The big picture

Detecting power system instabilities and optimizing asset utilization with Inform^{IT} Wide Area Monitoring PSG 850

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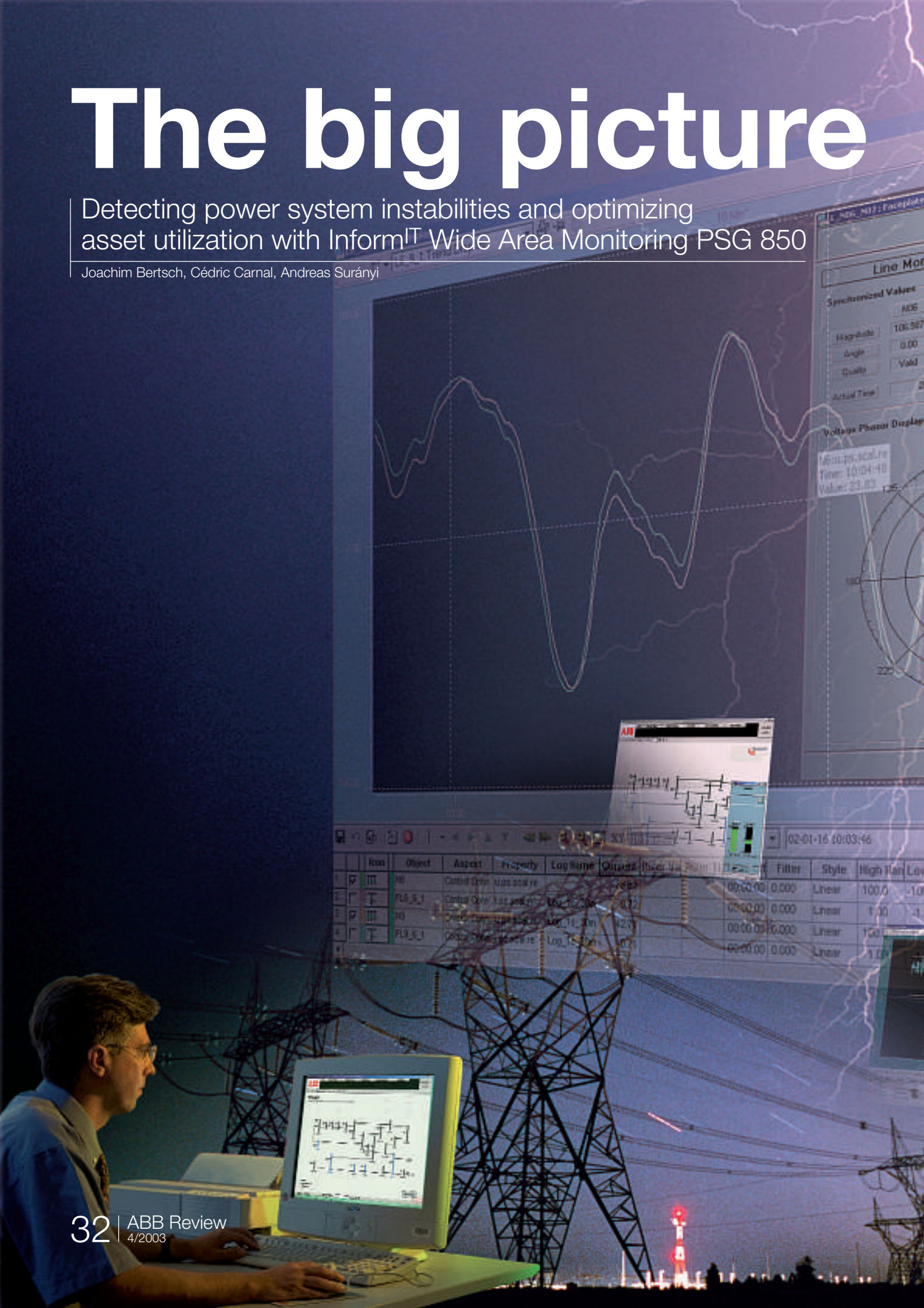

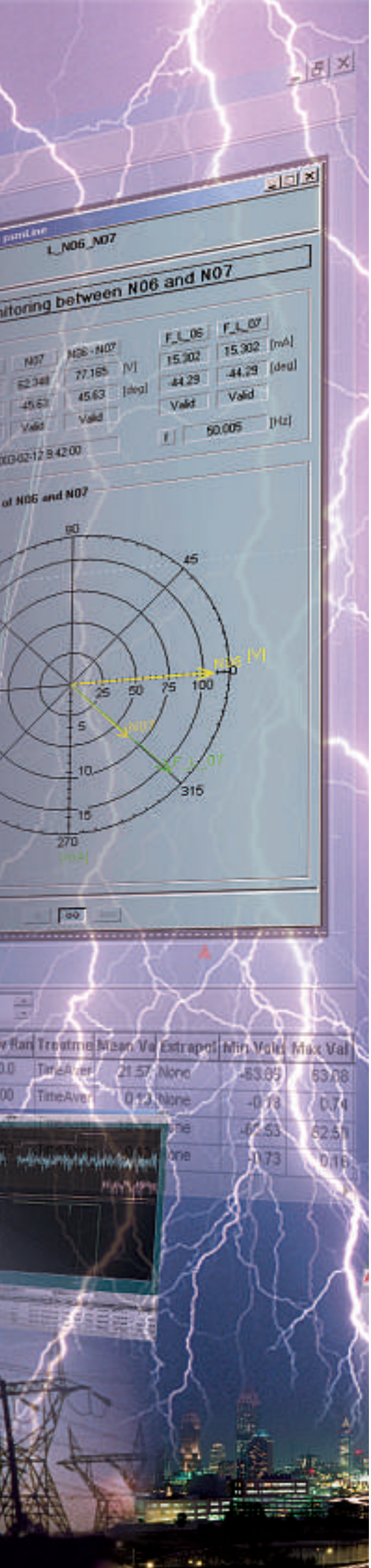

Developments in the world's power markets are compelling utilities to place greater emphasis on asset utilization in order to operate more profitably. But there is an equal need, as the recent massive blackouts in North America and Europe showed, to have safeguards in place that ensure total reliability for the transmission networks.

Increasing attention is therefore being given to the monitoring of power system dynamics. This requires information of higher accuracy and with update rates faster than those normally provided by traditional SCADA systems. In addition, it has to be synchronized over a wider geographical area than traditional protection systems allow.

With the introduction of phasor measurement units and recent advances in communication and computing it has become technically feasible to take a wide area approach to monitoring power system stability on-line. Inform^{IT} Wide Area Monitoring PSG 850 was developed as a state-of-the-art platform for just such an approach. IT-based, it offers solutions designed to optimize asset utilization as well as to prevent entire power networks from collapsing.

The world has come to depend on electricity so much that huge efforts – and investments – have to be made to ensure that it flows uninterruptedly. Apart from having to find the capital for this, the electric utilities are faced with another problem: market pressures are forcing them to maximize their profitability. Together, these factors provide a strong incentive for utilities to install technology that combines functionality for optimizing asset utilization and cost structures with that required to prevent power system outages. This is precisely what Inform^{IT} Wide Area Monitoring PSG 850 – one of a family of PSG modules/packages that also include wide area protection and control (PSG 870), wide area measurement (PSG 830) and wide area connectivity (PSG 810) (see figure on page 34) – was developed for. Inherent benefits of the PSG 850 solution include:

- Transmission capacity enhancement, achieved by on-line monitoring of the system safety or stability limits.
- Power system reinforcement (investment planning) based on feedback obtained during analysis of system dynamics.
- Introduction of a coordinated approach to stabilizing actions in cases of severe network disturbance.
- Triggering of additional functions, such as var compensation.
- Better understanding of a system's dynamic behavior.
- Installation of an early warning system designed to prevent potential blackouts.

Data utilization in wide area monitoring

Monitoring of entire power systems with PSG 850 is based on dynamic phasor measurement – increasingly being seen as the ultimate in data acquisition technology. Phasor measurement units (PMUs), located in critical areas of a network, allow fast measuring of the voltage and current phasors (ie, their magnitude and phase angles) and optimize process control on the basis of a dynam-

ic, highly accurate system overview. Several electrical utilities have already deployed PMUs in their grids, mainly for manual data acquisition and processing.

A key feature of wide area monitoring systems is the central acquisition of data from PMUs, enabling utilities to utilize phasor information wherever it is needed. PSG 850 provides the following customized forms of data utilization in support of utilities' asset management targets.

Monitoring of dynamic system behavior – stability assessment

At present, power system operation tends to be based on static or quasi-dynamic information extracted from rms measurements, mostly using SCADA systems. Phasor measurements at important nodes help system operators gain a dynamic view of the power system and initiate any necessary stabilizing measures in good time. Significant support is provided by stability assessment algorithms, which are designed to take advantage of the phasor measurement information. This increases the efficiency of power system operation and helps to maintain security at the desired level.

Monitoring of transmission corridors – congestion management

Energy is often traded over the transmission corridors interconnecting the power systems – an activity that adds significantly to the cost, and therefore price, of energy in liberalized markets. However, the transmission capacity of such corridors is often constrained by stability concerns having their origin in uncertainty about the underlying system status. The traditional solution – to reinforce transmission path capacity by installing new lines – has the advantage of offering high availability, but also the substantial disadvantage that line construction is time-consuming and requires huge new investments.

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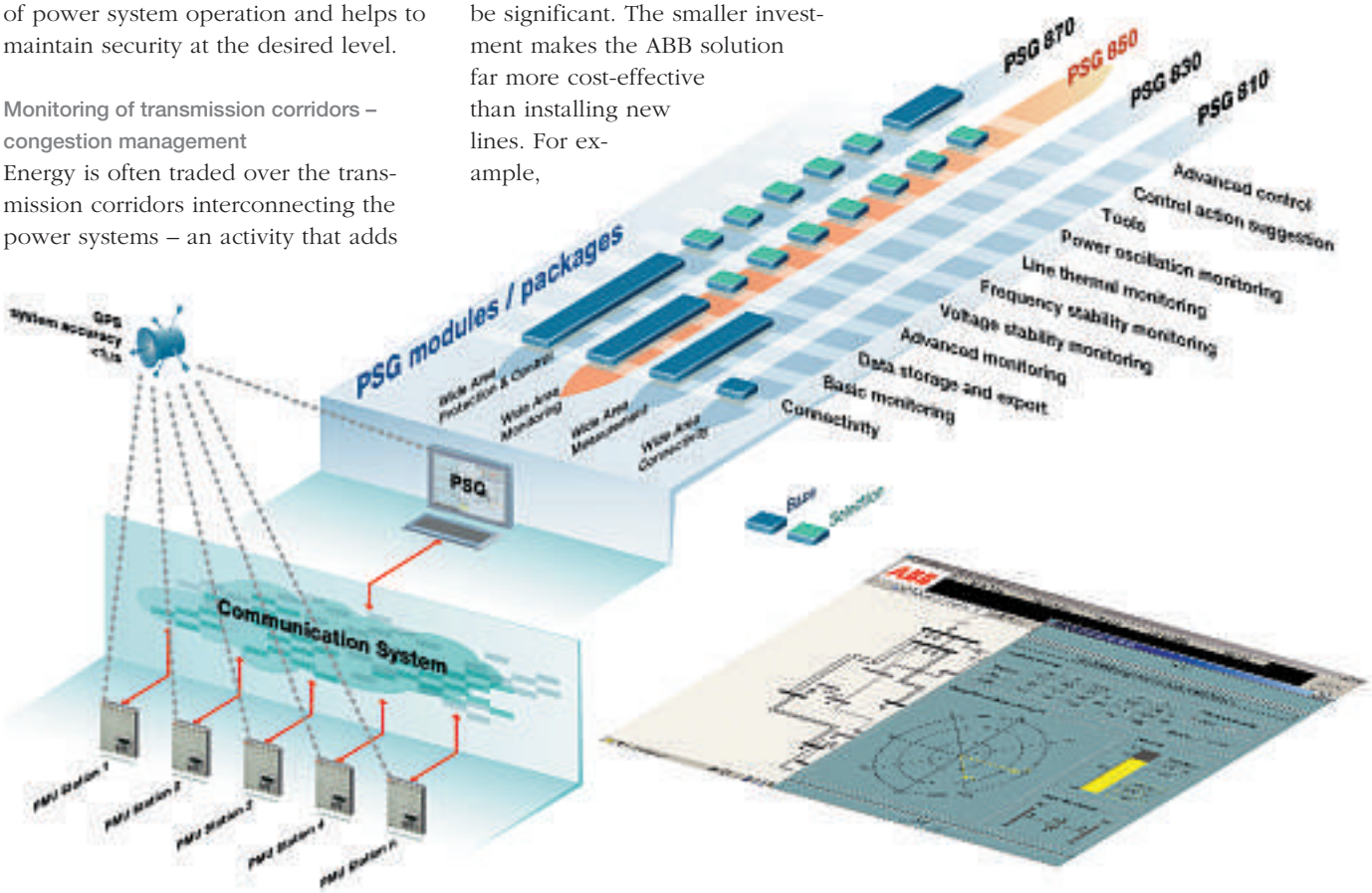
An alternative solution is to significantly improve asset utilization through wide area monitoring. This reduces uncertainties and, consequently, the operational risks. Under certain conditions, such as lower-than-assumed ambient temperatures, the dynamic capacity increase can be significant. The smaller investment makes the ABB solution far more cost-effective than installing new lines. For example, a 4 to 6 % increase in transmission capacity achieved by deploying a wide area monitoring system could help to postpone or even avoid major investments worth 10 to 100 million USD. PSG 850 is therefore also an important decision support tool for congestion management and investment planning.

Disturbance analysis and system extension planning

The continuous data storage functionality provided by PSG 850 is a very valuable source of information for the analysis of incidents and disturbances occurring in the power system. Besides improving the efficiency of power system analyses, it helps to determine and eliminate the actual causes of such inci-



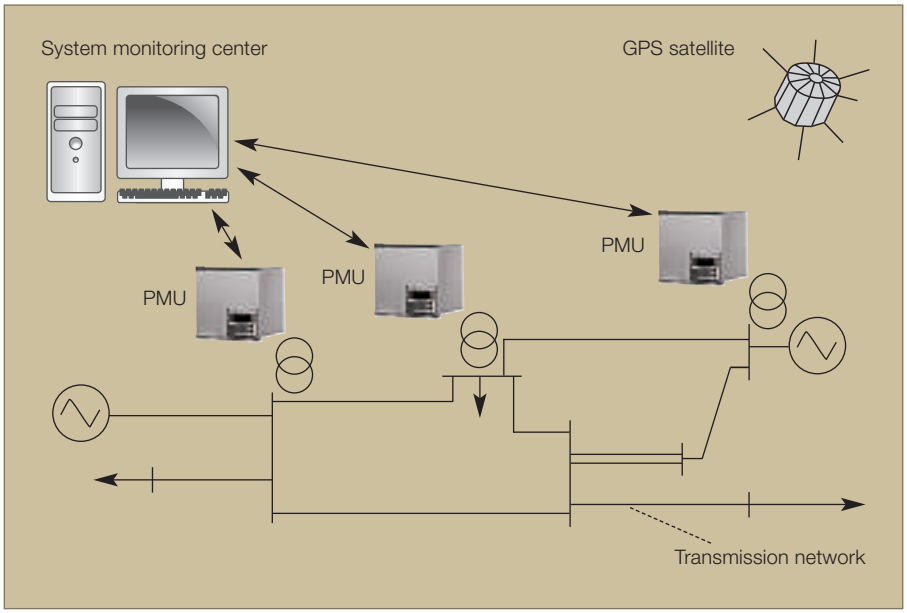
dents. This accurate identification provides a sound basis for the planning of system expansions and future system reinforcements.

System platform overview

Phasor measurement as basic technology

Wide area monitoring systems are essentially based on new data acquisition technology. Unlike conventional control systems, which use, for example, RTUs to acquire the rms values of currents and voltages, a wide area monitoring system acquires GPS[1)]-synchronized current, voltage and frequency phasor information measured by PMUs at selected locations in the power system. The measured quantities include both magnitudes and phase angles, being time-synchronized via GPS receivers with an accuracy of one microsecond. Until now, critical nodes in transmission grids have usually been monitored using static or quasi-dynamic data based on rms measurements. Phasors, measured at the same time, provide instant snapshots of the status of the monitored nodes. By comparing these snapshots, both the dynamic and steady state of critical nodes in transmission and sub-transmission networks can be observed. The result is *dynamic monitoring* of the power systems.

1 Configuration of a wide area monitoring system with synchronized phasor measurements from PMUs used as input for the system monitoring center



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System architecture of the wide area monitoring platform

The platform architecture for monitoring is made up of the following hardware:

- Phasor measurement units
- Communication links
- System monitoring center

PMUs are placed in the substations to allow the power system to be observed under all the different operating conditions (network islanding, line or generator outage, etc). Some redundancy is provided to secure this information in the event of certain data being unavailable, for example due to PMU outage or communication failure. The measured data are sent via dedicated communication channels to the PSG 850's system monitoring center (SMC) – a central computational unit in which the collected data are synchronized and sorted 1. This provides a snapshot of the power system's status.

In the case of meshed network topologies, the snapshot is then processed by the basic monitoring (BM) package, which is part of the SMC. BM denotes the set of algorithms included in all installations of the wide area platform as the basis for different software applications. This solution package has the following capabilities:

- Ability to provide consistent input data for all PSG 850 applications.
- Fast execution, leaving sufficient time to run additional applications within the sampling interval.
- Robustness – the system is resistant to the poor quality of some of the input data (availability, range, synchronization)

The reference phasor can be chosen from various points in the grid. Software applications, which are linked to the BM output, address various dynamic phenomena occurring in power systems. They predict the state of the power system and suggest appropriate actions to be taken by the system operators when an emerging instability is detected. An ergonomic graphical user interface (GUI) 2 displays the output information.

Historical data can also be accessed, allowing phasor data to be retrieved for subsequent analysis. A navigation facility is provided for easy selection and display of the required information.

Implementation activities and advanced software applications

To take full advantage of Inform[IT] Wide Area Monitoring PSG 850, a step-wise

1) GPS Global Positioning System

approach introduction is recommended: First, the utility and the PSG 850 supplier carry out an initial study to identify typical network problems and the most endangered of the areas in which the system is to be deployed. Afterwards, the appropriate monitoring algorithms and most suitable locations for installing the PMUs can be chosen. ABB has developed a complete set of algorithms that ensure optimized procedures during the various stages.

The fundamental software modules include a GUI (with single-line diagram, pop-up windows, trend displays), easily scalable PMU connectivity package, data storage capability and export functions for further analysis.

The following software applications are offered with Inform^{IT} Wide Area Monitoring PSG 850:

- Advanced monitoring
- Voltage stability monitoring for transmission corridors
- Line temperature monitoring
- Power oscillation monitoring
- Frequency stability monitoring
- Control action suggestions

Customer feedback has been good

Several systems with up to 16 PMUs have already been installed or engineered for practical application in high-voltage power grids. Feedback from prototype applications on customer sites is diligently recorded, and continues to confirm improvements in power system performance. Evaluation of the feedback shows that customer benefits include:

- Cost-effective grid operation based on observation of critical network areas.
- Increased grid utilization, facilitated by on-line monitoring of critical nodes.
- Detection and elimination of causes of power quality problems, made possible by the high accuracy of the underlying system of measurement.
- Thorough investigation of critical incidents.
- Provision of additional strategic information for the utility's grid planning department.

As a result of this positive feedback, several wide area monitoring pilot projects are now having their status upgraded to 'ready for commercial exploitation.'

Wide-ranging benefits

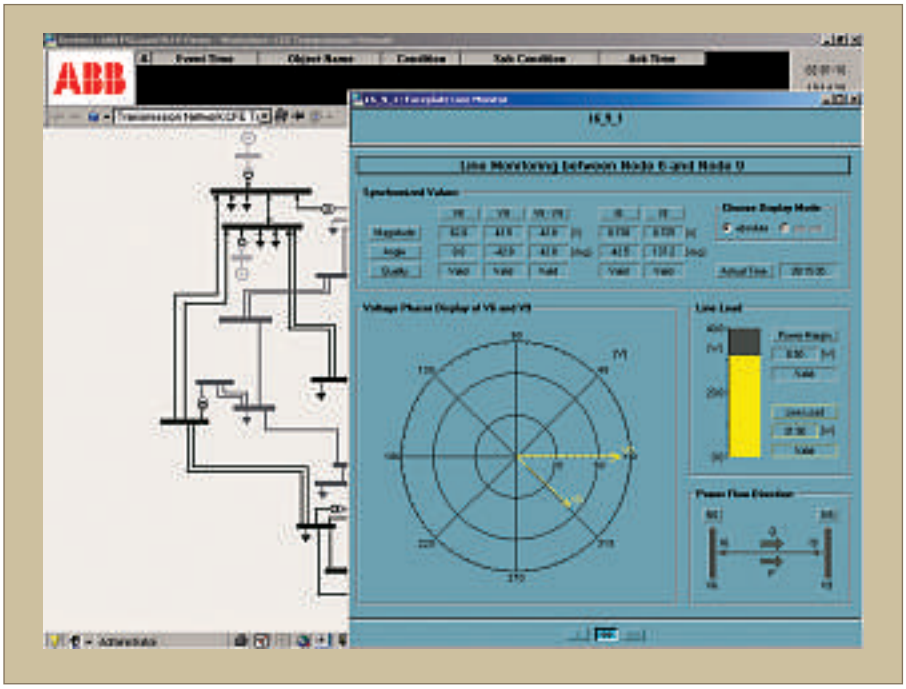
Experience with installed prototypes shows that wide area monitoring systems help to significantly improve grid utilization, especially during peak demand periods. Just as importantly, they facilitate the detection of critical factors influencing a network's fundamental stability.

When a wide area monitoring system is installed, utilities that operate power lines at high load levels can reduce their costs substantially by postponing investment in new infrastructure while still maintaining high grid availability.

In this context, Inform^{IT} Wide Area Monitoring PSG 850 goes well beyond the capability of existing local monitoring and protection equipment. It raises the level of asset utilization and can significantly contribute to future cost savings in a utility's long-term strategic investment planning.

Maximum benefit is gained from wide area monitoring when the utility and ABB jointly identify typical network problems and the most endangered areas.

2	Example of graphical user interface display provided by PSG 850. The popup line monitoring faceplate (on right) compares voltage phasors.



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