EXCELLENCE, SAFETY AND COMFORT

100 YEARS OF
RELAY PROTECTION IN SWEDEN

You are holding the results from 100 years of ABB relay protection in Sweden, and I hope this brochure will offer you an adventure into our technological innovations of the past and the present. This history has been collected through the tremendous effort of **Bertil Lundqvist**, our Senior Marketing Manager, and it dates back to 1883 when the company called ASEA was established. This company played an important role in the electrification of Sweden, providing technological excellence, safety and comfort for the industrial development of this country. The first stand-alone ASEA protection relay was developed and installed in 1905, and the first remote controlled station was in operation in 1925. Product development originally focused on the national market, but soon took a global perspective. In the mainstream of industrialization, ASEA grew into a real international player in its field.

The origins of the present company lie in the merger of ASEA and the Swiss BBC in 1988. To date, the company has delivered millions of protection and control devices throughout the world, as well as introduced a great number of major innovations in the protection and control field. ABB operates in nearly 100 countries and holds the leading position in power and automation technologies, enabling utilities and industrial plants to improve performance and lower environmental impact.

Our technological history can be divided into four main periods. The first period is the era of electromechanical relays, which started over 100 years ago. The next era is represented by static or electronic relays, which were introduced in the 1960s. The era of microprocessor-based relays started in the beginning of the 1980s, and the first fully numerical relay was developed in 1986. The present and still ongoing era of integrated control and protection started in 1994 with the launch of the 500-Series protection and control terminals.

ABB Power Technologies
Substation Automation Products

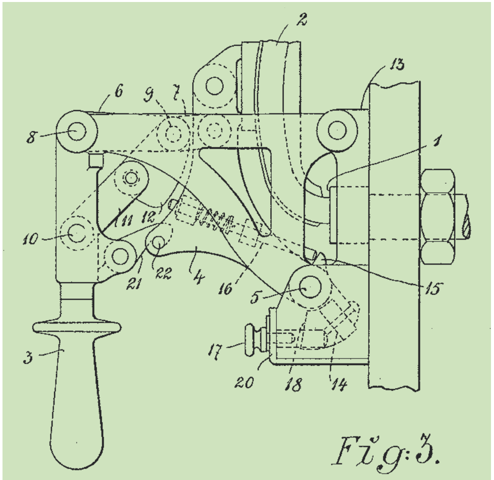
Knut Faber
Vice President

THE ERA OF ELECTROMECHANICAL RELAYS

The turn of the 20th century kicked off the triumph of electrification in many countries – also in Sweden. The first ABB time-overcurrent relay was born about the same time. Massive industrial growth between 1905 and 1960 increased the demand for electricity and power, thus expanding the number of generators and power stations. The rising need to move both goods and people from one place to another resulted in various electric transportation lines, such as tramlines, trolleys and electric railways. During this period, ABB developed and manufactured a large number of various types of electromechanical relays, only some examples of which are described here.

The introduction of current and voltage transformers, for example, with secondary current 5 A and secondary voltage 110 V for all levels of primary currents and voltages, enabled the development of stand-alone relays with additional protection functions. The TCB type time-overcurrent relay was first introduced in 1905.

The first relay functions were integrated in the breaker design, which acted as an overcurrent trip. This design was used in the first hydro power stations at the end of the 19th century. The first stand-alone electromechanical relay was produced in 1905. It was built with a bellow made of impregnated balloon cloth, which in combination with an air valve attenuated the movement of a solenoid to produce the required delay. This design was widely used in many installations, although the ageing of the textile bellow caused some problems.



The first stand-alone electromechanical protection relays were applied to supply electrical power for the manufacturing industry, as well as to illuminate churches and other city sights around Sweden.

In 1912, the first induction type relay was delivered to a hydro power station to generate 16 2/3 Hz power for the first electrified railway that transported iron ore from northern Sweden.

"In the roaring twenties, people were dancing in full swing and speeding forward in their brand-new motor vehicles."

Motor vehicles had come to take a permanent place in people's lives. The first motorway or "Autobahn" in Germany was opened in the 1920s. At the same time, the first transatlantic telephone calls became available to the public. At that time, talking three minutes between London and New York was an expensive luxury.

During this period, the role of electricity had changed from a necessity to comfort. Electricity was not only vital for the industry, but people in their everyday lives had become increasingly dependent on it.

The RI induction type time-overcurrent relay was developed in 1918 and is still used.

Thermal relays

The first thermal relay of designation RW type was developed in 1917 for three-phase motors. Its design was based on the bimetallic principle, which means the difference in the thermal elongation of two metals. The three-phase motor was invented by the founder of ASEA, **Jonas Wenström**, who was awarded with a patent for his innovation. This motor used AC power and supported the growth of industrial production in Sweden.

RI relay

The RI relay is perhaps the most well-known relay of this era. It was developed in 1918 by the famous designer, **W. H. Petersén**, and included a special contact switching feature. This relay was delivered to a considerable number of countries worldwide between 1920 and 1985. Although the last RI unit was produced in the 1980s, this relay is still used in many countries. This relay benchmarks the first electrical boom in Sweden and is an excellent example of a successful product with an extremely long life span. Actually, the same inverse time-overcurrent curve is still implemented in modern numerical relays to achieve time coordination. RI was the first relay to utilize high-speed resetting after trip operation, which allowed high-speed reclosing.

During the 1920s and 1930s, ABB introduced several relay innovations with sophisticated design. These solutions solved many conventional problems in a smart new way.

Earth fault relays

The sensitive directional earth fault protection relay was first designed in 1924. This RMS-type electrodynamic relay was replaced in 1938 with the even more sensitive RIRA-type earth fault relay, which was mainly used for hydro power generators.

Balanced beam relays

The first RBD-type balanced beam relays for AC were developed in 1925 to enable the differential protection with a stabilizing feature required for transformers and generators.

Power relays

The first power regulation system was launched in 1917, and the first induction type RE power relays came to the market in 1924.

Voltage regulating relays

An induction relay for regulating transformer voltage with tap changers was the newcomer in 1925. This relay was available in type RCA and RCE (RRCE for plug-in system RR).

Electromechanical relay system

Around the 1930s, a series of instantaneous maximum and minimum current and voltage relays of type RMJ were introduced. At the same time, the world's first modular relay system of type RR was presented. The RMJ was redesigned for the modular RR system with type designation RRMJ.

The line distance relay type RYZKC was launched in the 1950s and manufactured until 1985. It is still in operation worldwide today.

Electromechanical line distance relays

Line distance protection relays were intro-duced in Sweden in the 1940s when higher voltages became necessary for the transmission of electrical energy. Higher voltages enabled a greater electricity transmission over long distances, for instance from the hydro power plants in northern Sweden to the consumers in the southern parts of the country where the majority of electrical energy was needed.

In addition to these, a number of other electromechanical relay innovations of this era could be listed, including: poly-phase power relay of type RPAF, delayed undervoltage relay of type RODA, frequency relay of type RF 2, thermal relays of type RTV, earth fault relay of type RIMS 1, signaling relays and timers.

Instantaneous overcurrent relay type RRMJ was the world's first modular relay system.

"The dark years of the Great Depression in the thirties were enlightened by the first full-length Walt Disney film 'Snow White and the Seven Dwarfs'."

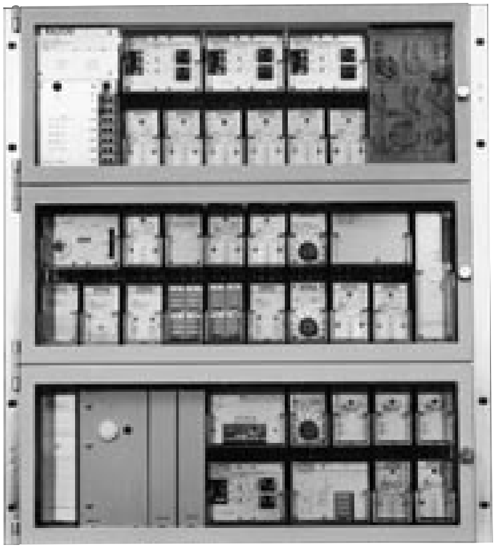
Despite the poverty of the depression and cruelties of war in the 1930s and 1940s, the comforts of life took a huge step forward in entering people's homes. Replacing ammonia with freon, refrigerant gas enabled the safe use of refrigerators in kitchens throughout the industrialized world. Many electrical household devices, like electric irons, had now become a part of everyday life.

"Striving for permanent peace, people in the sixties believed in 'flower power'."

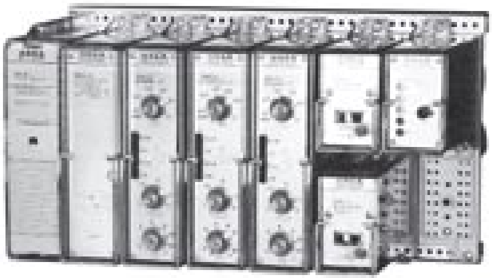
The legends of the emerging pop culture – The Beatles and The Rolling Stones – were followed by legendary achievements in science. In 1963, an artificial heart was used for the first time to sustain blood circulation during surgery in Houston. And the Soviet cosmonaut Yuri Gagarin was the first man to travel to space in 1961.

THE ERA OF STATIC RELAYS

The period of static relays extends from the 1960s to the 1980s. The load of static relays on instrument transformers was significantly lower than that of the electro-mechanical relays. This allowed smaller and less expensive transformers to be used. Static relays did not have moving mechanical parts, which reduced the need for maintenance. For instance, they did not have bearings, which could dry and sieze. Due to the development of electronics, it was possible to develop fast and sensitive relays for the protection of busbars and overhead lines.



The RAZOG line distance relay was the first relay with quadrilateral characteristics on the market.



The modular and compact COMBIFLEX assembly included a COMBITEST system, which significantly increased the personnel safety at substations.

COMBIFLEX relays and the modular building system

In 1960, the modular plug-in system of type RR was replaced by the COMBIFLEX system. The first static electronic relays were presented in the COMBIFLEX range, for instance, as timers, time-overcurrent relays and voltage relays. Later, a number of high performance static protection devices were also introduced. The first COMBIFLEX static relays were launched in 1969.

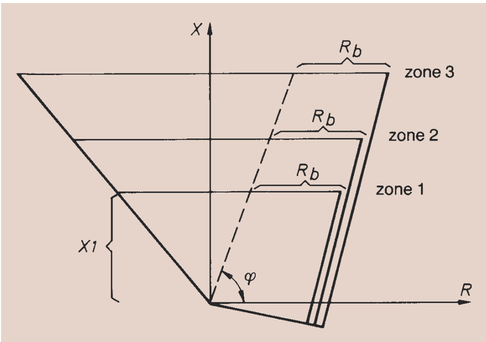
COMBIFLEX enabled combining a number of standardized modules into a single hardware structure. These modules contained measuring and timer functions as well as auxiliary relays. They were used to provide measuring functions, a number of trip contacts and ratings according to the customer specifications.

Another successful line distance relay for subtransmission was the so-called switched scheme relay of type RAZOA first launched in 1978.

Line distance relays

The world's first line distance relay with quadrilateral characteristics of type RAZOG entered the market in 1970. At that time, it was possible to implement these characteristics using static electronics.

The RAZOG was a three-phase switched scheme static relay suitable for protecting overhead lines and cables with an operate time of 21 ms at its shortest. The operating range in the impedance plane had the shape of a tetragon, thus resulting in a much better resistive coverage than the previous electromechanical mho-relays.



The quadrilateral characteristics of RAZOG.

A further state-of-the-art example of the static era is the full scheme distance relay of type RAZFE from 1975.

"One small step for a man – one giant leap for mankind."

With these words, Neil Armstrong became the first man to walk on the moon when he exited Apollo 11 in 1969. Through this space program, U.S. NASA made history flying higher than anyone before.

The 1970s benchmarked the beginning of ultra high-speed (UHS) relays with an operate time of one-quarter cycle to a half cycle. These innovations protected substations against the highly dangerous busbar faults, thus saving human lives and equipment. They also added safety to the comforts achieved through electricity.

RADSS – the success story for three decades

The RADSS bus differential relay was the first ultra high-speed relay with an operate time of one-quarter cycle to a half cycle. This relay utilizes the so-called medium impedance measuring principle with extremely high security and dependability as well as very low requirements on the current transformers. With RADSS, a saturation time of less than 2 ms is satisfactory for correct operation.

Today, the RADSS relay spans 34 years of excellent service all over the world. Its operating and stabilizing philosophy was developed in the mid-1960s and the first installation was made in November 1969, at the 130 kV substation in a power plant in Västerås, Sweden. This installation is still in operation. Today, numerous utilities worldwide apply RADSS to ensure critical busbar protection.

Since its world premier in 1970, more than 10,000 units have been delivered worldwide. With these 10,000 installed zones, RADSS has created an impressive track record: not a single verified incorrect operation incident has been reported. Both the number of delivered units and their performance figures probably represent a world record in this field.

The father and son

Thorleif Forford has worked with the development of RADSS relays and RADSS applications from the beginning of the RADSS era in the late 1960s. Today, he has many stories to tell about this product. He has seen many customers testing RADSS, taking it into use and even saving human lives only a few months after installation.

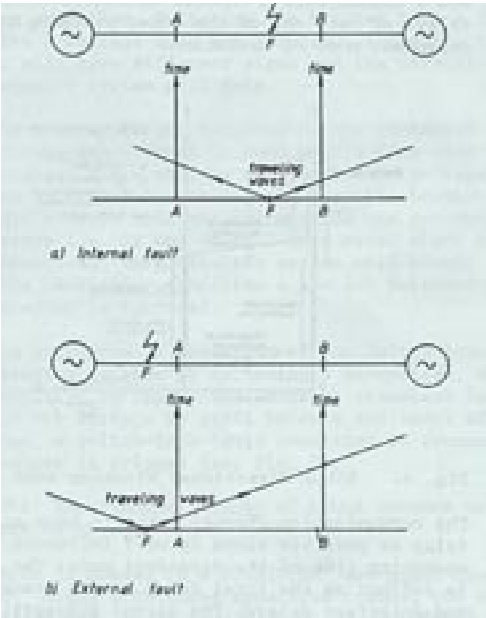
"To gain something you must have the courage to try something totally different. When we started to develop RADSS, there were many things that we did not know how would turn out at the end of the day. They turned out to work the way we wanted, and we were able to release a product with a 1 ms operate time. This product has now been in operation for decades," Thorleif Forford explains.

Thorleif Forford and the last RADSS delivery in 2003.

Today, RED 521 Differential Protection Terminal and REB 103 continue the tradition of RADSS.

Ultra high-speed line protection

A new approach to ultra high-speed line protection was introduced in 1976 with the traveling wave detector relay type RALDA. This directional wave detector measures sudden changes in voltages and currents. The relative polarities of the voltages and current change "waves" are compared to determine the direction of the fault. This concept has been used in many applications, especially for series-compensated lines, where conventional distance relays have limited functionality. Even today, customers appreciate RALDA's superior speed performance, which allows power systems to operate closer to their designed stability limits. With its 2-4 ms operate time, RALDA presents a great advantage, reducing the time to trip a faulted line to one cycle.



RALDA traveling wave principal.

The RALDA traveling wave relay measures the sudden changes in voltages and currents.

"Night-time soap operas made their premiere in the seventies in living rooms around the world. The broadcasting boom had started..."

A majority of families in the industrialized world received a new member. In America alone, the vast majority of all households had a TV in 1970. Technology made headway into routine office life: fax machines, word processors and central computers became more common. In Seattle, Washington, a Harvard drop-out, Bill Gates, started a computer software company together with Paul Allen in 1975.

Approximately ten years after Intel engineers headed by Federico Faggin invented the world's first single chip microprocessor in November 1971, ABB released its first microprocessor-based protection relay. This step was to be followed by the breakthrough of numerical protection and control technology later on. Using numerical technology in protection relays improves performance and flexibility, providing new features such as self-supervision and recording of disturbance values. These improvements increase the reliability of the secondary system and allow more efficient use of the primary equipment.

Microprocessor-based relays first began to replace static relays at the beginning of the 1980s. At first, they were the so-called "hybrid" solutions, where time-critical filtering was performed with analog electronics. A typical example is the REZ 1 – a universal phase and ground distance relay for permissive and blocking schemes with 1-4 directional zones.

The first computer-based substation control system

ASEA delivered the first substation control system (SCS 200) in 1983. This system was delivered to the Swedish State Power Board. The system provided the plant with versatile control, interlocking, recording, alarm handling, auto reclosing, power system restoration, voltage regulation and energy measurement functionalities. This system also featured remote control communication. At that time, protection relays did not have serial communication, and the relay operation was transmitted to the substation control system via binary inputs. The operation data was stored in the event register.

Fault location

The fault locator, RANZA, was introduced in 1983 to offer a truly numerical approach to the fault distance calculation for the first time. The measuring signals were stored in a memory, and a system algorithm was used to calculate the distance to the fault with significantly better accuracy than was possible with analog electronics.

RACID:

A universal phase and ground overcurrent relay for lines and cables with instantaneous, time-delayed and start functions. Its time-delayed function is programmable for definite time, normal inverse, very inverse and extremely inverse. This relay can also display information about faulted phases.

The microprocessor three-phase time-overcurrent relay with phase and earth fault overcurrent was introduced in 1985.

The RACID microprocessor time-overcurrent relay.

RACIF:

A low-power version of RACID performing the same protection functions. This relay does not need an auxiliary power supply since it is self-powered from the CTs. An electromagnetic indicator stores phase and trip indications, also after loss of power supply.

REG 100:

A multifunction generator protection relay with differential, underimpedance, overexcitation, overvoltage and other protection functions. This relay was introduced in 1987.

Numerical line distance protection

The world's first fully numerical line distance protection terminal, RELZ 100, was presented in 1986. This was also the first multifunction relay, which integrated a number of functions, including:

- Full scheme line distance with 5 zones
- Load-compensated operation
- Phase selector
- Power swing blocking
- Disturbance recorder – 1 ms resolution
- Event recorder
- Overcurrent
- Fault locator
- Built-in protection communication schemes

RELZ 100 line distance terminal.

REB 100:

A busbar protection relay with the same analog measuring principle as RADSS. This relay facilitates an electronic comparator to reduce the current transformer requirements by reduced power consumption with reference to the measuring circuit and with microprocessor logic and supervision. This relay was introduced in 1994.

Numerical COMBIFLEX relays

Numerical technology was also used to revitalize the COMBIFLEX modular measuring and protection relays in the 1990s. Many of the new relays were made pin-compatible with the earlier electromechanical and static relay types. This was done to allow the retrofit of existing installations. The flexibility of these relays was increased by enabling wider setting ranges and more functionality in each plug-in module. For example, a RXKL 1 timer replaced over 50 types of earlier timelag relays.

A modern COMBIFLEX relay type RXHL411 non-directional time-overcurrent protection.

Securing our customer's investments has always taken high priority in our product development. Therefore, after the merger of ASEA and BBC, the COMBIFLEX building system was also adapted for the 900-Series of relays developed by BBC.

"In the eighties, typewriters were increasingly set aside to make room for personal computers."

In the beginning of this decade, cellular phones made their first U.S. appearance in Chicago. In England, prince Charles married Lady Di. Voyager I explored Saturn, and people on Earth started to be concerned about pollution and other environmental issues. At the same time, MS-DOS extended the ability for efficient written communication skills from secretaries to company managers.

People today are living "on line". The industrial, urban, high-tech and real-time communicating world could hardly exist without electricity. Recognizing the importance electricity has to play, ABB utilizes new technologies and creates new innovative solutions for substation automation and protection. For instance, protection and control functions using the same information from the primary equipment can be integrated within one terminal. No separate push-buttons or equipment are needed.

The 500-Series terminal concept

The 500-Series terminal concept, introduced in 1994, takes full advantage of microprocessor technology, thereby offering greater functional flexibility. These terminals utilize a new platform concept consisting of hardware modules and a function library for protection, monitoring, control and communication. The 500-Series terminals provide more data on the primary system performance, for instance, through condition monitoring functions (monitoring of CTs and VTs, etc.) than the older generation protection relays. This data is refined and used at the substation level and can be transferred to network control systems for operation, analysis and maintenance purposes.

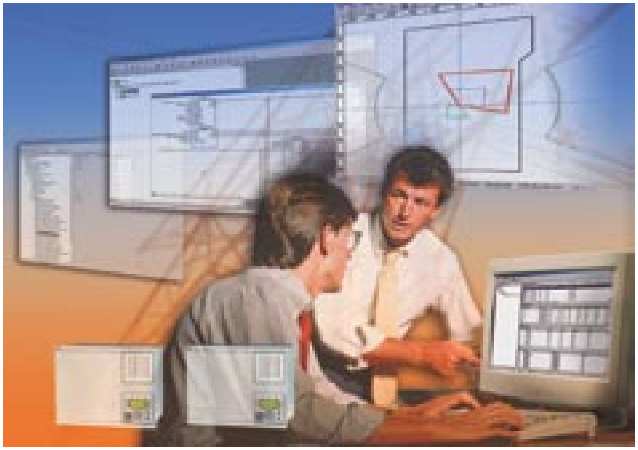
The 500-Series terminals provide protection, control and monitoring for a wide range of applications, such as the protection, monitoring and control of:

- Breakers and disconnectors
- Busbars
- Generators
- Overhead lines and cables (differential and distance protection)
- Shunt reactors
- Transformers
- Railway power systems
- Wide area monitoring and control

RET 521 provides fast and sensitive protection, control and monitoring for different types and sizes of transformers.

CAP 540 software tool for engineering, setting and evaluation

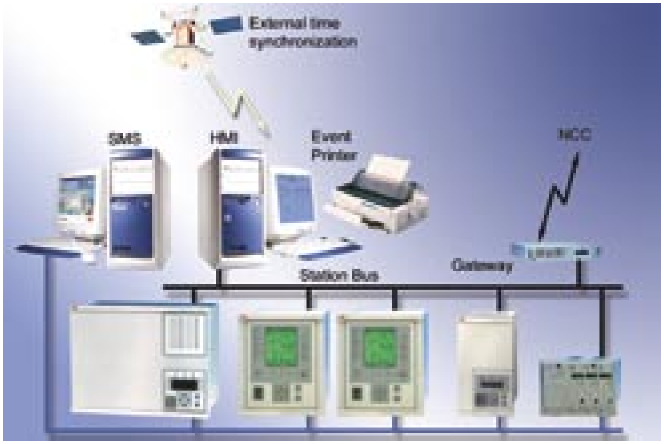
The 500-Series terminals can be fully adapted to application-specific needs with a graphical CAP 540 software tool for setting, configuration and evaluation. The efficient off-line engineering functionality of this tool speeds up the engineering phase by allowing the terminals to be engineered according to customers' order specifications already before the delivery.



The 500-Series terminals can be used as stand-alone units, or they can be integrated into a substation automation system via serial communication. Furthermore, when these terminals were introduced, the COMBIFLEX building system was adapted to the 500-Series building system to allow the use of both product families in the same installation.

Substation Monitoring System

The high functionality and huge amount of information stored in the 500-Series terminals can be handled with the Substation Monitoring System (SMS). This system can be utilized for setting parameters, monitoring service values and self-supervision status, disturbance and event handling. The SMS can be implemented locally and/or remotely in a central office via a public dial-up telephone network or standard TCP/IP network. This direct access to selected information enables efficient utilization of the data stored in the numerical devices.



Fully automated substation

Substation automation allows on-line control and monitoring of primary and secondary equipment. Integration of functions and serial communication reduces space requirements and wiring. Furthermore, these features increase functionality, for instance enabling automatic interlocking. Also new automatic restoration systems based on information from the terminals can be considered to reduce outage times.

The physical structure of a fully automated substation consists of bay and station levels. In substations, the entire substation is controlled and supervised from the station level, while individual lines, transformers and other units are protected and controlled from the bay level. A truly distributed system is achieved by distributing computing power to the bay level terminals.

Power system simulation

The history of the traditional power system simulation has its roots back in the 1920s. In 1985, the physical models of the high voltage object were replaced with a hybrid computer-controlled power system simulator.

The low level electronic analog models represented the power system circuits and equipment, including the current and potential transformers, which feed the relays under test via high power amplifiers. The relay outputs trip and recloses miniature breakers, just as HV breakers do in real service. The interaction between the power system and the protection relay under test can therefore be simulated accurately and in real-time. This was the most important development of an analog power system simulation.

In 1999, the analog simulator was replaced by a fully numerical simulator. In this simulation, the mathematical power system models, such as lines, transformers and other units are executed in real-time by a powerful HP 9000 supercomputer.

“Instead of watching TV, millions of people are clicking their mouses on the Internet. It’s the way to spend an evening at home in the nineties.”

The online population in the 1990s totaled approximately 30-60 million. In 1998, there were an estimated 5 million web pages, and this number has been growing exponentially. People can stop moving around, because the world now moves into their homes through computer screens.

Recent achievements

The RES 521 Phasor Measurement Terminal and REO 517 Protection and Control Terminal for Railway power systems were both launched in 2002, representing the latest achievements in the 500-Series.

RES 521 provides synchronized phasor measurements for wide area monitoring, protection and control applications. It greatly improves the observability of the power system dynamics. This in turn increases the reliability of power systems and allows power utilities to use their existing transmission systems more efficiently, which reduces the need to build additional transmission lines.

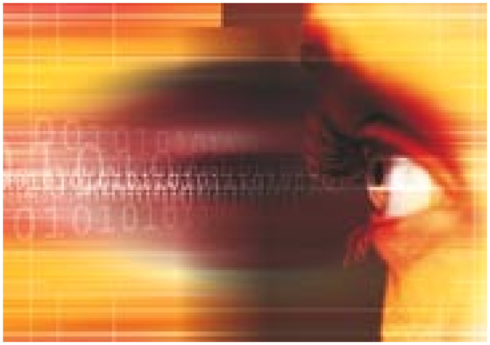
Competition is getting more intense in almost every field. In many countries, the deregulation of electricity markets and privatization have dramatically changed the frame of rules for power utilities. Short-term requirements on financial results are combined with restructuring and mergers. In other countries, the lack of generation and transmission capacity leads to blackouts. New intelligent solutions are needed to reduce outages, maximize results and minimize costs. Information Technology (IT) in substation automation promises significant developments to reduce costs and improve operating performance, as well as to enhance information management.

Information Technology (IT) in substation automation promises even greater developments to reduce costs and improve operating performance and information management for users through the horizontal and vertical integration of processes.

Information technology (IT) adapted for substation automation and standardization improves the availability of real-time data and its processing. This enables more efficient utilization of the power system.

The search for information from different sources and various systems in different formats from on-line islands of reference material to paper copies is extremely time consuming. Additionally, there is a risk that the information is not up-to-date. IT will allow information to be managed in a way that has not been possible before.

This allows plant operation and asset life-cycle management to be improved, as information, such as technical data, circuit diagrams, maintenance information and location, from every piece of equipment is kept together and can be easily managed.



"Is there life on Mars?"

The search for life on Mars took a giant leap forward when the Mars Odyssey probe found huge reservoirs of ice just beneath the surface. If the ice melted, creating warm pockets of water, the conditions could be suitable for life to develop. However, NASA scientists are cautious on this subject, pointing out that single-cell beings would be the most likely inhabitants of Mars rather than the little green men with attitude problems.

100 YEARS OF RELAY PROTECTION IN SWEDEN

HISTORICAL HIGHLIGHTS:

1905	First electromechanical time-overcurrent relay
1930	Electromechanical plug-in relay system
1940	Electromechanical distance relay
1969	COMBIFLEX static plug-in relay system
1969	Ultra high-speed bus differential protection
1970	First static distance relay
1974	Static distance relay for EHV/UHV
1976	Static ultra high-speed line protection
1982	Microprocessor-based fault locator
1983	Computer-based substation control system
1986	Numerical distance relay
1994	500-Series terminals with integrated protection and control – fully automated substation
1997	Graphical IEC 61131-3 configuration and parameter setting
2000	Numerical protection for transformers and busbars
2002	Phasor Measurement terminal for wide area monitoring and control

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