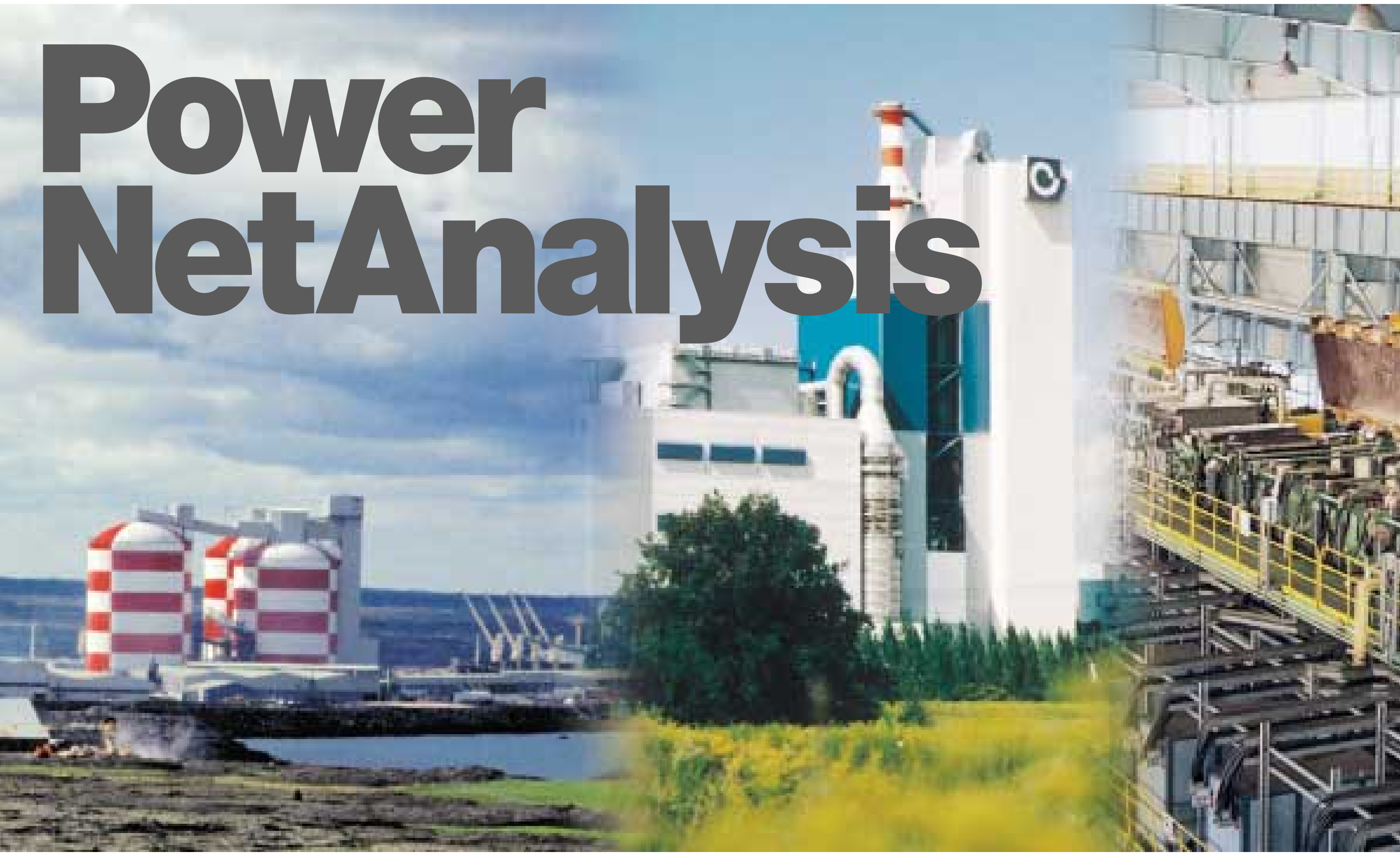
# Power NetAnalysis

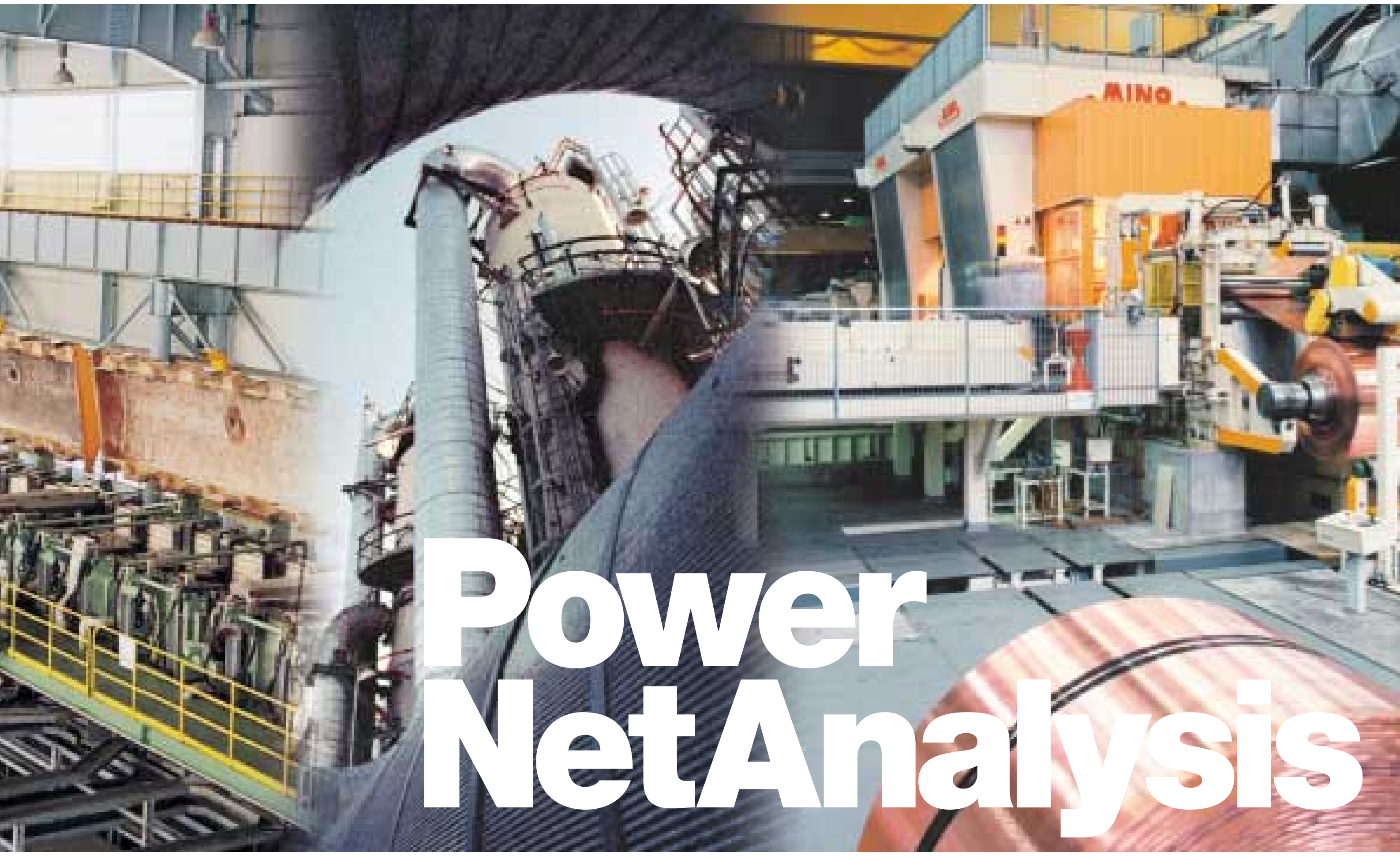


## Optimizing industrial networks

Lars Hartung, Thomas Eulitz, Wolfgang Biergans

**Industrial networks, already complex by nature, are constantly being modified as industry expands and modernizes to keep pace with changing markets. Optimizing processes and improving their performance, however, often leads to more power being consumed because the process energy is converted in a shorter time. This can cause voltage problems in weak factory networks. Only in very few cases are disturbances due to voltage dips interpreted as such, since they tend to occur sporadically and are difficult to replicate. In extreme cases, poor power quality can be the cause of damage to equipment, leading to much longer downtimes.**

Power NetAnalysis is a service offered by ABB to industry to help it identify weak points in its power networks and to speed up approval for planned extensions by verifying up front, with the help of computed load forecasts, how they are likely to influence the power grid. Mathematical modeling and on-site measurements provide the basis for strategies for complying with limits and standards under given economic constraints, as well as proposals for solutions to



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existing problems and simulations of the possible consequences of planned network extensions.

The goal of Power NetAnalysis is to determine how industrial networks can be utilized better. To this end, ABB investigates different concepts, takes account of the capital investment each requires, describes solutions to existing network problems, and suggests how planned extensions to production plant could be configured in a way that is network-compatible. The advantages of this are clear: fewer operational disturbances due to voltage fluctuation, plus higher availability for the installation. Often, the utilization of the power supply system can also be improved – and the cost of the energy lowered – by reducing the reactive power. The results of the analysis provide valuable information about how a planned project will comply with power quality guidelines, eg the IEEE recommendations or EN legislation. A question that often arises when planning new production lines or upgrading plants is: 'How will the new plant equipment affect network stability and what disturbances could they cause in the network?'. Converter manufacturers cannot give a 'blanket' guarantee that no inadmissible power system disturbances will be caused by their products, since such disturbances depend, in the first place, on the stability of the in-plant network.

Power NetAnalysis has benefits for all industrial plants operating machines consuming large amounts of electrical energy. The wide spectrum of possible disturbances ranges from all-too-frequent replacement of fluorescent tubes through plant outages to adverse effects on the ripple control frequencies used to operate street lighting. ABB has already performed network analyses for most industrial branches. What the service program is capable of can be seen from the following example from the metallurgical industry, in which extreme load cycles had been causing voltage problems on a very regular basis.

**The problem**

In 1997, after a new tandem mill for copper and brass strip had been installed at Schwermetall Halbzeugwerk GmbH & Co. KG in Stolberg, Germany, huge voltage fluctuations occurred that disturbed operation of not only the new mill but also the adjacent cutting machine. This manifested itself, in particular, during the initial pass, when the load peaked at double the nominal power. The regulating transformers tried to stabilize the medium voltage by initiating frequent tap-changing, but this took place too slowly to prevent over-voltages from occurring. These caused damage to the cutting machine and resulted in excessive outages, whereupon ABB was contracted to perform a network analysis.

**Net calculation**

Besides the damage caused at the 500-V level, the voltage problems also affected the medium-voltage loads. To determine the full extent of these problems, a detailed analysis was carried out for both the critical 10-kV and the low-voltage level, and therefore included all the main loads, eg the large drives. In order to realistically simulate the plant, it was also necessary to take account of the converters and the system perturbations they cause. The various types of drive (cycloconverters and DC drives for the tandem mill and older types of DC drive for the cutting machine) therefore appeared in the analysis as mathematical models defined by their electrical behavior at typical operating points.
At the medium-voltage level, the network model simulates the function of the filter

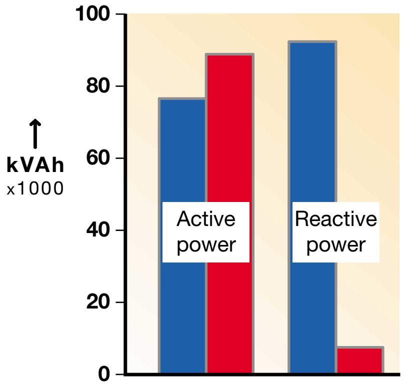
## CALPOS® – planning and information system for power supply networks

With electrical energy markets all over the world deregulating, the utilities are in urgent need of new planning tools that will enable them to succeed in the newly competitive environment. CALPOS® (www.calpos.de) meets this need in every respect: With it, industrial and supply networks at any voltage level and with any network configuration or number of nodes, can be quickly and interactively defined, analyzed and optimized. Besides the 'classic' network calculation modules, eg for calculating load flow and short circuits, for dimensioning the protection or for dynamic system analyses, CALPOS® also offers modules, eg for probabilistic reliability analyses or reliability-oriented maintenance optimization, that tackle the new questions that the liberalization of the energy markets has raised.

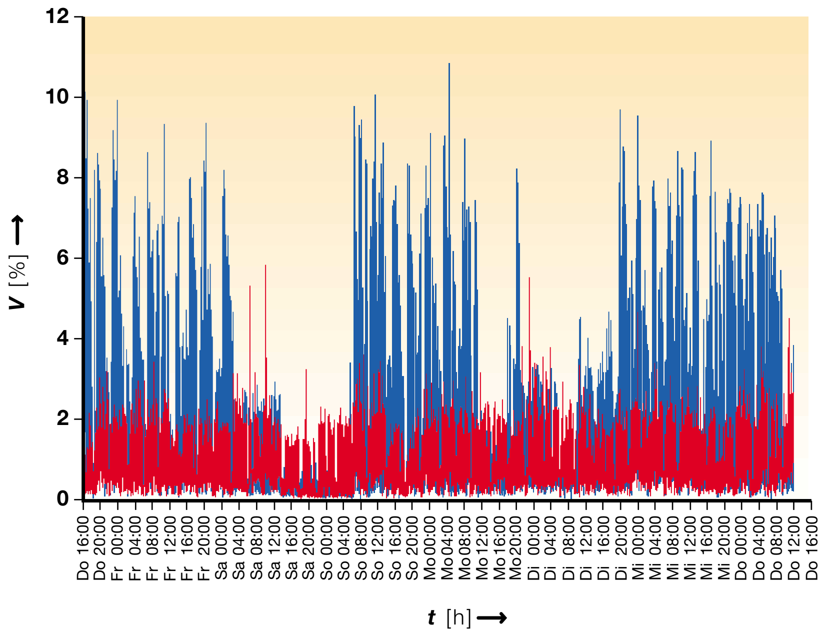
The probabilistic reliability analysis, for example, allows the supply reliability of different plant and network concepts to be quantified, and with it the cost-benefit ratio evaluated far beyond the traditional, qualitative (*n*-1) criterion. In addition, the supply reliability and voltage quality of individual industrial, commercial or private consumers in existing networks can be quantified and used as a measure of the supply quality or for a financial evaluation.

Because of its modularity, CALPOS® enables the network planner to create a PC-based planning system exactly to his own specifications. In such a case, CALPOS® increases the user's productivity through, among other things, a data management system with automatic plausibility check as well as integrated interfaces to all commercially available database formats. A direct link to Geographic Information Systems (GIS) or the user's own network information systems guarantees optimum user friendliness. That it also features an interactive graphic operator interface to the Windows standard goes without saying.

**1** Daily active and reactive power consumption with (red) and without (blue) dynamic compensation




**2** Fluctuation of medium voltage (*V*) with (red) and without (blue) dynamic compensation



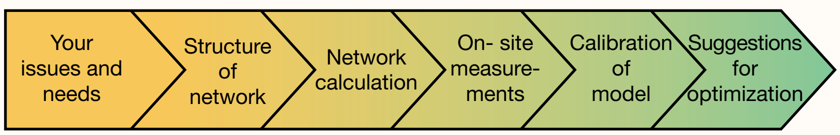

systems as well as the response by the regulation transformers and cable runs. The characteristic data of the entire plant network, including the 110-kV infeed, were entered in the CALPOS®, network calculation program. The model was completed with information and data on the power transmission line, provided by the power supplier himself. This first stage in the network analysis was based only on the documentation of the installation configuration. It showed the critical areas in network operation, which were subsequently looked at more closely:

- High reactive-power consumption by the high-power cycloconverters of the tandem mill drives **1**
- Very low short-circuit power rating of the 10-kV busbar
- High harmonics loading at the 10-kV level

## Power NetAnalysis at a glance

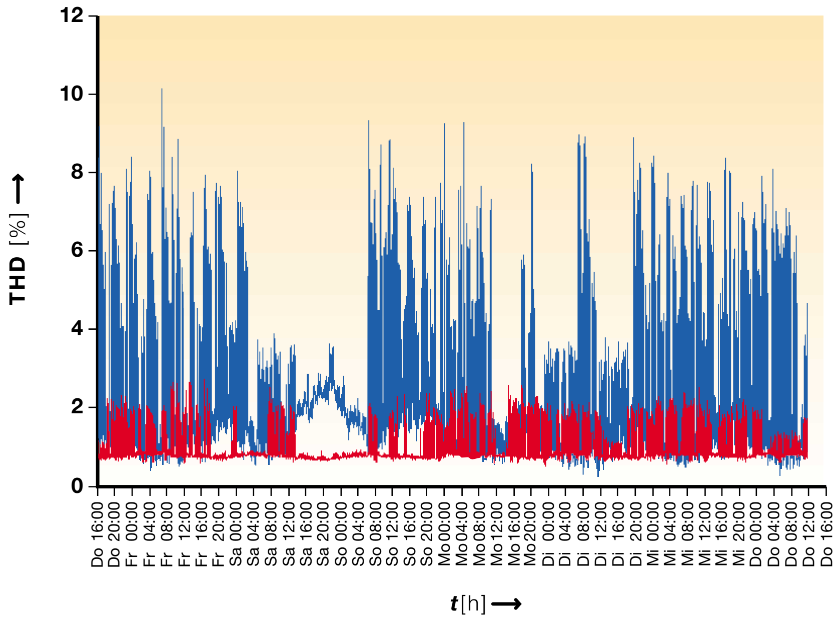
- Power NetAnalysis offers a detailed report on the actual status of your in-plant network. It informs you about measurement results, evaluates them and explains special features.
- Power NetAnalysis checks whether or not your plant complies with all standards and keeps within specified limits.
- Power NetAnalysis suggests solutions for optimized operation of your network. The comparison of different approaches ensures that you can choose the most economical concept for your plant.
- Power NetAnalysis describes ways in which you can lower your energy costs by reducing losses and reactive power, increase the service life of your electrical equipment, and so improve the availability of your plant.

Power NetAnalysis has been prepared for remote diagnostics.

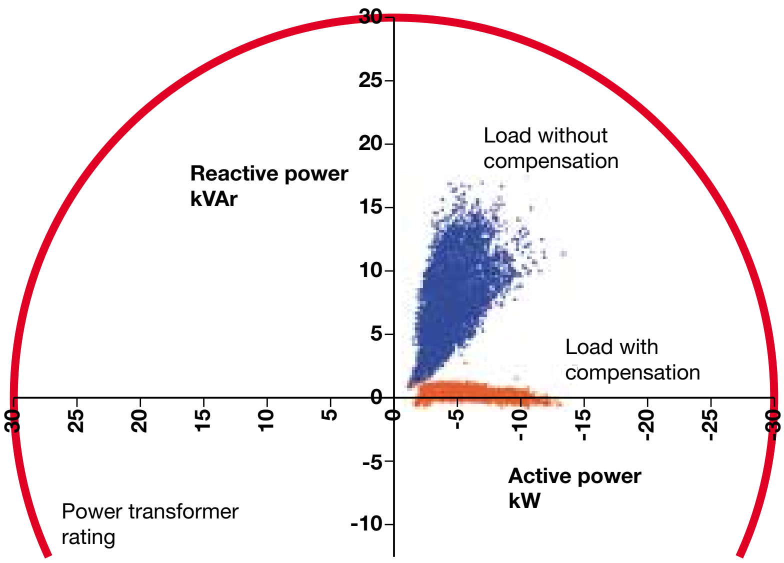


3 Harmonics content with (red) and without (blue) dynamic compensation

THD *Total Harmonic Distortion*




4 Transformer capacity utilization with active and reactive power, with and without dynamic compensation *(all scale values x 1000)*




■ Resonances between the transformers and the filter circuits of the cutting machine, due to the sidebands of the cycloconverters

Voltage dips were caused especially by the combination of high reactive power consumption and low short-circuit power rating.

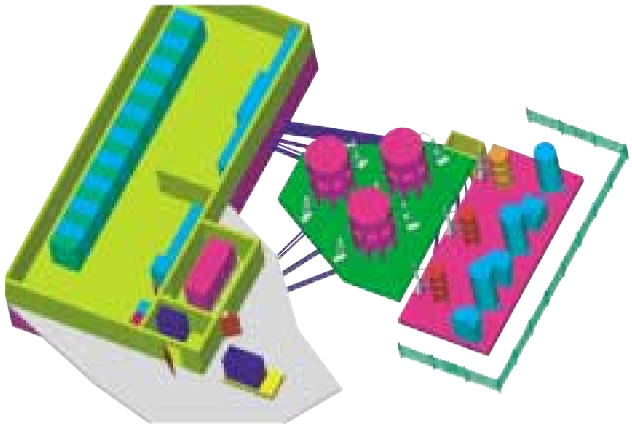
## Site measurements

The measurements verified the relationship between the reactive current and the drop in voltage. The inherently complex behavior of an industrial network can only then be studied satisfactorily by means of mathematical modeling when the simulation response is in complete agreement with the network behavior, as confirmed by measurements. Because of this, the network calculation is further refined until the results largely reproduce reality. In addition, the locally measured data document both the previous and the new network behavior.

## Network simulation

The results that were obtained showed that, in the case of the extreme voltage fluctuations on the 10-kV busbar, only by providing dynamic compensation at the plant network's MV level could the plant network be stabilized as required. The model of the energy supply system was therefore expanded in order to be able to simulate the network conditions with this extension. The model offered valuable support during the initial design of the filter equipment: negative effects of the compensation on the network environment were identified early, and

5 Dynamic compensation system for 24 MVA with damped filter circuits



therefore could be avoided. For example, the filter circuits had to be designed in such a way that they would not disturb the ripple control frequencies of the power supplier.

Based on the results of these simulations, ABB Automation Systems delivered in 1999 a 24-MVA dynamic compensation system.

## Operational improvements

- A drastic reduction in voltage fluctuation 2
- No more disturbances on the network side
- Switching by the regulating transformers reduced practically to zero
- A reduction in harmonics and compliance with IEEE recommendations 3
- Infeed transformer subjected to lower loads despite increased active-power load 4
- No more costs for reactive power

## What Power NetAnalysis offers

Power NetAnalysis was developed especially for industrial plant operators who are planning to expand their production capacity. The modeling allows the new installation's effect on the plant network to be simulated. Different configurations can be investigated for known load cycles of the planned installation in order to determine the most cost-effective variant for the particular network. Approximations of solutions that have been found can be run at different operating points. For example, the installations can be checked for compliance with standards and limits and, as in the described example, the required filter equipment calculated.

The complexity of industrial power distribution networks is something which is often underestimated. In weak networks, load peaks cause voltage dips, which can seriously affect production. In the case of the mentioned strip rolling mill in Germany, Power NetAnalysis solved problems being caused by low voltage quality by providing data on which a solution – the 24-MVA dynamic compensation system shown in 5 – could be based.

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