It‘s all about saving your money

Power Factor Correction and Energy Management

FRAKO Kondensatoren- und Anlagenbau GmbH

Teningen, Germany

Asian Customer Information Seminar

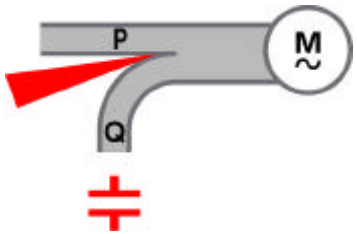
Sept. 1999

FRAKO Energy Management System (EMS)

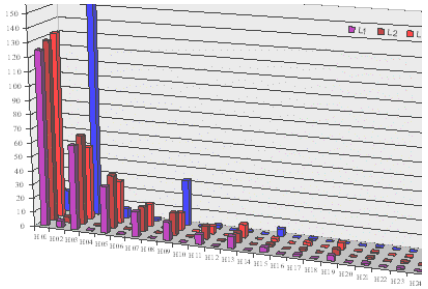
- **Jochen M. Braun**
- **FRAKO Kondensatoren- und Anlagenbau GmbH**
- **Head of Business Unit Energy Management**

FRAKO Program Segments

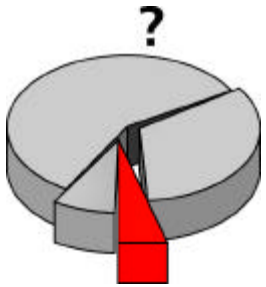
Power Factor Correction



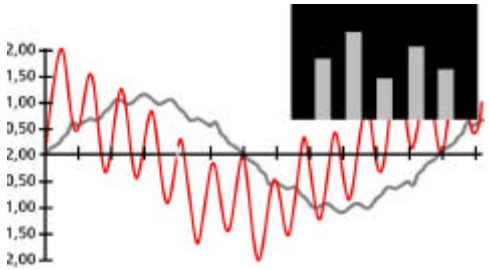
Analysis



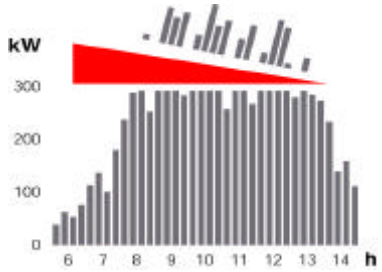
Cost Allocation



Mains Monitoring



Maximum Demand Control



Energy Management

FRAKO Energie Management System (EMS)

- 1. Basics of Energy Management (EM)
- 2. Mains Monitoring
- 3. Maximum Demand Control (Load Shedding)
- 4. Power Factor Correction with FRAKO EMS
- 5. Additional Components and Software
- 6. FRAKO Energy Management Sets
  - Mains Monitoring Set
  - Maximum Demand Set
  - Maximum Demand Set +
- 7. Integrated FRAKO Energy Management

  Various installations utilizing the FRAKO Starkstrombus™
  Mains Monitoring / Load Shedding /
  Metering electrical energy and other energies and media
- 8. Questions & Answers

1. Basics of Energy Management

Basics of Energy Management

- **Different meanings of term “Energy Management" depending on group of people where it is used:**

- **Persons involved in maximum demand control use it to name their products**
- **Persons involved in building management systems use it mainly for intelligent heating, cooling and ventilation systems**
- **Persons involved in FRAKO products use it mainly for the control and reduction of electrical energy cost**

- **There is a common understanding between these three versions.**

Basics of Energy Management

- **What exactly is energy management?**
  "Energy Management" has become a frequently used term in recent years.
- **Since we could not find a unique definition, we propose the following:**

  – **The function of EM is fulfilled when**

  1. data relevant for energy consumption, cost or power quality are measured and collected which

  2. are then used as input for monitoring, signaling, and/or controlling apparatus for reduction of energy consumption or cost and assuring power quality.

Basics of Energy Management

- **Purpose of FRAKO Energy Management Systems:**

Help our customers save money.

Basics of Energy Management

- **How FRAKO Energy Management System helps customers save money:**
  - **Reducing electricity bill**
  - **Increasing electrical power quality**
  - **Reducing costs for resources besides electricity**

Basics of Energy Management

- **Increasing quality of electrical power**

  The mains quality becomes an increasingly important issue for power engineering.

  Power quality problems can lead to very costly failures and destruction of electrical equipment and switchgear.

  FRAKO Energy Management System continuously monitors mains conditions and reports immediately when some parameter are out of bounds - much less costly than waiting for a blown fuse or production loss.

Basics of Energy Management

- **Reducing electricity bills**

  Electricity bills for industrial & commercial customers consist of three parts:

  - **active work (kWh)**
  - **reactive work (kVArh)**
  - **maximum demand (kW)**

- **Each of these parts can be reduced with FRAKO Energy Management System**

Basics of Energy Management

- **Electricity bill - active work (kWh)**

  All customers need to pay for active work.
  The energy consumed is measured by a meter
  and a price per kWh is charged.

  A useful means of reducing electrical energy consumption is comprehensive monitoring:

  For this purpose, one of the domains of FRAKO Energy Management System is monitoring of active work.

Basics of Energy Management

- **Electricity bill - maximum demand (kW) (1)**

  Dimensions of cables and transformers depend on maximum demand. The value charged is determined by averaging the power drawn over fixed periods of mostly 30 minutes.

  Costs vary from 17.3 to 25.7 RM p.month depending on the local situation.

Basics of Energy Management

- **Electricity bill - maximum demand (kW) (2)**

  These costs can be considerably reduced, when trend calculation during each period is carried out.

  In case of high forecast of mean power exceeding the maximum demand, loads can be shed in order to

  reduce power drawn in running measuring period, which has been perceived as critical.

  FRAKO Energy Management Systems include instruments for such a purpose.

Basics of Energy Management

- **Electricity bill - reactive work (kVArh)**

  Current carried by mains bus not only carries flow of active work but also that of reactive work.

  Here zero net energy is being consumed. Reactive energy is energy oscillating between consumer and utility.

- **This component calls for larger cables and bigger transformers, leading to increased costs.**

  For this reason reactive work is also being charged by the utility.

  FRAKO Capacitors Banks can easily reduce these charges to zero and can be operated within the FRAKO EMS.

Basics of Energy Management

- **Reducing costs of resources other than electricity**

  FRAKO Energy Management System can also monitor consumption of gas, water, pressurized air, fuel, etc...

Basics of Energy Management

- **Modularity**

  FRAKO Energy Management System includes a stand-alone instrument for each of the four domains:

- **Mains monitoring** — **EMA 1101**
- **Maximum demand control** — **EML 1101**
- **Energy metering** — **EMF 1101, EMKI 1101/1103**
- **Power factor correction** — **EMR 1100**

  Each instrument is equipped with RS 485 interface for connecting to FRAKO Power Bus and can be integrated into FRAKO Energy Management System.

Basics of Energy Management

- **FRAKO Starkstrombus™ (Power Bus)**
  - **Two wires, twisted and shielded pair**
  - **Transfer rate: 76.8 kbit/sec**
  - **Max distance covered: approx. 5 km**
  - **Master - slave system:**
    - Max 8 masters
    - Max 116 slaves

- **Stand-alone units mentioned are slaves:**
  EMF 1101, EMR 1100, EML 1101 and EMA 1101

Basics of Energy Management

- **Masters and Slaves**
  - **Masters:**

Bus Central Units	**EMZ 1000, ... 1102**
Communication Processor	**EMP 1100**

  - **Slaves:**

- EMF 1101
- EMR 1100
- EML 1101
- EMA 1101

} Stand-alone units

Basics of Energy Management

- **What do masters EMZ and EMP do?**
  - **Request actual data from slaves for further processing**
  - **Serve as interface between**

    FRAKO Power Bus (RS 485) and
    PC,
    PLC or BMS (RS 232)

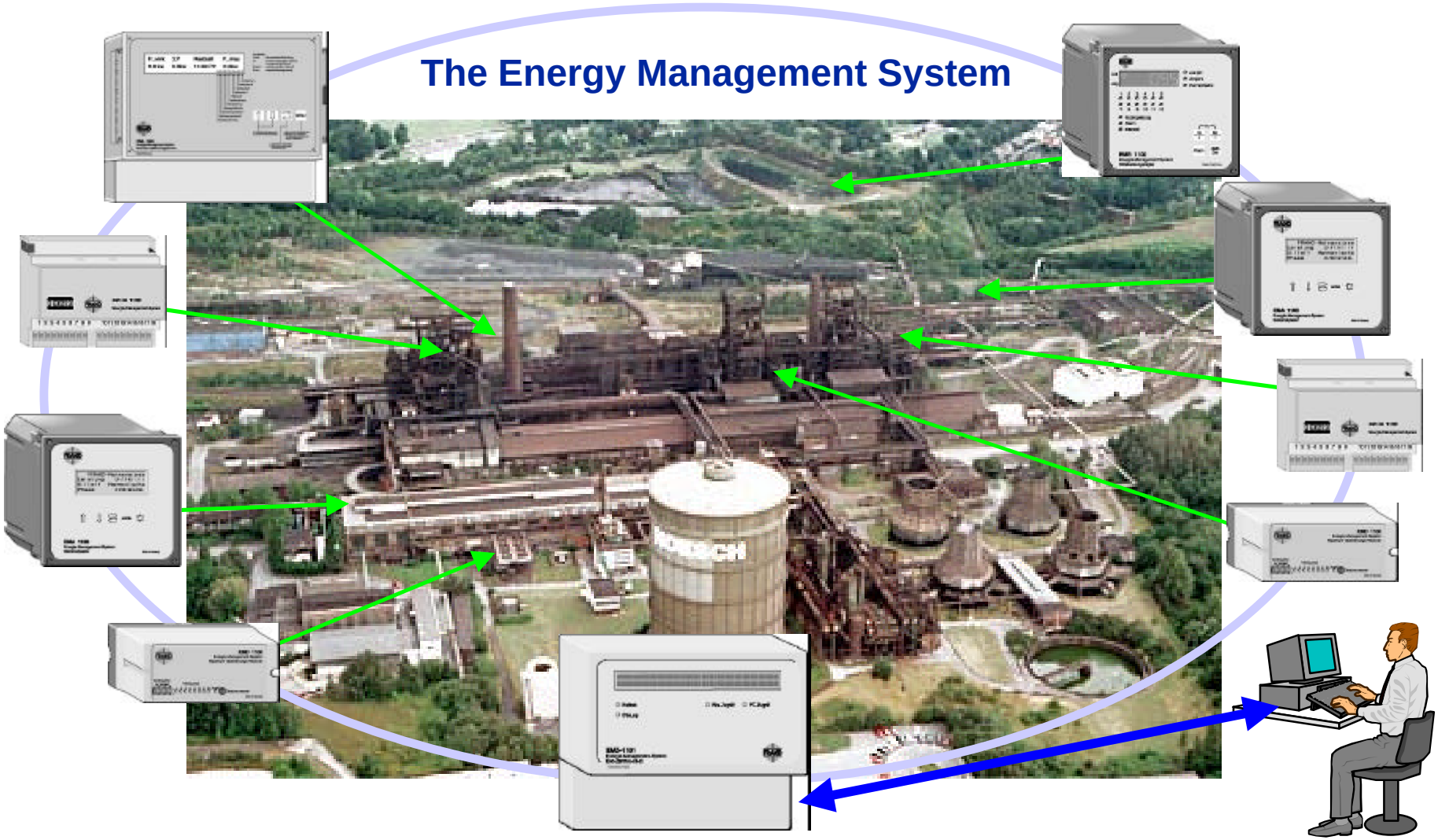
Basics of Energy Management

- **Supplementary functions provided by**

  FRAKO Energy Management System :

- **State and alarm reports from other systems can be handled**
- **Analog signals (0 or 4 to 20 mA) can be included in display of EM-data on screen**

Integrated FRAKO Energy Management System



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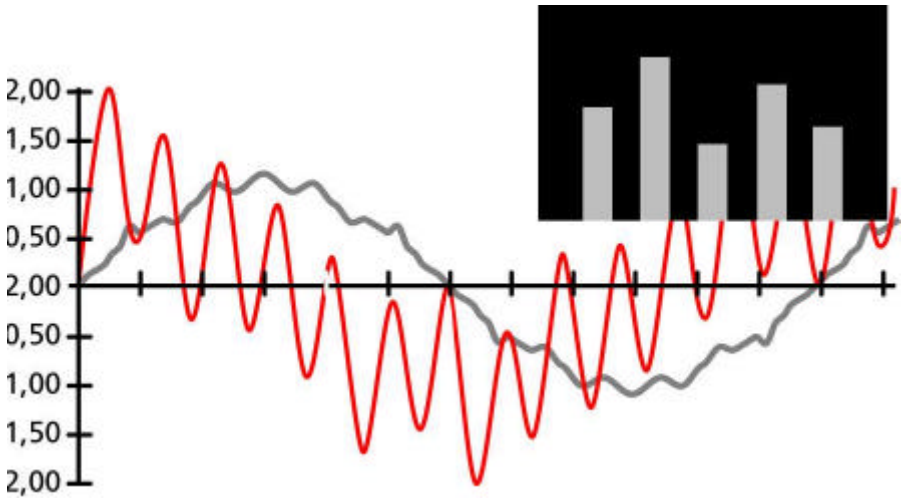
2. Mains Monitoring

Providing qualified information for various purposes



Mains Monitoring Instrument EMA 1101

- **Objectives:**
  - **Prevent unexpected power failures**
  - **Prevent equipment failure due to high percentage of harmonics**
  - **Prevent failure and destruction of equipment due to voltage or current overloading**
  - **Get early information on bad power quality**

Mains Monitoring Instrument EMA 1101

- **Functions:**
  - **3-phase measurement V, I, phi**
  - **3-phases calculation of P, Q, S**
  - **Monitoring of harmonics, Udf, Idf**
  - **Active and reactive work meters**
  - **Measurement of two temperatures**
  - **LCD 4 x 20 characters**
  - **Contact for tariff switching**
  - **Alarm contact**

Mains Monitoring Instrument EMA 1101

Mains Monitoring Instrument EMA 1101

All relevant measuring data are registered.

Phasenwerte L3

Phasenwerte L2

Phasenwerte L1

S 559.3 kVA	I 736 A
P 555.7kW	U**Y** 222 V
cos φ 1.00	U**klirr** 2.9 %

	U	effektiv	I
L1/2	386 V	L1	736 A
L2/3	391 V	L1	946 A
L1/3	388 V	L1	886 A

Harmonische L3

Harmonische L2

Harmonische L1

U1 386 V	U7 1.8 %
U3 2.8 %	U9 0.9 %
U5 4.2 %	U 11 0.1 %

Gesamtleistung

S 559.3 kVA	cos φ 1.00
P 555.7kW	Asym. 12 %
Q 46.1 kvar	f 50 Hz

Klirrfaktor

U**kl 1** 2.9 %	I**kl 1** 7.9 %
U**kl 2** 2.8 %	I**kl 2** 9.0 %
U**kl 3** 3.1 %	I**kl 3** 8.9 %

Analyses mains conditions;
monitors and prevents breakdowns.

Mains Monitoring Instrument EMA 1101

- **Two examples for application:**

  Central Institute for Calibration in Germany:
  15 EMZ 1102 with up to 18 EMA 1101 and 5 energy meters

  Huge recreation area in northern Germany:
  1 EMZ 1102, 1 EML 1101 + 10 EMD 1101, 5 EMA 1101 and 50 energy meters

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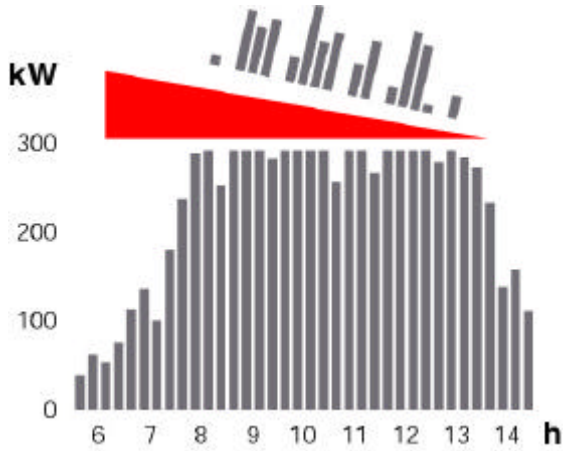
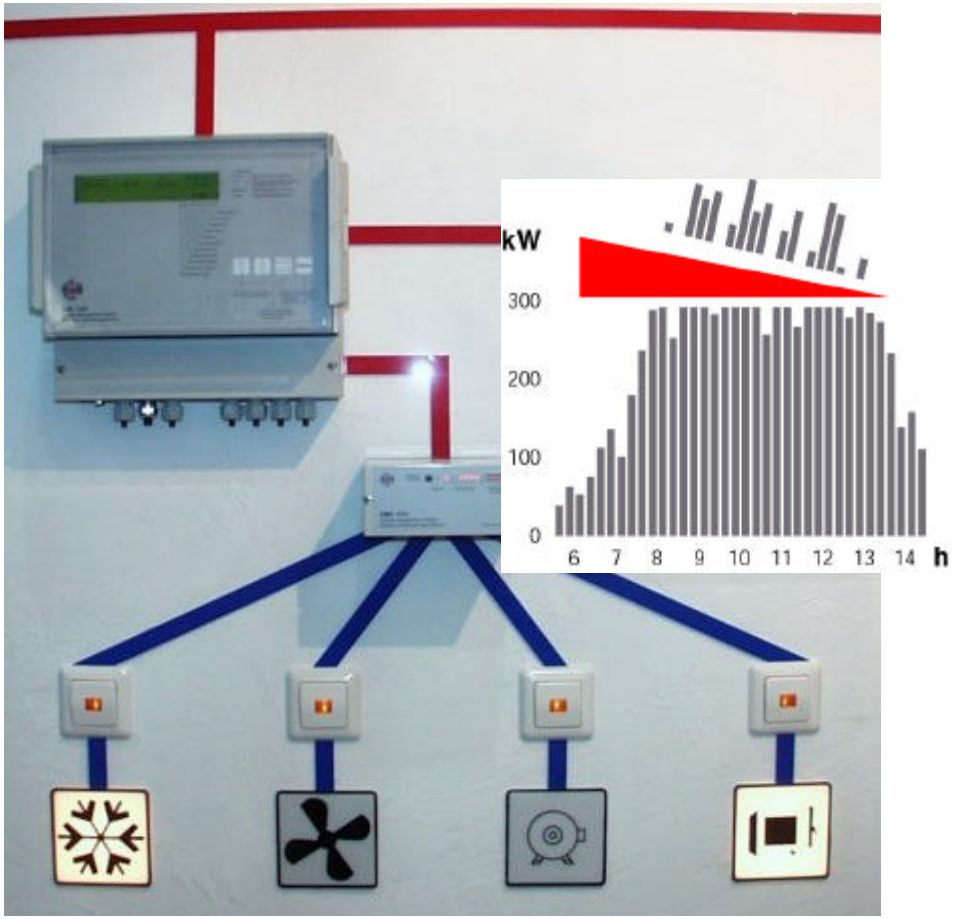
3. Maximum Demand Control

Load Shedding



Maximum Demand Control

- **Cost reduction preventing power surges by shedding loads within defined measuring periods**

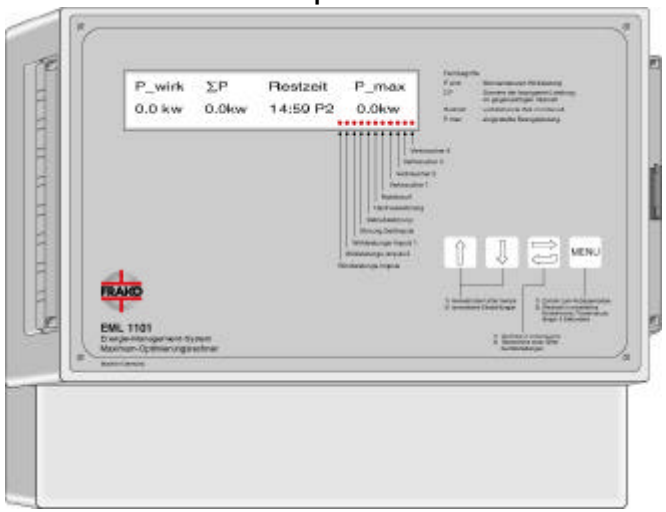


Mode of determining charges for maximum demand

- **A kW-meter measures the highest average value of kW, that occurs each month.**
- **Each month is subdivided into approximately 1500 measuring periods of 30 minutes.**
- **The average value of kW is taken over each measuring period of 30 min.**
- **The highest average value of kW that has occurred during a month is then charged.**
- **Costs vary from 17.3 to 25.7 RM p. month depending on the local situation.**

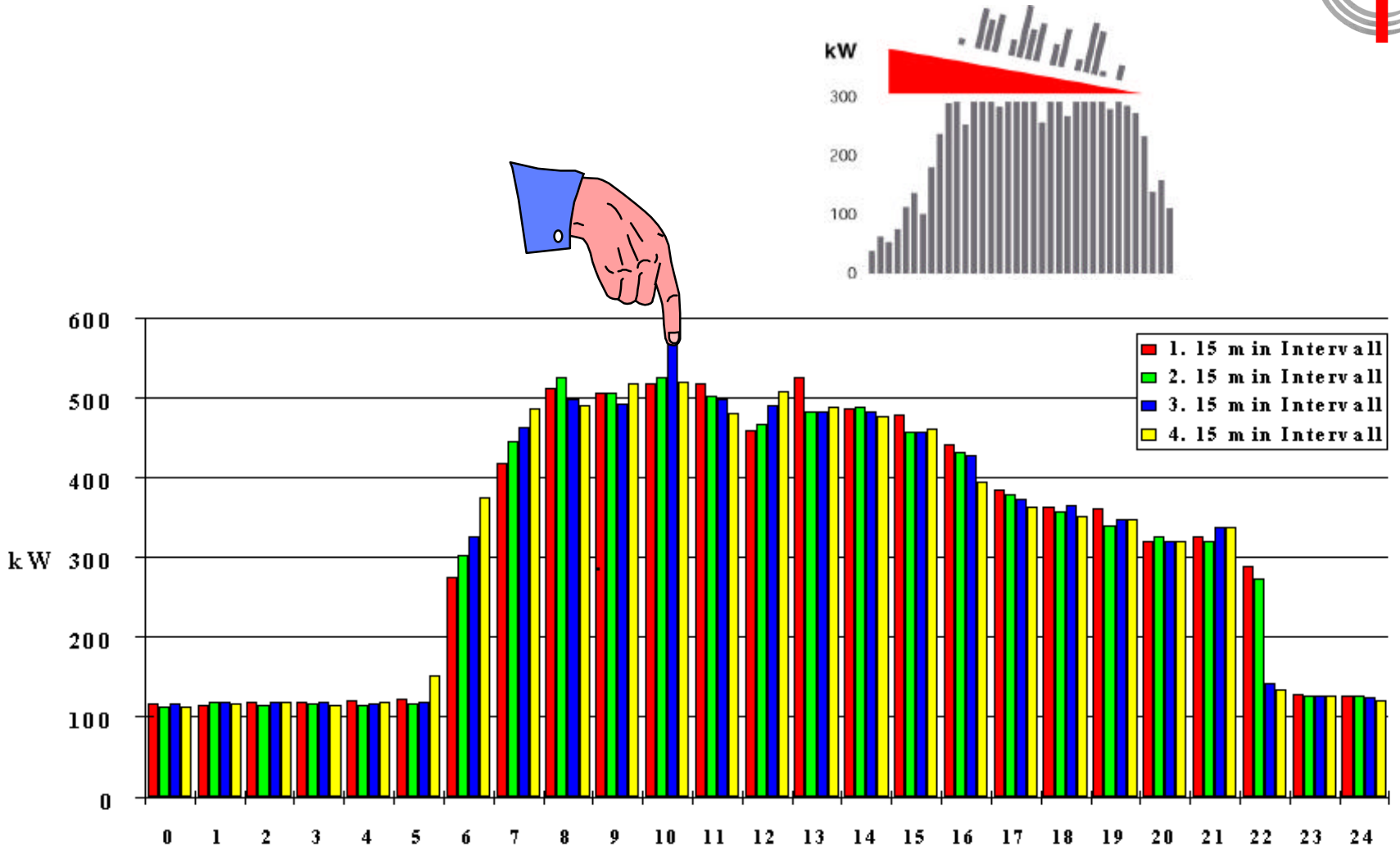
Chances to influence the peaks

Time kVA puls

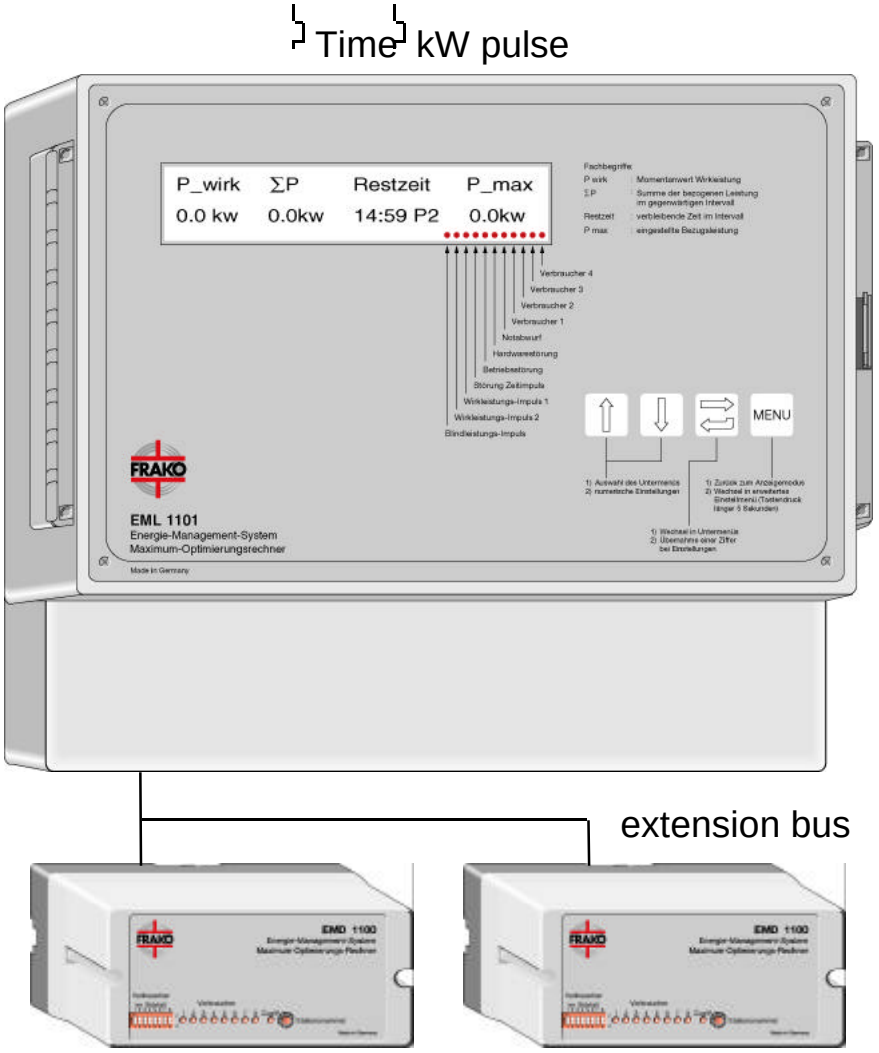


- **The fact that average values of kW are charged, gives the customer enough time to keep track of the accumulated kWh that have been used up in the current measuring period.**
- **On this basis the customer can decide whether loads should be shed in order not to exceed a desired value of maximum demand.**
  This is the basic function which EML 1101 provides:
  - **Minimum input:** **time pulse and kW pulse**
  - **Output:** **relays, that switch off loads**

„Cutting off“ peaks



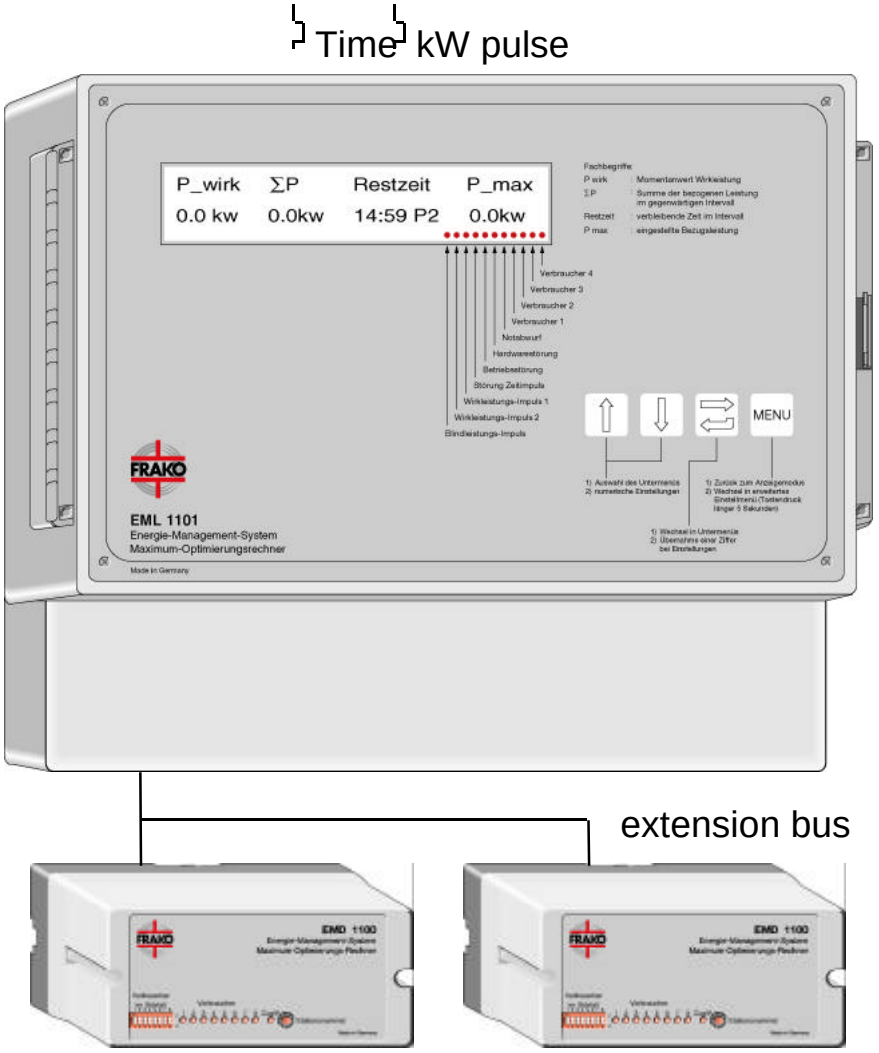
Maximum Demand Controller EML 1101



Maximum of 84 control channels

- **Functions:**
  - **Operation software**
  - **PC/printer interface**
  - **4 switch-off channels**
  - **4 application profiles**
  - **Emergency dump**
  - **Sub-bus for extension modules**
  - **Connection for kW pulse and time pulse**
  - **Help menu guidance**
  - **Bus connection (optional)**

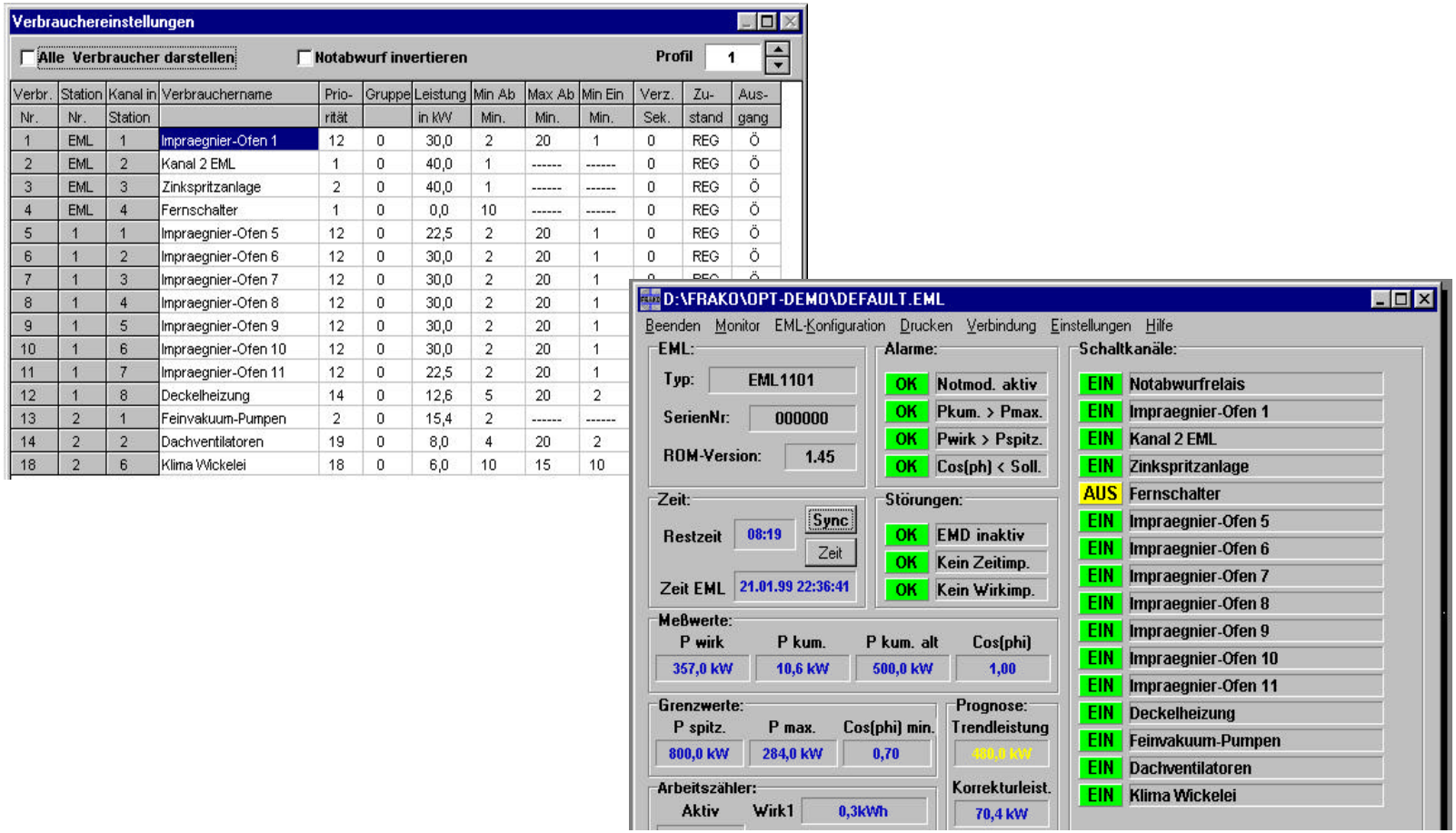
Maximum Demand Controller EML 1101



Maximum of 84 control channels

- **Functions:**
  - **Maximum savings via trend calculation**
  - **Direct configuration or via laptop**
  - **Min. input: time and active work pulse**
  - **Modular setup**
  - **4 + 1 relays (250 VAC, 4 A)**
  - **2 contacts for 4 profiles**
  - **2 Alarm contacts**

Display of Maximum Demand relevant Data



Maximum Demand Controller EML 1101

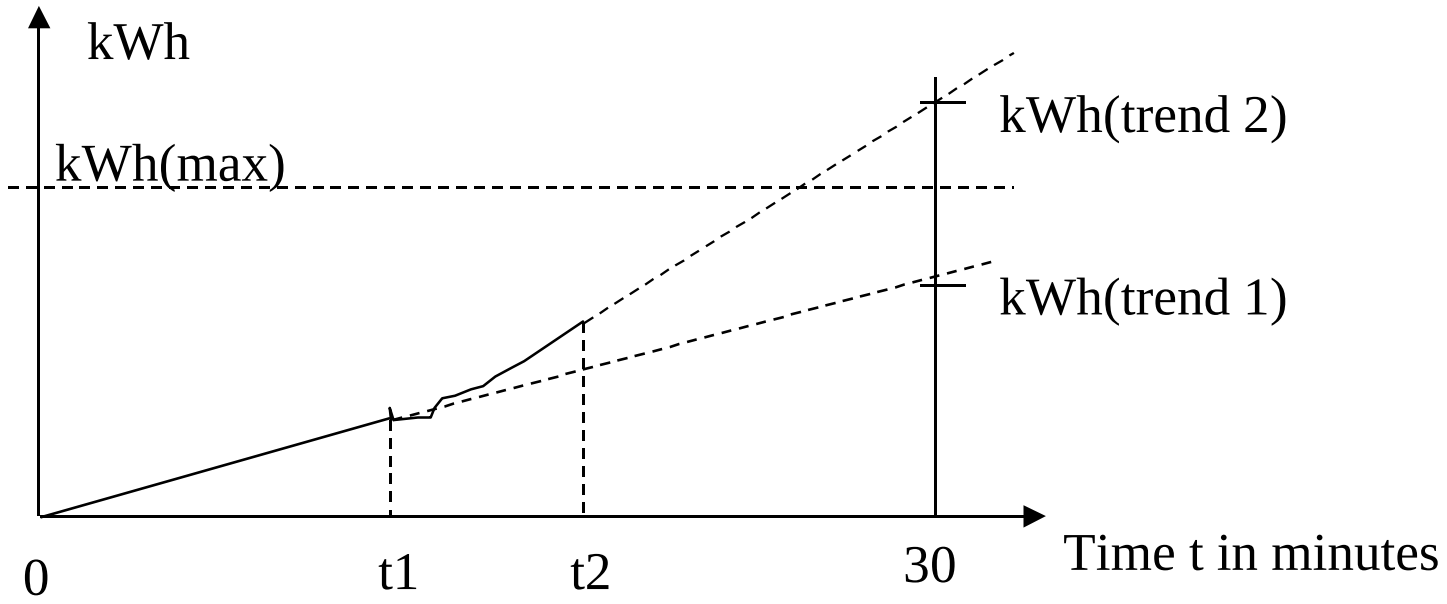
- **Individual settings for each channel:**
  - **Rated Power/Peak Consumption**
  - **Priority**
  - **Min. OFF**
  - **Max. OFF**
  - **Min. ON**
  - **Time/Power priority**
  - **Output (NC/NO)**

  ... limits switch-off times for each consumer to a sustainable degree.

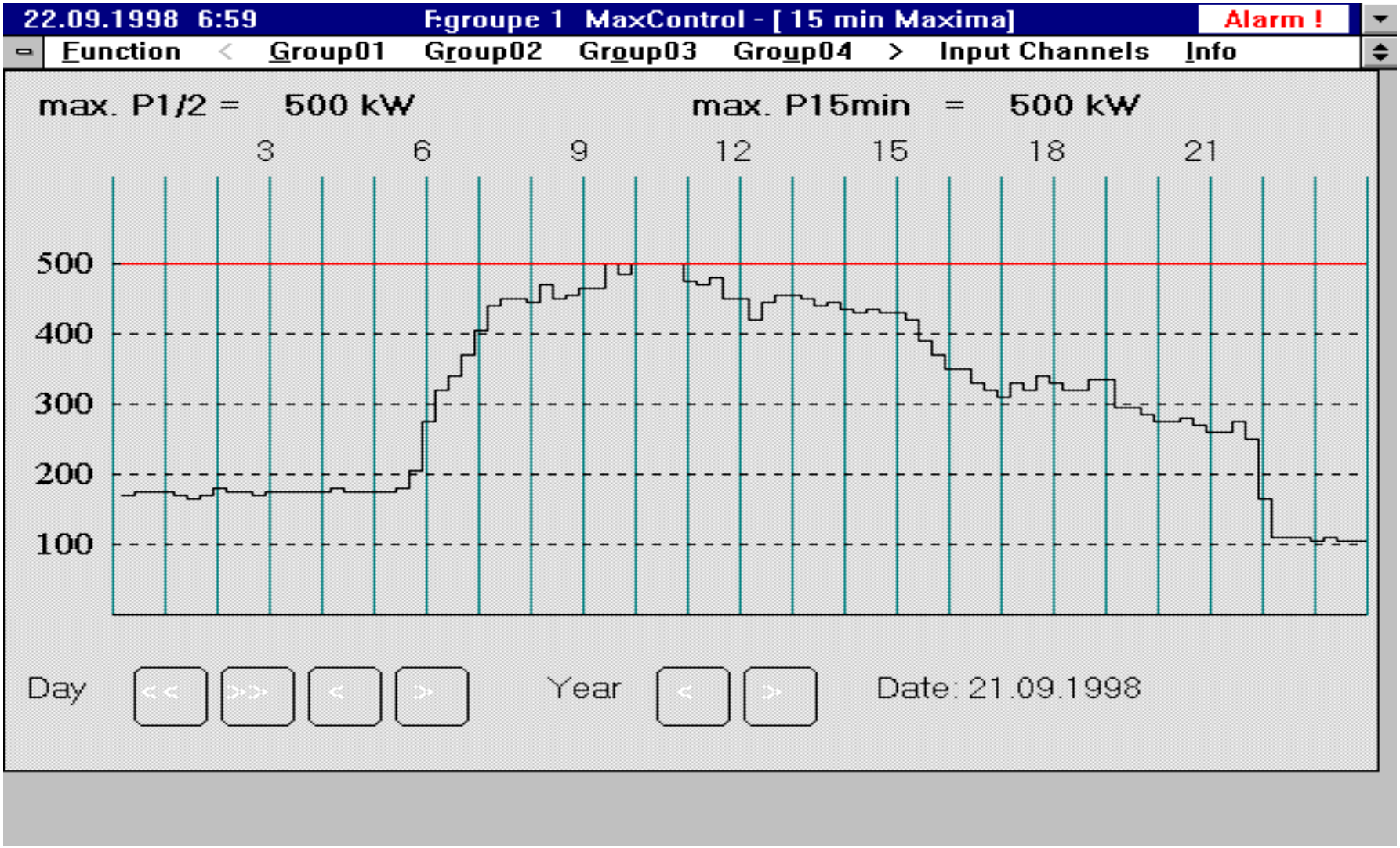
- **Basic settings:**
  Target maximum demand, pulse rates, CT-ratio, VT-ratio, number of profiles, number of add-on stations, number of kW-meters connected, etc...

Basic facts about algorithm implemented in EML 1101:

- **kW averaged over 30 minutes = kWh registered during 30 minutes mutiplied by 2.**
- **The maximum value of average kW is related to maximum value of kWh(max) accumulated during 30 minutes.**



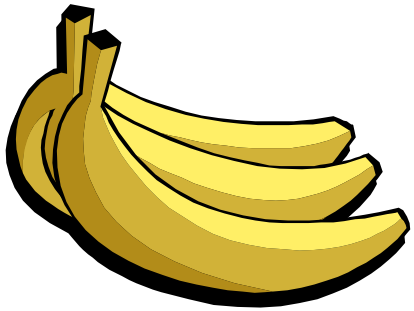
Example for a limited profile

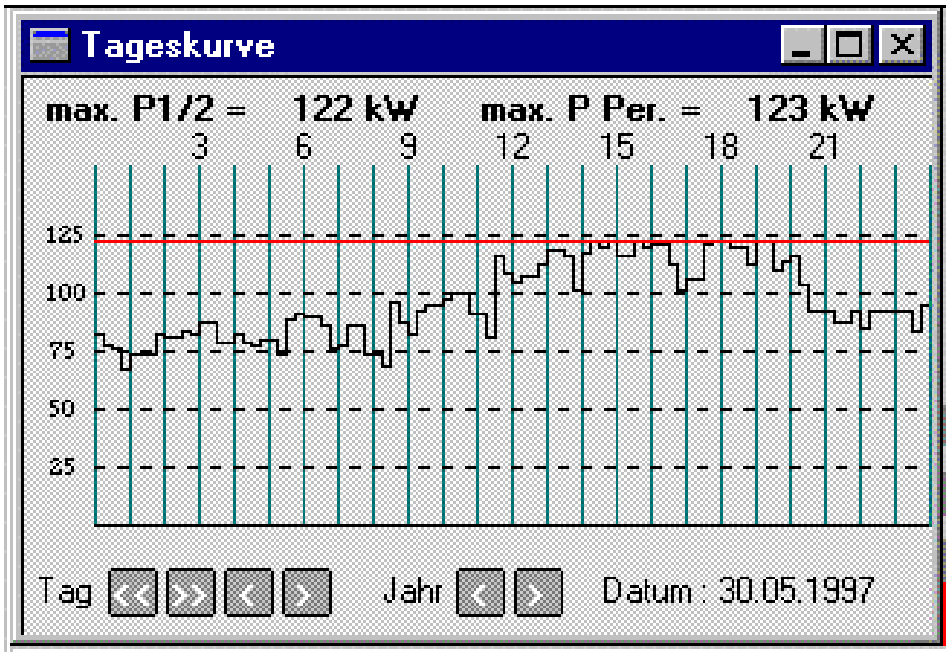


Example of Food Storage Building

Before Optimizing **180 kW**

After Optimizing 120 kW

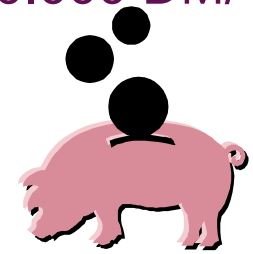




Daily Demand

Reduction:

ca 20.000 DM/Year



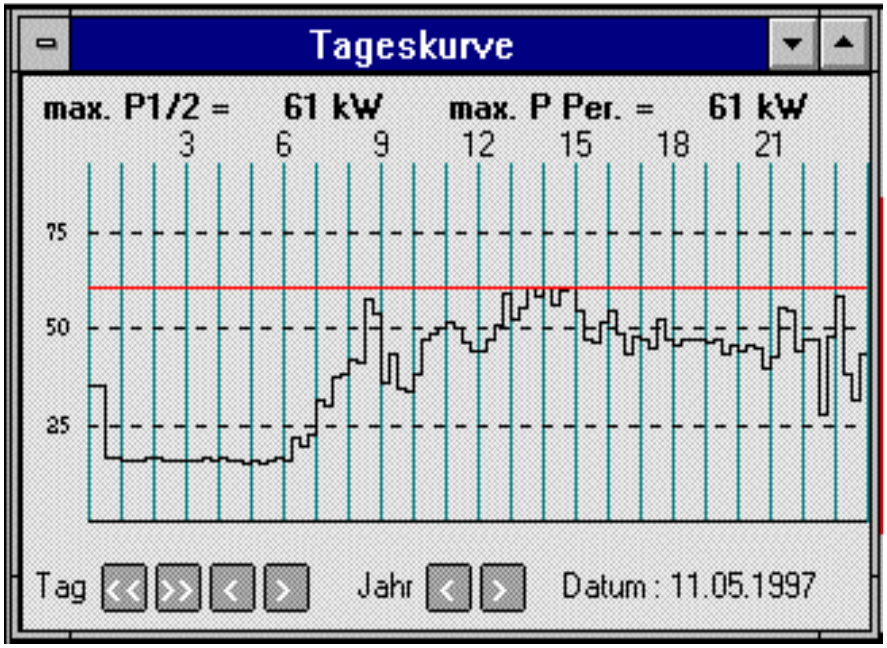
Amortisation:

ca. 1 Year

Example of Hotel Ludinmühle, Freiburg

- **Consumers:**

Daily Power Profile



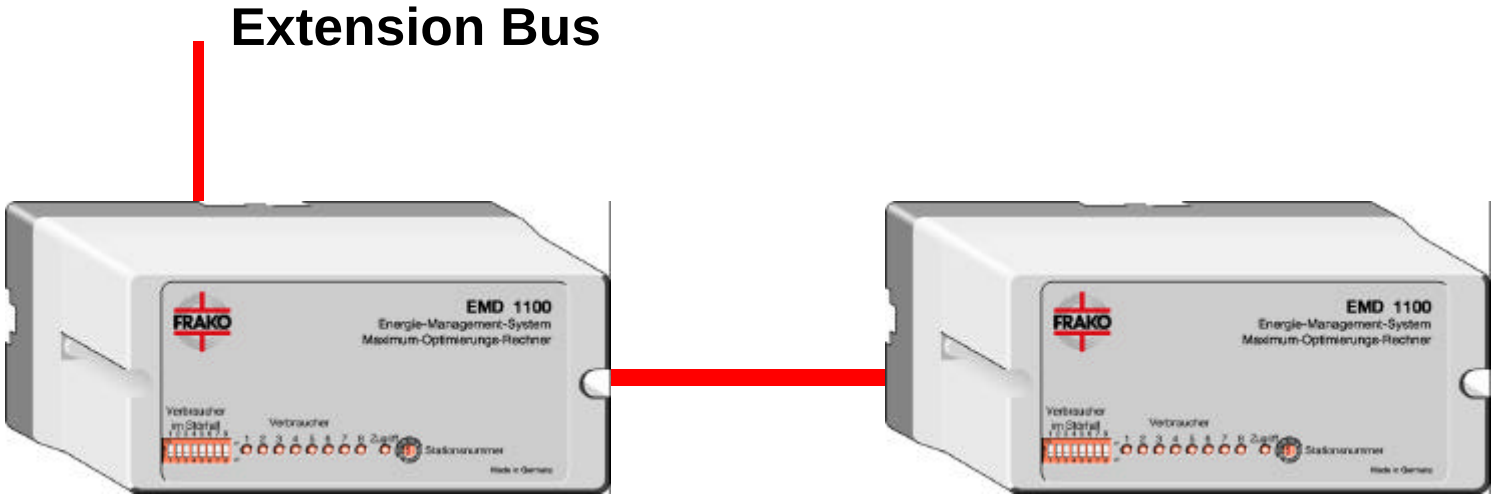
Day / Year / Date:

- **Kitchen range**
- **Double-boiler**
- **Deep fat fryer**
- **Frying plate**
- **Swimming pool pumps**
- **Sauna furnace**
- **Steam bath**

Switch-off Options in various Areas

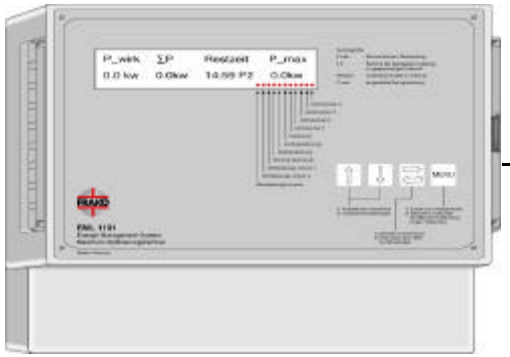
Hotel, Catering	Brewing	Butchering	Industry
Washing machine	Cooling	Cooling	Ventilation systems
Dryer	Ventilation	Passing machine	Light e.g. 1/3
Ironing machine	Water preparation	Cutter	Compressed air
Gutter heating	Cylinder pump	Baking cabinets	Canteen
Refrigeration	CIP cleaning	Smoking chamber	Drying cabinets
Double-boiler		High-pressure cleaner	Warming cabinets
Plate warmer		Heating	Air conditioning systems
Baking ovens		Washing machine	
Frying pan		Dryer	
Deep fat fryer			
Tilting-type frying pan			
Kitchen range			
Grill			
Ventilation			

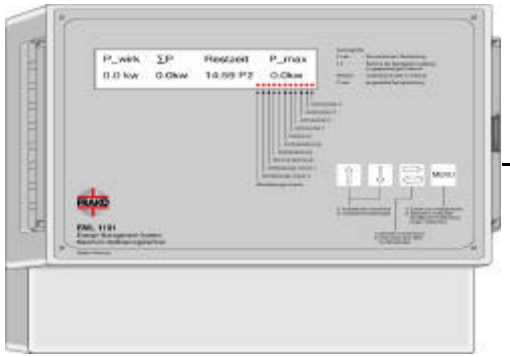
Add-on stations EMD 1101

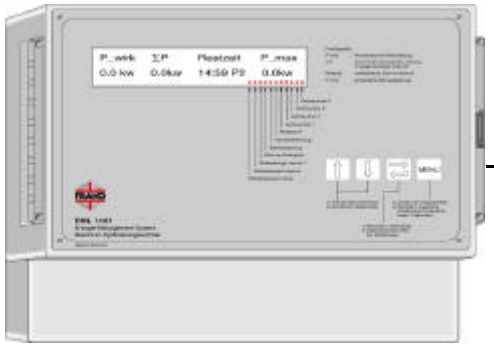


- 8 relays (250 VAC, 4 A)
- 8 LEDs
- 8 dip switches
- RS 485 interface for connecting to extension bus

Maximum Demand Controler EML 1101 for remote access







Modem

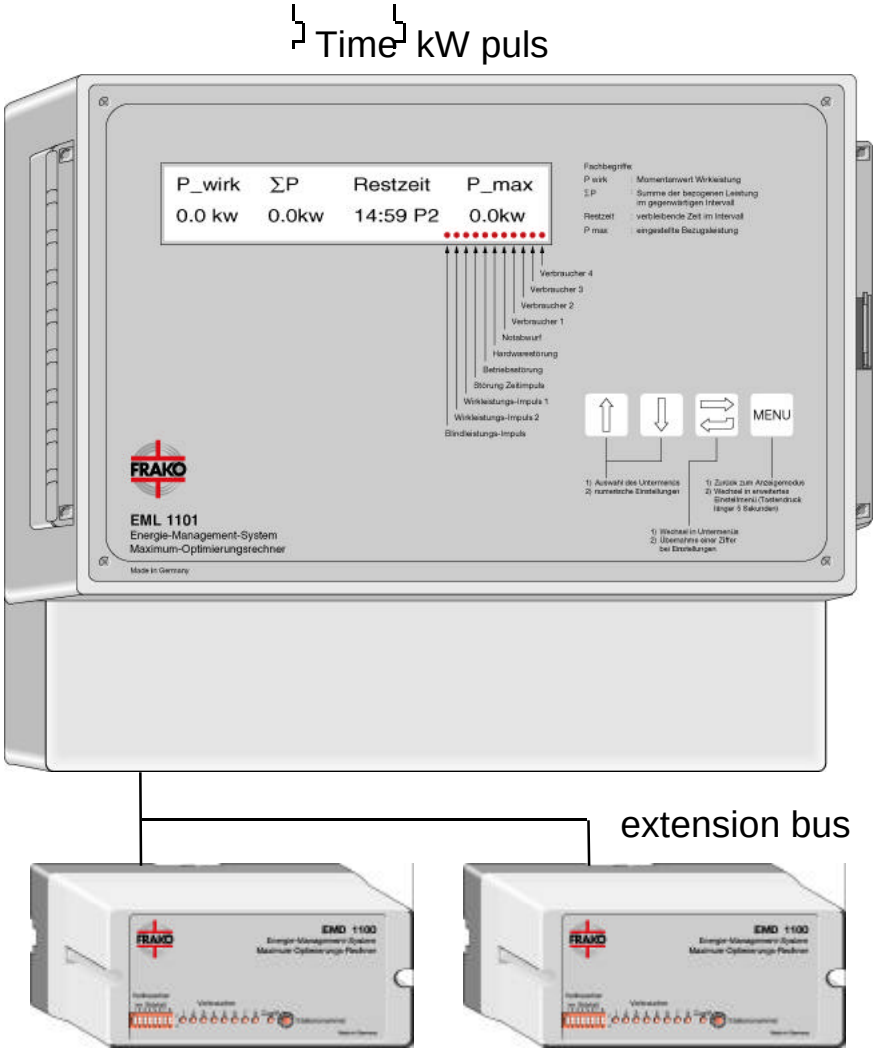
Modem

Modem

Modem

- **Configuration Software OPT-SW**
- **Extremely easy configuration of EML 1101 via PC**
- **Connection via modems possible**
- **Monitoring of all relevant data**

Maximum Demand Controler EML 1101



Maximum of 84 control channels

- **First steps in planning of installation of an EML 1101:**
- **Inspect electricity bill**
- **Create load list with load settings**
- **Possibly measure daily power curve**
- **Estimate time of payback of investment**

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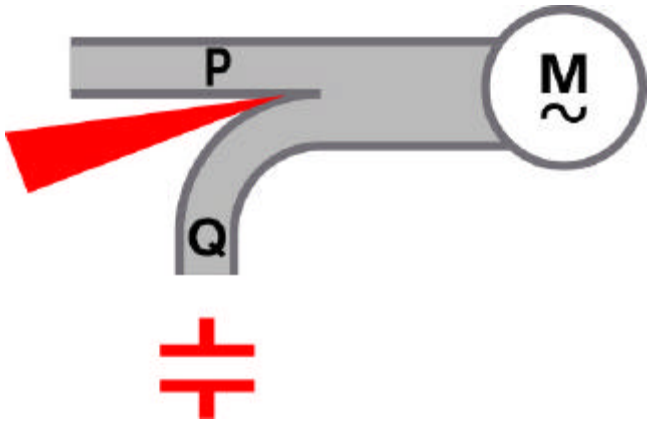
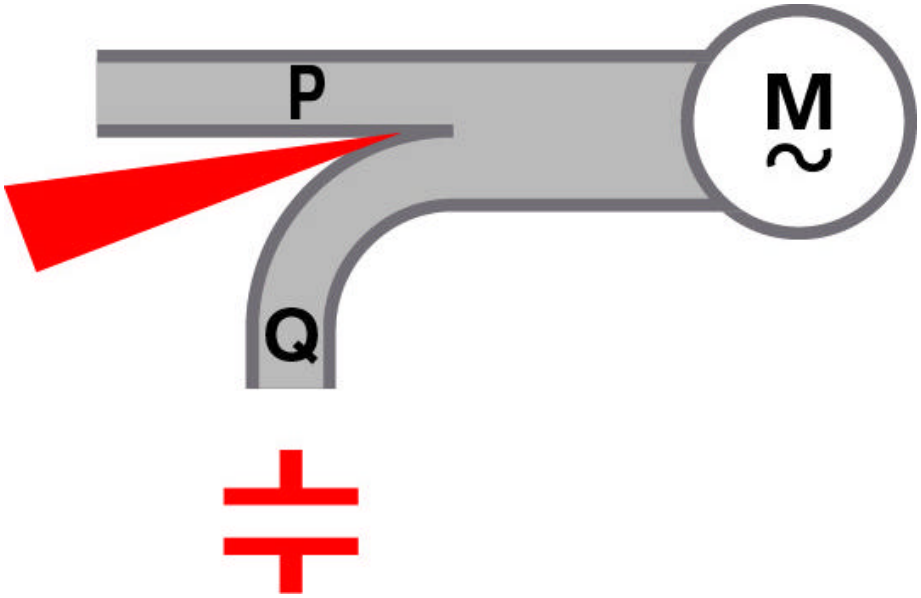
4. Power Factor Correction with FRAKO EMS

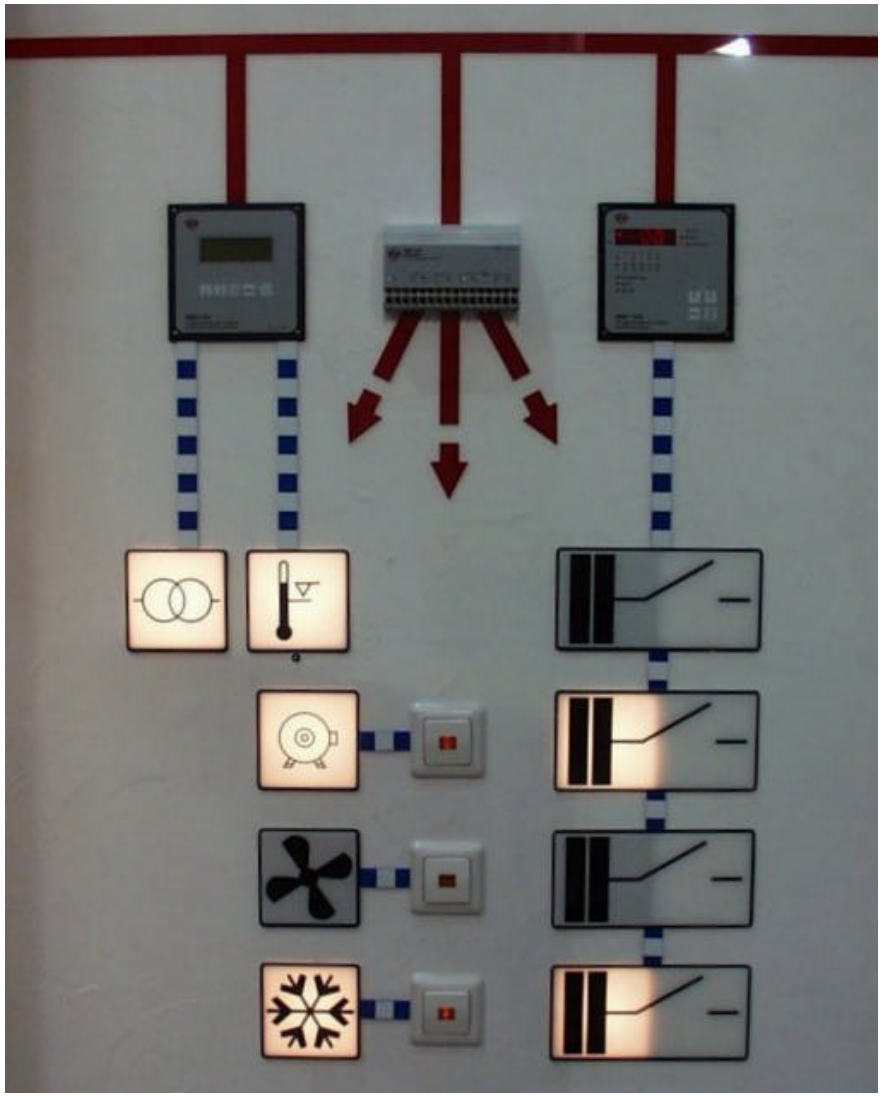
Utilizing FRAKO Capacitors and Power Factor Relays



Power Factor Correction and Mains Monitoring

- **Complete reduction of reactive power costs**
- **Monitoring of mains parameters**

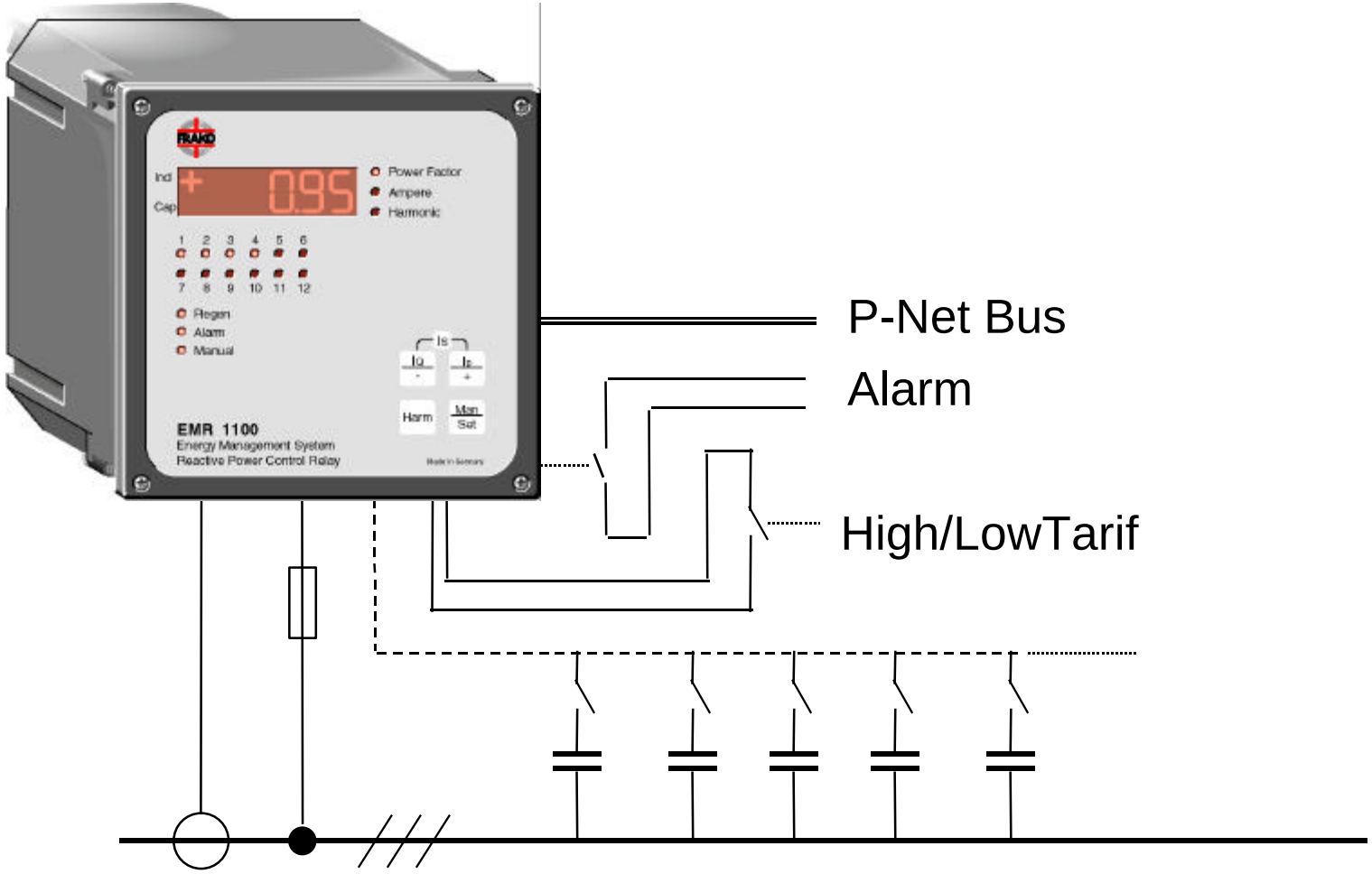




Reactive Power Relay EMR 1100

- **Automatic identification of phases orientation**
- **Monitoring of harmonics**
- **Irms-monitoring**
- **Four-quadrant control**
- **Switching cycle counters**
- **Individual control of discharge time for each stage**

Reactive Power Relay EMR 1100



Reactive Power Control Relay EMR 1100

FRAKO products :

Reactive Power Control Relay EMR 1100

Self-adapting :

to check the phase position

$$c/k = \frac{0{,}385 * Q}{U * CT_{Ratio}}$$

to adjust CT Ratio

1 : 2 : 2 : ...

to set stage sequence

Records and indicates:

- Alarm
- PF
- and the required capacitor rating:

- Alarm
- cos-phi
- 127 kvar

Why power factor correction?

economical use of:

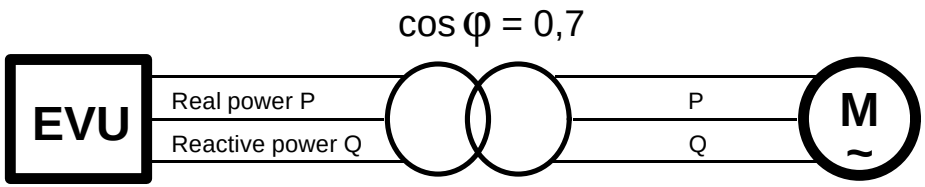
- transformers
- cables
- switchgears

reduced losses

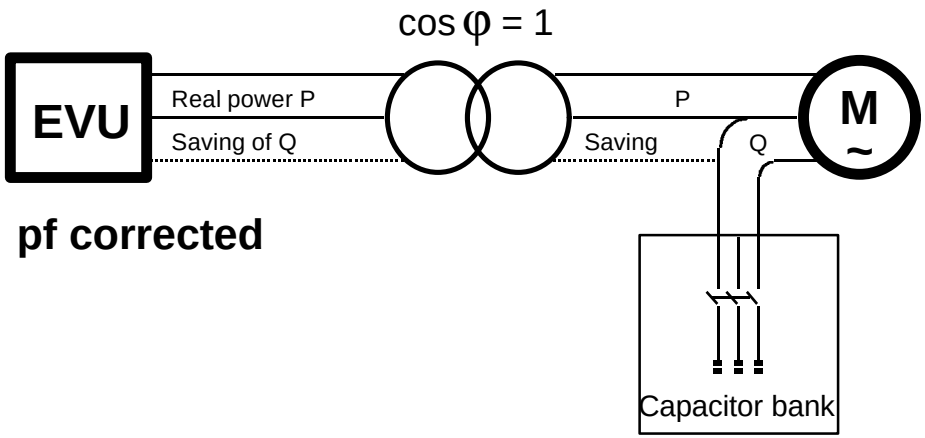
reduced voltage drop

leading to:

→ **reduced costs**



no pf-correction



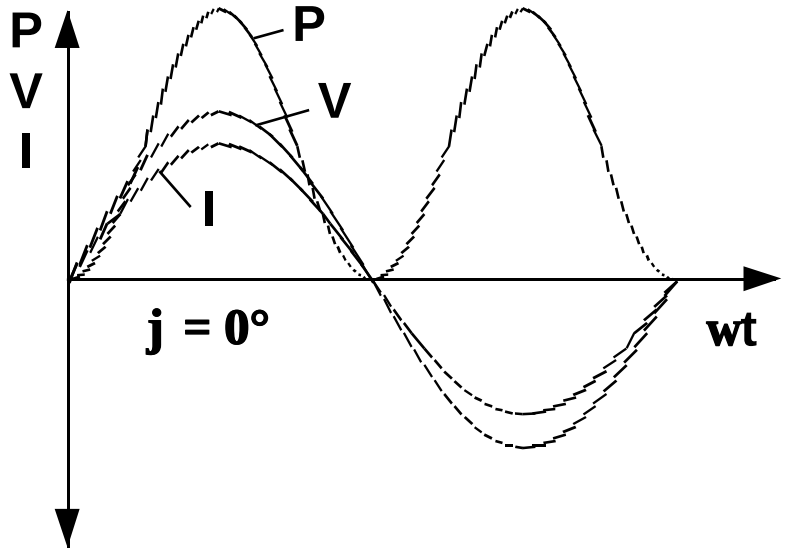
pf corrected

Basic Facts

Real Power

Non-reactive loads without inductive and capacitive components, such as electric heaters, give rise to simultaneous zero passages of voltage and current.
Voltage and current are in phase. The phase shift φ is zero: φ = 0°.

Voltage, current and power at non reactive loads (φ = 0°)



Real power is the component that is transformed into non-electrical power (e.g. heat, light, mechanical power).
For non-reactive loads the power is being calculated as product of r.m.s.-values of voltage and current.

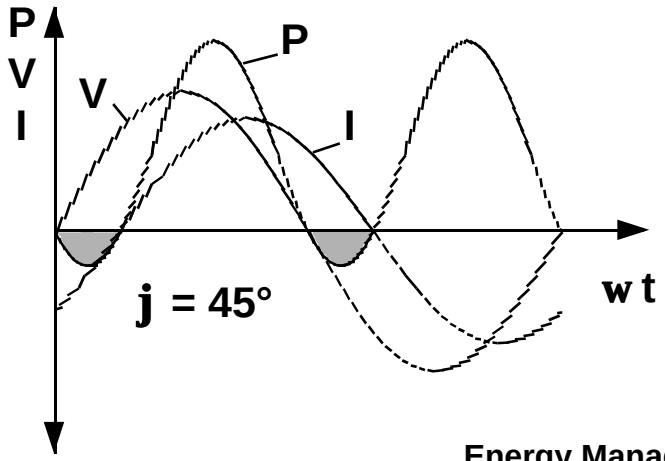
$$P = V \cdot I$$
[W] [V] [A]

Basic Facts

Real and reactive power

Practically loads are not purely non-reactive, but there is a reactive component involved. This applies for all loads thatdepend on magnetic fields, e.g. asynchronous motors, chokes and transformers. Rectifiers also consume reactive power.
The energy for generating the magnetic field and its polarity reversal oscillates between generator and load.
Zero crossings of voltage and current do not occur at the same time. The phase shift φ is different from 0°.
Current lags for inductive and leads for capacitive loads.
The momentary values of P can be positive and negative, reflecting an oscillating part of energy flow.

Voltage, current and power for load with non-inductive and inductive component (φ = 45°):



An example with phase shift φ = 45°
P(t) is temporarily negative.
The real power is given by:

$$P = V \cdot I \cdot \cos \varphi$$

[W] [V] [A]

Basic Facts

Power factor cos phi

The cosine of the phase shift between voltage and current relates active and apparent components of power P, work W and current I.

It is called power factor.

$$\cos \varphi = \frac{P}{S}$$

[W] / [VA]

The type plate of electrical machines normally carries the power factor at full load

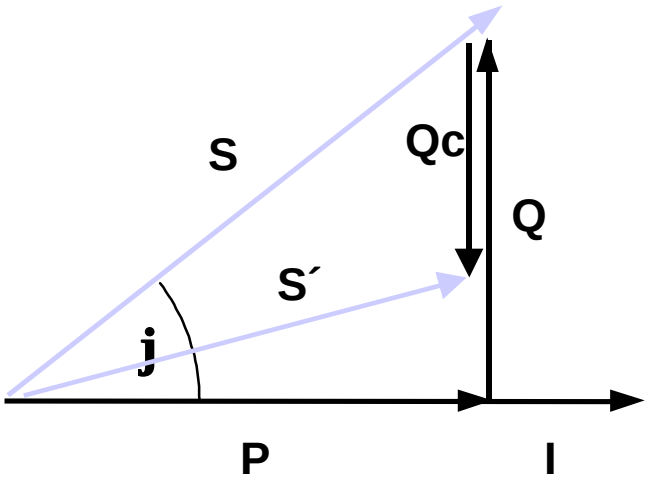
Basic Facts

Apparent power

The apparent power S is the all-important parameter for rating loads of electical networks. Generators, transformers, switchboards, fuses and cross sections of cables have to be designed such that they can handle the maximum apparent power.

Apparent power is the product of r.m.s. voltage and r.m.s. current.

Apparent, active and reactive power:



$$S = V \cdot I$$

[VA] [V] [A]

Apparent power is the geometric sum of active and reactive power:

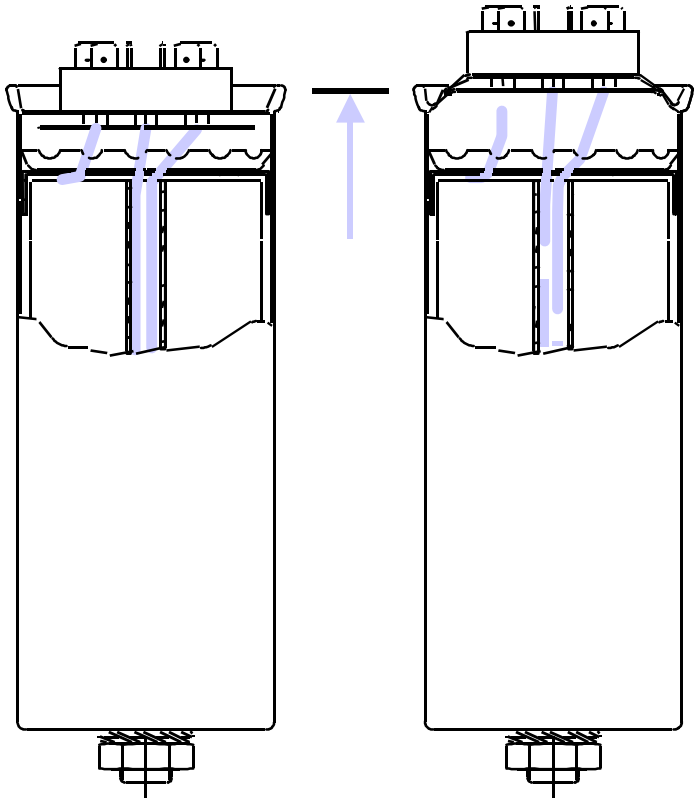
$$S = \sqrt{P^2 + Q^2}$$

[VA] [W] [VAr]

Overpressure Disconnector

Highest possible safety standard is met only when in addition to a very reliable normal functioning there is a device that

- reacts to inner build up of pressure
- disconnects the winding from the mains without leading to rupture of the casing



For this purpose FRAKO uses a seamed lid with a membrane function.

With an overpressure of three bars, the lid pushes 10mm upwards and disconnects the winding from the mains without arcing back.

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- 5. Additional Components and Software
- 6. FRAKO Energy Management Sets
  - Mains Monitoring Set
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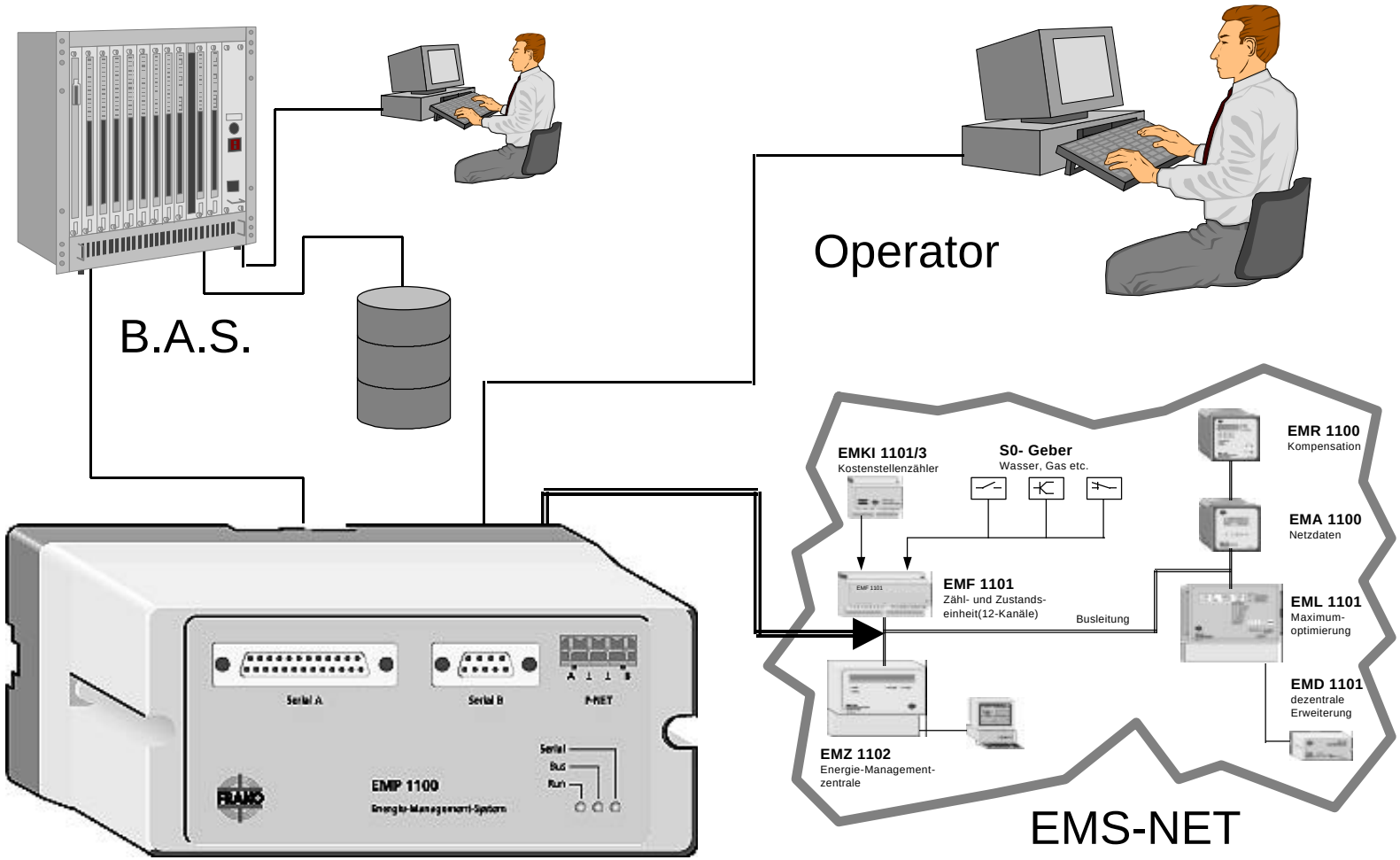
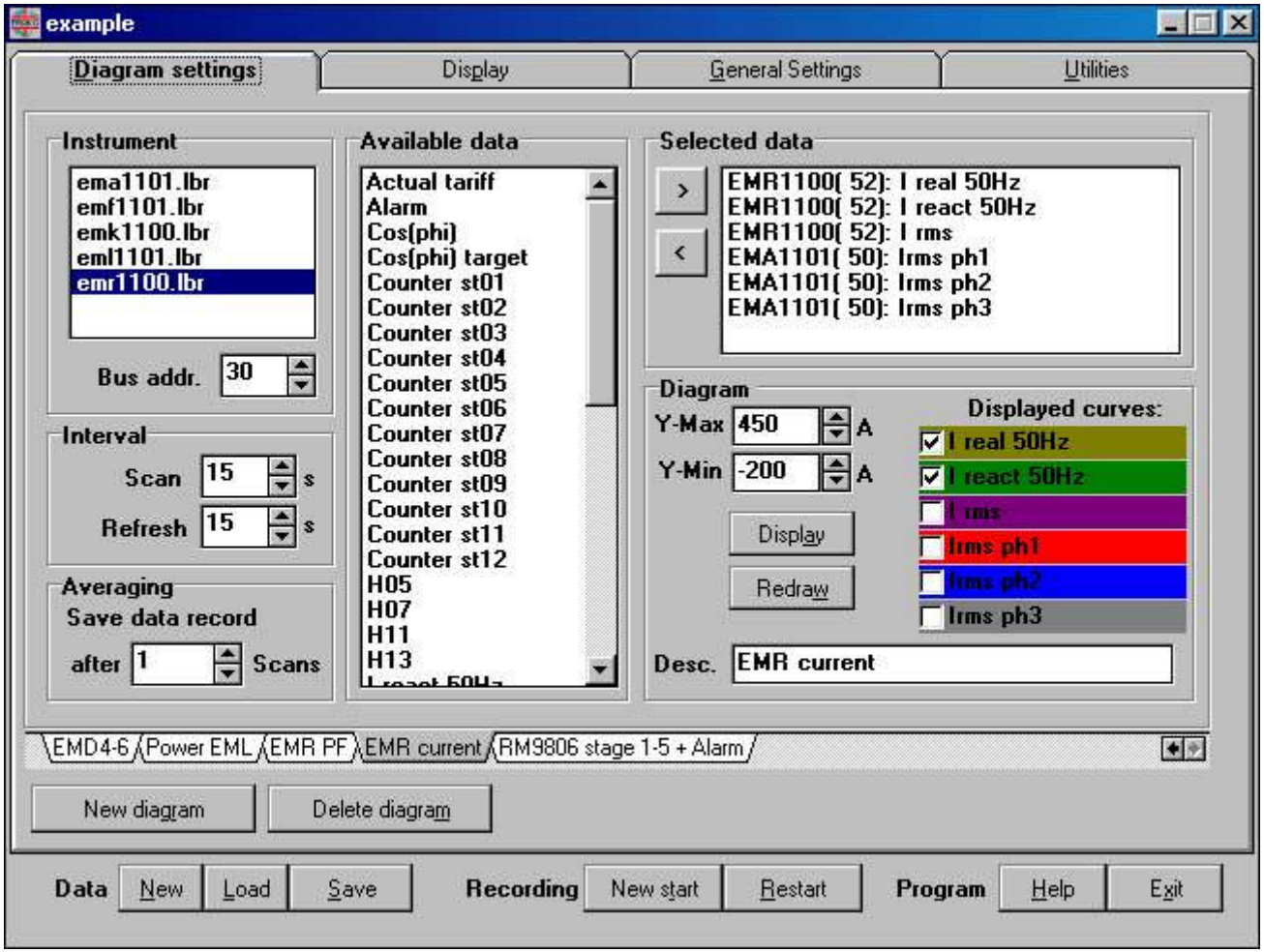
  Metering electrical energy and other energies and media
- 8. Questions & Answers

5. Additional Components and Software

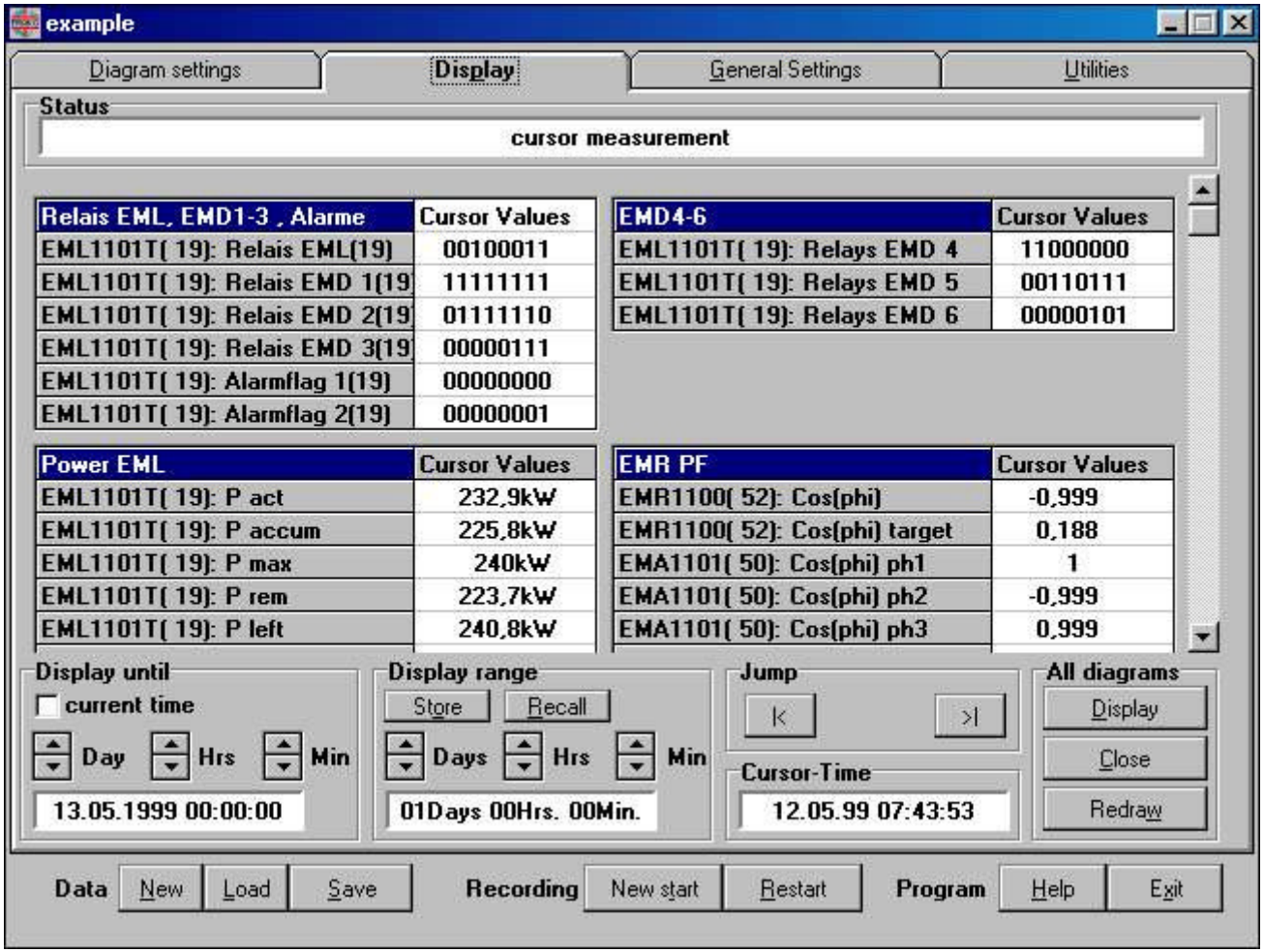
Bus Interface EMP 1100



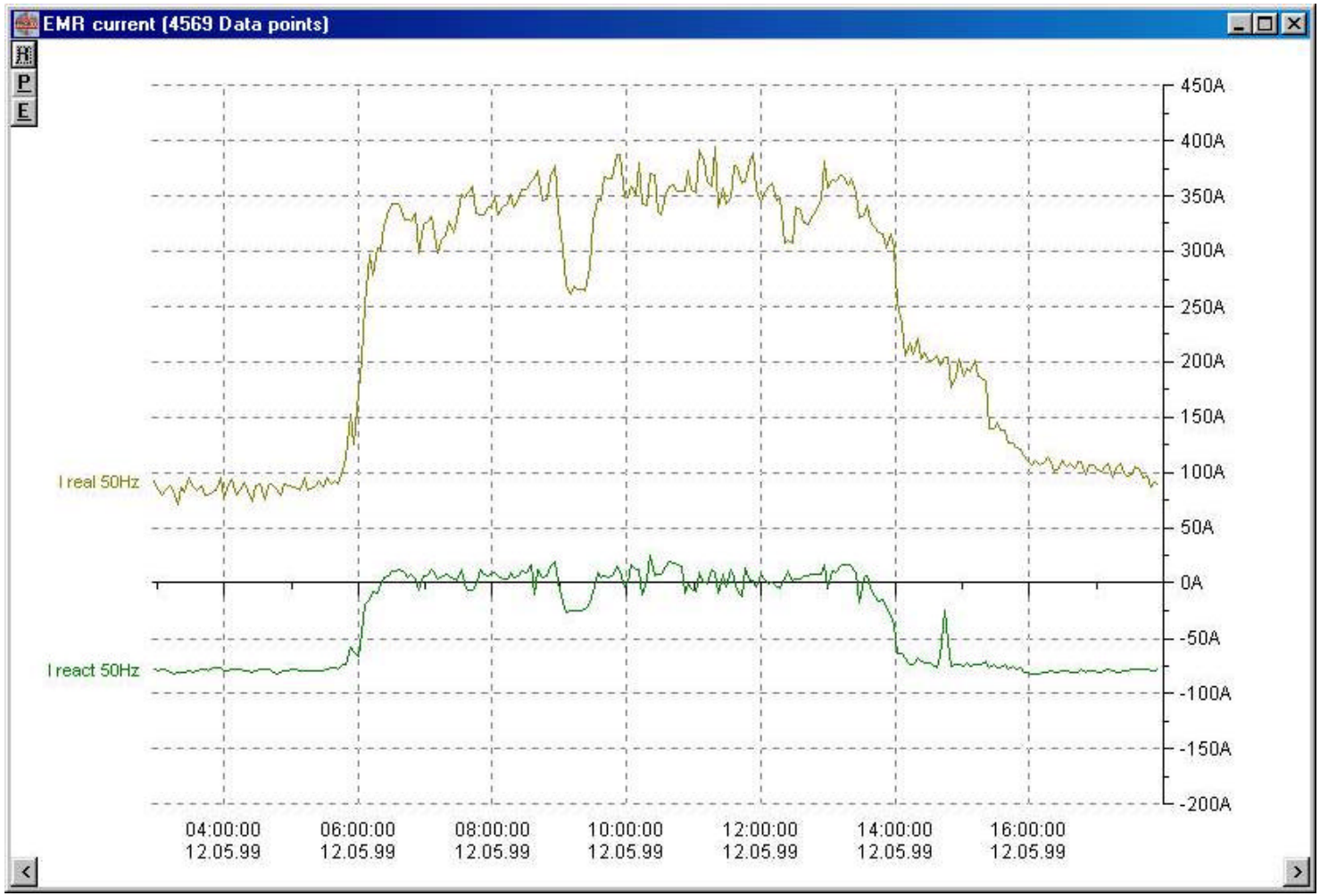
Visualisation Software EM-Graph
Diagram Settings



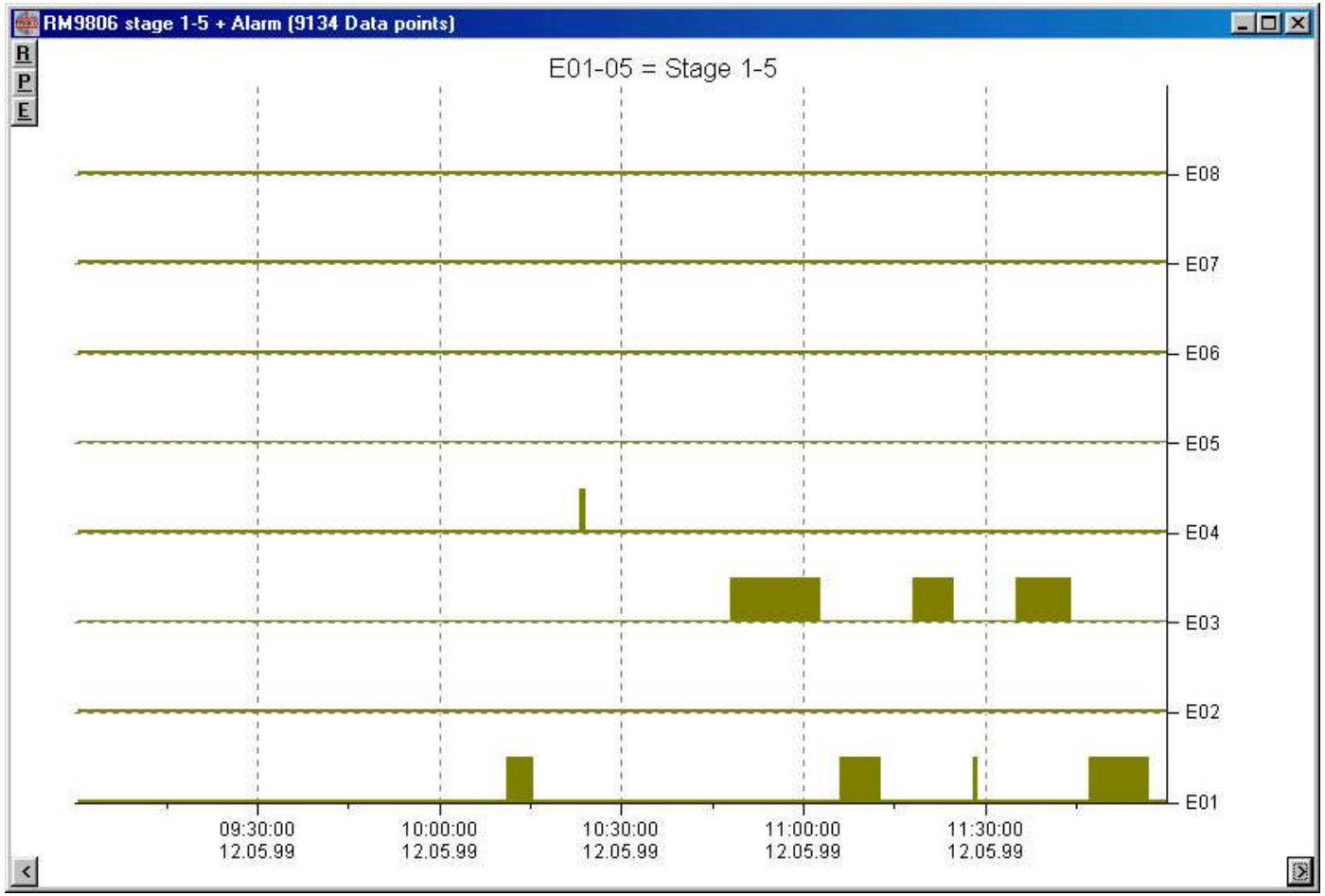
Visualisation Software EM-Graph
Display Mode



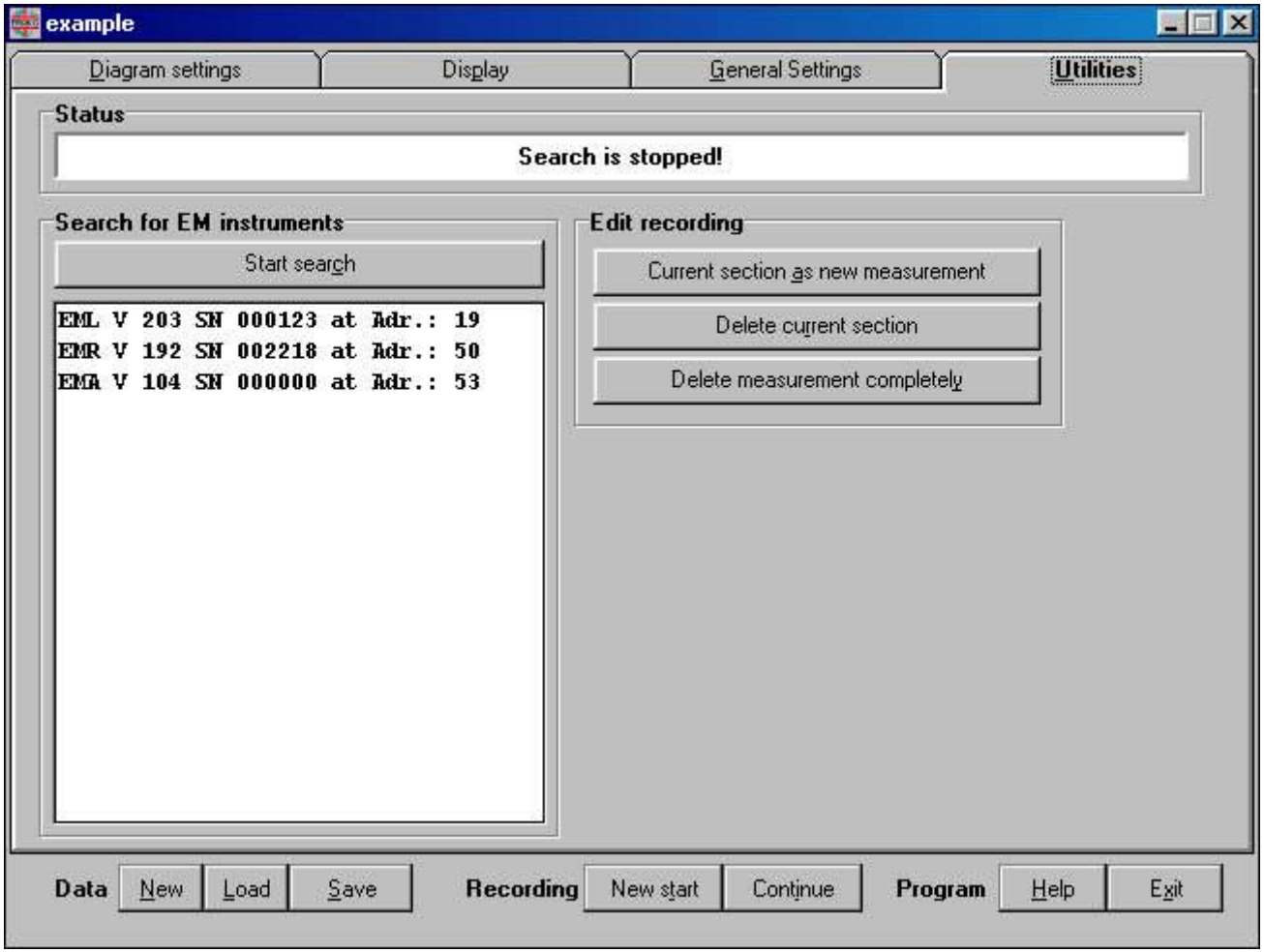
Visualisation Software EM-Graph
Current Analysis



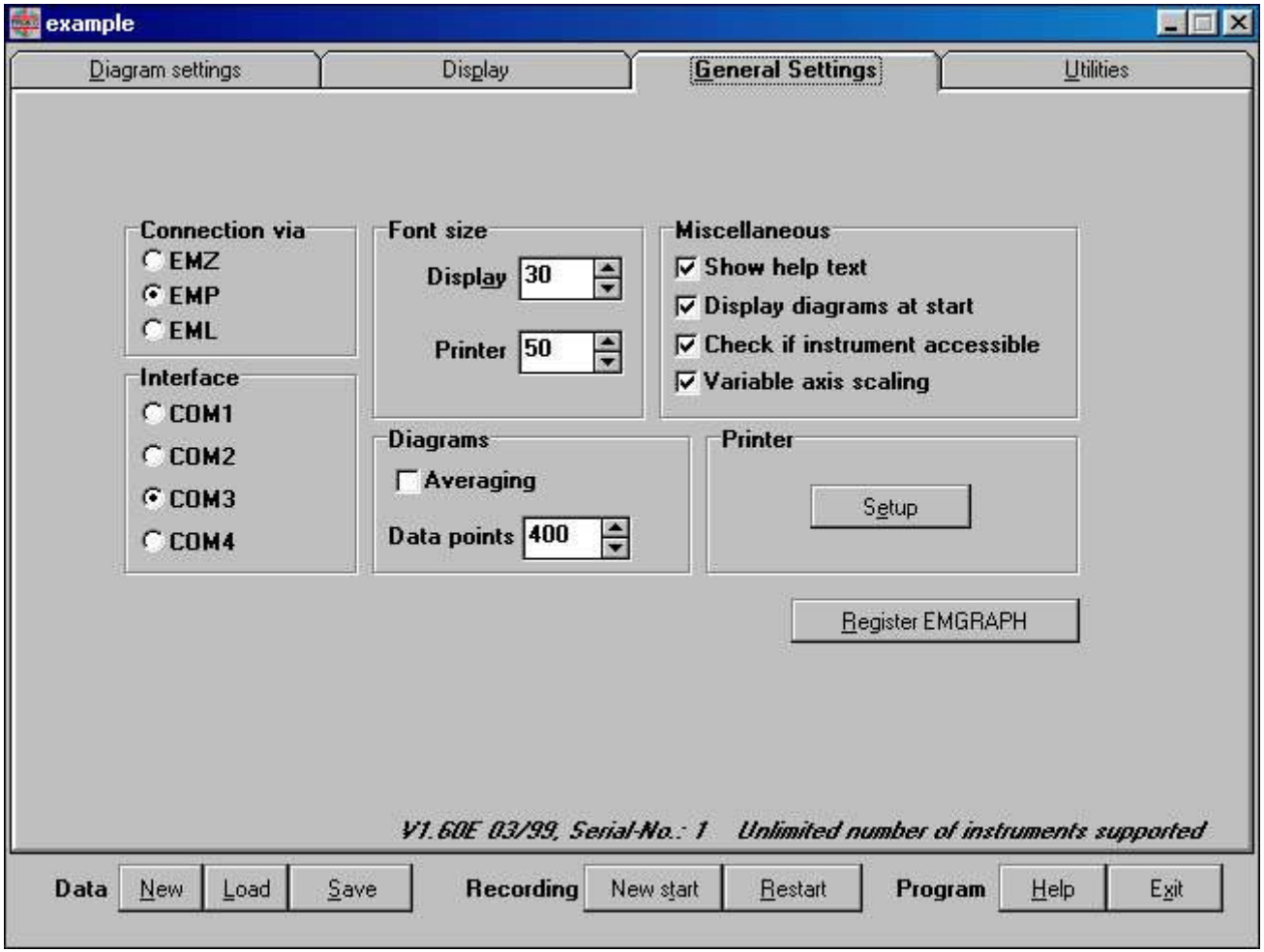
Visualisation Software EM-Graph
Reactive Power Stages



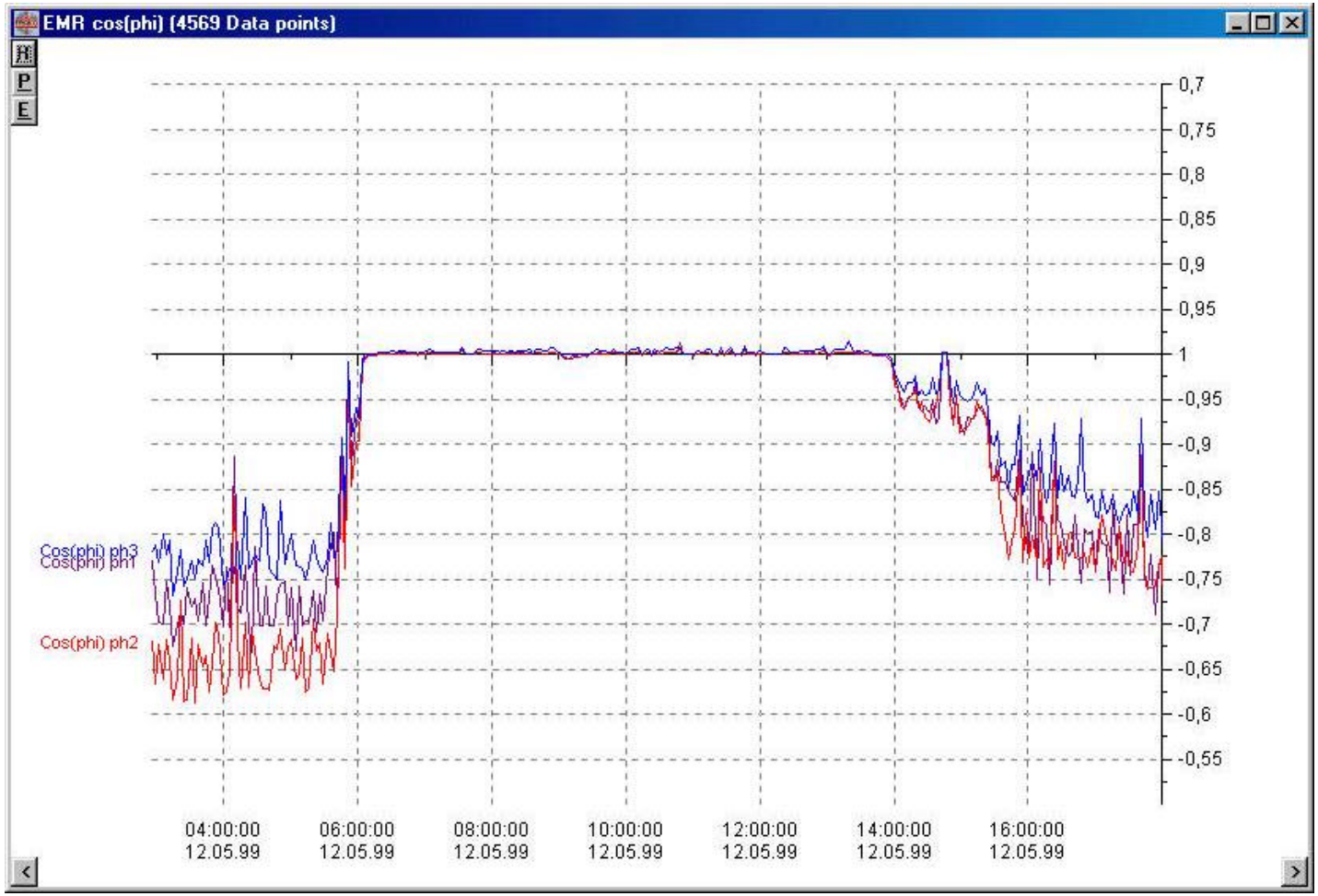
Visualisation Software EM-Graph
Utilities Screen



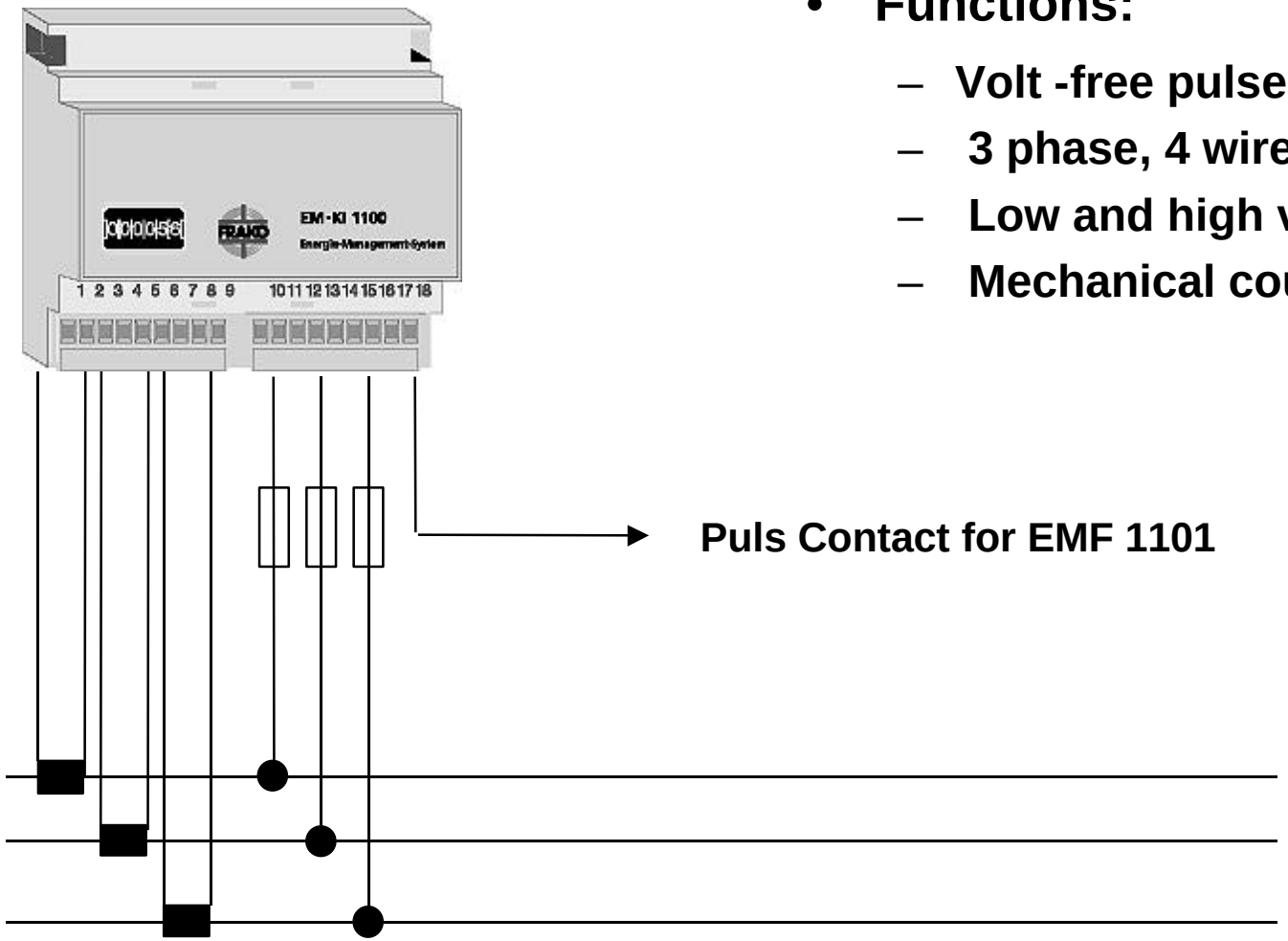
Visualisation Software EM-Graph
General Settings



Visualisation Software EM-Graph
Power Factor Display

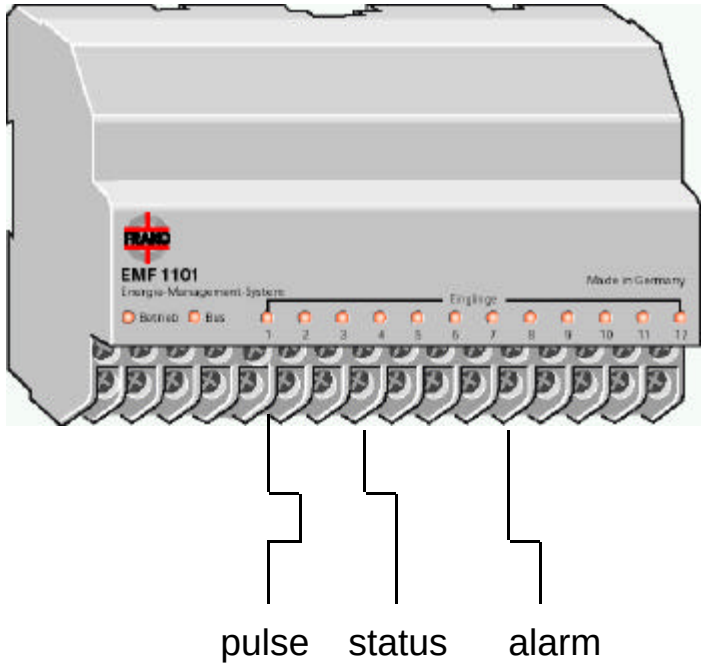


Power Meter EMKI1101/1103



- **Functions:**
  - **Volt -free pulse output**
  - **3 phase, 4 wire connection**
  - **Low and high voltage**
  - **Mechanical counter in kWh**

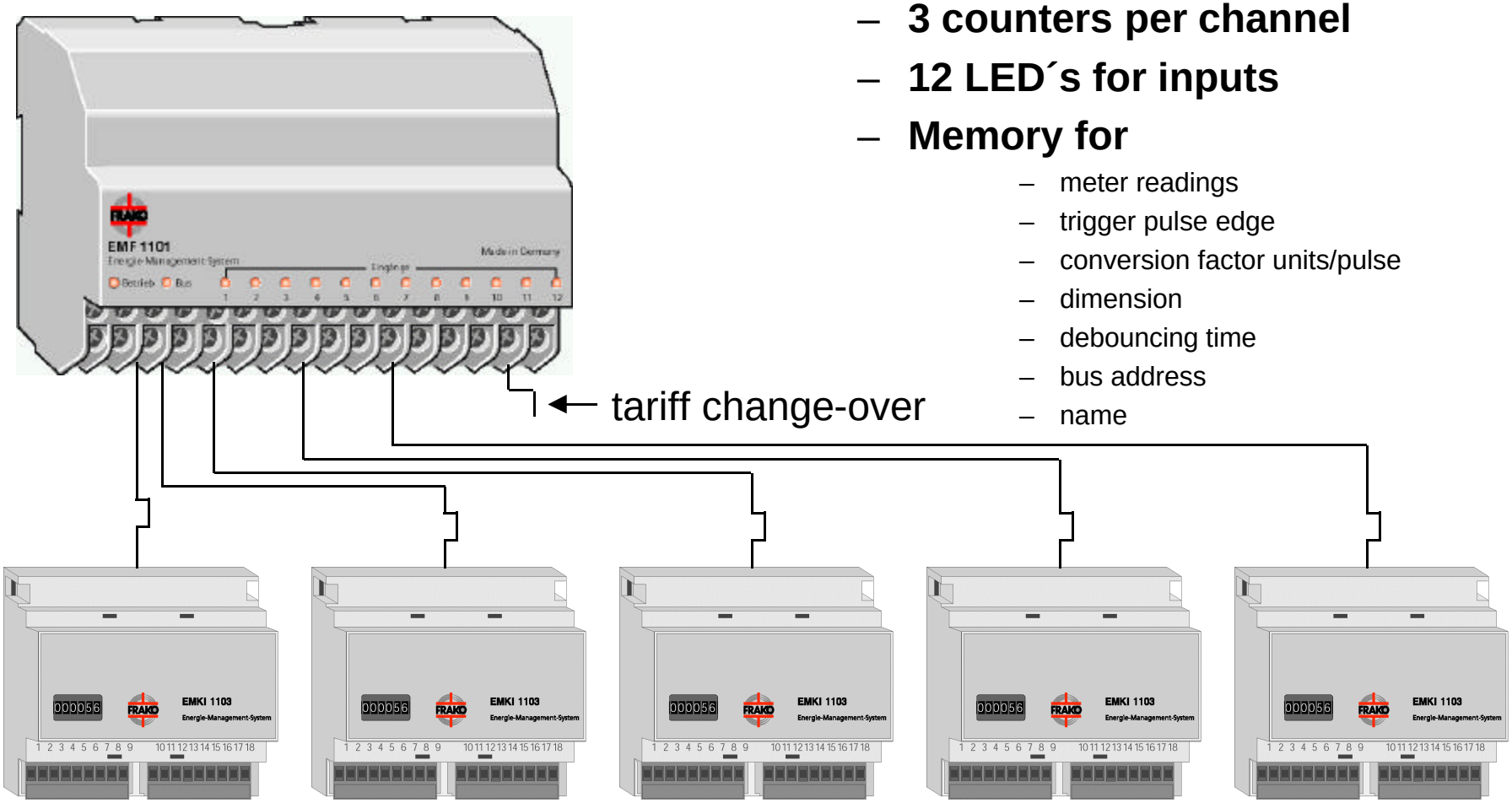
Metering and Status Report Unit EMF 1101



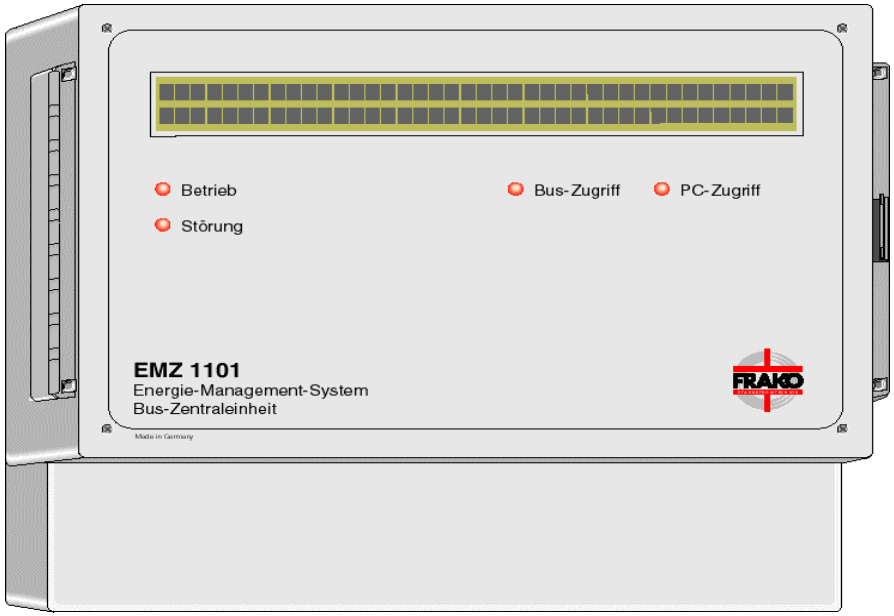
- **Objectives:**
  - **Continues puls sampling independently from bus connection**
  - **Saves counts in case of power failures**
  - **Meter counts can be pre-set**
  - **Counter value is 5 byte on each counting port**
  - **12 ports**
  - **Supplies power for external transformers**
  - **Channel 12 for HT/LT switching**

Metering and Status Report Unit EMF 1101

- **Functions:**
  - **12 binary input channels**
  - **3 counters per channel**
  - **12 LED´s for inputs**
  - **Memory for**
    - meter readings
    - trigger pulse edge
    - conversion factor units/pulse
    - dimension
    - debouncing time
    - bus address
    - name

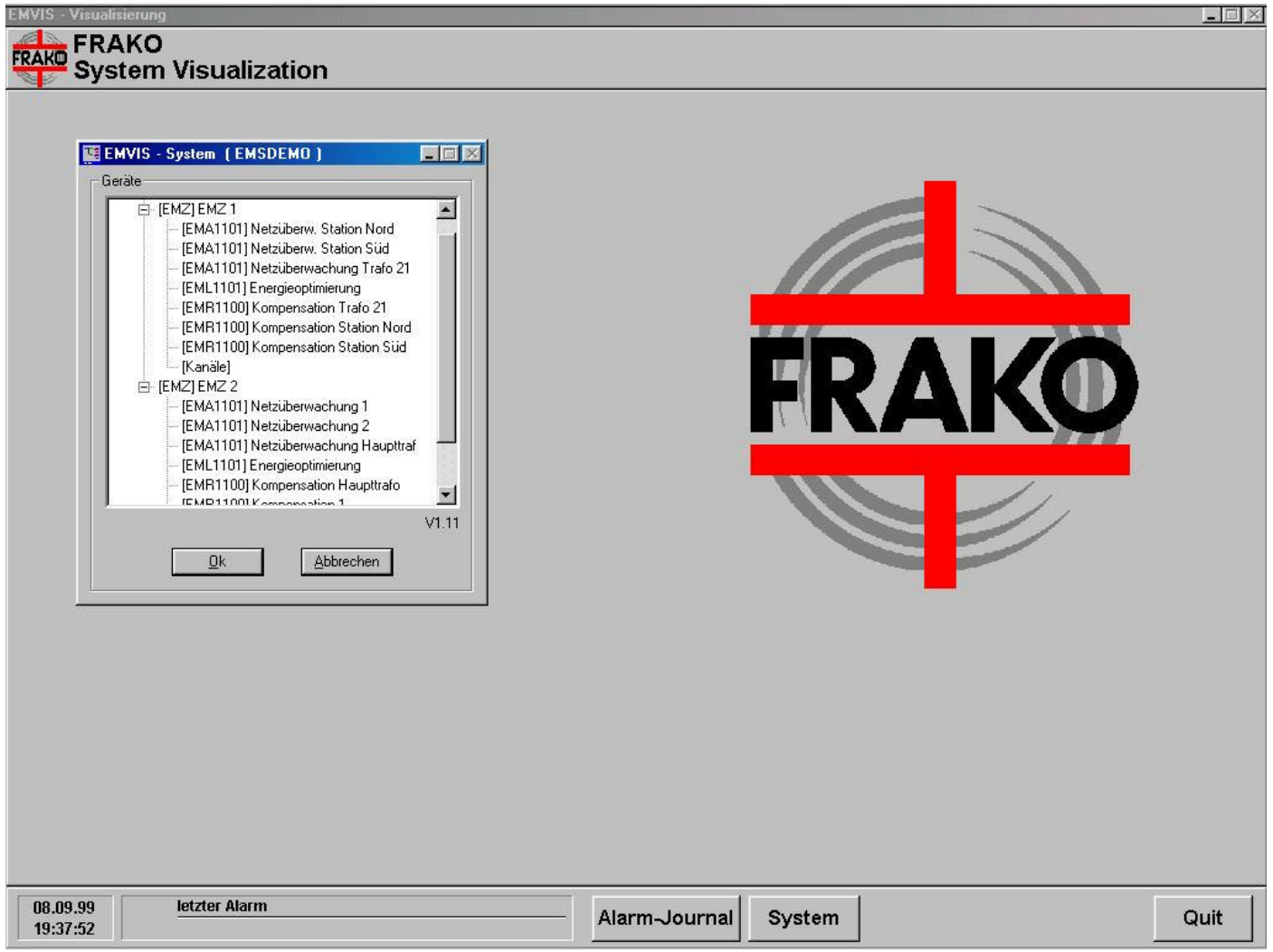


Bus Central Unit EMZ 1200 S, M, L, XL

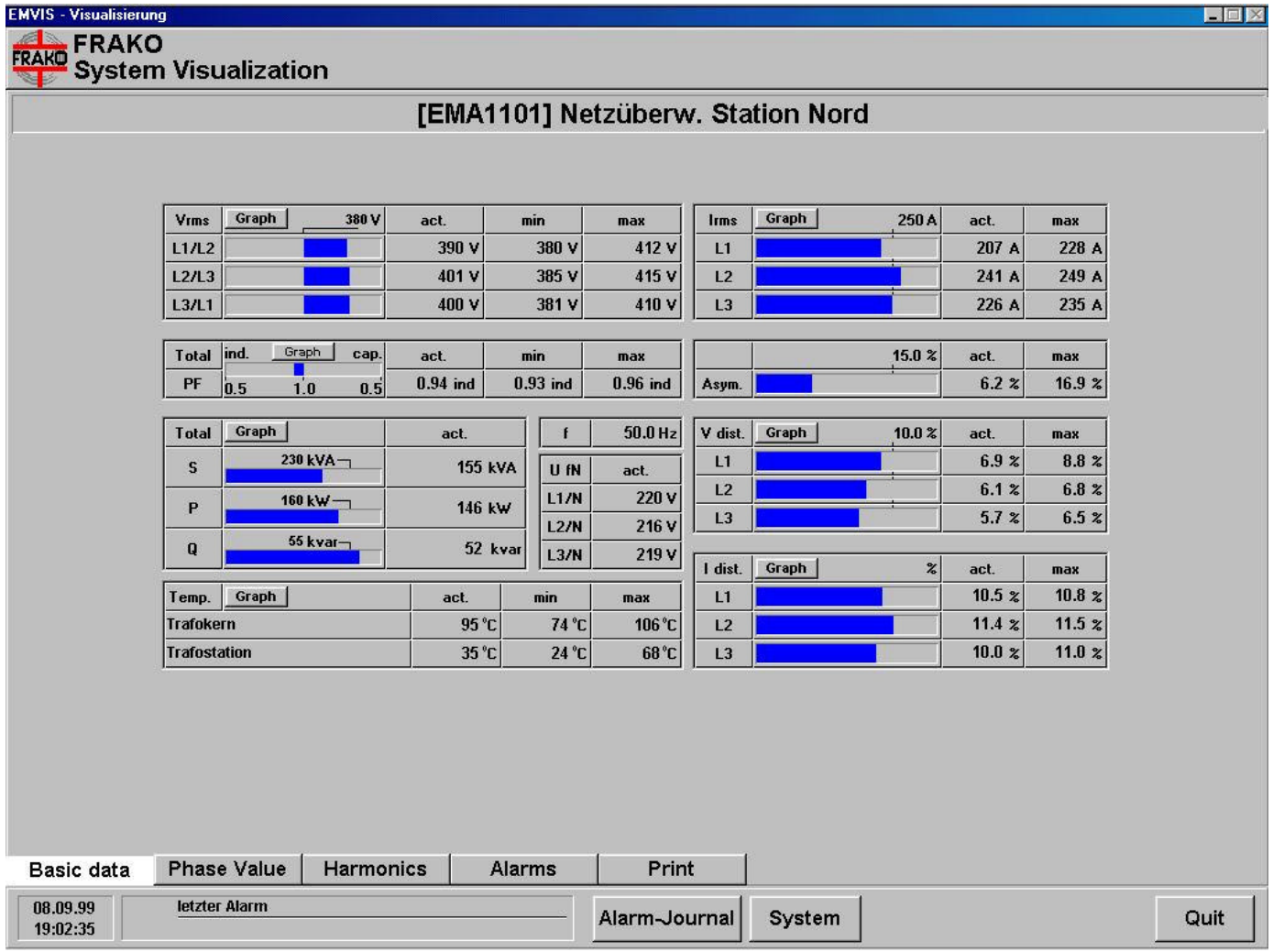


- **Data storage and interface:**
  - **Display of time, date**
  - **Remaining storage capacity**
  - **Memory capacity: 100 days**
  - **Serials RS 232 and RS 485**
  - **Parallel interface (Centronics)**
  - **Built-in flash EPROM**
  - **Alarm messages via printer**
  - **Programmable alarm relay**

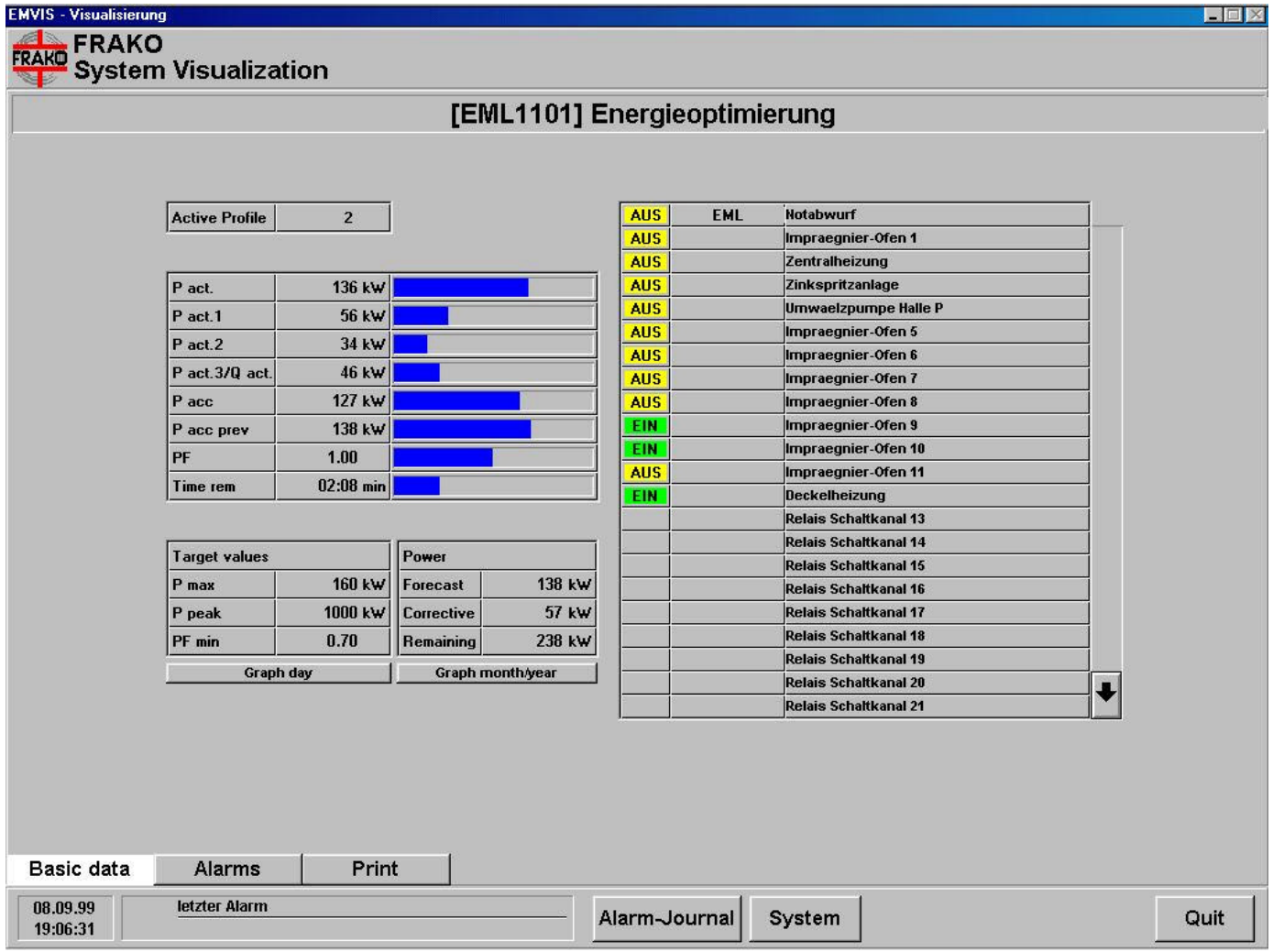
EMVIS
Energy Management Visualization Software



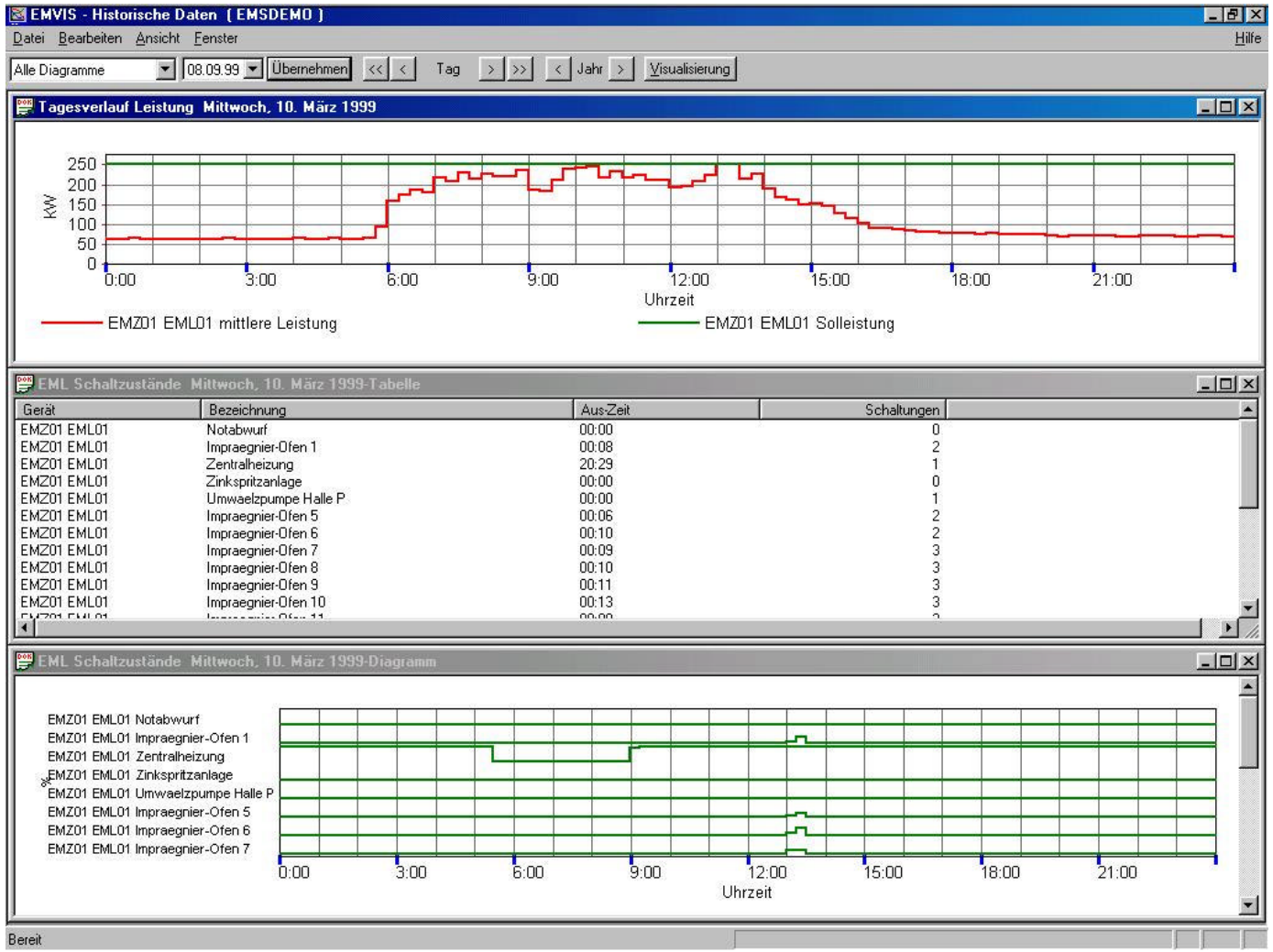
EMVIS Mains Monitoring



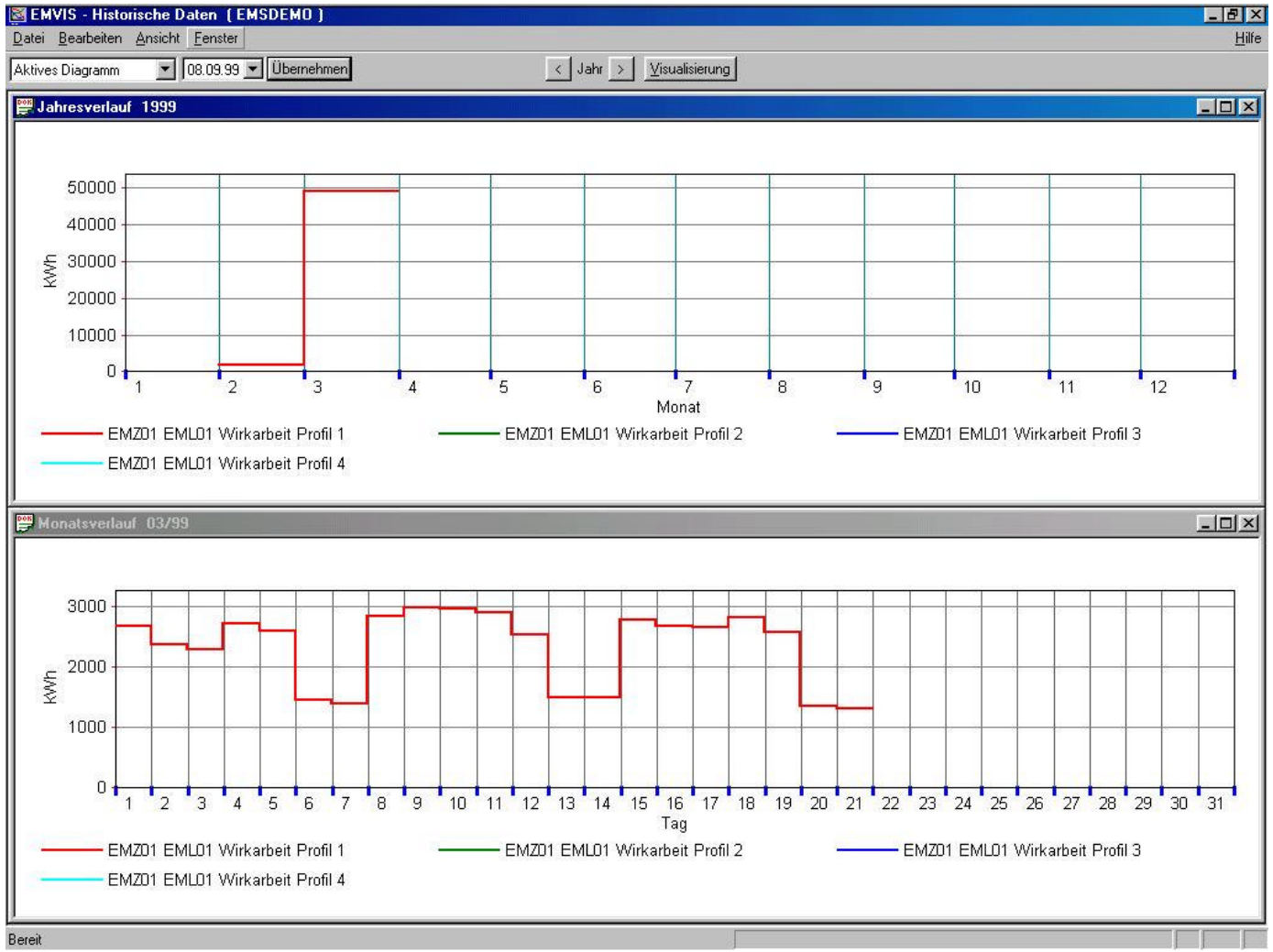
EMVIS Maximum Demand Control



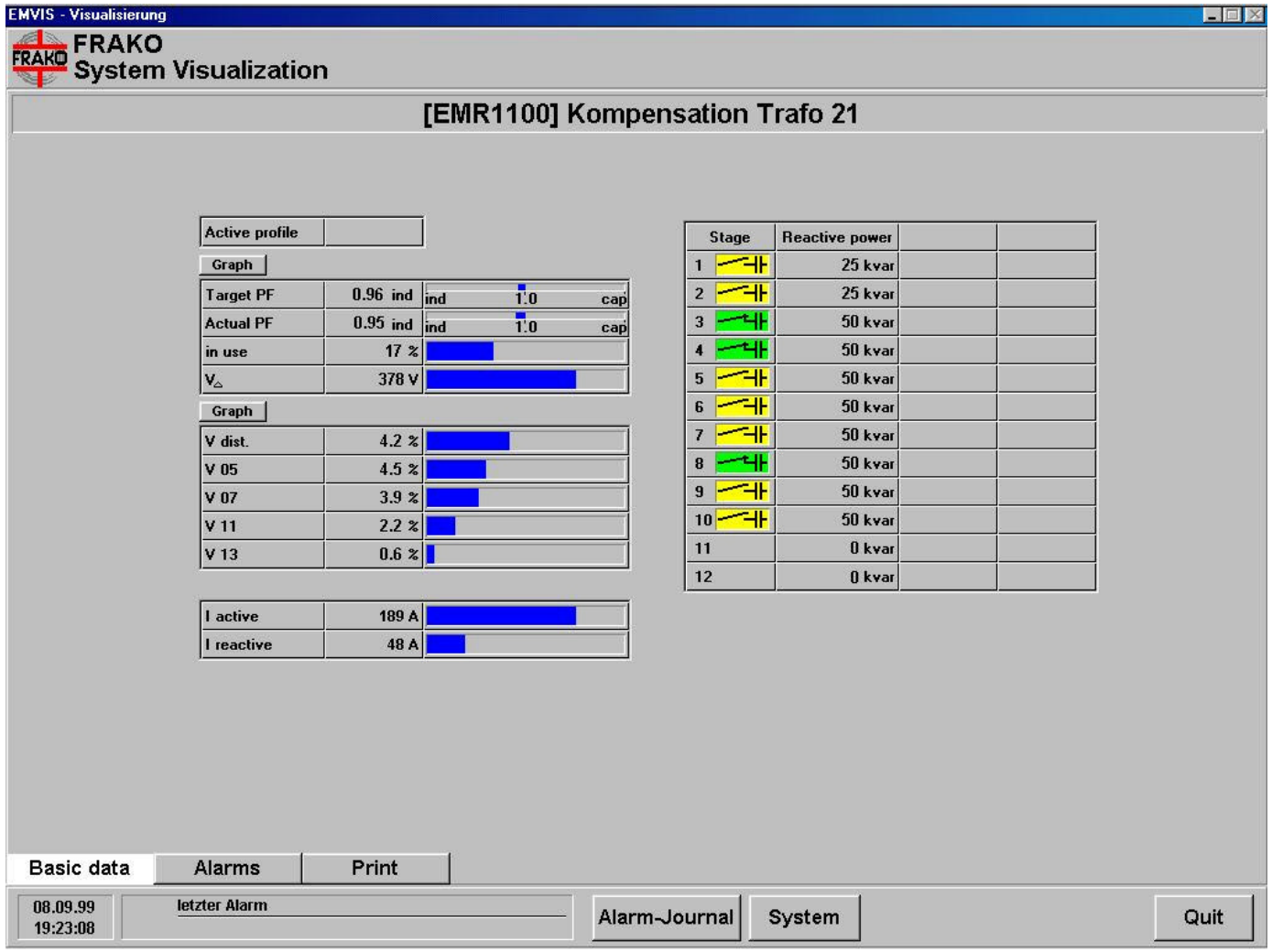
EMVIS Maximum Demand Control



EMVIS Maximum Demand Control

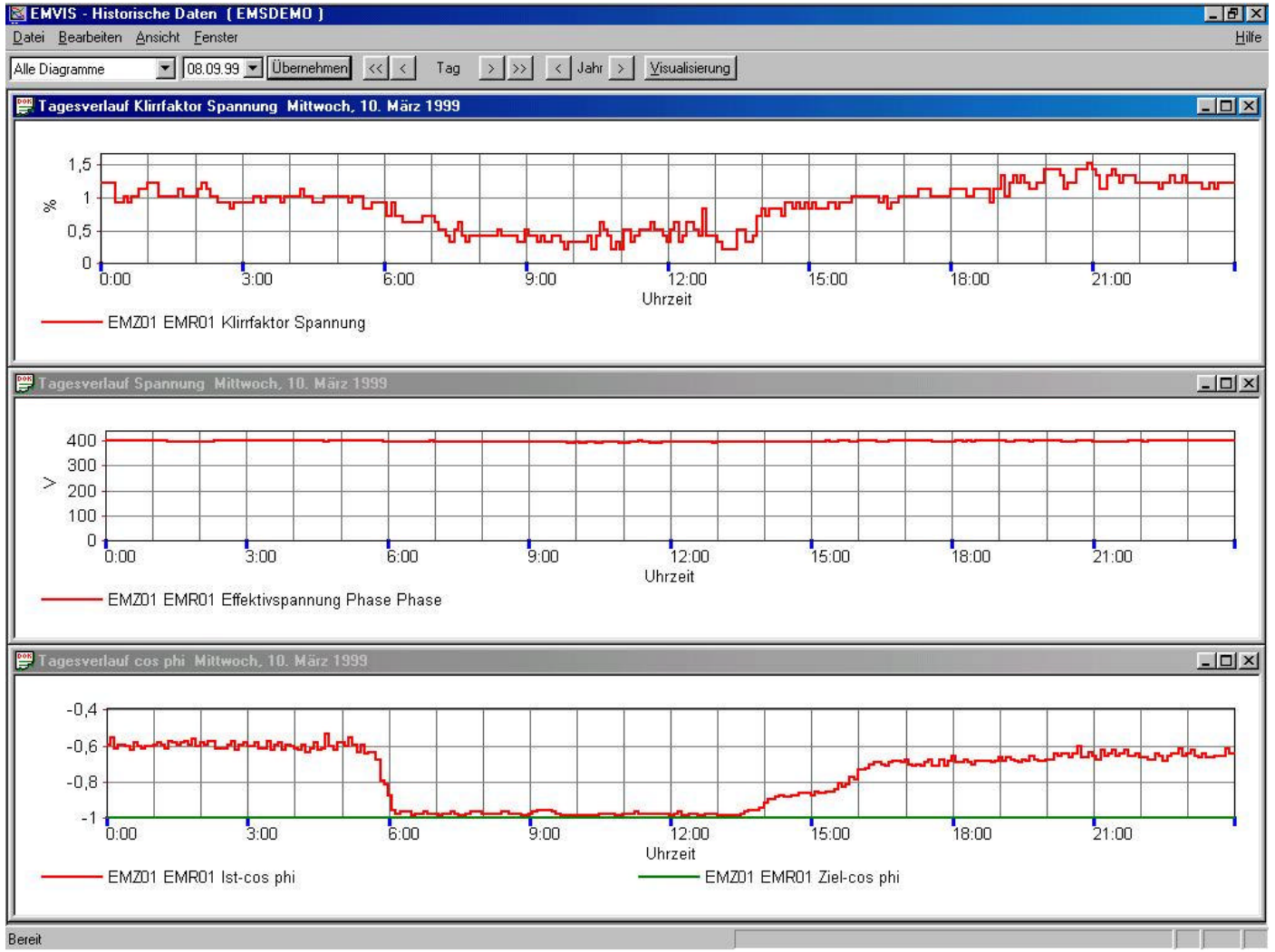


EMVIS Compensation

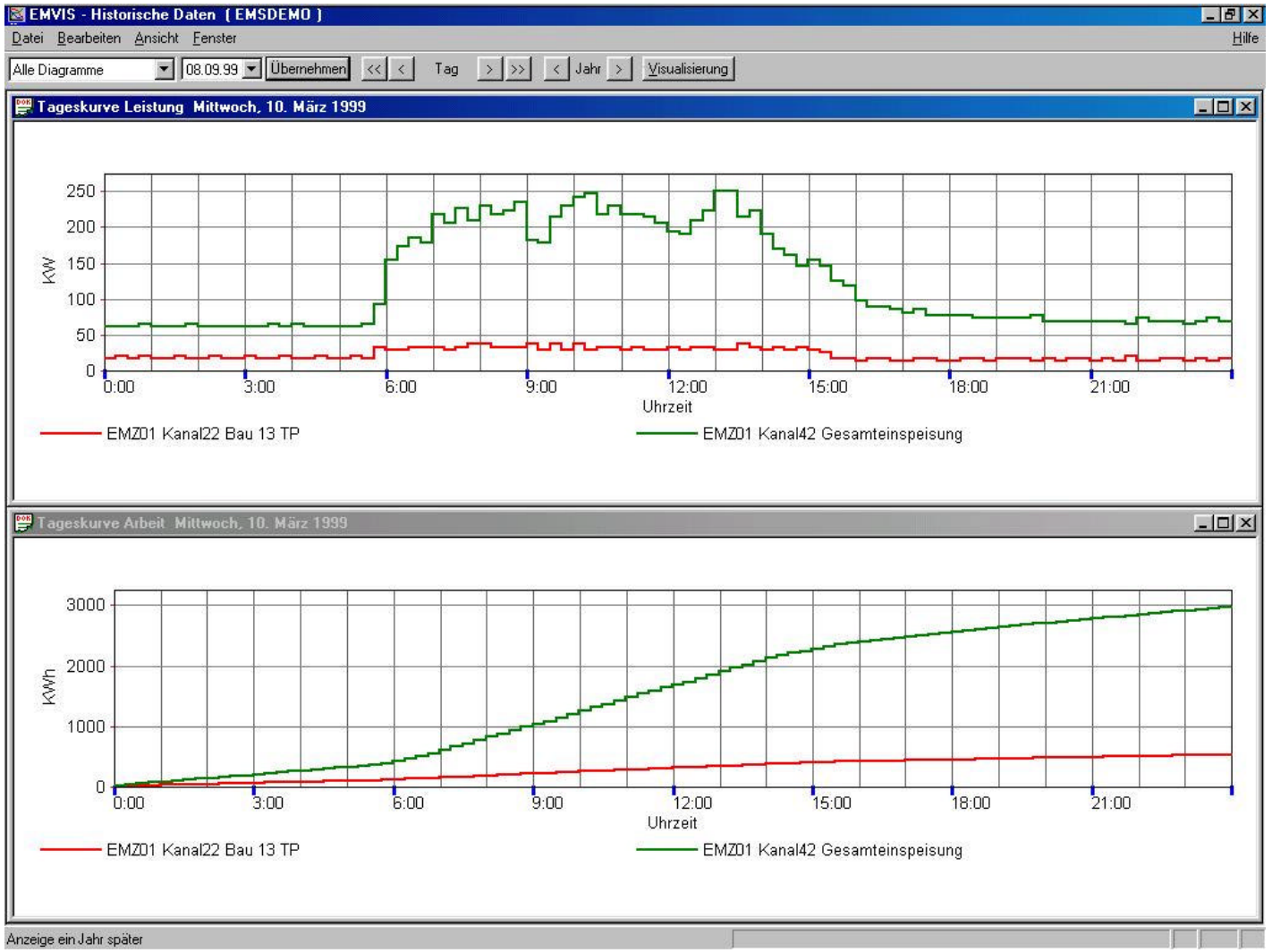


EMVIS Mains Monitoring

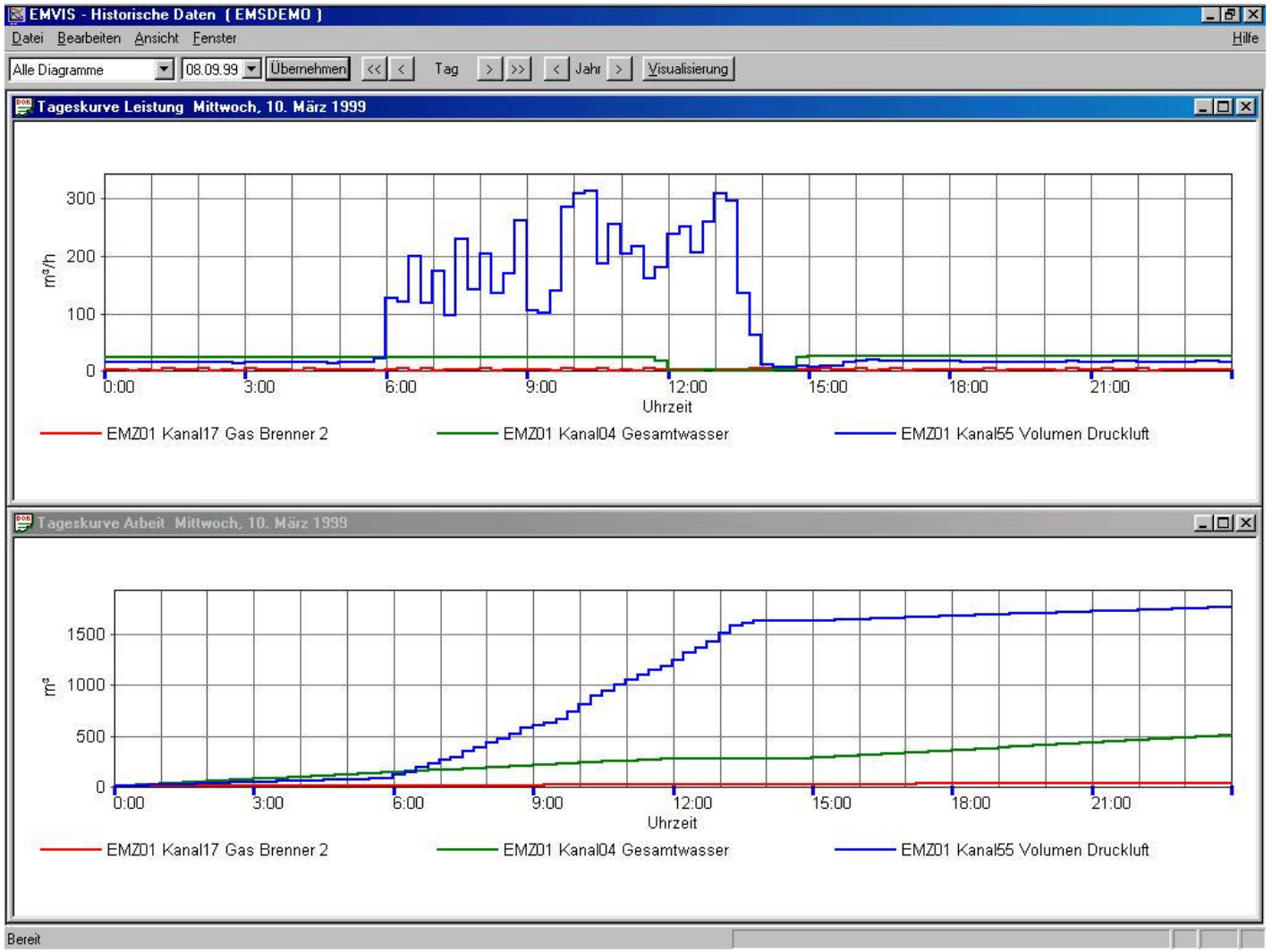
EMVIS Mains Monitoring



EMVIS Energy Meters

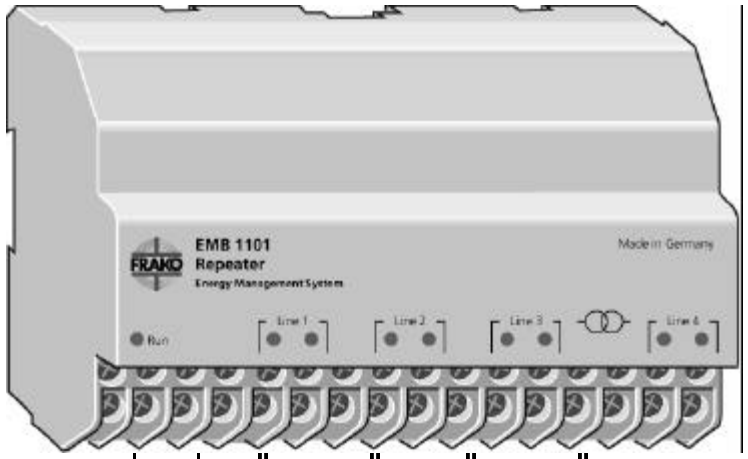


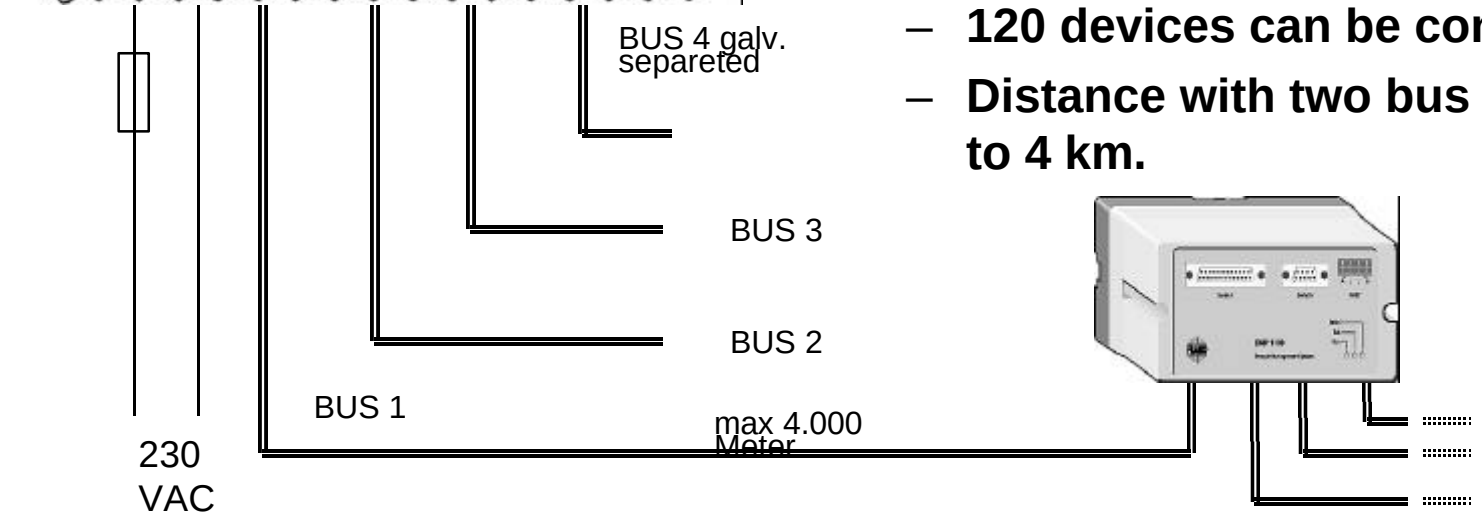
EMVIS Metering of Media



Repeater EMB 1101

- **Bus structure with limitless modularity**
- **Bus faults are detected, reported and logged. The individual devices continue to operate self-sufficiently**
- **Application data:**
  - **Length up to 1.5 km**
  - **With bus couplers up to 15 km**
  - **120 devices can be connected**
  - **Distance with two bus couplers up to 4 km.**





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  - Maximum Demand Set +
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6. FRAKO Energy Management Sets

Mains Monitoring Set

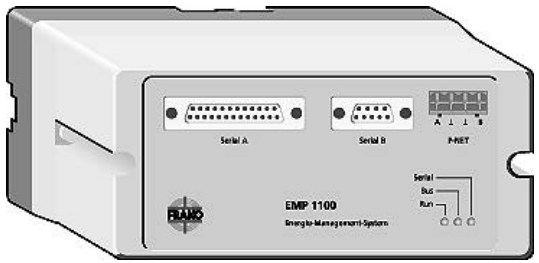
Maximum Demand Set

Maximum Demand Set +

Mains Monitoring Set

- **consisting of**
  - **1 Mains Monitoring Instrument** **EMA 1101**
  - **1 Communication Interface** **EMP 1100**
  - **1 Visualization Software** **EM-Graph**

+



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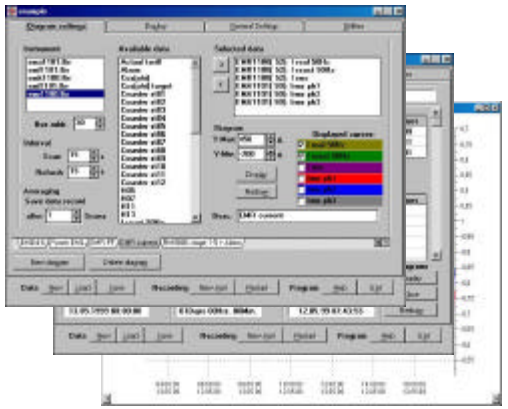


Maximum Demand Sets

- **for 4 channels, consisting of**
  - **1 Maximum Demand Controler** **EML 1101S**
  - **1 Optimizing Software for PC-Operation** **OPT-SW**

- **for 12 channels, consisting of**
  - **1 Maximum Demand Controler** **EML 1101S**
  - **1 Optimizing Software for PC-Operation** **OPT-SW**
  - **1 Extention Module** **EMD 1101**

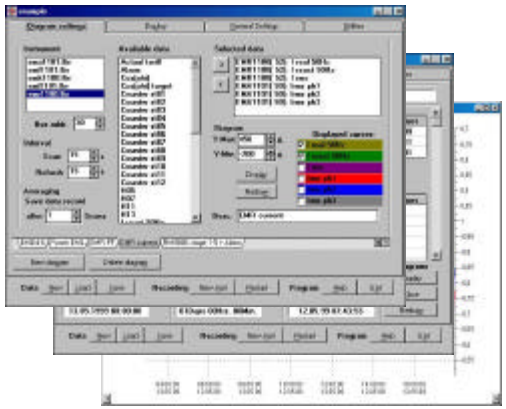
- **for 20 channels, consisting of**
  - **1 Maximum Demand Controler** **EML 1101S**
  - **1 Optimizing Software for PC-Operation** **OPT-SW**
  - **2 Extention Modules** **EMD 1101**

Maximum Demand Sets+

- **created like the Maximum Demand Sets plus**
  - **1 Visualization Software** **EM-Graph**

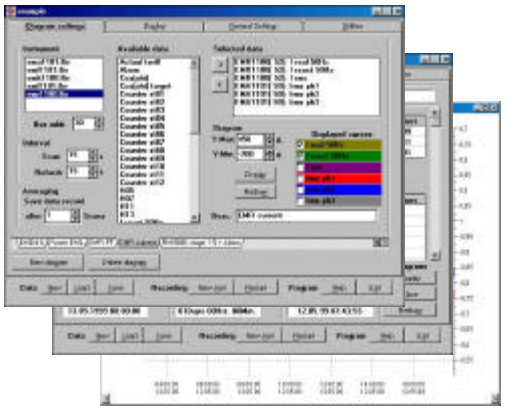
4 Channels

+



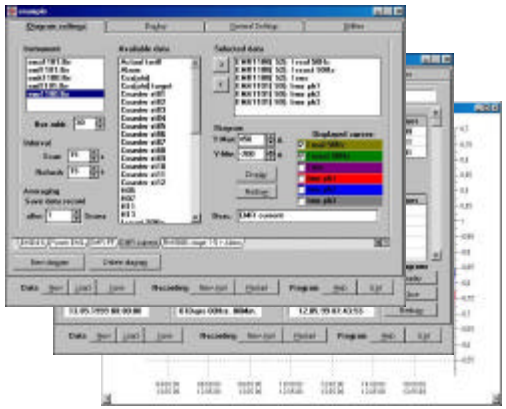
12 Channels

+



20 Channels

+



Energy Management Packages

					Number of sets ordered:		
					1	5	10
Mains Monitoring Set, consisting of							
	-	1 EMA 1101			2.630,00	2.370,00	2.100,00
	-	1 EMP 1100					
	-	1 EMGraph					
Maximum Demand Set, consisting of				**Number of channels**			
	-	1 EML 1101S		**4**	1.980,00	1.760,00	1.590,00
	-	1 OPT-SW	- 1 EMD 1101	**12**	3.080,00	2.740,00	2.470,00
			- 2 EMD 1101	**20**	4.700,00	4.180,00	3.760,00
Maximum Demand Set +, consisting of							
	-	1 EML 1101S		**4**	2.780,00	2.470,00	2.230,00
	-	1 OPT-SW	- 1 EMD 1101	**12**	3.880,00	3.450,00	3.110,00
+	-	1 EMGraph	- 2 EMD 1101	**20**	5.500,00	4.890,00	4.400,00
					Net Pricing in DM per Set		

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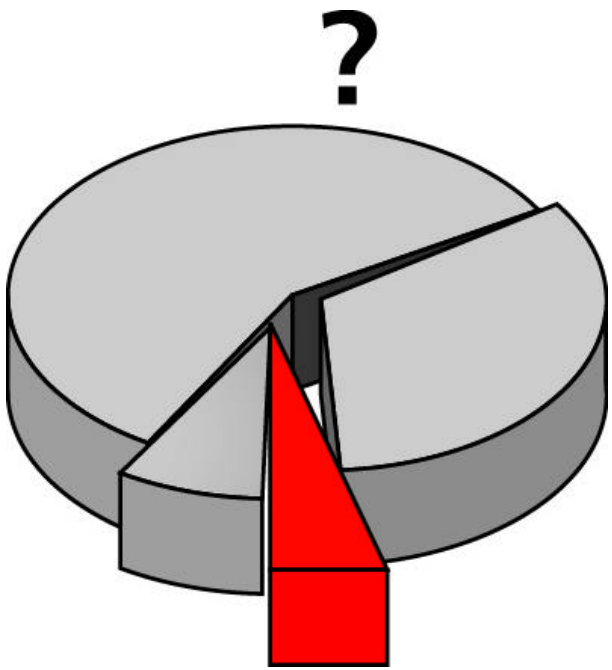
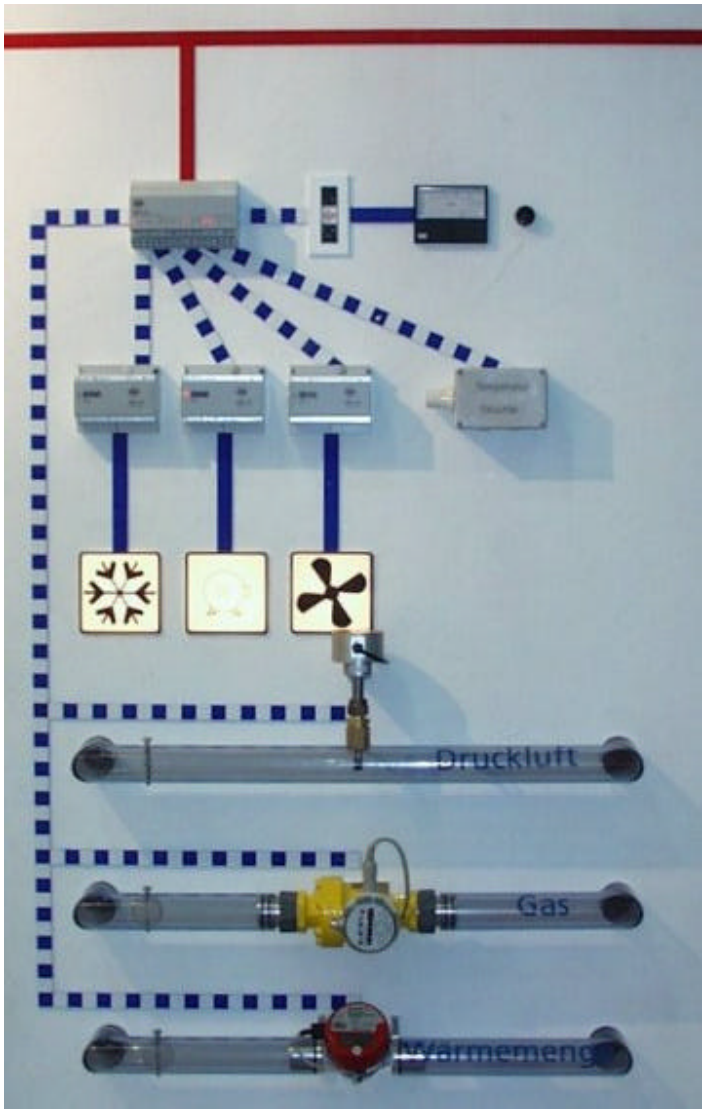
7. Integrated FRAKO Energy Management

Various installations utilizing the FRAKO Starkstrombus™

Samples of Integrated FRAKO EMS

- **Transparency of interrelations releases potential for savings**

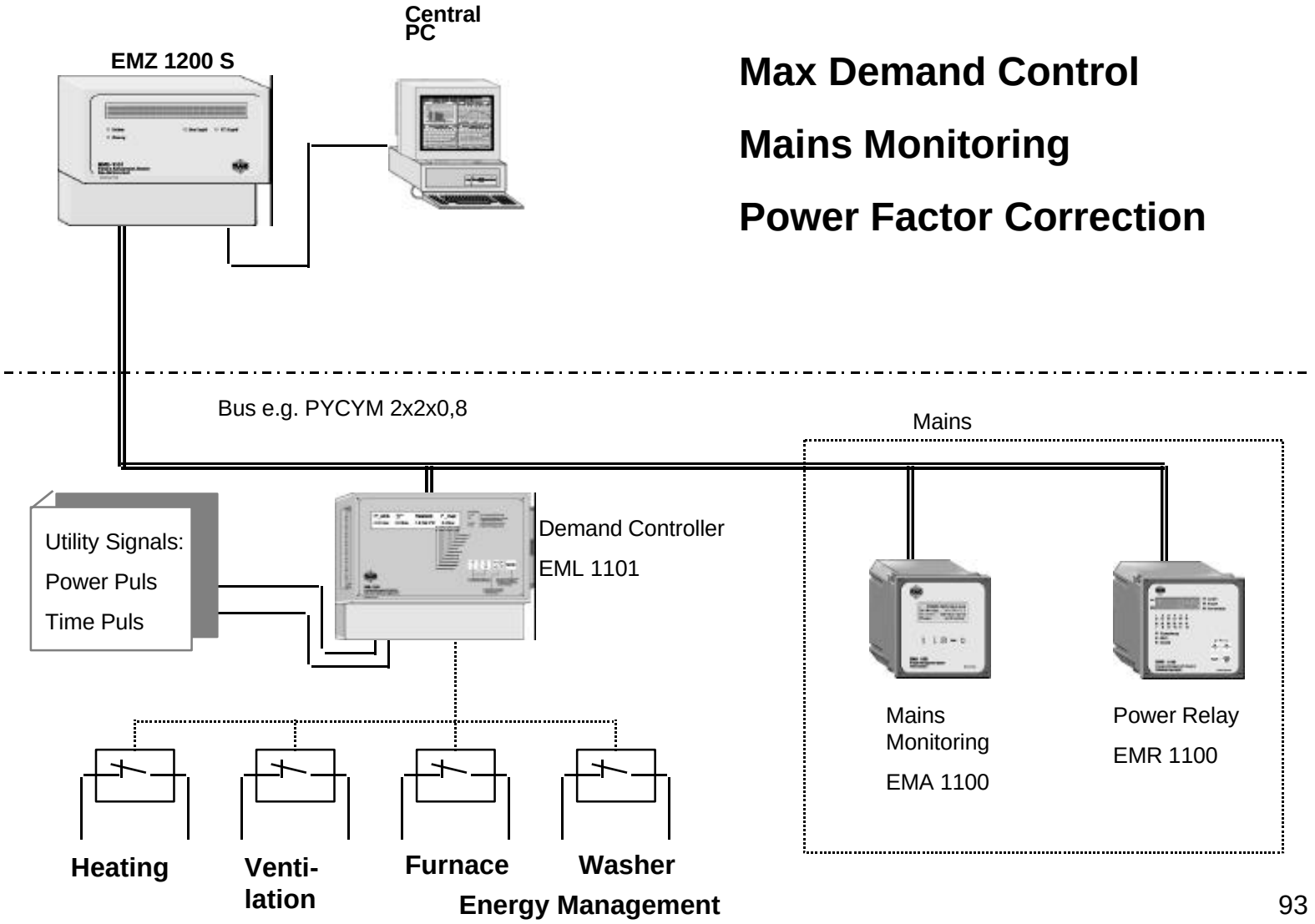




Max Demand Control

Mains Monitoring

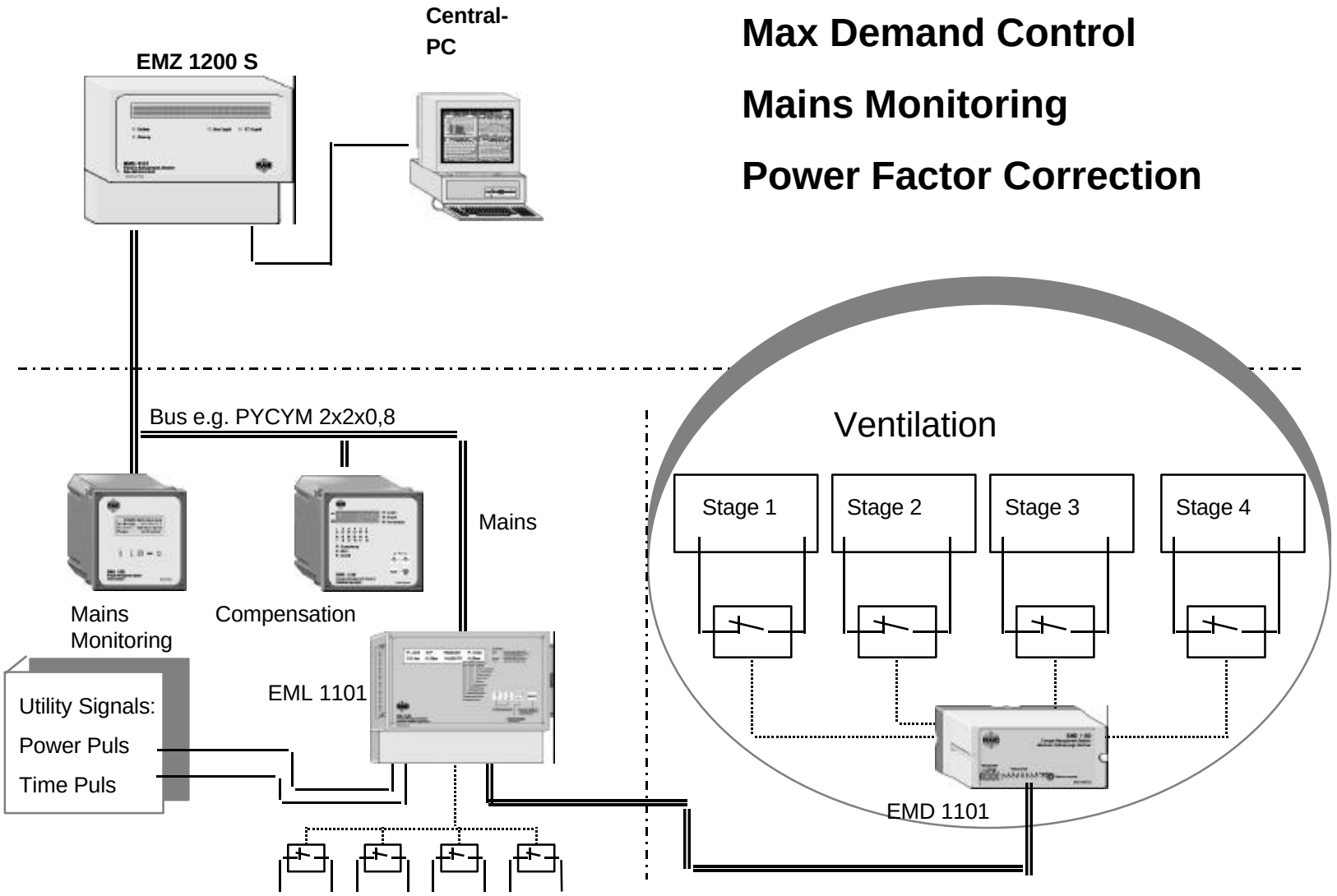
Power Factor Correction



Max Demand Control

Mains Monitoring

Power Factor Correction



Summary (1)

- **Reactive power compensation enables you to eliminate costs for reactive power**
- **Maximum Demand Control reduces costs for peak performance**
- **Energy Management systems originally designed for electrical power are also capable of mapping metering data and status information of other media**

Summary (2)

- **Automatic recording, documentation and graphical processing of energy data create transparency**
- **Operational reliability increases**
- **Insight into and awareness of operational process is created**
- **It is not only possible to take cost-effective measures on specific processes but also to evaluate the results.**

It’s all about saving your money

FRAKO Power Factor Correction and Energy Management

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