

# POWER FACTOR CORRECTION

## K . 99 / 3

### LV power capacitors



## Introduction

The striving to ensure proper profitability of enterprises and high costs of electric energy have forced consumers to continuously control the energy consumption level. Rational energy economy requires control of reactive power consumption too. It is even more important because it is relatively easy to optimise reactive power intake without interfering with the number of working machinery or decreasing the total active power consumed by an enterprise. Using well – known laws of physics and the fact that majority of equipment draws inductive reactive power, it is possible to reduce reactive power intake by adding capacitive loads to a supply system. This way the reactive power drawn by inductive equipment is compensated with the capacitive loads. This method of optimisation is called power factor correction (or reactive power compensation). Devices that compensate reactive power in a supply system by drawing capacitive reactive energy are called power capacitors.

## Capacitor construction, operating conditions, possible risks

A typical power capacitor consists of a group of bundles, discharge circuit, protection system, connection terminals and casing. Depending on the way the bundles are connected and on the number of connection terminals, the capacitors divide into two kinds: single – phase and three – phase. Three – phase capacitors can have both cylindrical and cuboidal shape, while single – phase capacitors are cylindrical only. The bundle is an essential part of every power capacitor (it is also called the “element”). It is made from insulating polypropylene film metallised in vacuum conditions and placed in a nonflammable, non – toxic environment, e.g.: resin, gel or gas. The bundles in capacitors offered by Twelve Electric are enclosed inside cylindrical metal cans. The most important advantage of modern bundles, in comparison to the old technology using oil – soaked paper as the dielectric, is their ability of self – healing, that is limiting the effects of a short circuit between electrodes to a very small area by evaporation of aluminium from the affected place. The bundle is the most important component so its precision and technology determine technical and qualitative parameters of a capacitor. The MKP, MKK (cylindrical) and K.99/3 (cuboidal) capacitors offered by Twelve Electric consist in a number of design solutions to increase their safety and extend the lifetime. The supply is connected in a standard way using fast – on or bolt terminals. Required IP degree is achieved thanks to the casing design and the system of special shrouds and glands. For operation safety reasons, as capacitors are energy storing devices, they have to be fitted with discharging resistors ensuring voltage decrease to less than 50 V within 1 minute from the moment of the capacitor disconnection. It is an important parameter to look at while buying a capacitor, because Polish standard is less restrictive than in some other countries and requires 75 V after 3 minutes. Discharging resistors can be fitted on the capacitor’s external (visible) or internal terminals (inside the casing). The method is shown on the rating plate. It is essential for proper operation that the regulator’s control algorithm conforms to the same discharge time standard as the capacitors. Another important safety measure in modern capacitors is the overpressure protection system protecting the capacitor against explosion. A capacitor with this kind of protection has a specially designed casing and bundle fe-

eding wires. In case of operation in a variance with technical requirements there is a risk of sudden temperature growth caused by avalanche self – healing process in the bundle. This process can be initiated by short circuits between electrodes being the results of the dielectric ageing, operating temperature increase or energising the capacitor with distorted voltage. The aluminium vapours released during the process increase pressure inside the casing to the level at which it expands. Casing volume expansion is possible thanks to the special shaping with a system of capacitor body folds. As the effect of casing “stretching”, the special wire (with a weakened point) feeding the bundle tears apart and disconnects damaged capacitor from the power supply. The voltage decay stops the short circuits, self – healing process and further pressure increase. This prevents a blowout. In gas capacitors the bundle feeding wire is led through a ceramic pipe for additional protection of internal components against arcs. It is worth to know that some suppliers offer resin cast capacitors without anti – explosion protection, but filled with special material – vermiculite – capable of absorbing the energy of an explosion and protecting the capacitor against blowout. Vermiculite changes its consistence though, and by irretrievably losing its initial properties becomes unusable. This is why even if only one of single – phase capacitors making a three – phase resin cast capacitor breaks down, the whole device has to be replaced significantly increasing the usage costs. When using K.99/3 three – phase capacitors offered by Twelve Electric it is in most cases only a matter of replacing the faulty single – phase capacitor. The process of power (capacitance) drop begins with the first punch – through in any point of the bundle. The arc accompanying a punch – through damages the dielectric around it. High temperature of the arc causes evaporation of the metallised layer automatically separating the damaged area. The part of bundle separated that way gains high resistance and ability to withstand high voltage. Self – healing process takes only a few microseconds and is insignificant for the total capacitance (10 000 such processes decrease the capacitance by less than 1 %). The ability of self – healing makes the capacitor work properly during and after a punch – through. The process is only dangerous when the avalanche effect begins. It results in the activation of the anti – explosion protection or in vermiculite damage. This is why capacitors manufacturers specify their products’ operating conditions very rigorously. The better a capacitor is, the more tolerant the requirements and the longer guaranteed lifetime. Temperature is the most decisive parameter. Ensuring operating conditions meeting a manufacturer’s temperature range specification is essential for proper operation and long lifetime of a capacitor. Exploitation in a temperature higher than recommended can cause capacitance (and power) decrease in a very short time. The determinant of a capacitor’s temperature tolerance is its climatic category.

The highest quality capacitors can work in temperatures from – 250°C to +550°C. There are two main reasons for a capacitor operating temperature increase. The first is too high ambient temperature, which can be reduced quite easily by ventilation or, in extreme cases, by air conditioning. The second cause is the current flow through the capacitor exceeding the nominal. It usually takes place when energising a capacitor with distorted voltage. A capacitor’s reactance is inversely proportional to the supply voltage frequency, which makes it fall whenever higher harmonics (multiples of the base frequency 50 Hz) appear in the supply network. The re-

actance drop is followed by higher currents flowing through the capacitor, leading to bigger power losses manifesting in the form of intense emission of heat that cannot be removed by the capacitor itself. It brings to temperature rise inside the capacitor. Unfortunately the permittivity of fundamental component of the bundle, polypropylene film, is inversely proportional to the temperature. It loses its dielectric properties in an increased temperature, punch – throughs begin, hence the self – healing process reducing the active area of capacitor electrodes (capacitance drop). If it comes to the point where self – healing begins to “avalanche”, the whole capacitor breaks down. This makes it so important to mind the manufacturer’s technical specifications, especially those informing about the operating temperature range.



## Capacitors types

Twelve Electric offers a broad variety of capacitors to meet our Customers’ unique requirements. There are single – and three – phase capacitors available in a wide range of powers and supply voltages. We sell cylindrical and cuboidal capacitors. Refer to the tables for detailed information on power, voltage and dimensions. All the capacitors we stock comply with safety and ecological regulations and on request can be delivered with conformity declaration. The K.99/3 capacitors have been attested by the Electrotechnical Institute (Instytut Elektrotechniki).

## Capacitors made in the MKP technology

The capacitors manufactured using the MKP technology are built from high – quality propylene film bundles placed in cylindrical aluminium casings. Time of continuous operation of the MKP capacitors reaches 100 000 hours. They are offered in single – phase version for power range from 0.7 kvar to 5 kvar and in three – phase version for power range from 0.5 kvar to 25 kvar. The capacitors characterise with compact design of the casing allowing easy vertical or horizontal installation. The technology provides self – healing. The capacitors have an overpressure protection and built – in discharging resistors. They are low – weight and PCB – free. Thanks to fast – on terminals they are easy to connect to feeding cables.

### MKP capacitors technical information:

Operating voltage range $U_N$	400 ÷ 525 V
Output power	5 ÷ 25 kvar
Operating frequency	50 ÷ 60 Hz
Permissible overvoltage $U_{max}$	$U_N + 10\%$ up to 8 h/day $U_N + 30\%$ up to 1 min/day
Permissible overload $I_{max}$	1,5 $I_N$
Inrush current $I_s$	200 $I_N$
Dielectric losses	<0,5 W/kvar
Capacitance tolerance	-5 % ÷ +15 %
Terminal – terminal test voltage	2,15 $U_N$ , 2 s
Terminal – casing test voltage	3,6 kV, 2 s
Expected lifetime	100 000 h
Climatic category	-25/D
Cooling	natural or forced
Relative humidity	max. 95 %
Operating attitude	up to 4000 m n. p. m.
Mounting and earthing (grounding)	M12 or M8 bolt
Casing	aluminium
Protection degree	IP20, optionally IP54



other damage to the capacitor, nitrogen, as an incombustible gas, is a perfect protection against fire. The use of the newest technologies helped to attain a product of the highest quality, characterising by lowered mass and volume, extended lifetime, increased inrush currents and fire safety, and lower losses.



### Capacitors made in the MKK technology

They represent the latest kind of power capacitors incorporating advanced technical and technological solutions. What distinguishes this kind of capacitors is the impregnant used, a neutral gas. The bundle of a gas capacitor is placed inside a specially shaped aluminium casing and undergoes the process of vacuum drying until all moisture is removed. Immediately after the drying it is impregnated with nitrogen and the casing is hermetically closed. The biggest advantage of gas impregnation is that it ensures better homogeneity than impregnation with oil, which is thanks to the gas's better penetrative properties. It reduces the risk of partial discharges and increases the capacitor's lifetime to up to 115 000 hours of continuous operation. Yet another plus of nitrogen is its neutrality to the environment that makes disposal of an exploited capacitor uncomplicated and eco – friendly. Mechanical damage to the capacitor can mean its unsealing, but it does not mean that it has to be replaced immediately. Despite the exposure to atmospheric factors, the capacitor can work properly even up to 5000 hours. Gas impregnation technology in the capacitors of greater power significantly reduces their mass. Gas capacitors can be mounted both vertically and horizontally giving more freedom in capacitor bank enclosures design.

Gas capacitors up to 30 kvar have only one polypropylene film bundle. Each phase is separated with an insulating divider. It shortens and simplifies internal connections of the capacitor. The capacitors above 30 kvar use the traditional system of three bundles, but internal connections are made in a particular way to ensure minimum resistance and inductance. It helps to greatly reduce losses in the capacitor. Specially formed edges of the film increase tolerable inrush current to 200xI<sub>N</sub>. This lets the capacitors be used in every application with fast switching of the capacitor, not always allowing for full discharge, or where the supply voltage is of poor quality. Gas capacitors are capable of self – healing and have an overpressure protection. Another advantage of gas impregnation is the lack of polypropylene swelling typical for impregnation with oil or gel, seriously increasing the risk of pressure growth inside the enclosure. Furthermore, the reduction of polypropylene swelling effect reduces the loss of quality of contact between the bundle and the metallised layer. In case of short circuit or

### MKK capacitors technical information:

Operating voltage range U <sub>N</sub>	400 ÷ 525 V
Output power	5 ÷ 60 kvar
Operating frequency	50 ÷ 60 Hz
Permissible overvoltage U <sub>max</sub>	U <sub>N</sub> +10 % up to 8 h/day U <sub>N</sub> +30 % up to 1 min/day
Permissible overload I <sub>max</sub>	1,3 I <sub>N</sub>
Inrush current I <sub>s</sub>	200 I <sub>N</sub>
Dielectric losses	<0,2 W/kvar
Capacitance tolerance	-5 % ÷ +10 %
Terminal – terminal test voltage	2,15 U <sub>N</sub> , 10 s
Terminal – casing test voltage	3 kV, 10 s
Expected lifetime	115 000 h
Climatic category	-25/D
Cooling	natural or forced
Relative humidity	max. 95 %
Operating attitude	up to 4000 m n. p. m.
Mounting and earthing (grounding)	M12 bolt
Casing	aluminium
Protection degree	IP20, optionally IP54



The shape and size of enclosures is chosen in a way allowing easy installation of our capacitors (they are often used as a replacement for older types of capacitors) and effective removal of heat from inside of the construction. Each single – phase capacitor used to build a K.99/3 capacitor comes fitted with a discharge resistor and anti – explosion protection, and can work in temperature from – 250°C to +550°C. The design basing on single – phase capacitors lowers the cost of usage by allowing replacing only a damaged component capacitor in case of fault.

### Series K.99/3 three – phase capacitors

The series K.99/3 capacitors are intended for individual or group compensation of reactive power. They are available in power range from 2.5 kvar to 60 kvar for all typical supply voltages: 230, 400, 440, 525 V. The casing design ensures easy mechanical and electrical installation. Special build of the casing provides protection degree up to IP56. The K.99/3 manufactured by Twelve Electric are built from high – quality single – phase capacitors produced in the MKP technology, connected into either star or delta circuit. Technical parameters of a capacitor built this way depend on the quality of single – phase capacitors used for its construction. A characteristic of our solution is the possibility of choosing an untypical set of single – phase capacitors, which allows building of a three – phase capacitor precisely for the reactive power specified by a Customer. The set of single – phase capacitors is placed in a specially designed enclosure. It is made from sheet metal galvanically processed from both sides and powder coated. Connection of feeding cables is easy thanks to special construction of the terminal block ensuring proper fastening and electrical contact. Supply cable entry with special rubber grommets keeps the protection degree at IP44. The enclosure dimensions depend on power of the capacitor and allow for the volume increase in case of anti – explosion system activation. K.99/3 capacitor enclosures are available in three sizes (depending on power of the capacitor – see table 1)..



Rated power [kvar]	Base dimension [mm]	Height [mm]
2,5 ÷ 7,5	236 x 132	230
12,5; 15; 30	236 x 132	255
10; 20; 25	236 x 132	230
35 ÷ 60	422 x 132	255

Table 1. K.99/3 capacitors dimensions.

### **K.99/3 capacitors technical information:**

<b>Operating voltage range <math>U_N</math></b>	<b>400 ÷ 440 V</b>
<b>Output power</b>	<b>2,5 ÷ 50 kvar</b>
<b>Operating frequency</b>	<b>50 ÷ 60 Hz</b>
<b>Permissible overvoltage <math>U_{max}</math></b>	<b><math>U_N + 10\%</math> up to 8 h/day</b>
<b>Permissible overload <math>I_{max}</math></b>	<b>1,5 <math>I_N</math></b>
<b>Inrush current <math>I_s</math></b>	<b>200 <math>I_N</math></b>
<b>Dielectric losses</b>	<b>&lt;0,5 W/kvar</b>
<b>Capacitance tolerance</b>	<b>-5 % ÷ +15 %</b>
<b>Terminal – terminal test voltage</b>	<b>2,15 <math>U_N</math>, 2 s</b>
<b>Terminal – casing test voltage</b>	<b>3,6 kV, 2 s</b>
<b>Expected lifetime</b>	<b>100 000 h</b>
<b>Climatic</b>	<b>-25/D</b>
<b>Cooling</b>	<b>natural or forced</b>
<b>Mounting position</b>	<b>vertical</b>



### **Usage advantages**

All capacitors offered by Twelve Electric are made by esteemed manufacturers who carry out broad research to optimise production technology, especially to attain a bundle with the best operating and temperature parameters. Thanks to advanced research works and many years of experience in production of capacitors, our partners produce capacitors with very low level of active power losses (less than 0.4W/kvar with a discharge resistor) and notably extended lifetime. The design and materials used make the capacitors in our offer more durable and ensure proper operation in difficult conditions. Increased temperature range is especially important, as it notably extends the capacitors' lifetime. Guaranteed time of continuous operation equals 100 – 130 thousand hours, depending on the type of capacitor.

Increased thickness of the dielectric (polypropylene film) is also important as it enables the capacitor to work with overload currents reaching 1.3x $I_N$  ( $I_N$  – nominal current). Operating parameters that good have been achieved by effective heat removal. They guarantee proper operation of capacitors offered by Twelve Electric in increased temperatures or with

low level of higher harmonic deformation of the supply voltage. Furthermore, thanks to high – quality materials and the newest technology, the capacitors in our offer characterise by high durability and resistance to overvoltage and inrush currents during capacitor power – up. All the capacitors are eco – friendly and PCB – free. The design solutions used make the capacitors easy to install and having small dimensions. In order to achieve a highest quality product, their manufacturer subjects the capacitors to restrictive tests to determine their leaktightness, punch – through resistance (impulse test) and to analyse losses. Capacitors made in the MKP technology characterise by good technical parameters, while keeping a competitive price. Gas impregnated capacitors (MKK) represent the latest achievements of technology. Innovative solutions, such as vacuum drying, or specially designed edges of the bundle provide the best overload parameters.

### **Installation and maintenance**

Assuring proper installation and operating conditions is vital for a capacitors' lifetime and, consequently, for the effectiveness of conducted power factor correction. Capacitors should be used within the tolerance of declared IP degree, which is why it is so important to analyse the conditions they are to work in, with special consideration given to the humidity, dustiness, pollution and temperature. Proper installation requires an adequate space to be provided for freedom of air exchange and effective heat removal. Correct temperature has the key meaning for the operation and lifetime of a capacitor. Exploitation in a temperature higher than that recommended by the manufacturer can bring a capacitor to capacitance (and power) loss in a short time. This is why, when choosing a place to install capacitors, the average daily (sometimes even yearly) temperature has to be known. The capacitors cannot be fitted in close proximity to sources of heat. It has to be taken into consideration if the chosen place provides additional space for ventilation or air conditioning in case of difficulties in maintaining proper temperature. Through analysis of higher harmonics for purposes of power capacitor energising, the presence of higher harmonics, harmful to the capacitor, has to be verified. Remember that capacitor heat emission growth takes place as an effect of current flows exceeding the nominal value. It often happens when a capacitor is energised with deformed voltage. The capacitors in Twelve Electric's offer are easy to install. They can be connected using cable ends, fast – on connectors or bolt clamps. Remember that presence of capacitive load requires higher rating of connecting and protecting equipment, and redimensioned cables. Mechanical connection of feeding cables has to be made with care of its strength, durability and reliability. Proper tools and spring washers have to be used.

### **Standards:**

PN – EN 60831 – A1:2004  
PN – EN 60831 – 2:2000

### **Certificates:**

Attestation no. 0965/NBR/08 issued by the Electrotechnical Institute.

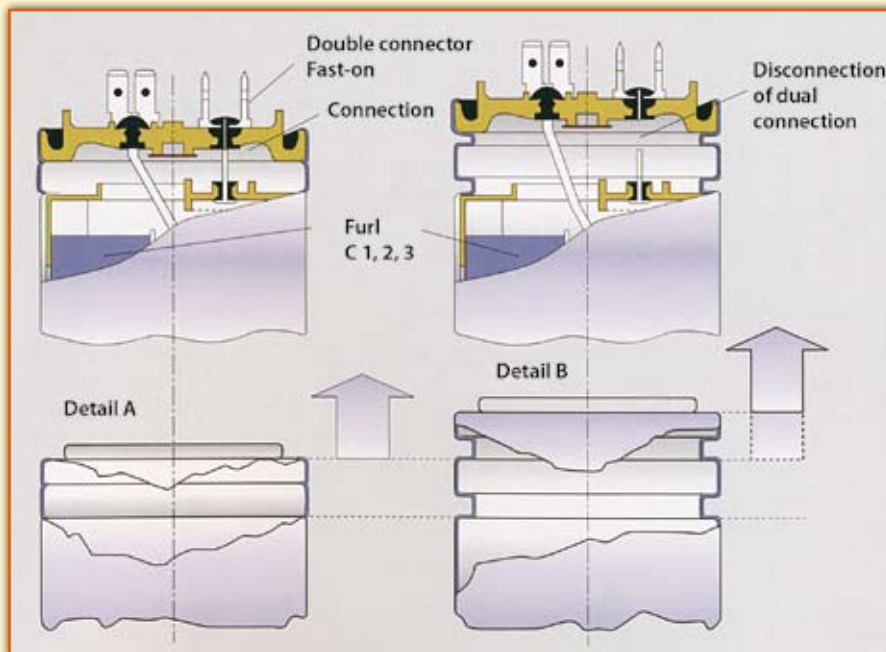
Q [kvar]	Capacitance C [μF]		Rated current In [A]		Dimensions [mm]		
	400 V	440 V	400 V	440 V	H	B	A
2,5	3 x 16,5	–	3 x 3,6	–	223	130	236
5,0	3 x 33,3	3 x 27,4	3 x 7,2	3 x 6,6	255	130	236
7,5	3 x 49,8	–	3 x 10,8	–	223	130	236
10,0	3 x 66,6	3 x 54,8	3 x 14,4	3 x 13,1	223	130	236
12,5	3 x 83,0	–	3 x 18,0	–	223	130	236
15,0	3 x 99,9	3 x 82,2	3 x 21,7	3 x 19,7	255	130	236
20,0	3 x 132,6	3 x 109,6	3 x 28,9	3 x 26,2	223	130	236
25,0	3 x 166,0	3 x 137,0	3 x 36,1	3 x 32,8	255	130	236
30,0	3 x 199,3	3 x 164,4	3 x 43,4	3 x 39,4	255	130	420
35,0	3 x 232,6	3 x 191,9	3 x 50,6	3 x 45,9	255	130	420
40,0	3 x 265,6	3 x 219,3	3 x 58,0	3 x 54,5	255	130	420
45,0	3 x 298,6	–	3 x 65,0	–	255	130	420
50,0	3 x 331,6	3 x 274,0	3 x 72,0	3 x 65,6	255	130	420

\*) other rated voltage available on request

Table 2. K.99/3 capacitors technical information:

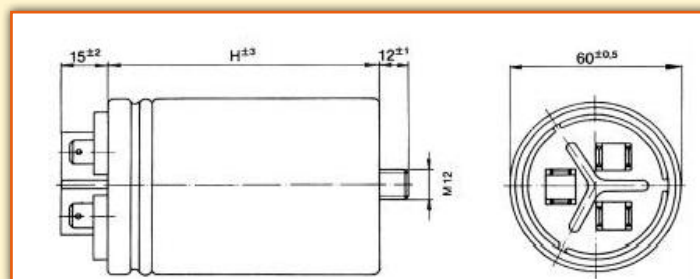
Q [kvar]	Capacitance C [μF]		Rated current In [A]		Dimensions [mm]
	400 V	440 V	400 V	440 V	D x H
1,0	3 x 7	3 x 6	1,4	1,3	60 x 160
1,5	3 x 10	3 x 8	2,2	2,0	60 x 160
2,5	3 x 17	3 x 13	3,6	3,3	60 x 160
5,0	3 x 33	3 x 27	7,2	6,5	60 x 200
10,0	3 x 66	3 x 55	14,4	13,1	85 x 270
12,5	3 x 83	3 x 68	18,1	16,4	85 x 310
15,0	3 x 99	3 x 82	21,7	19,7	85 x 310
20,0	3 x 132	3 x 114	28,9	27,3	85 x 380
25,0	3 x 166	3 x 138	36,1	31,9	85 x 420

Table 3. MKP capacitors technical information.

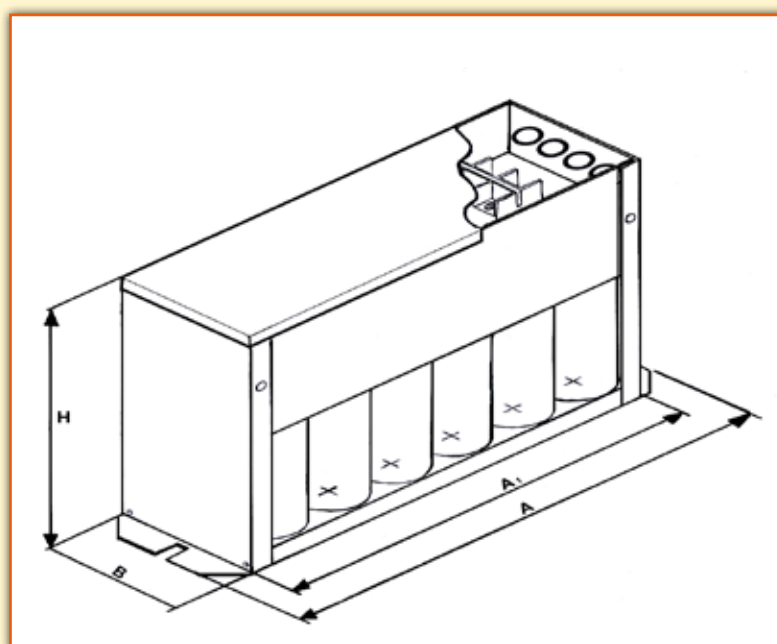


**Fig 1. Overpressure disconnecter.\***

\* – according to materials of Epcos AG



**Fig 2. Dimensions of capacitor type MKP.**



**Fig 3. Dimensions of capacitors type K . 99 / 3.**







## TWELVE ELECTRIC'S OTHER OFFERS

### POWER FACTOR CORRECTION

**MRM - 12**  
*power factor regulators*



**BK - T - 95**  
*capacitor banks*



**DWD - 12**  
*filtering reactors*



**IKT - 12**  
*individual compensator*



### NETWORK QUALITY MONITORING

- **AS - 3plus**  
*Network Parameters Analyser with graphical display*
- **AS - 3 mini**  
*DIN - mounted Network Parameters Analyser*
- **AS - 3energia**  
*energy costs Analyser with elements of energy quality analysis*
- **AS - 3diagnoza**  
*porte Network Parameter Analysers with set of measuring clamps*
- **AS - Multi 2002**  
*system software for data transfer, visualisation, reports and alarms*



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