

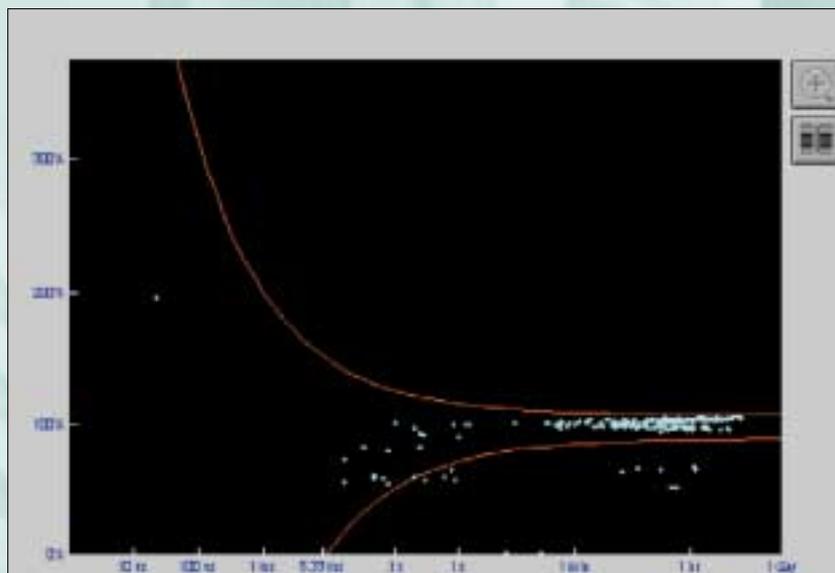
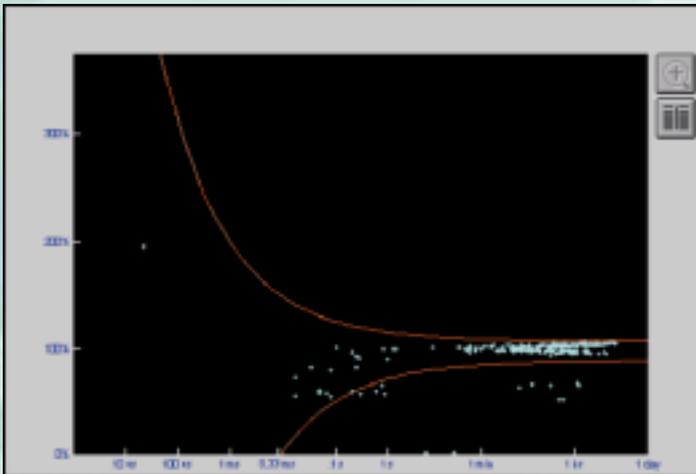
# Power Quality Application Guide



## *Voltage Dips*

### *Predictive Maintenance – The Key to Power Quality*

5.2.1



# *Voltage Dips*

## *Predictive Maintenance – The Key to Power Quality*

David Bradley  
Rhopoint Systems Ltd  
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## **Copper Development Association**

Copper Development Association  
Verulam Industrial Estate  
224 London Road  
St Albans AL1 1AQ  
United Kingdom

Tel: 00 44 1727 731200  
Fax: 00 44 1727 731216  
Email: [copperdev@compuserve.com](mailto:copperdev@compuserve.com)  
Websites: [www.cda.org.uk](http://www.cda.org.uk) and [www.brass.org](http://www.brass.org)



European Copper Institute  
168 Avenue de Tervueren  
B-1150 Brussels  
Belgium

Tel: 00 32 2 777 70 70  
Fax: 00 32 2 777 70 79  
Email: [eci@eurocopper.org](mailto:eci@eurocopper.org)  
Website: [www.eurocopper.org](http://www.eurocopper.org)

# *Voltage Dips*

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## **Predictive Maintenance – The Key to Power Quality**

Equipment for logging disturbances in the supply system has been available for many years. Early instruments were limited in their capabilities, measuring only voltage and presenting the results via a chart recorder. Modern instruments perform many more measurements and store data electronically for detailed analysis on a personal computer. As a result, the measured data can be analysed in a number of different ways so that one data collection exercise can satisfy several measurement needs.

A wide range of equipment is commercially available ranging from simple single phase units that are plugged into a socket outlet to permanently installed three phase monitors connected into building management systems. The simpler instruments are often useful in determining the location, nature and scale of the problem before undertaking a full survey.

Most instruments record events that exceed pre-set thresholds, for example, voltages outside the normal tolerance, or dips that fall outside a chosen tolerance curve, such as the CBEMA curve (See Section 5.1). This approach reduces the volume of data recorded, making storage and analysis easier, but it reveals nothing about how many events occur that are just inside the set thresholds. These thresholds can be set by the user but, if they are set too tightly, the recorder is flooded with relatively uninteresting data that takes time to analyse. If the thresholds are set too loosely then significant events may be missed completely.

An alternative approach, conceived by Reliable Power Meters Inc. (USA) and Rhopoint Systems Ltd (UK) is known as 'full disclosure monitoring'. The recording instrument has a large semiconductor memory supplemented by a hard disk drive, so that the data capture capacity is very large. This allows the collection of all data, with a very tight threshold set dynamically to suit the conditions. Software in the host PC, which may be on a network or at the far end of a modem link, imposes thresholds according to the user's requirements at the time of analysis. The thresholds are applied during analysis, not during data collection, so there is no dead zone and no data is discarded. The same data can be re-analysed with different thresholds as often as required. In practice there is a measurement threshold but it is automatically set during the measurement so that the instrument is not flooded with data under unusual conditions. Measurements are always gathered, but are filtered if necessary before storage. Full disclosure monitors rely on high data sampling rates and powerful digital signal processing to measure all parameters – including harmonics and transients – on every cycle. Because all the data is gathered, the instrument can measure voltage deviations, including transients, harmonics, flicker, power factor, power consumption and frequency.

This technique allows predictive maintenance techniques to be applied to power systems. Predictive maintenance techniques have long been employed to prevent failure in mechanical equipment such as engines, and in electro-mechanical equipment, such as motors. By analysing the frequency spectrum of vibration in bearings, for example, and comparing how the frequency spectrum changes over time, it is possible to provide early warning of impending failures and schedule maintenance to correct the problem.

Similar early warning of incipient problems in an electrical distribution system can now also be achieved by comparing historic data, in other words by examining the trend of each parameter over time.

As discussed in Section 1 of this Guide, electrical power is a raw material, but it is unusual in that it is consumed as soon as it is generated and cannot be subjected to quality checks before use. Knowledge of the real quality of power delivered by the supplier is vital to any total quality management system.

## **Benefits of continuous monitoring**

In many government, military, financial, and commercial 'mission critical' applications, computers run 24 hours a day, 365 days a year. These vital computers may be performing diverse tasks such as co-ordinating the landing of the space shuttle or processing millions of Euros in transactions. Consequently, owners and operators of these systems make significant investments in their infrastructures to prevent disruption or downtime. Every major data centre, for example, has large UPS and back-up generator power systems, with a carefully laid out power distribution system. The goal is a simple one, to achieve 'up time' or system availability as close as possible to 100 %. (The principles of resilient design are discussed in detail in Section 4 of this Guide.)

# *Predictive Maintenance – The Key to Power Quality*

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Continuous monitoring of the power supply is an integral part of any proactive management programme. It provides many benefits, some of which are:

- ◆ It provides a historic record of power quality allowing identification of trends – such as an increase in the number or severity of dips or the growth in harmonics – that can be used to schedule preventative maintenance. The elimination of unscheduled shutdowns is of great financial benefit in, for example, data centres and financial trading operations. Predictive techniques provide the information required to achieve maximum ‘up time.’
- ◆ It provides data for determining the loading of existing transformers and backup supplies and for planning future expansion. The data is useful in determining whether investment is being spent in the most appropriate areas.
- ◆ Key personnel can be alerted immediately when a power problem is detected by issuing alarms or by sending messages to pagers or PC screens. Immediate notification allows action to be taken to isolate a problem and prevent a domino effect that would jeopardise the entire facility.
- ◆ Harmonics must be monitored on a continuous basis to ensure that, over time, the incremental addition of loads does not cause excessive heating that can lead to the premature failure of transformers, conductors and circuit breakers.
- ◆ Continuous monitoring provides the data to perform a post-mortem on disruptive power disturbance incidents. This data is needed to determine how and where events were caused, leading to an understanding of how they may be avoided in the future, and how the effects may be mitigated.

Utilities can also reap benefits from continuous infrastructure monitoring. Several utilities are now deploying power-monitoring instruments in their distribution systems to improve operational efficiencies. Some are also instituting pro-active power quality monitoring programmes to benefit their customers, either as part of a power delivery contract or to improve good-will.

## **Comparing historical data**

A predictive maintenance programme can be established by installing monitors at critical locations. Each monitor performs a survey for a reasonable business period such as a week or a month. When the survey is finished the data is downloaded and saved, and the monitor is automatically reset to perform another survey for another week or month. Each survey database is archived, and the databases are compared periodically. Multiple databases collected over long periods of time (typically a year or longer) provide engineers with a comprehensive history of the power supplied to the plant. By continuously tracking the changes on a weekly or monthly basis, conditions that are either new, or are deteriorating, will be highlighted. Increases in event activity, event amplitude, or the emergence of new types of events will indicate potential problems. Instruments that use set thresholds capture events ‘by exception’ - events are only recorded once they become large enough to be disruptive – these instruments cannot be used in a predictive maintenance programme. They can only be used in a reactive manner for performing post-mortems of disruptive events.

The fundamental difference between ‘full disclosure monitoring’ and the traditional set threshold approach is shown in Figure 1.

Setting thresholds creates measurement dead zones inside the dip tolerance curve. Events within these zones – events that are not yet important but may be indicators of future problems – will be missed completely. Full disclosure monitoring uses tight adaptive thresholds, collecting all events and establishing an accurate baseline for future comparison.

# Predictive Maintenance – The Key to Power Quality

The objective of a complete power monitoring strategy is to improve availability or uptime. Collecting data is only the first part of the story; the next step is to turn it into information that is useful in terms of describing system performance so that action can be taken to ensure future availability. This analysis is carried out by innovative software running on a personal computer.

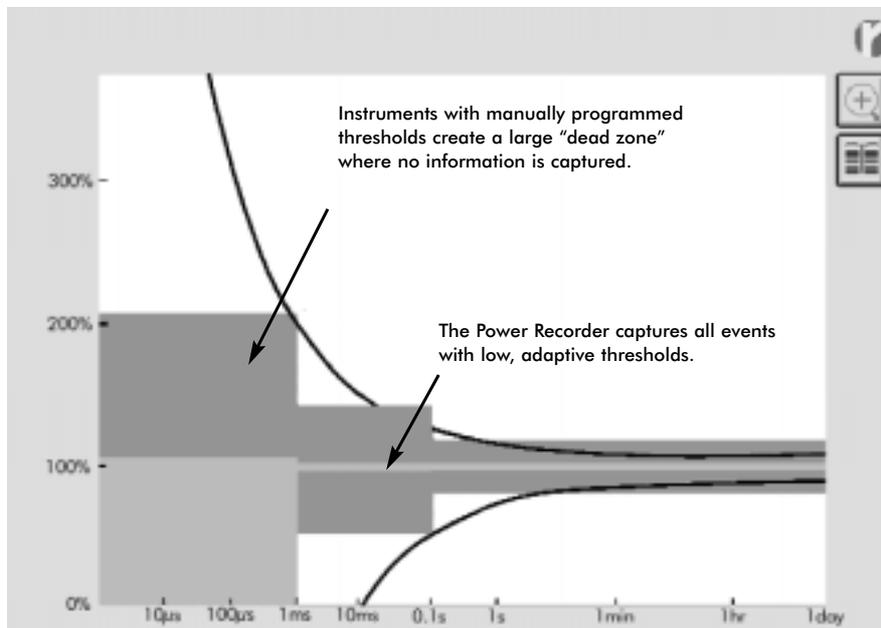


Figure 1- Full disclosure versus threshold capture

## Power Quality Index

Power quality is not a simple concept; there is no single describing parameter, so it is difficult to quickly describe a change. One of the innovations is to describe a 'power quality index' (PQI) based on voltage disturbance events as a single number. Perfect power is assigned a PQI of zero, while events lying on, for

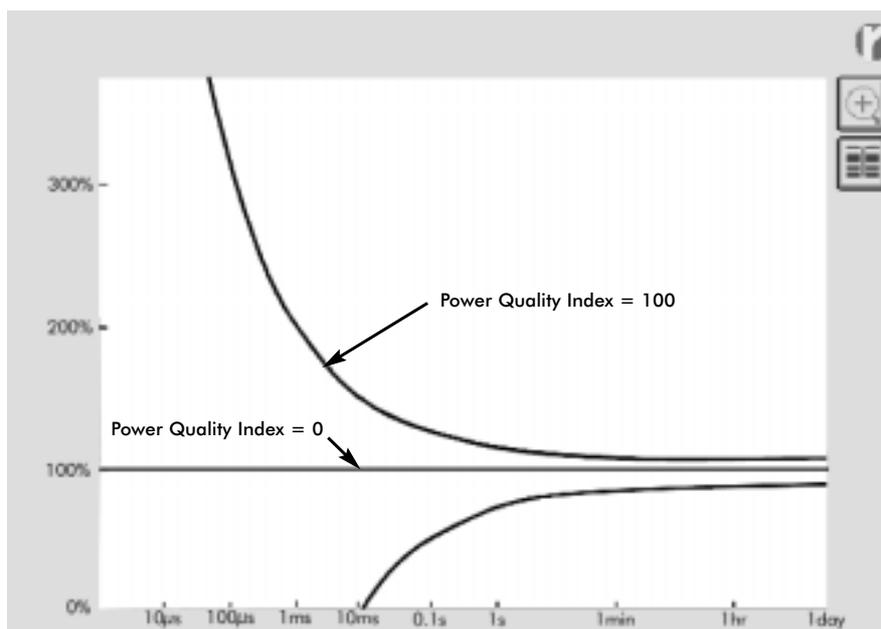


Figure 2 - Power quality index calculation

# Predictive Maintenance – The Key to Power Quality

example, the CBEMA curve are assigned a value of 100, as shown in Figure 2. Events between the two, and events lying outside the curve, are assigned a value that is proportional to the distance from the curve. The root mean square of the individual events is presented as the PQI for the site for the period of that survey, together with the maximum PQI for the period. Comparison of the PQI for a series of surveys on one particular site gives a very quick appraisal of the trend in the quality of power and an idea of where to concentrate further effort.

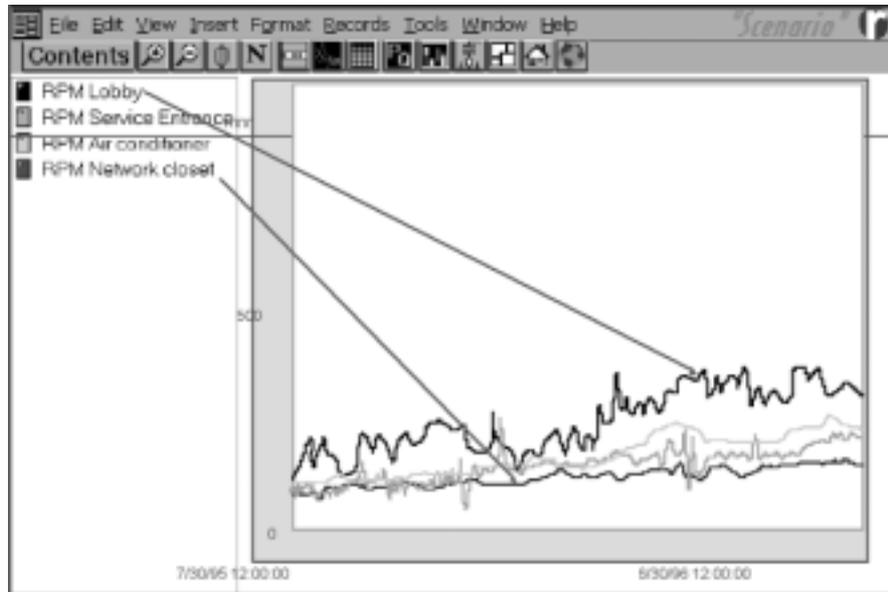


Figure 3 - Power quality index plots at four locations

Figure 3 shows the RMS value of the power quality index plots for four power monitors installed at four locations in a manufacturing plant. Index plots show when the power quality is deteriorating (index goes up) and when power quality is improving (index goes down) or if the power quality is fluctuating. In this example, the index for the monitor installed in the Network Closet shows the most stable power situation, while the index for the Lobby monitor is going up at the fastest rate and is fluctuating to a greater extent. It is apparent which points have worse power quality than others and are worthy of investigation first. If the index is allowed to continue to increase, this location will inevitably suffer some undesirable consequence. Once action has been taken to correct the situation, the PQI should begin to fall. Hence, the PQI is both predictive, in that it allows the identification of growing problems, and retrospective in that it confirms the efficacy of the action taken.

As described in Section 5.1, there are several characteristic curves in use including CBEMA, ITIC and ANSI. Full disclosure monitors allow the use of any of these or a specially edited version of any one of them.

## Manipulating the data

The software provides tools to allow the user to delve further into the data that makes up the index. These tools offer great flexibility by allowing the user to compare and trend any parameter against any other parameter, to compare the data at one location with another location, or compare one survey to another. The user can also isolate any aspect of the data. Figure 4 shows a plot of the RMS value of the power quality index for the Service Entrance monitor along with the maximum index of the worst case event (note that the data for the other locations have been turned off and is not included in the plot). Certain index values have significance. For example, power failures have indices near 1000 since the distance to 0 % voltage from nominal voltage compared to the distance to the curve from nominal is about ten to one. It would not be possible to experience over-voltages that are ten times nominal voltage with durations of several seconds or longer.

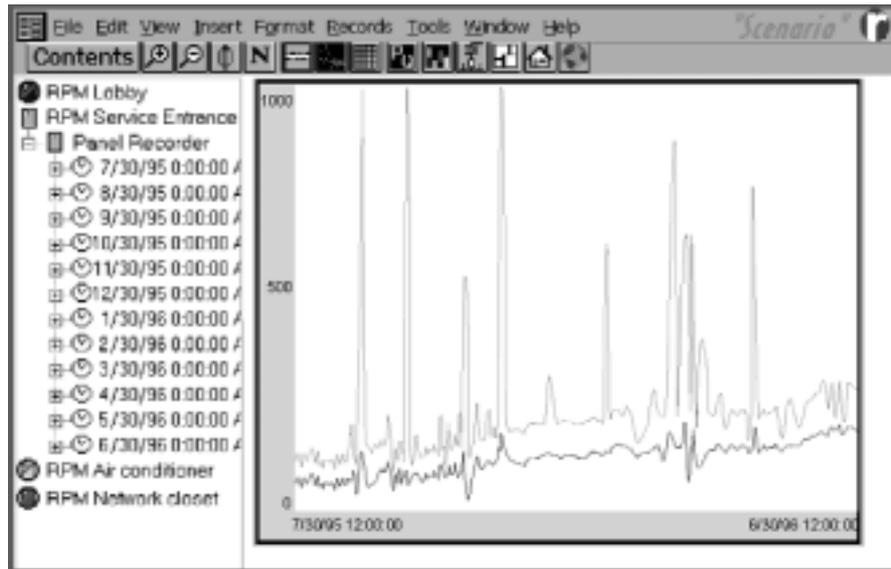


Figure 4 - Power quality index, RMS and maximum

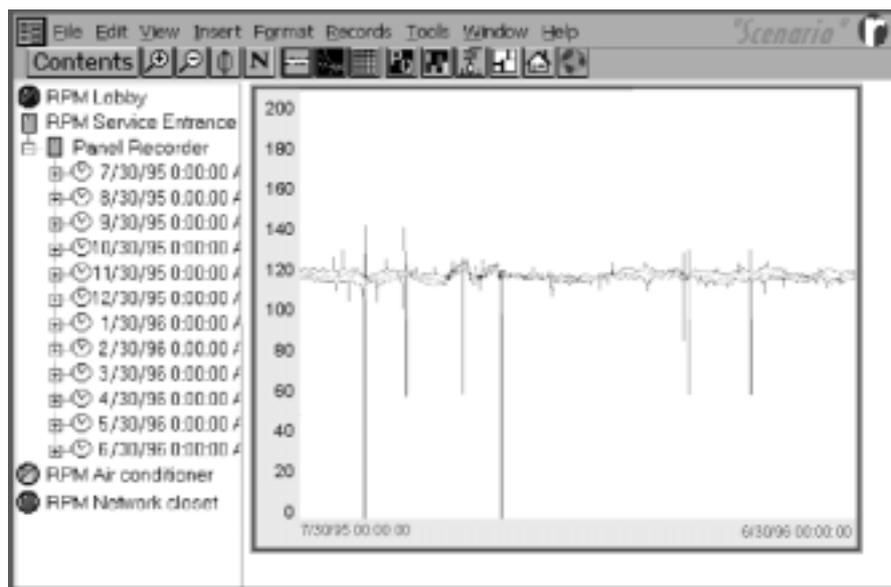


Figure 5 - RMS voltage history

Figure 5 shows the RMS voltage history recorded over a year in twelve separate one-month surveys; all individual surveys have been joined together to form a continuous plot.

## Highlighting trends

Following the progress of the index is one method of highlighting deterioration or improvement in power quality. Another approach is to plot each event on a power tolerance curve (such as the CBEMA curve) and decrease the brightness of the events as age increases, Figure 6. The shading makes it easy to see if events are getting worse or better. In this example there is a 'migration' effect in the seconds region showing that sags are steadily becoming worse over time. Clouds of events whose perimeters are brighter than the inside indicate a region where problems are expanding. If the centre of a cloud of events is brighter, problems are consolidating in one area.

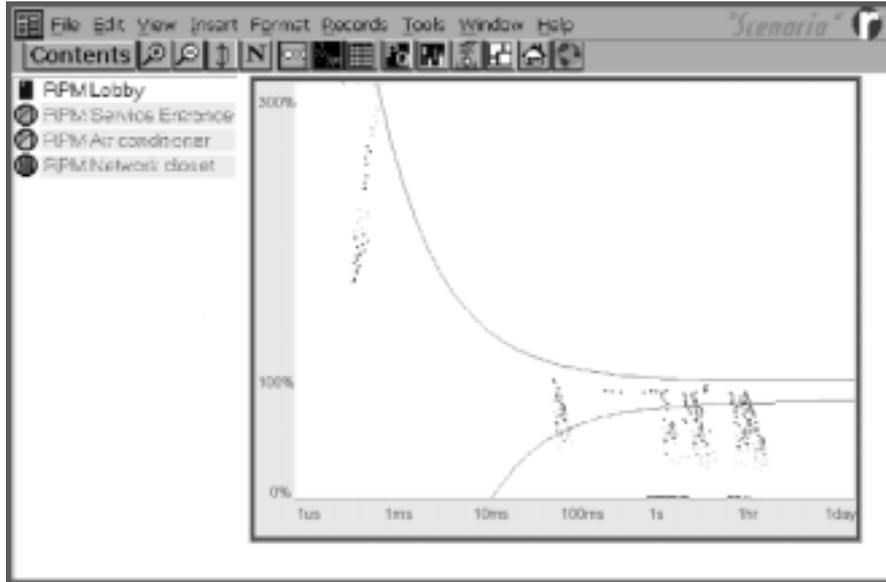


Figure 6 - Power tolerance curve with shaded events

## Conclusion

Full disclosure monitoring combined with powerful software tools can establish the baseline conditions of the power system and provide the basis for short and long term comparison. This allows the use of predictive maintenance to warn of incipient faults before failure of the distribution system occurs and provide the information needed in the quest for zero downtime.

# Network Partners

## **Copper Benelux**

168 Avenue de Tervueren  
B-1150 Brussels  
Belgium

Tel: 00 32 2 777 7090  
Fax: 00 32 2 777 7099  
Email: mail@copperbenelux.org  
Web: www.copperbenelux.org

Contact: Mr B Dôme

## **Copper Development Association**

Verulam Industrial Estate  
224 London Road  
St Albans AL1 1AQ  
United Kingdom

Tel: 00 44 1727 731205  
Fax: 00 44 1727 731216  
Email: copperdev@compuserve.com  
Webs: www.cda.org.uk & www.brass.org

Contact: Mrs A Vessey

## **Deutsches Kupferinstitut e.V**

Am Bonneshof 5  
D-40474 Duesseldorf  
Germany

Tel: 00 49 211 4796 323  
Fax: 00 49 211 4796 310  
Email: sfassbinder@kupferinstitut.de  
Web: www.kupferinstitut.de

Contact: Mr S Fassbinder

## **ECD Services**

Via Cardinal Maffi 21  
I-27100 Pavia  
Italy

Tel: 00 39 0382 538934  
Fax: 00 39 0382 308028  
Email: info@ecd.it  
Web: www.ecd.it

Contact: Dr A Baggini

## **European Copper Institute**

168 Avenue de Tervueren  
B-1150 Brussels  
Belgium

Tel: 00 32 2 777 70 70  
Fax: 00 32 2 777 70 79  
Email: eci@eurocopper.org  
Web: www.eurocopper.org

Contact: Mr H De Keulenaer

## **Hevrox**

Schoebroeckstraat 62  
B-3583 Beringen  
Belgium

Tel: 00 32 11 454 420  
Fax: 00 32 11 454 423  
Email: info@hevrox.be

Contact: Mr I Hendriks

## **HTW**

Goebenstrasse 40  
D-66117 Saarbruecken  
Germany

Tel: 00 49 681 5867 279  
Fax: 00 49 681 5867 302  
Email: wlang@htw-saarland.de

Contact: Prof Dr W Langguth

## **Istituto Italiano del Rame**

Via Corradino d'Ascanio 4  
I-20142 Milano  
Italy

Tel: 00 39 02 89301330  
Fax: 00 39 02 89301513  
Email: ist-rame@wirednet.it  
Web: www.iir.it

Contact: Mr V Loconsolo

## **KU Leuven**

Kasteelpark Arenberg 10  
B-3001 Leuven-Heverlee  
Belgium

Tel: 00 32 16 32 10 20  
Fax: 00 32 16 32 19 85  
Email: ronnie.belmans@esat.kuleuven.ac.be

Contact: Prof Dr R Belmans

## **Polish Copper Promotion Centre SA**

Pl.1 Maja 1-2  
PL-50-136 Wroclaw  
Poland

Tel: 00 48 71 78 12 502  
Fax: 00 48 71 78 12 504  
Email: copperpl@wroclaw.top.pl

Contact: Mr P Jurasz

## **TU Bergamo**

Viale G Marconi 5  
I-24044 Dalmine (BG)  
Italy

Tel: 00 39 035 27 73 07  
Fax: 00 39 035 56 27 79  
Email: graziana@unibg.it

Contact: Prof R Colombi

## **TU Wroclaw**

Wybrzeze Wyspianskiego 27  
PL-50-370 Wroclaw  
Poland

Tel: 00 48 71 32 80 192  
Fax: 00 48 71 32 03 596  
Email: i8@elektryk.ie.pwr.wroc.pl

Contact: Prof Dr H Markiewicz



Rhopoint Systems Ltd  
Holland Road  
Oxted  
Surrey RH8 9AX  
United Kingdom

Tel: 00 44 1883 722222  
Fax: 00 44 1883 712938  
Email: [systems@rhopoint.co.uk](mailto:systems@rhopoint.co.uk)  
Website: [www.rhopoint.co.uk/systems](http://www.rhopoint.co.uk/systems)

*David Bradley*

## **Copper Development Association**

Copper Development Association  
Verulam Industrial Estate  
224 London Road  
St Albans AL1 1AQ  
United Kingdom

Tel: 00 44 1727 731200  
Fax: 00 44 1727 731216  
Email: [copperdev@compuserve.com](mailto:copperdev@compuserve.com)  
Websites: [www.cda.org.uk](http://www.cda.org.uk) and [www.brass.org](http://www.brass.org)



European Copper Institute  
168 Avenue de Tervueren  
B-1150 Brussels  
Belgium

Tel: 00 32 2 777 70 70  
Fax: 00 32 2 777 70 79  
Email: [eci@eurocopper.org](mailto:eci@eurocopper.org)  
Website: [www.eurocopper.org](http://www.eurocopper.org)