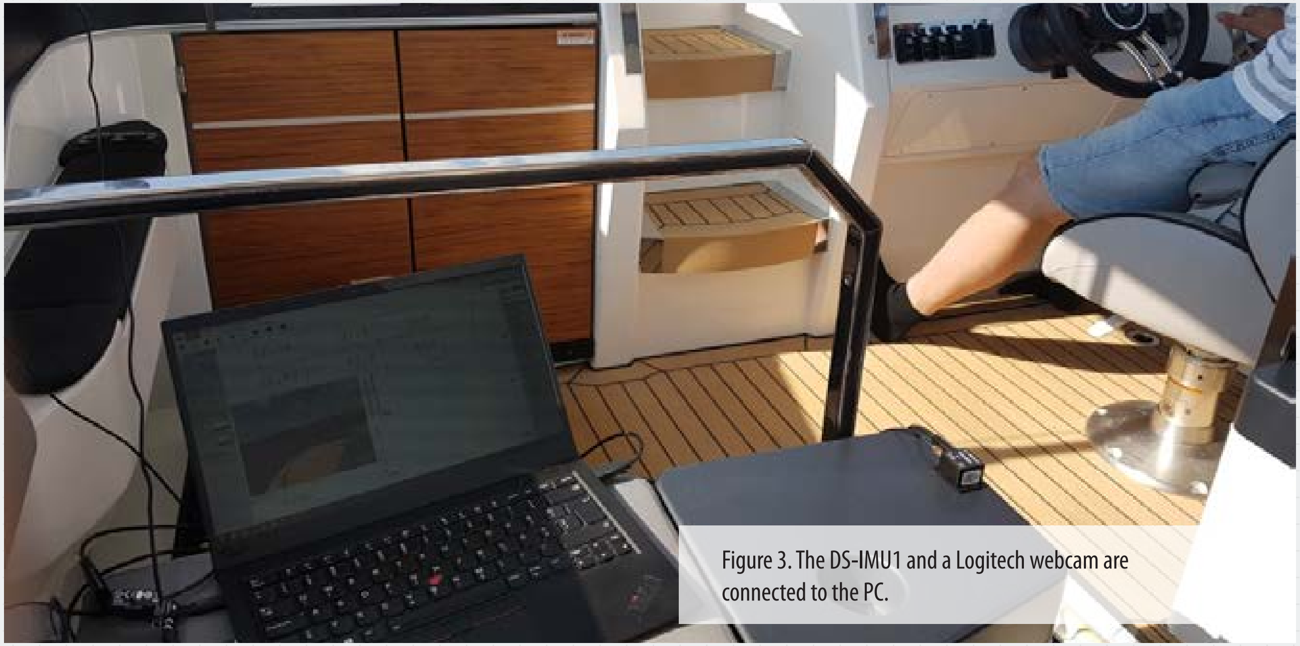


Figure 3. The DS-IMU1 and a Logitech webcam are connected to the PC.

Measurement setup

The 28 Cabin Electric boat is best suited for sailing on lakes because of the displacement hull design, nevertheless, measurements were performed at sea using this hardware setup:

- SIRIUSi HS 4x HV, 4x LV DAQ system
- DS-CLAMP-1800 DC current clamps
- DS-BP2i battery pack
- DS-IMU1 inertial sensor
- Logitech C920 webcam

Data recording, visualization, and analysis were done with the DewesoftX software package with the POWER-OPTION. For the electrical power calculation, the DC Power system configuration of this Power option was used.

The voltage signal from the batteries was connected to the HV amplifier, DS-CLAMP-1800 DC current clamps were connected to the LV amplifier - see figure 2. The current clamps were chosen for this application as they are easy to mount. Dewesoft battery packs, DS-BP2i with a total capacity of 192Wh gave some hours of equipment power autonomy.

Besides electrical values, boat speed and position were also important parameters meaning that also a DS-IMU1 inertial sensor has to be applied. Such sensors are a combination of multiple sensors like gyroscope, accelerometer, magnetometer, pressure sensor, and a high-speed GNSS receiver. Coupled with sophisticated algorithms they deliver very accurate and reliable navigation and orientation.

For the visualization of the testing process, a standard webcam was connected as well - see figure 3.

The setup was prepared and all sensors connected within just half an hour as the current clamps with TEDS chips inside the connectors are automatically recognized in the Dewesoft software.

Measurements

To verify the specifications of two electric motors and the power on the batteries, measurements of DC and voltage on the batteries (charging and discharging) and calculations of the power output had to be performed.

The stability and the performance of the boat were tested in different real-life situations measurements were done at different driving conditions - during extreme maneuvering and maximum speeds:

- Steady acceleration
- Rapid deceleration
- Turn
- Single motor ride
- Turn with one motor

The various maneuvers were performed during the test. The measurement screen comprises all the data needed - showing the DC voltage, current, and active power for each battery, while video and data from the inertial sensor provide additional information on the testing conditions. The current signals - the blue and gray curves, indicate that several steady acceleration tests were performed.

The screenshot in figure 4 shows the measurement of steady acceleration that was repeated several times. Alfastreet is mainly interested in the final speed of the boat and the power and efficiency of both powertrains. The measured boat speed is an indication that 28 Cabin Electric is designed for a luxurious cruising experience.

Measurement results

The measurements in detail documented the technical characteristics of the boat - characteristics of the interaction between the electric twin 10kW motors and the displacement hull of the boat. Furthermore, the test results confirmed the previously done simulations regarding the maximum engine power and the maximum final speed of the boat.

The test has shown that measurements of different parameters can be performed quickly with one SIRIUS system and different sensors. As an upgrade to these measurements, a test of electrical quantities could be performed directly on both electric motors to give an even better insight into the electric motor performance.

Conclusion

Alfastreet is actively expanding their market and the most selling boats are electric boats, especially suitable for the lakes, where the fuel drive is forbidden.

As a producer, Alfastreet has to know the performance of the boat and its characteristics while driving. Such results, especially for the new boats such as this one, will bring a better understanding of the options for improvements and also a better selling predisposition with more information.

With these measurements, Alfastreet gained exact knowledge of the characteristics of the tested electric boat, and can now better assume other characteristics with different propulsion. They can also use the characteristics for technical declaration and sale descriptions promoting the advantages of the type 28 Cabin Electric.

The measurements performed are the basis for the boat buyers to design their version of the electric boat. For the customers of Alfastreet, the most-needed information is the maximal range, maximal speed, and cruise speed to better know which vessel and which propulsion to choose - and the measurements are declaring those most accurately.

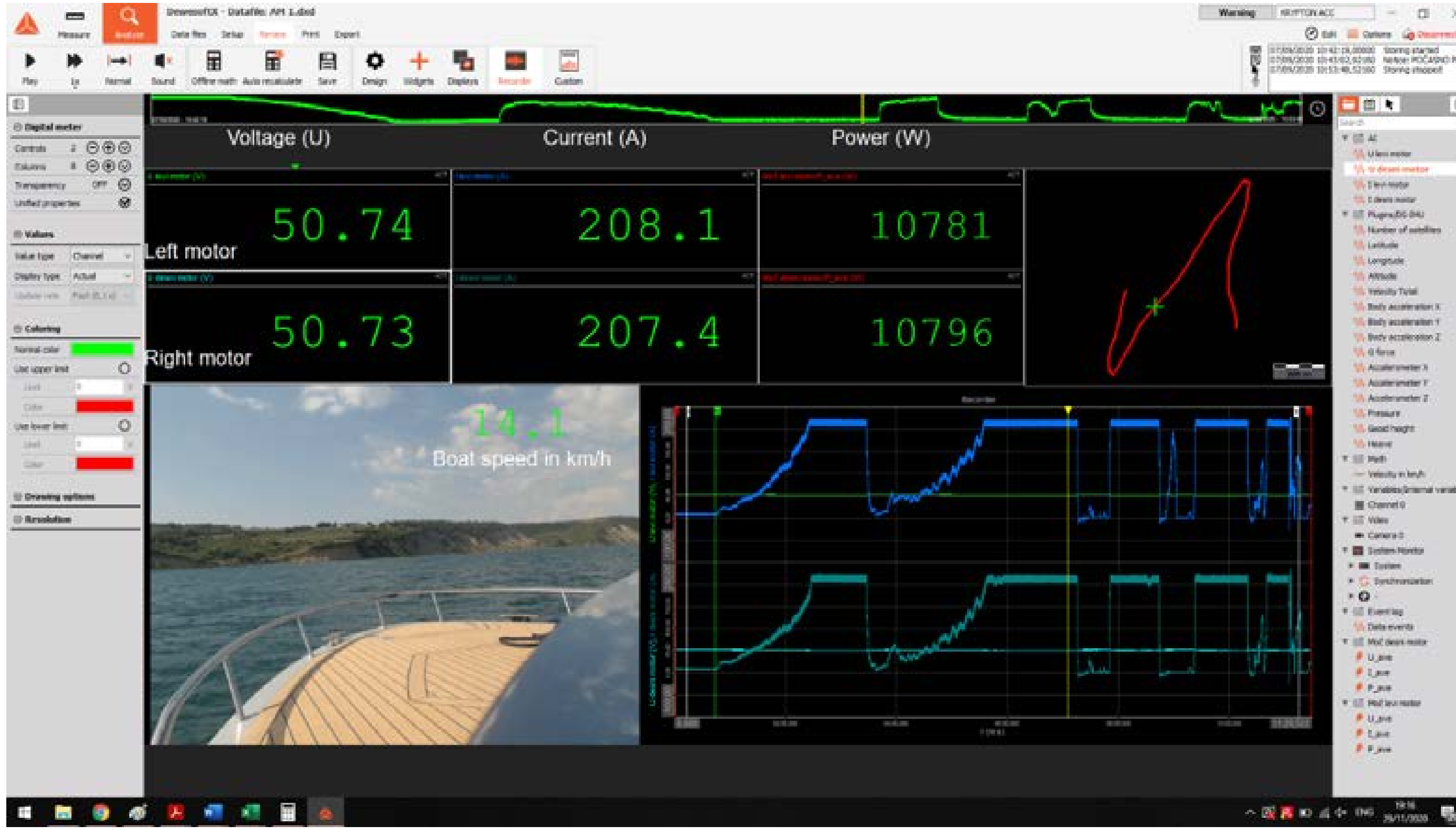


Figure 4. A webcam and an inertial sensor allow the creation of a measurement screen that is both comprehensive and clear.

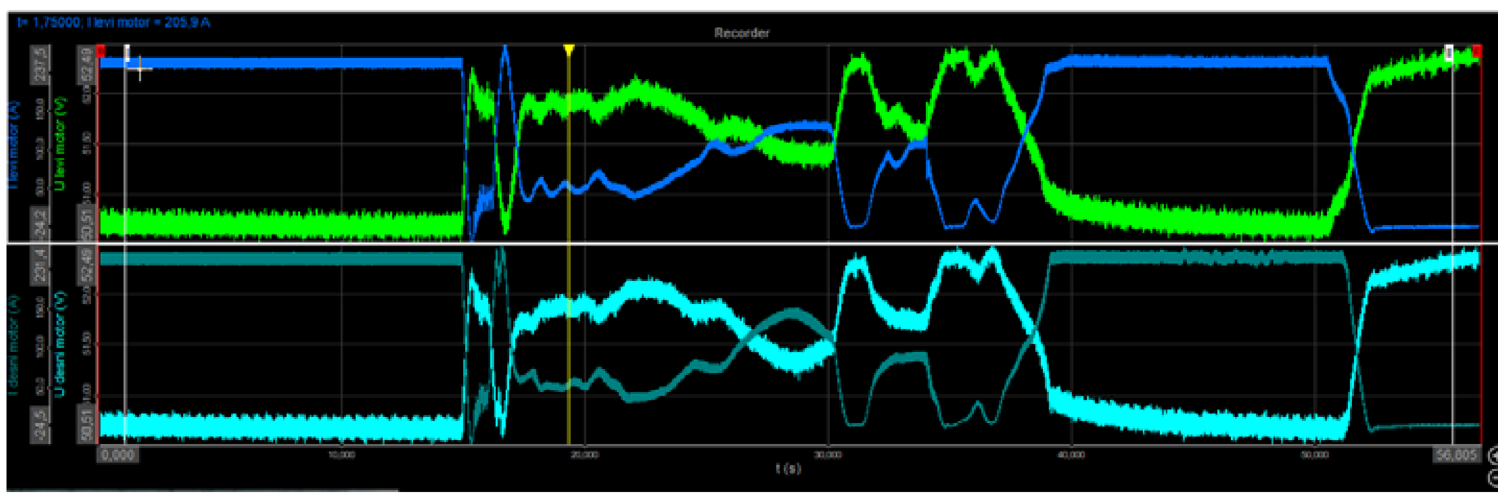
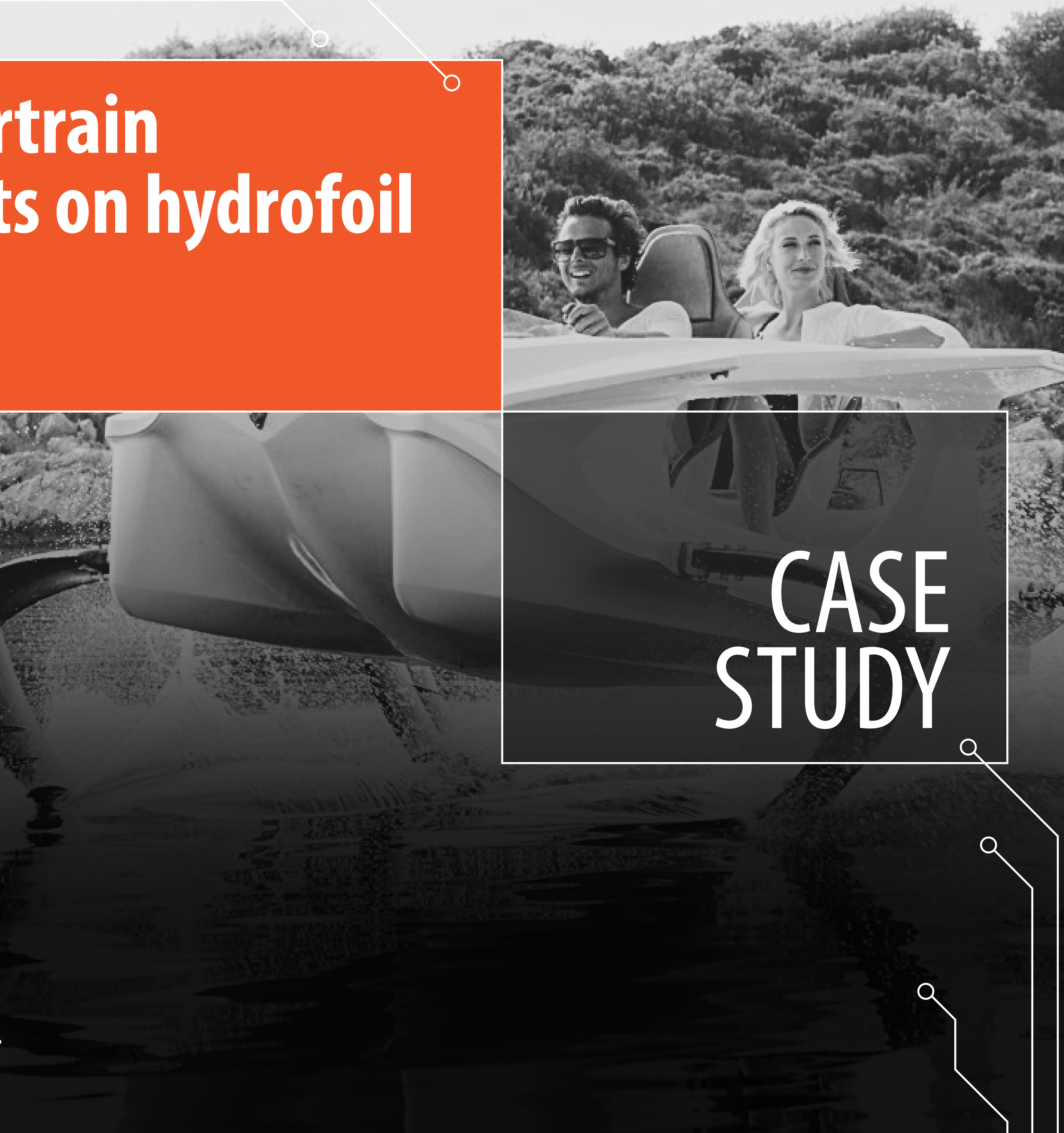


Figure 5. Voltage and current (blue and gray) signals during the deceleration test of the boat.

Electric powertrain measurements on hydrofoil

Quadrofoil, Slovenia



The Quadrofoil Q2 has been characterized as an "ecologically sound electric hydrofoil sports car for the water". For a complex product such as this, it is necessary to continuously carry out extensive measurement procedures with test equipment. Dewesoft has helped Quadrofoil in measuring the performance of the electric powertrain of their prototype hydrofoil watercraft.

CASE STUDY

The Slovenian high-tech company Quadrofoil wants to revolutionize nautical science with what is said to be the first all-electric "water supercar".

The Quadrofoil

The Q2 is an advanced two-person electric watercraft weighing just 100 kilograms. It can reach speeds up to 40 km/h (24.85 mph) and has a turning radius of 7 meters (23 feet). The Q2 watercraft has C-shaped hydrofoils – allowing an above-the-water and super silent flying experience.

Available in two models - Q2A Electric with a 3.7Kw outboard motor and Q2S Electric, consumers with the sportier 5.5Kw motor. Capable of fully recharging in three to four hours, the Q2A/Q2S Electric motors are managed by an intuitive Battery Management System (BMS) that monitors each cell's performance.

Q2 is designed and manufactured by the Slovenian business Quadrofoil, a hi-tech electrical engineering company with the mission to shape the future of the nautical industry and the way society embraces water transportation.

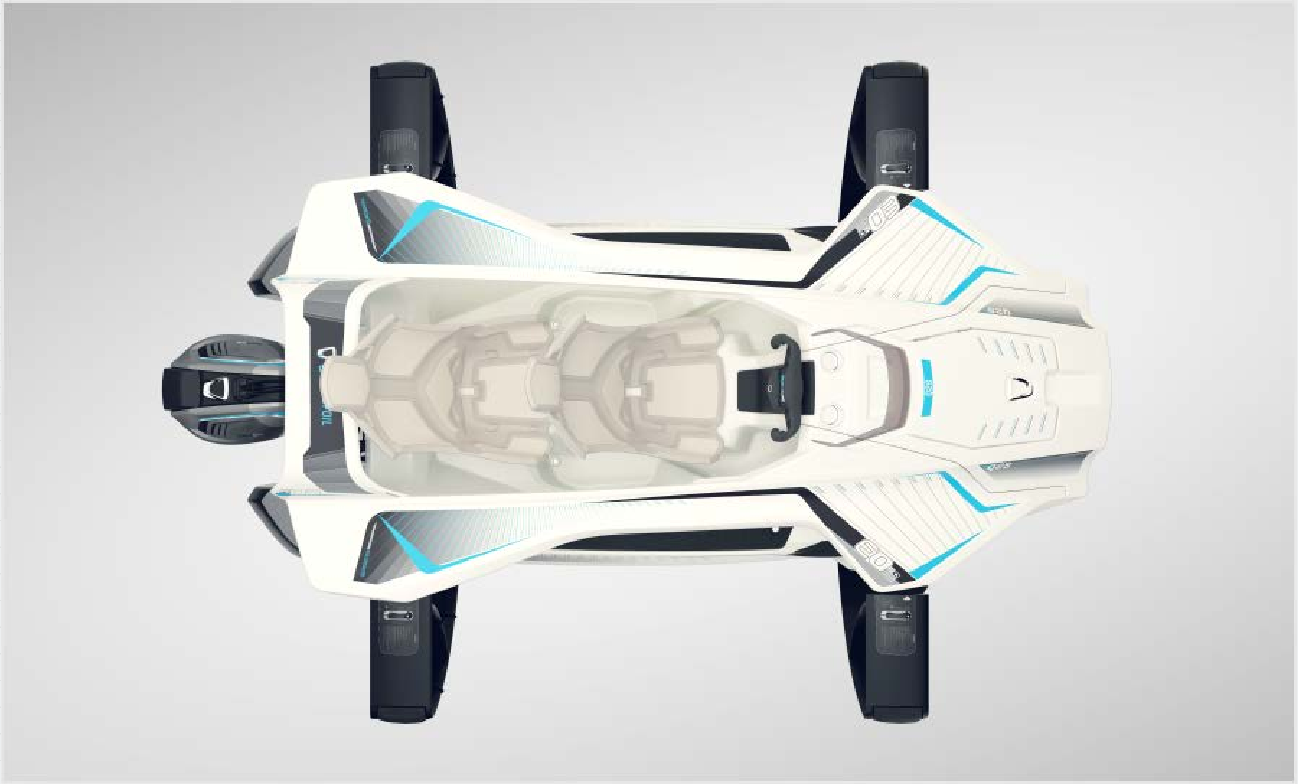
Hydrofoils let a boat go faster by getting the hull out of the water. When a normal boat moves forward, most of the energy expended goes into moving the water in front of the boat out of the way by pushing the hull through it. Hydrofoils can lift the hull out of the water so it only has to overcome the drag on the foils instead of all of the drag on the hull.

From a speed of twelve km / h, the buoyancy of the four wings or foils of the Quadrofoil is sufficient to lift the hull out of the water, the draft is reduced to 15 centimeters - and the super-sport boat becomes even more agile.

Figure 1. The design of the electric Quadrofoil Q2S.

The task

Dewesoft set up the measurement of both the DC and the AC part of the Q2 powertrain to measure the efficiency and quality of power conversion of the brushless motor power inverter. Additionally, the position, velocity, acceleration, and orientation of the watercraft were measured using an inertial measurement unit (IMU) - an electronic device that measures and reports a body's specific force and angular rate. Two cameras were used to monitor how much water the hydrofoils drew during operation.



Measurement setup

The equipment used for the measurement was:

- SIRIUSi-PWR-MCTS2 - a power supply unit
- SIRIUSi-HS-4xHV-4xLV - a data acquisition unit
- DS-BP2i - a battery pack
- 4x DS-CLAMP-500DCS - current clamps
- DS-IMU2 - an inertial measurement unit
- 2 cameras
- Laptop running Dewesoft X3.

This setup allowed gathering detailed data on the relation between power requirements and the behavior of the watercraft.

Measurements

Firstly, the current clamps were mounted onto the power leads going from the battery to the power inverter and also on the AC side of it, going to the motor. Because the space underneath the motor cover is really tight, the cover had to be completely removed and everything covered in a stretch wrap to protect the electronics from the water.

Then the IMU was mounted as close to the center of the watercraft as possible and the two accompanying GPS antennas to the rear and front ends of the watercraft. One camera was placed on the side of the craft, looking at the left rear foil, and the second one high above the craft, fixed on a beam that was tied to the rear seat, providing a view of the front of the craft.

The battery pack, power supply for the current clamps, SIRIUS HS, and a laptop was placed onto the rear seat, everything was connected and wrapped in a few plastic bags to provide some protection from the water that could splash onto the seat.

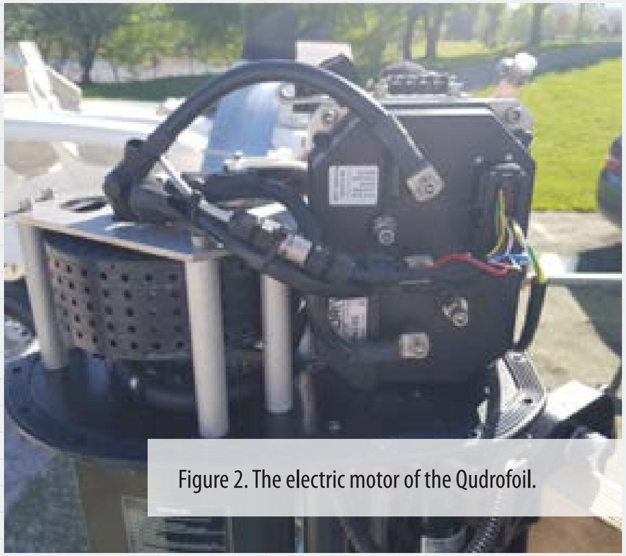


Figure 2. The electric motor of the Qudrofoil.

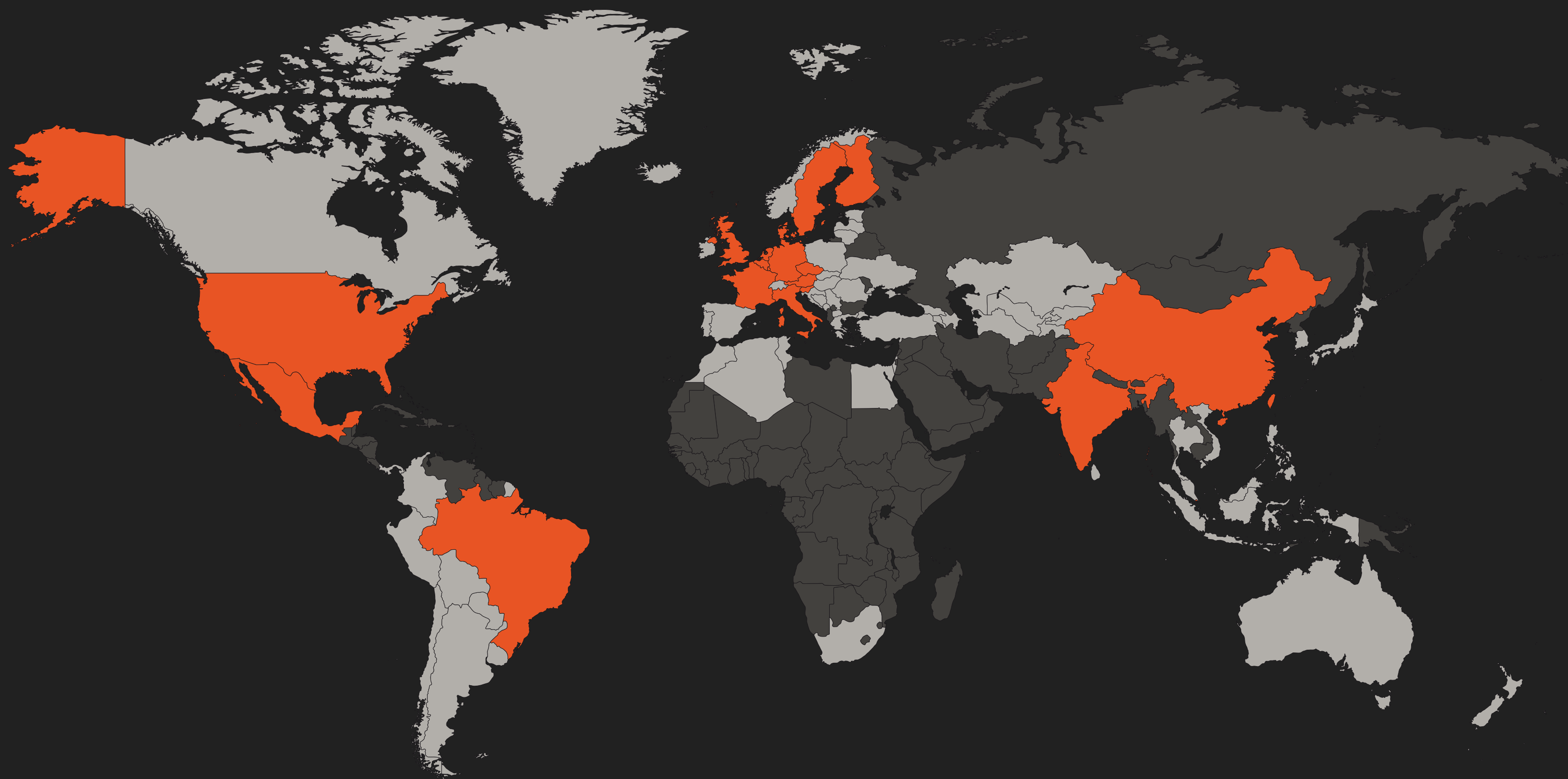
Finally, the Quadrofoil team put the craft into the water and their test driver did a few shorter runs, setting up the foils into different positions and making one long run in conclusion.

Conclusion

The data collected showed that the watercraft needs to reach approximately 10 - 12 km/h to rise out of the water and onto the hydrofoils, for which it requires about 13 to 14 kW of power. Reaching this stage, the power requirements drop to about 8 to 10 kW for cruising speeds between 24 - 30 km/h.

The efficiency of the power inverter was between 95 and 99 percent throughout the whole measurement. A strong indication that the inverter is efficient, which again ensures that more energy is available for propulsion and that cooling requirement is low, allowing for a more compact and lower cost cooling solution.

Quadrofoil aims to be one of the leaders in e-mobility in the nautical industry. In the future, the product range will include vessels for personal daily use as well as for public and cargo transportation – all using eco-friendly hydrofoil technology.



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