
## ABSTRACT

Power Diagnostix by Megger has developed the ICM*monitor* - a versatile and modular design engineered to monitor online or temporary PD activity in power transformers and in other assets such as rotating machines or HV cable accessories. The article brings an overview of the ICM*monitor* functionalities, features, options for installation, and many more.



## KEYWORDS:

diagnostics, monitoring systems, partial discharge

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**Aging and degradation of insulating media are inevitable, hence poorly monitored systems (offline or online) may allow accelerated insulation deterioration to go unnoticed and potentially result in failure**

# The Power Diagnostix by Megger ICM*monitor*:

## A versatile device for on-line or temporary partial discharge monitoring of power transformers

Keeping the power on, the mission of Power Diagnostix (PDIX), is vital to the success of any power grid operator. Safe, reliable, and efficient operation of high voltage assets, such as power transformers, is a paramount task. During the service life of a power transformer, aging and degradation of insulating media are inevitable, hence poorly monitored systems (offline or online) may allow accelerated insulation deterioration to go unnoticed and potentially result in failure, unplanned outages, missed performance targets, and regulatory fines. In extreme cases, insulation failure increases the possibility of fires, explosions, and serious damage to adjacent equipment and or injury to operations personnel. This extreme case represents significant financial, environmental, and social costs for the responsible utility.

Low energy electrical discharges or partial discharges (PD), occurring in the insulating medium of power transformers, gradually erode the electrical, mechanical, and chemical stability of the insulation. Therefore, continuous or temporary PD activity monitoring in power transformers represents an essential condition assessment element for their safe and reliable operation. Only by monitoring PD levels over an extended period can asset owners confidently identify PD insulation issues. Accurate monitoring and immediate PD detection allow tracking changes in PD activity and evaluation of effective preventive measures, a logical action from both a technical and a financial perspective. PD monitoring systems will also confirm that the HV assets operate as expected at their highest efficiency level. Various vertical product testing standards (e.g., IEC60076-3, IEEEC57.12.90/91, IEEEC57.113, and others) set out acceptable levels of PD in power transformers. The test methods and procedures are taken from the general horizontal standard IEC60270.

Therefore, owners and operators in the electrical energy industry require robust and easy-to-use PD monitoring equipment backed up by state-of-the-art diagnostics expertise. PDIX, known for its range of PD sensors and testing instruments, developed the ICM*monitor* to evaluate the condition of electrical insulation systems by utilities, service providers, manufactures, and research institutes worldwide.

The ICM*monitor* has been designed to:

- provide reliable insulation condition analysis via PD activity levels and event-based pattern recording,
- make the installation and commissioning work seamless,
- communicate via established industry protocols (e.g., IEC 61850),
- provide early warning of potential issues,
- overcome, via an easy-to-use software, the challenges and complexity of PD diagnostics based on PD patterns,
- cope with noisy onsite measurement conditions by using various filters and noise rejection techniques.

The ICM*monitor*'s PD transformer monitoring technique 'sees' what is happening inside the tank of a transformer or

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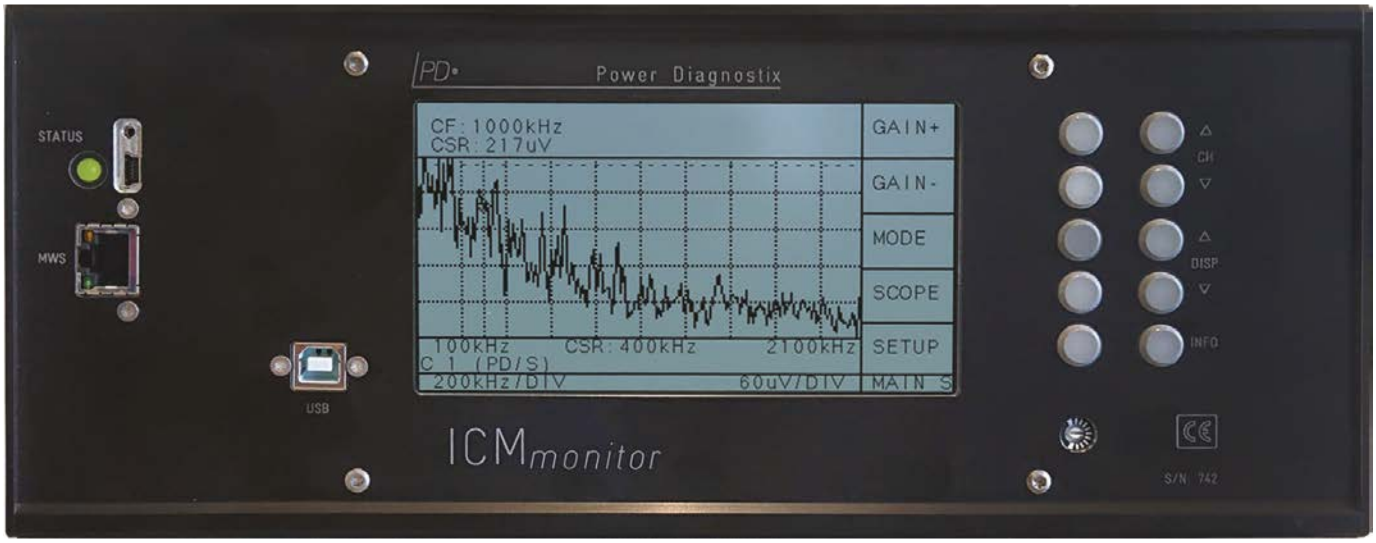


Figure 1. ICM*monitor* for DIN rail mounting

**Owners and operators in the electrical energy industry require robust and easy-to-use PD monitoring equipment backed up by state-of-the-art diagnostics expertise**

to its bushings by exploiting the fact that PD activity emits high-frequency electromagnetic signals. To measure the PD pulses and the associated high frequency signals, the ICM*monitor* system relies on custom-made adapters and coupling devices (quadrupoles) to accurately record both: the PD signal and the synchronization voltage. In parallel, the unit also acquires other background signals (e.g., PD currents in the earthing cable of the transformer) via radio frequency current transformers (RFCT) clamped on to cable terminations and using special gating features to tune disturbances out.

The analogue signals coming from the sensors placed on the transformer are converted by the ICM*monitor* data acquisition cards and processed digitally within the unit into spectral information or 'phase-resolved partial discharge patterns,' also known as PRPD patterns. These plotted patterns are associated with different types of molecular breakdown. The analysis of the PRPD pattern and the PD levels facilitates proper identification of the type of defect. Typical and recognizable defects such as delamination within paper layers in a transformer are clearly observed in PRPD outputs. Because of the complexity and variety of potential defects within the insulation medium, the ICM*expert* SW provides advanced analysis to identify the exact type of defect. The ICM*expert* SW compiles the know-how of PDIX staff and many years of field expertise to offer a very accurate interpretation of PRPD.

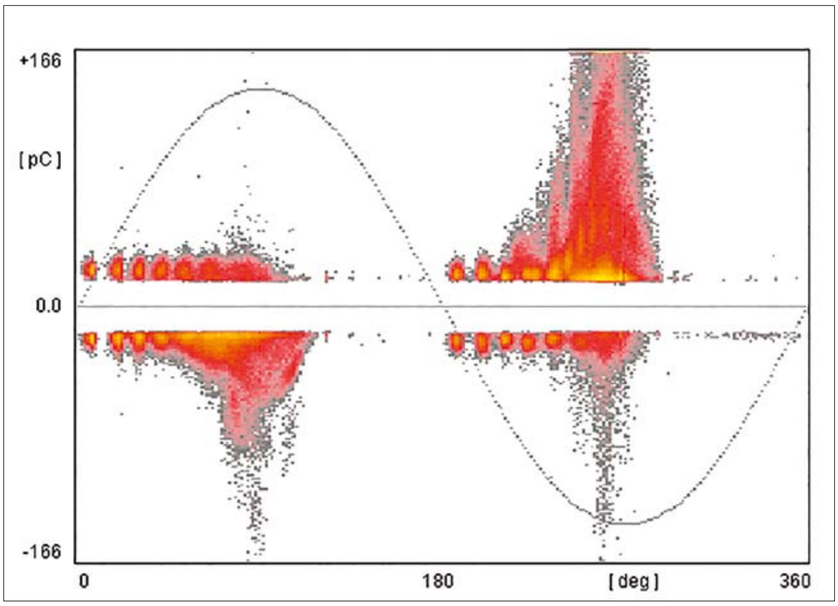


Figure 2. Phase-resolved pattern of PD caused by a contact problem of a transformer bushing's field control layer

In the case of online (continuous) monitoring, several conditions must be taken into account. First, the monitoring system should be reliable for the entire expected service life of the transformer (approximately 40 years). Second, all sensors attached to the monitoring unit must be resilient to prolonged use under a variety of operational and environmental conditions. Finally, the monitoring system's modular configuration should allow users to swap out components or sensors while retaining the rest of the assembly. An online monitoring system is designed to high-quality specifications, easy to use, and easy to upgrade or reconfigure.

In comparison to the solution presented herein, PD testing based on the ultra-high frequency (UHF) electrical signals emitted by PD activity warrants mention. In contrast to the HF measurement method, where the entire test and measurement setup, from the power transformer to the monitoring device, has to be first subjected to calibration (as per IEC 60270), the UHF signal cannot be calibrated! UHF signal detection is contingent on antennas placed into the transformer tank. The detectable signal strength heavily depends on the UHF antenna design, the PD signal's travel path, the direction of the sensor and position of the PD signal source, and many other conditions. Hence, a UHF signal can be used as an indicator only and not as a qualitative measure to compare against predefined acceptance or warning levels. Furthermore, in the case of UHF detection not all kinds of PD activity can be detected, especially if is hidden in areas where there it significantly attenuated UHF signal transmission path to the sensor.

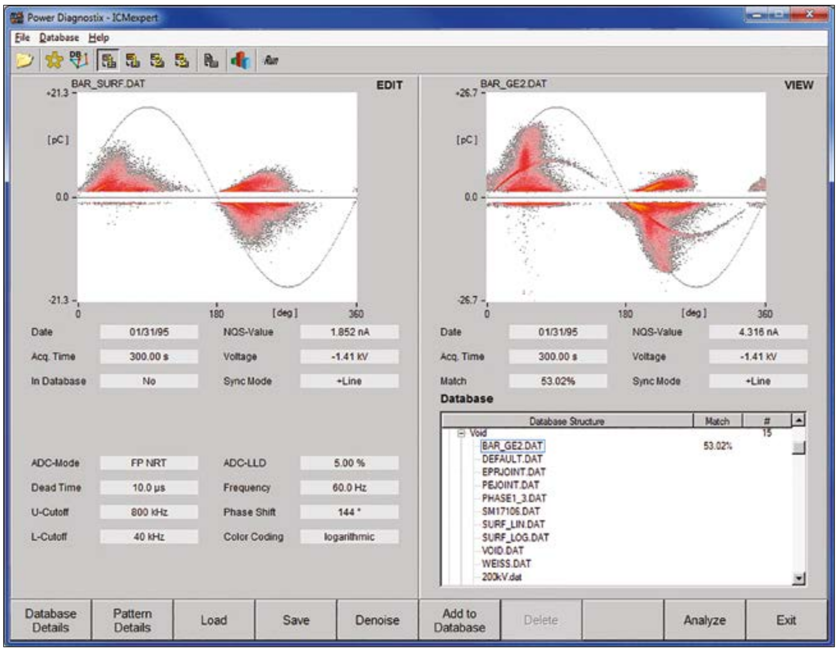


Figure 3. ICM*expert* application window

**The ICM*expert* SW compiles the know-how of PDIX staff and many years of field expertise to offer a very accurate interpretation of PRPD**

In the case of power transformers with an oil-paper insulation system, a decision to test for PD will often be triggered by the results of dissolved gas analysis (DGA) tests. PD activity will generate gaseous by-products especially hydrogen and methane, that can be quantified by DGA. The rate at which the gas is being generated can also indicate the severity of the PD activity. However, DGA provides little or no information about the location of the PD activity inside the transformer tank or about the high voltage bushings' insulation status. At Megger, the correlation between DGA and dielectric frequency response (DFR) testing was investigated. DGA and DFR results pinpointed a PD problem inside the HV bushings, finding contamination generated by PD activity. X-wax was found in the inner layers of the condenser OIP bushings.

The ICM*monitor* accompanying software has been conceived to allow remote access to multiple monitoring instruments in a substation, namely one monitoring system has been fitted for several transformers. The ICM*monitor* software provides key features such as long-term trending, data history structure, complete alarm setting, coloured PRPD pattern acquisition, and automated data acquisition. It is important to highlight that ICM*monitor* allows for the integration of other sensors, including but not limited to temperature, DGA, and moisture in oil, which in turn provides an overall image of the monitored asset.

The ICM*monitor* software installed on a PC allows data capturing, visualization of current measurements, and recording of screenshots which can be exported at will or integrated into specialized reports. The software can start in a mode displaying the instrument HMI where the user is able to toggle between the monitored channels visualizing various trending curves. Larger systems consisting of several ICM*monitor*-ed transformers in a substation or a wider area can be monitored from one centralized PC. This computer with the ICM*monitor* installed software will cyclically connect to all installed ICM*monitors* to collect monitoring data. In general, such wider networks are being built using the fiber optic serial interface option.

As previously alluded, the basic ICM*monitor* software can be augmented by the ICM*expert* module, an advanced expert software component that provides database-supported handling of all measurement files and supplemental information. The capability of this software goes far beyond the storage of pattern(s), equipment photo(s), comments, and all instrument settings (for each data set) to sophisticated PD pattern comparison and classification.

For power transformers, the ICM*monitor* uses the capacitive (test or voltage) tap of the high voltage bushings. Due to the great variety of tap designs in HV bushings in the market, Power Diagnostix has designed a vast family of surge-protected bushing adapters (BAs). These adapters are provided to a variety of transformer manufacturers and power utilities. Polytetrafluoroethylene (PTFE) cables terminated

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Figure 4. Installed bushing coupling unit and bushing adapter

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with Threaded Neill–Concelman (TNC) threaded connectors are sufficiently robust to ensure the connectivity to the bushing coupling units (BCUs) consisting of protected electronic analogue circuits capable of splitting the bushing tap signal for accurate PD and voltage measurements. Several BCUs coming from the transformer's bushings are arranged together into a coupler termination box (CTB) designed to be mounted on the transformer wall. This is the connection point where the ICM*monitor* (for permanent online monitoring) or the portable ICM*monitor* placed inside an ICM*outlander* box (for temporary monitoring) gets connected via high-quality coaxial cables.

The delivery options for the ICM*monitor*, designed as a standalone device to suit the client's needs, vary from full or half rack mount to a rail mount or mounted within an outdoor stainless steel cabinet or event special waterproof enclosures.

Several means are achievable in terms of connectivity to the device, both for alarming and visualization of acquired data.

For easy / conventional SCADA integration, the monitoring device can be connected via dry alarm contacts. In this way, beyond ICM*monitor* power failure, key values such as Qp (peak charge) and / or independent NQS (an averaged PD discharge current) can be published, and alarm thresholds can be adjusted to onsite conditions.

USB connectivity is another available option to establish a seamless connection to a laptop or a PC during the installation and commissioning stages.

For a permanent monitoring connection, the LAN connectivity (RJ45 Ethernet port) is generally used. To this port, there are several connectivity options. A PC can be connected either locally or remotely. Several options can be exercised for remote connectivity: remote connectivity via the power utility intranet or cyber-secure (VPN owned) encrypted tunnels for remote connectivity via an LTE/3G/GPRS wireless modem.

Another use of the LAN port is for IEC 61850-7-4 MMS connectivity. In this case, there are two major alternatives employed by power utility partners: a hardware-based device communication gateway (DCG 61850) or connectivity to a PC serving via IEC 61850 information.

In the case of an IEC 61850 hardware-based Device Communication Gateway (DCG 61850), no additional software is needed. This interface, coupled to the ICM*monitor*, is designed in accordance with IEC 61850. Hence, a full description of all data sets and IEC 61850 relevant documents are available for seamless integration by the power utilities, OEMs, or third-party firms. An operating system independent pro-

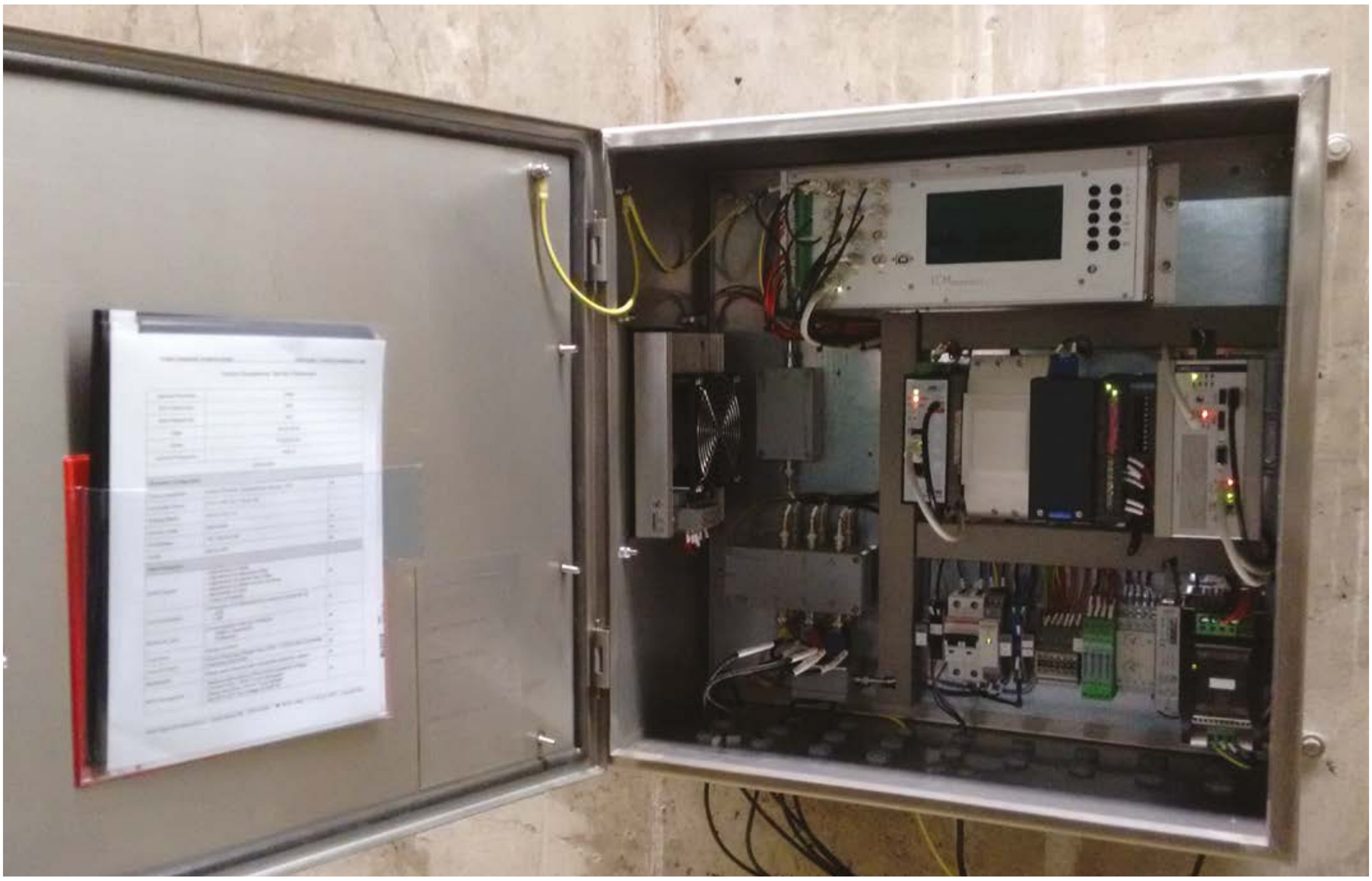

Figure 5. ICM*monitor* installed in an outdoor stainless steel cabinet

visioning of the Intelligent Electronic Device (IED) Capability Description (ICD) file is available. In the case of the DCG 81850 interface, each channel is a separate logical node dedicated to PD activity, a Self-Protecting Digital Content (SPDC) data object (IEC 61850-7-4). Specifically, the interface provides a time-stamped partial discharge peak discharge (Qp) alarm. Extending the standard number of discharges (NQS) alarms for each IEC 61850 data object is also available. Qp is the apparent charge value of PD activity, and NQS is the averaged discharge current (obtained by integrating the discharge values, summing them up, and dividing the sum by the acquisition time). Other information provided via this interface includes current readings of NQS, Qp, and alarm status per channel.

Where the PC IEC 61850 software interface is preferred, all the above-mentioned provisioning and information classes presented are available: provision of ICDs for third party data integration, a full description of all data sets, and IEC 61850 relevant documents and all data sets (e.g., current readings of NQS, Qp and alarm status per channel).

**Several options can be exercised for remote connectivity: remote connectivity via the power utility intranet or cyber-secure (VPN owned) encrypted tunnels for remote connectivity via an LTE/3G/GPRS wireless modem**


Figure 6: A DCG 61850 module offers MMS connectivity between ICM*monitor* and a control PC

**In case the end customer prefers to carry out temporary online monitoring, a specially designed ICM*outlander* enclosure for the portable ICM*monitor* unit is recommend**

In this case, the ICM*monitor* software runs as a service without a Graphical User Interface (GUI).

In case the end customer prefers to carry out temporary online monitoring, a specially designed ICM*outlander* enclosure for the portable ICM*monitor* unit is recommended. This ruggedized enclosure is suitable for a temporary test of weeks at a time. The unit can be powered and left near the transformer under test. While the ICM*outlander* is monitoring the transformer, either via the firm intranet (a LAN Ethernet connection) or an LTE modem, the essential information regarding partial discharge phenomena within the transformer can be retrieved remotely for expert analysis, which will lead power utility test and operations engineers to sound technical and financial decisions. The advantage of this solution is that the costs of many systems can be optimized via an investment in hardware at the transformer level: the BAs, BCUs, CTBs, followed by a smaller number of ICM*outlander* devices shared across a wider fleet of transformers. Several PDIX utility customers have selected this solution to optimize costs versus permanent online monitoring of the entire transformer fleet. Permanent ICM*monitor*-ing devices have been ordered for critical operation and other specially selected transformers within the fleet.

In conclusion, the ICM*monitor* is a versatile and modular design engineered to monitor PD activity (on a permanent or temporary basis) in power transformers and in other assets such as rotating machines (generators, motors) or HV cable accessories (terminations, joints). Due to the available number of measurement channels, one unit can monitor several transformers or generators together with step-up transformers as part of complex Combined Heat and Power (CHP) applications. The ICM*monitor* is a fundamental tool to secure continuous, safe, reliable, and efficient operation of essential assets in the power utility network.

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## Author

**Dr. Mihai Huzmezan** is the Managing Director (CEO) of Power Diagnostix (PDIX) by Megger. His professional career runs from Academia to R&D and over 20 years of senior executive experience in international companies focused on communications systems, controllers, and embedded systems with applications on secure communications for critical energy infrastructure, aerospace, and biomedical equipment and components.

He is part of several professional organizations, including The Association of Professional Engineers and Geoscientists of British Columbia and the Institute of Electrical and Electronics Engineers. His hobbies include skiing and sailing. Mihai received his Ph. D in Control Systems from the University of Cambridge, UK.