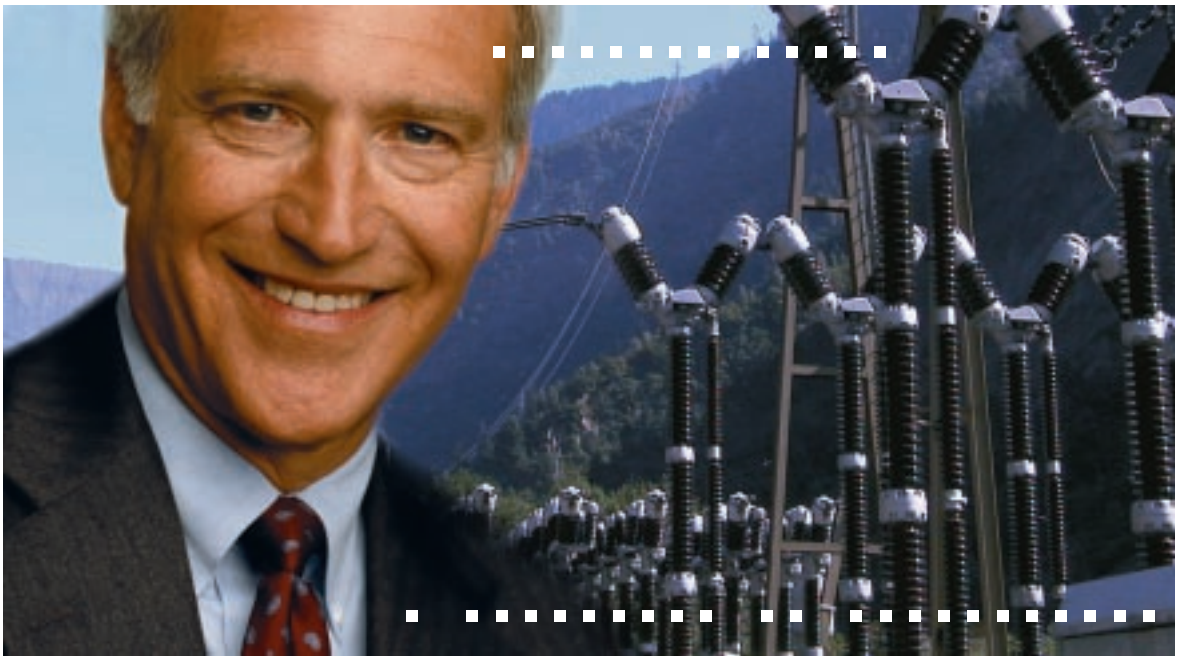
Industrial IT

For power system monitoring



Anticipating future needs for far-sighted investments

Motivated by the rapidly growing needs for diagnosing the health of substation equipment the following question ist raised:

"Why Power System Monitoring?"
It is obvious that there will be dramatic, possibly even revolutionary changes, – compared with the more evolutionary changes to date –, to the extent that the full range of distributed and embedded power generation systems has to be envisaged.

The three main driving forces for power system monitoring are:

- **Peoples perception**
- **Environmental concerns**
- **Technology developments**

Assuming that these predictions to be probable, recommendations are given for future oriented Power System Monitoring (PSM) concepts. Visions are indicated to respond to the changing from current transmission and distribution systems to possible future systems in the most cost-effective way. These are suggested to be

- **by extension of existing equipment to achieve maximum utilisation**
- **with minimum manpower effort**
- **at minimum cost by application of intelligent monitoring systems**

Bearing this scenario in mind, the future utility requirements for PSM are anticipated and guidance is provided for implementation projects at power utilities.

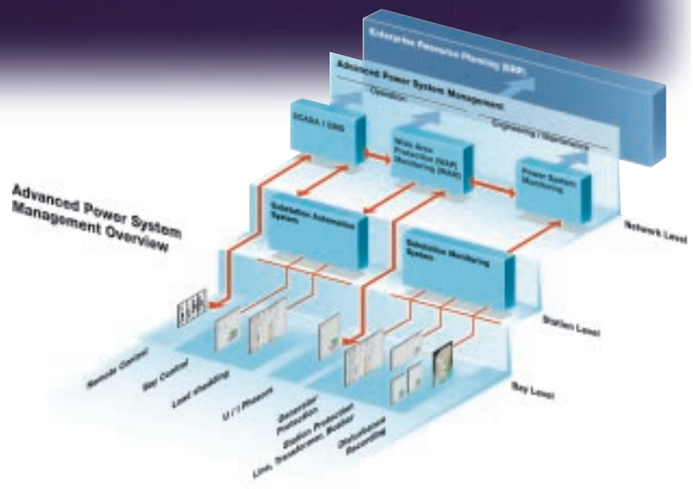
Industrial^{IT} is the ABB commitment to the real time integration of automation and information systems across the business enterprise.

Utility Environment

The utility environment is changing dramatically from its historical perspective. It is now an increasingly competitive arena with significant pressure for greater system reliability and improvement of customer satisfaction, while similar emphasis is placed on cost reduction.

At the same time, the utility plant is ageing. When load growth diminishes, there is lessened need for system expansion. With less new equipment being installed, the average age of the system increases. In fact, it is estimated that the age of more than 60% of all power transformers and associated substation equipment installed in industrialised countries is in excess of 25 years.

The human resource issue is also becoming critical. All industries, including the utility industry, demand that more to be accomplished with less manpower. Not only is the number of substation maintenance personnel decreasing, but also the



diagnostic and equipment experience bases, which is a critical aspect of time-based maintenance. Attrition may be lowering the historical costs of maintenance, but the increasing costs of equipment failure is an offsetting dynamic that must be taken into consideration. New substation maintenance strategies must be implemented if the requirements of today's utilities are to be met.

There are solutions to these concerns:

- **Comprehensive power system monitoring**
- **Online diagnosis of the health of substation**
- **Condition related asset management**

Integrated substation protection systems, which are enhanced with advanced monitoring systems, in combination with wide area network and mobile phone technologies enable the right information to be distributed to the right people anywhere at the right time. (Figure 1)

Driving factors for Future Developments

The driving factors for the futures developments are:

- **Environmental issues e.g.CO2, SF6, Oil contamination, PCB, Electro smog (EMI)**
- **New options for power generation e.g. Combined cycle power plants managed by local independent power producers (IPP), fuel cells 1 kW – 1MW, natural resources (wind, wave, heat, solar, biomass)**
- **Future substations e.g. Self-supervised, movable, automated operation, recyclable, environmental friendly**
- **Financial constraints e.g. Replacements with new equipment only if cost effective, new equipment fully automated, life time of existing equipment to be extended by monitoring**

The development of more open market arrangements in power systems with separate generation, transmission, distribution and supply activities requires a review of traditional planning methods.

Dynamic ratings, life cycle performance assessment and maintenance strategies are techniques in rapid development and at a stage where integration in system planning and operation strategies is appropriate.

As a growing number of power consumers see economic benefits in installing modern co-generation plants, the numbers of generators being connected within distribution networks is increasing rapidly. They cover generators ranging from 1 kW photovoltaic panels to multi-MW wind-farms and co-generation schemes. The main technical connection issues, which are of concern to utilities, are:

- **Voltage rise and instability**
- **Impact of islanded system operation**
- **Increase in short circuit current levels**
- **Impact on power quality**
- **Dynamic behaviour of the networks**

In order to be prepared for the future investments have to be made today responding to the raising need for advanced tools for power system planning, reliability assessment and analyzing the impact upon power quality. Apart from this, online monitoring of the power system quality is a key topic.

Means to Work Systems Harder

The pressure from regulatory control bodies and competition is creating the need to provide shareholder value. Changes in the organisation as well as changes to the process employed to work the system harder will be considered. The following future developments will have an impact upon how utilities will continue to operate their systems.

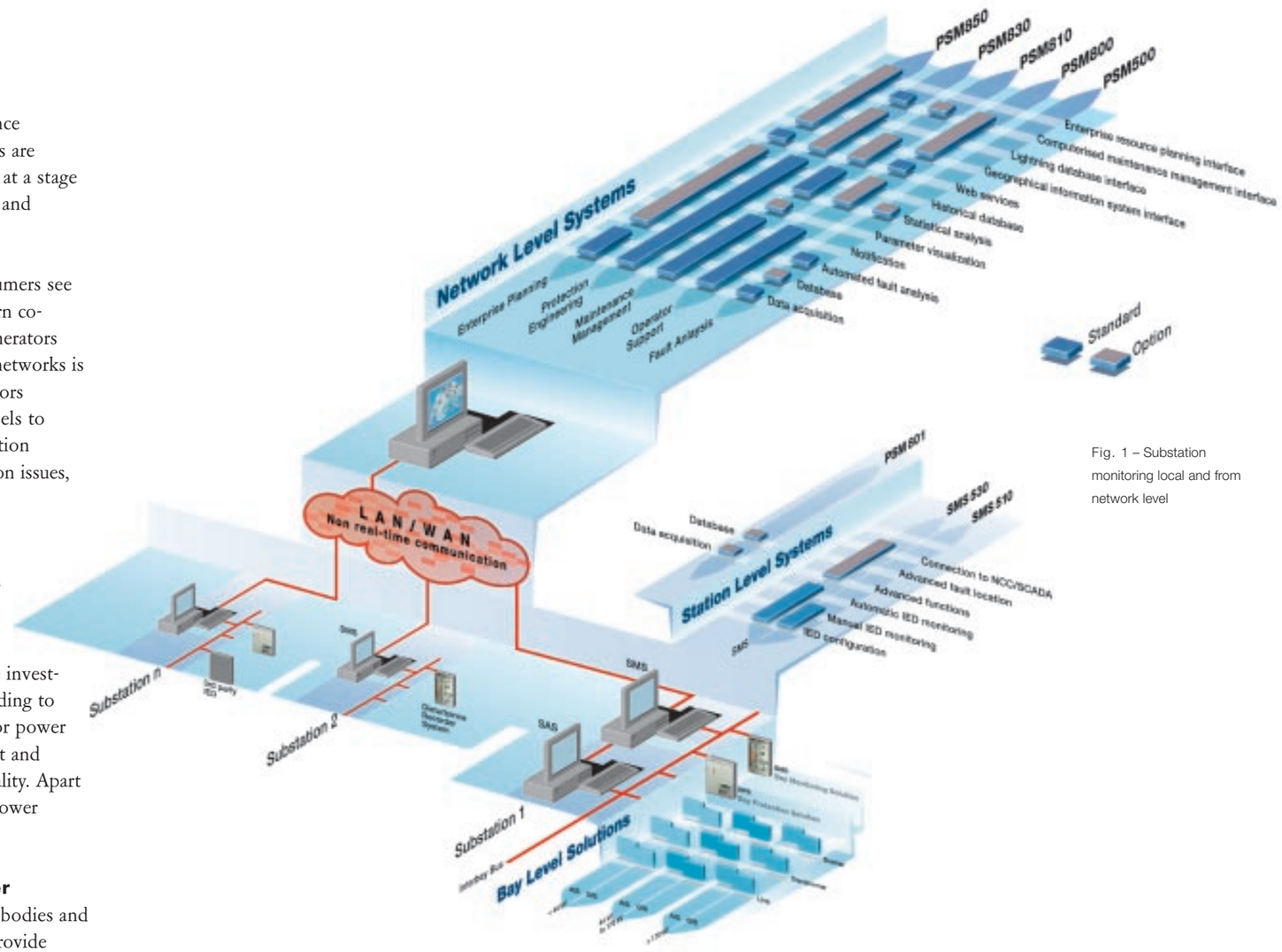


Fig. 1 – Substation monitoring local and from network level

Technical Developments

The innovations derived from new technologies, which enable utilities to work their systems harder include:

Better Modeling and more detailed technical analysis. Using these techniques it is often possible to assign enhanced ratings to transmission equipment and hence increase system power transfers.

Better analysis of system conditions. As a result of increased power transfers across the system there is a reduction in operational "margins for errors". This means that accurate prediction and analysis of power system condition is vital.

A reduction in time scales in which operators can act. To this end better alarm data analysis is required, together with automatic instead of manual actions.

Substation monitoring for better Information

Substation monitoring to reduce the time to find and fix problems
The Substation Monitoring System SMS530 in conjunction with intelligent electronic devices (IED) for protection is an effective price/performance platform for homogenous and scaleable system solutions for evaluation and diagnosis of faults in substations and on power transmission lines. It provides condition-related data from secondary as well as from the primary equipment for fault analysis and fault statistics, and enables remote parameterization of IEDs.

In cases of emergency,critical decision making depends on the availability of accurate and reliable real-time information concerning the type and cause of faults to empower the operator to take the right actions to maintain power system integrity.

Substation Monitoring collects data and transforms it into informations
The immense flexibility and functionality of numerical protection IEDs provide a wide range of features and functions for monitoring, event and fault recording as well as for dynamic adaptations to the actual network situations. The numerical protection devices continuously collect data about disturbances in the electrical network and provide condition related process information of the state of the network and of the primary substation equipment.

These data are automatically retrieved cyclically, event triggered, or upon request. The diagnostic data evaluation provides indication and historic trend information derived from process data from primary and secondary equipment to support maintenance decisions as well as adaptation of protection parameters.

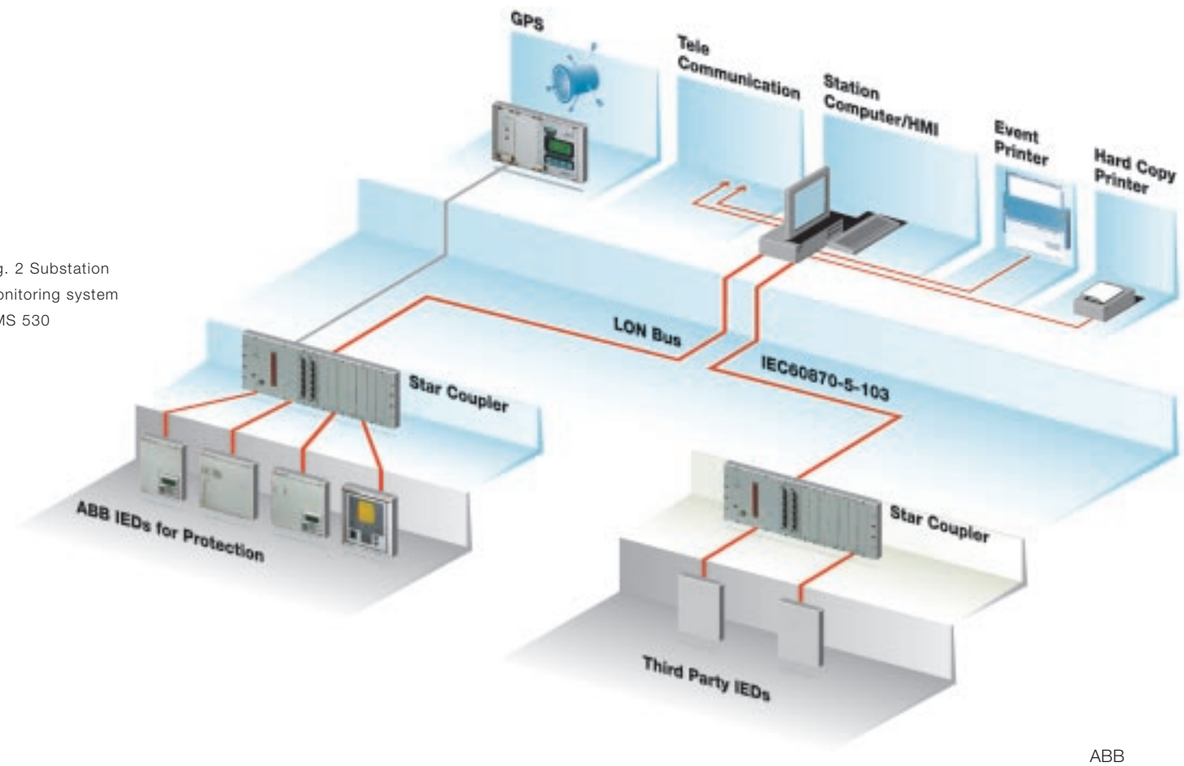


Fig. 2 Substation Monitoring system SMS 530

Power system monitoring for performance assessment

Disturbance recording is a function, which can either be integrated into protection IEDs or performed by dedicated fault and sequence of event recorders like Indactic 650. The time resolution of dedicated devices is often higher, and allows more accurate analysis of the power system behaviour before, during and after faults. Integrated disturbance recording, on the other hand, is a very cost effective add-on if numerical protection IEDs are used. Therefore the total number of disturbance recorders has increased with the introduction of numerical technologies. On the one hand, more data is available for faster finding and fixing of faults, on the other hand the handling of the vast amount of data produced requires better systems for data processing.

Apart from recording disturbances, the disturbance recorders also acquire service data, which can be used to evaluate the condition of circuit breakers and power quality data with regard to supply interruptions, voltage sags and variations etc. (Figure 3)

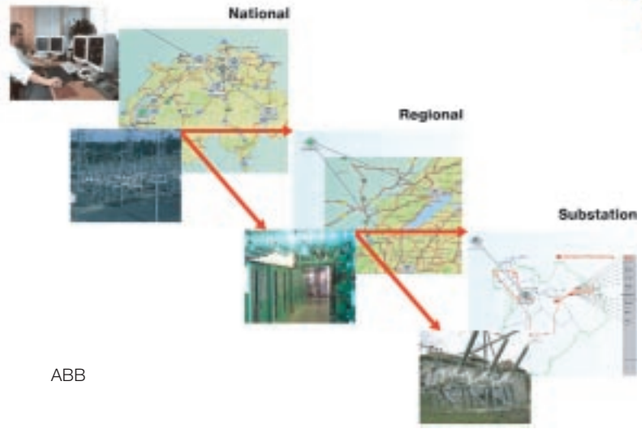
For easy handling and management of all these data, Inform^{IT} provides for centralised retrieval and transmission of data, and for transforming data into information and knowledge to enable the maintenance and protection engineer to asses the condition of the entire power system.

Inform^{IT} is a decision support system for the operator, protection & maintenance engineer with access to available information from all IEDs at any time from everywhere.

- **Protection related information**
- **Direct access to substation monitoring and automation systems**
- **Remote parameter setting**
- **Assessment of power quality**
- **Historical data base for enterprise resource planning**
- **Visualisation of faulted areas via geographical information system (GIS)**
- **Identification of weak spots in combination with lightning data base**
- **Support of maintenance and asset management systems**

Fig. 3 Recording of disturbances, circuit breaker duties and power quality

Fig. 4 Inform^{IT} for central retrieval, evaluation and management of data



Instability detection for preventing power system collapse

The continuous increase in the consumption of electrical power and shortage of power generation increase the risk that instability problems encompass large area in power systems. These problems can be summarised in: (Table 1)

- **Rotor Angle Instability**
- **Frequency instability**
- **Voltage instability**
- **Cascade line tripping**

As these phenomena usually lead to power system collapse and to blackouts in large areas the economical consequences are very extensive.

Dominating/Critical System Components		
Time Scale	**Generators**	**Loads**
Fast	**Angular Instability** **Transient** **Steady State**	**Fast Voltage Instability**
Slow	**Frequency Instability**	**Slow Voltage Instability**

Table 1 Classification of power system instabilities

Assessment of Instabilities

PsGuard System is the ABB solution for wide area monitoring that incorporates the latest information technologies for detection of instabilities and for determining the most effective countermeasures to prevent power system collapse.
A typical application is the assessment of voltage instabilities:

The power transfer capacity of a transmission line is defined by its specific Power/Voltage characteristic The maximum power transfer occurs when the load impedance is equal to the line impedance. (P/Pm = 1). If the load increases beyond this critical point the voltage collapses rapidly and power can no longer be transferred. (Figure 5).

PSGuard allows on-line monitoring of power transfer capacity of lines. In case a voltage decline is recognised the safety margin towards maximum load is assessed and transmitted to alert the dispatcher that he can to take appropriate actions to avoid system collapse. If the load increases so rapidly that the dispatcher does not have enough time to respond, automated corrective measures can be initiated to counteract voltage collapse.

Strategies to Counteract System Disturbances

The trend is to maximize asset utilization by reducing operating security margins with the aid of enhanced monitoring and maintenance techniques. These developments cause significant changes in power system control, protection relaying and broadband communications.

During disturbed condition, data from the supervisory control and data acquisition (SCADA) system, actual network configuration, protection relay signals and operational procedures all need to be considered when arriving at the appropriate decision for corrective actions. This is problematic with the (SCADA) systems available today due to vast data volumes involved and the restricted amount of data that can be transferred from substations.

The advantages of an automated system which accelerates the decision making process are obvious. Such a knowledge-based system is feasible, which use data downloaded from system transient monitors, disturbance recorders, fault locators and protection relays.

The overall benefit of such systems is to

- **increase plant availability**
- **improve response times to disturbances and faulted plant**
- **decrease operating costs**
- **increase plant utilization**

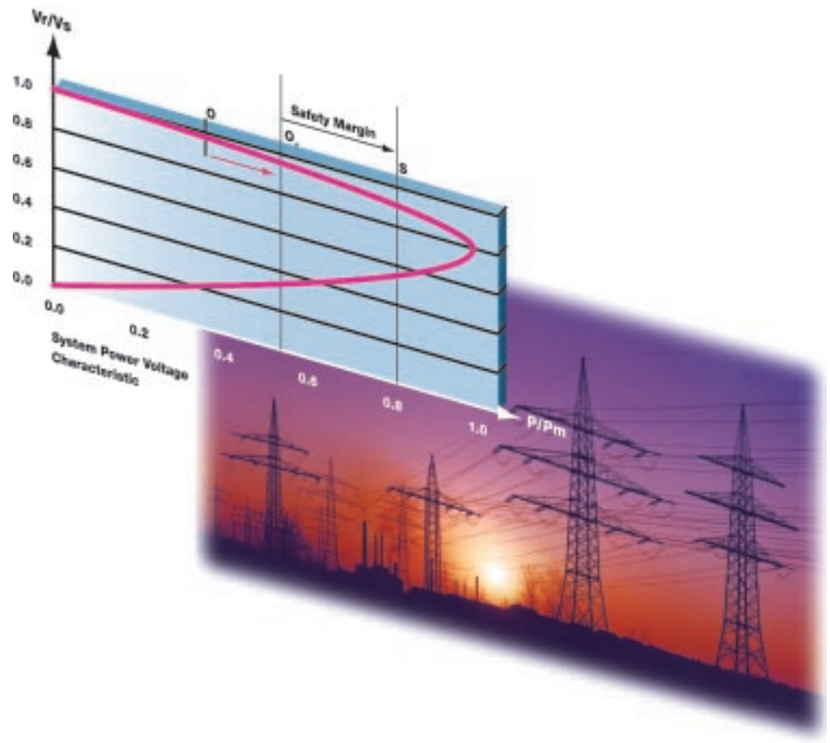
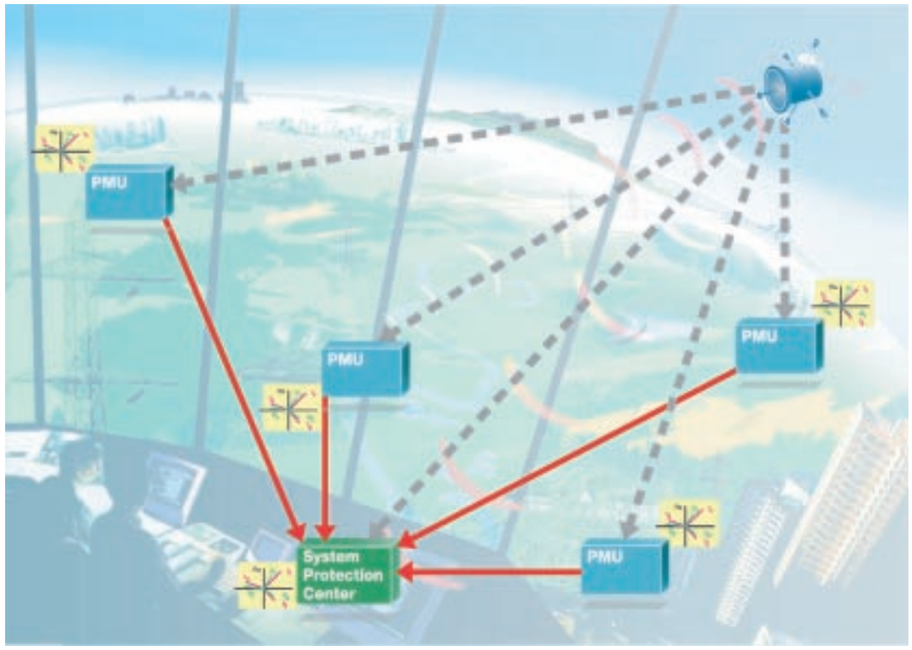


Fig. 5 Voltage instability assessment on power transmission lines

Measures to prevent Power System Instabilities

It is recognised that it is not feasible or possible to predict or prevent all multiple contingency events, that could occur randomly and could lead to power system collapse. However, a wide area monitoring protection system allows a set of co-ordinated measures to be identified, which would mitigate or prevent damage from large area disturbances. A system of such complexity requires phasor measuring units (PMU) that is located at critical locations in the network to provide the necessary process data, a central unit for fast data processing and for supporting the decision for the initiation of the right measures to counteract against these disturbances. (Figure 6)

Fig. 6 Phasor measurement units (PMU) monitoring power system behaviour



Implementing PSGuard for performance improvement

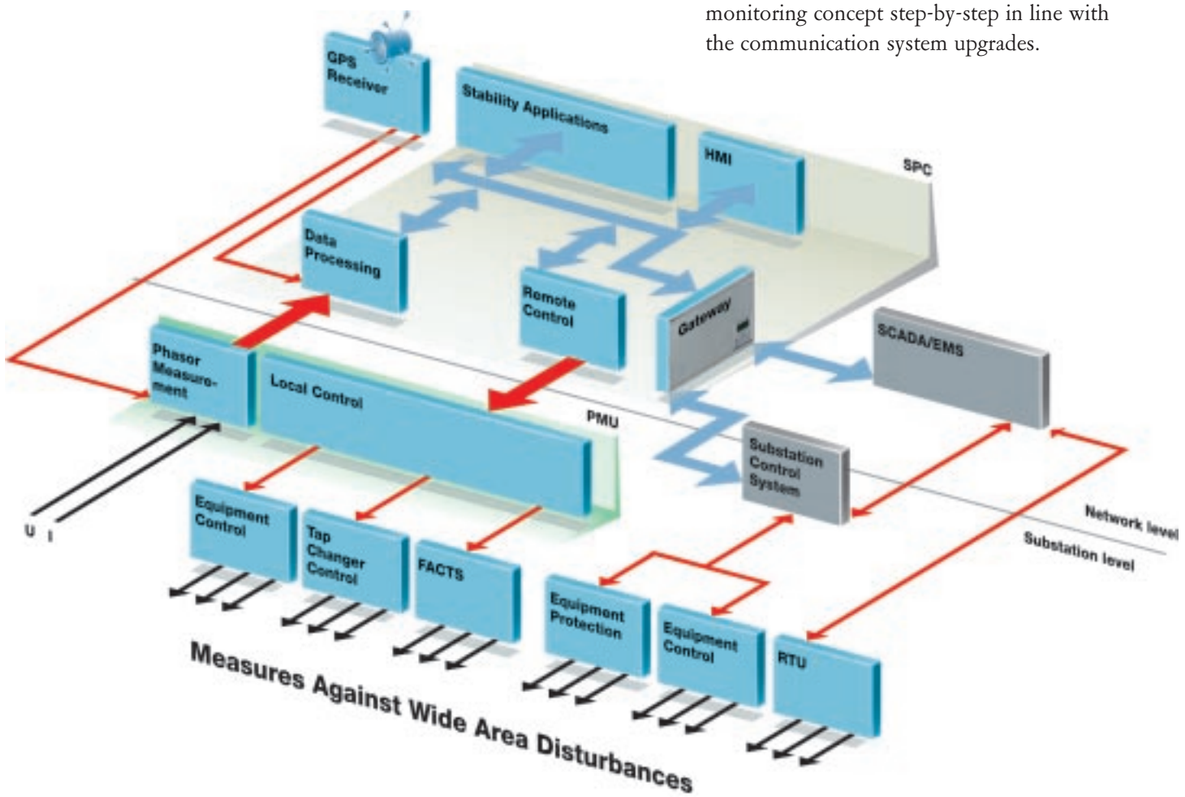
PSGurad is intended to complement protection and monitoring systems, which prevent damages to the protected objects in case of faults. Protection schemes for transmission lines, power transformers, busbars and generators are maintained as active self-contained safety elements. The main task of PSGuard is to detect transient instabilities and to indicate incipient power system disturbances. Therefore, any interaction with the installed protection and control systems must not jeopardise their safe operation.

There are two levels of interaction: (Figure 8)

- **At the network level to alert the operator and to suggest measures to counteract power system collapse. This new quality of information is derived from digital phasor measurement units (PMU) and cannot be obtained from analogue voltage, current or frequency measurements.**
- **At the substation level to initiate automated predetermined local actions e.g. transformer tap changer blocking, load shedding, izlanding and automated power restoration after temporary outages.**

Local defensive actions, e.g. tap changer adaptations and load shedding rely on locally available information only and are not dependent on communication links to the system protection centre (SPC). This makes it possible to implement a power system monitoring concept step-by-step in line with the communication system upgrades.

Fig. 8 PSGuard complimenting older generation control and protection



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