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SELF- SUPERVISION TECHNIQUES
REx 5xx- series line terminals

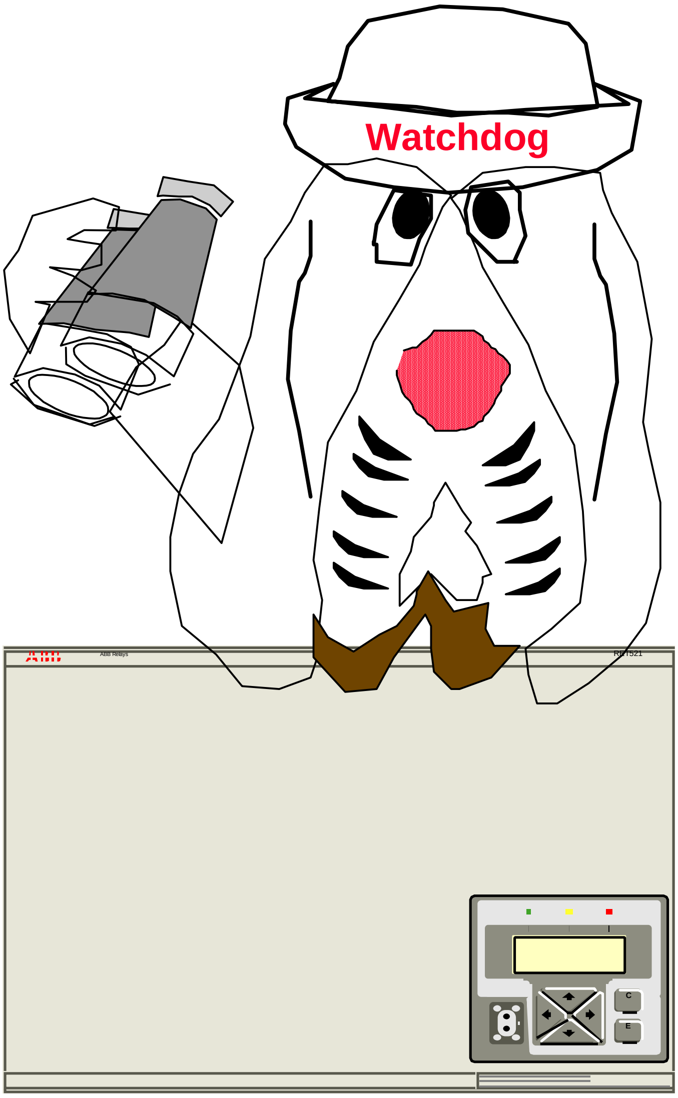

ABB Automation Technologies
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1 INTRODUCTION

One of the major benefits of microprocessor technology is that no additional hardware is required for the self-supervision, a function that increases the availability and reliability of the whole system, by ensuring that product and system faults can be detected immediately.

The self-supervision can be performed by software functions, utilizing standard features as watchdog functions, checksum etc., and some extra software functions, to get as much coverage as possible for the self-supervision. However, the self-supervision must be as simple as possible, to keep the reliability high.

The current and voltage circuits, and the communication links, can also be monitored continuously by a SMS or SCS system, e.g. by taking measuring values from Main 1 and Main 2 at regular intervals during steady state conditions and comparing these values. An other option is reporting to the control center for comparison with the result from the state estimation

Messages from the self-supervision system can be available both locally and remotely, which further simplifies fault tracing, and cuts down the time for repair, e.g. by identification of defective parts.

As an example of the improved availability with self-supervision, the **M**ean **T**ime **T**o **R**epair **(MTTR)** can be compared with conventional static or electro-mechanical equipment without supervision.

With a test interval of e.g. 2 years, the MTTR without supervision is approximately 1 year, since a fault will most likely not be detected until the next test is performed. With supervision, a fault can normally be repaired within 48 hours, see figure 1 below. This means that the MTTR will be 2 days instead of 365 days, a significant improvement.

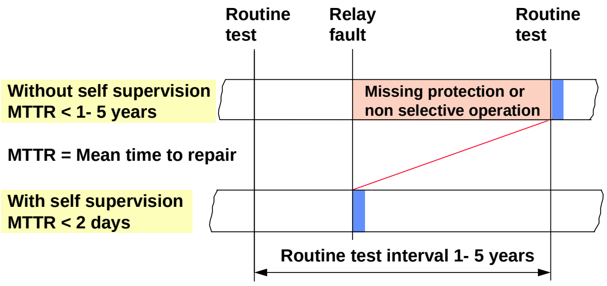

Figure 1. Impact of self-supervision.

As an extra benefit the software based self supervision has an inherent capability, which is very attractive for protection and control equipment in an Electrical Power System: **The risk for unwanted functions is decreased.** The error detection by the self-supervision is normally used to block the equipment.

Thus the probability for unwanted functions is decreased, at the expense of missing operations. However, missing operations are much easier to deal with, e.g. via back-up systems.

As a conclusion, **Self- supervision of protection and control hardware and software reduces both downtime as well as the maintenance costs, as the regular maintenance period can be extended.**

2 GENERAL

The relay protection is a vital part of the fault clearing system. However, periodical testing and self-supervision of the protection is important to secure the fault clearing function.

For relay equipment without self-supervision, a fault is not detected until the equipment does not operate correctly, or detected by maintenance testing. To reduce the risk for a missing function, periodical maintenance testing is performed. The test interval is determined by the probability for a fault in the equipment. **M**ean **T**ime **T**o **F**ailure (**MTTF**), and by the fact that a fault in principle can be undetected for 50% of the time between test intervals. Together with an evaluation of the acceptable probability of a missing fault clearing of a primary fault.

By experience, the test interval for equipment without self-supervision has been in the range of 1- 4 years. Numerical Relays with self-supervision will of course decrease the need for manual testing. Thus, the maintenance cost can be reduced with maintained security and dependability for fault clearing. A suitable test interval for numerical relays with self-supervision has to be established, but test intervals of 4- 8 years are used.

3 SELF-SUPERVISION IN NUMERICAL RELAYS

Self-supervision and self-diagnosis are features, which are very difficult and expensive to implement in static analogue equipment. Complexity increases and in turn effectiveness decreases quickly to a point where it is not technically or economically justified.

In a microprocessor-based system, a certain processing time can be allocated to perform selected checks and verifications. The results can be compared e.g. with previously obtained. Detected discrepancies can initiate corrective measures or deactivate certain functions or the whole equipment. This feature leads, properly adapted, to maintenance by request rather than to a maintenance routine testing of the relays.

Self-supervision can, as any system not is 100 % reliable. The self-supervision versus manual testing is a matter of the complexity of the protection equipment. Less complex function as over current protections can be self supervised to a very high degree, for more complex functions such as distance protection or generator protection, a combination of self supervision, manual supervision, i.e. via evaluation of the protection equipment performance via disturbance recordings, and manual testing will give the best result.

It is important that the self-supervision is designed with an optimized performance with respect to detection ability versus the complexity. It is important that the self-supervision is designed not to jeopardize the protection function. This optimization is limiting the detection degree for the self-supervision in complex protection functions. A rudimentary self supervision function, as for example a " watch dog" function has very limited detection ability, and thus contributes in a limited way to increase the availability. The self-supervision in numerical relay's can be designed with fairly high detection ability.

The self-supervision can be designed with reference to the probability for a fault in different components. In principal active components are considered to have a higher fault rate than passive components.

The detection ability α can be defined with reference to the different components failure rate λ. (Faults/year)

$$\alpha = \frac{\lambda_2 \cdot 100}{\lambda_1 + \lambda_2}$$

α = Detection ability in %

λ_1= Failure rate for not self supervised components

λ_2 = Failure rate for self supervised components

The self-supervision in modern numerical relay's can detect around 85- 90 % of all faults with the failure rate taken for various components taken into account. The non supervised components are mainly passive components such as interference suppression devices and output relays, with very high MTTF (100-200 Years) The detection ability is almost as high as for manual testing with secondary injection of test quantities such as current and voltages for distance protection. The detection ability for self-supervision and manual testing can be complementary. I.e. the self-supervision detects fault which the manual testing does not detect and vice versa.

However, the time for fault detection with self supervision is in the order of seconds compared with the time to detect a fault with manual testing, which is in the range of years, i.e. a fault can be hidden in average half the manual test interval, see figure 1. This difference makes the self-supervision more effective than manual testing.

The unavailability for redundant protection with different detection ability in the self-supervision, combined with manual testing with the detection ability α = 90 % and α= 98 % is shown in figure 2. The curve shows only the unavailability with reference to capability to trip. Unwanted tripping is not considered. However, with numerical self-supervision, the probability for unwanted tripping is also decreased

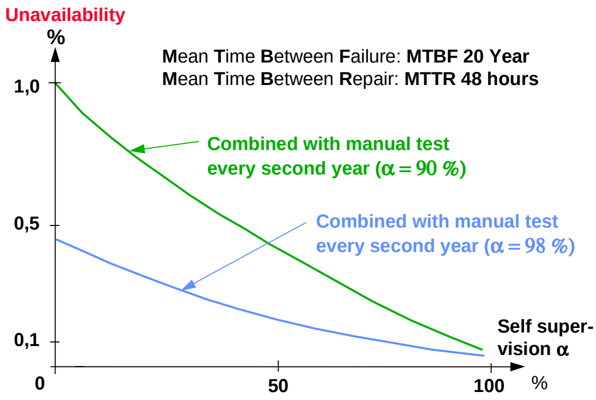

Figure 2. Unavailability for redundant protection

The Self-supervision is in principal continuous. It has been in wide use since microprocessor based relays were introduced in the beginning of the last decade (around 1980). In most case it supervises the software with checksums and other methods, supervises the existence of certain signal or compare signals. It detects catastrophic failures immediately and hence can be used to block the protection at a failure, i.e. prevents the instantaneous incorrect function, which could occur in static relays. Thus the probability for an unwanted function is decreased, and the probability for a missing function is increased. The design is normally made to increase both security and dependability.

The self-supervision is normally designed to be as simple as possible, with a limited amount of extra software and hardware. The advantage of this design principle is that the failure rate is lower than in the supervised circuits. False signals are not allowed; otherwise the benefit of the self-supervision is lost. However, most actions, alarm or blocking has to be delayed by an appropriate time to avoid spurious function of the self-supervision, i.e. during transient conditions or during interference. These delays are of no consequence when calculating the unavailability. The unavailability is determined by the mean time to repair. (MTTR)

The relay parts that deal with measuring quantities in practice supervised to 100 %. An unsymmetry supervision of the primary measuring quantities will of course detect an unsymmetry and give alarm, but the fault can be in the primary system, in the measuring transformers or in the relay's analogue parts.

However, the main drawback of the self-supervision is that output and input relay's cannot be activated and fully supervised.

Thus a state of failure to operate is difficult to detect, when the output or input relay's are faulty. But the failure rate is extremely low for normal applications (Electromechanical relays MTTF >100 years)

4 SELF-SUPERVISION IN A MODERN LINE TERMINAL

The described relay refers to ABBs line and breaker terminals Type REX 5xx.

4.1 Hardware/terminal platform

The protection is more accurately described as a line terminal as it can contain almost all functions required for a line. The terminal has a modular hardware and software structure, with multi-processor technology and multiple I/O boards, interconnected via a motherboard in the front, see figure 3. All terminals are designed with modules from the same hardware library. The terminals are part of a common modular system, with standardized plug-in boards, which allows for easy modifications and repair, as well as future upgrading. The transformer module can be equipped with up to 5 voltage and 5 current input transformers. In the A/D converter module the signals are filtered and sampled using a multiplexed 2 kHz sampling frequency. The information is sent over a 1 Mbit/s Manchester coded bus to the various DSPs. The main processing module can have up to 12 DSPs and one 32-bit CPU (Central Processing Unit). The CPU is used for logic and communication, see figure 3.

Figure 3 also illustrates the signal and information flow as a "pipe-line" within a line terminal. 5 currents and 5 voltages are connected to the A/D converter, which has a sampling rate of 2 kHz or 40 samples/cycle in a 50 Hz system. In addition the phase quantities, the $3I_O$ of the parallel line and the bus voltage are included to allow mutual compensation and synchrocheck. In order to increase the dynamic range to 0,01-110 times rated current, the current sampling is divided in two ranges. The 2 kHz signal is filtered down to 1 kHz with sliding average filtering. This over sampling technique gives both fast operation and good transient behavior. The guaranteed frequency bandwidth is 5-300 Hz, which allows transient recording up to the 5th harmonic as well as correct filtering and adaptive algorithms for the different protection functions.

Each millisecond, numerical data for 10 analogue values (5 voltage, 5 current) are sent to 12 DSPs, which are operating in parallel. This means, a separate continuous measuring microprocessor is used for each main function, which allows for both rapid and complex algorithms, as well as tailor made filtering for each function. The total capacity of the DSPs and CPU is approximately 100 MIPS, which is higher capacity than in a standard PC.

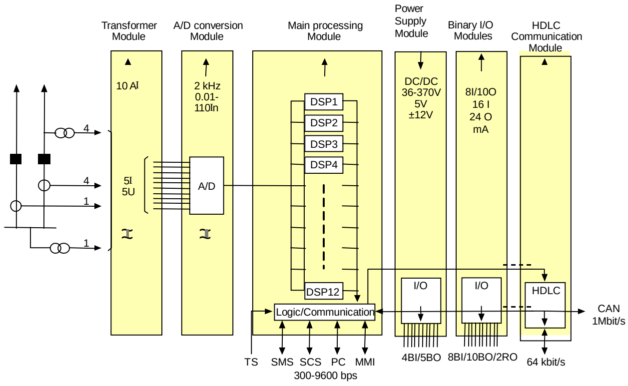

Figure 3 Hardware/terminal platform

The data from the A/D converter is available for all 12 DSPs. Each DSP performs both the specific filtering and algorithm, required for each function. By this architecture each DSP with its software can be seen as one protection function, which also can be comprehensively tested separately. A program change in one DSP will not affect any of the others. Since both the multiprocessor design and several algorithms are reused from earlier well-proven designs, this further demonstrates the "back-wards" compatibility and documented reliability of the functions. The same is valid for future modifications and extensions, which can be carried out in each DSP separately. By this way of handling software and hardware, the quality requirements of ISO 9000-3, and the users, can be met.

The terminal can for example include a 5-zone full scheme distance function with quadrilateral characteristic. This function is implemented using 3 DSPs. Basically each zone can be regarded as a separate function, programmable forward, reverse or undirectional, which also is available in the logic and via binary input and binary output signals. Zone 1 has load compensation to avoid overreach.

Line differential current functions, based on 56/64 kbit digital communication are available and a number of more function in a functional library.

These high performance line protection algorithms have been installed in more than 20000 line terminals world-wide since 1987 and successfully used up to 800 kV The separate fault locator function, located in an additional DSP, includes compensation for load and mutual coupling, and is also based on a well proven principles. (Fault locator type RANZA)

For the directional earth fault a third harmonic filter is included to ensure correct function when used with capacitive voltage transformers. For the undirectional earth fault protection, a second harmonic restraint function is included to prevent false operations during transformer inrush. Two DSPs are used to perform the current differential algorithm. This also includes a CT-saturation detector, which desensitizes the protection during CT saturation. Autoreclosing, synchro check and breaker failure is included as individual functions. A separate DSP is used for the handling of disturbance recorder data.

4.2. Software platform

The software platform is structured in different levels according to fig. 4

- Hardware close software incorporating basic elements such as start-up routines, self supervision, operative system, etc.
- Functional platform, containing a software library for different functions, programmable logic/ timers, HMI etc.
- Product specific configuration

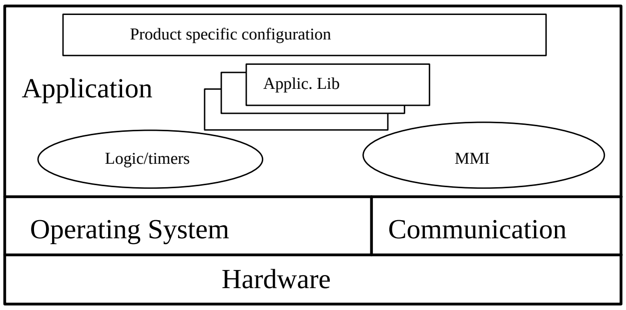

Figure 4. Software platform

The application library contains all the protection, control and monitoring functions as software modules, which has been developed as well as possibilities to connect future modules. The application library for protection and control functions are shown in figure 5, and the application library for monitoring and auxiliary functions is shown in figure 6.

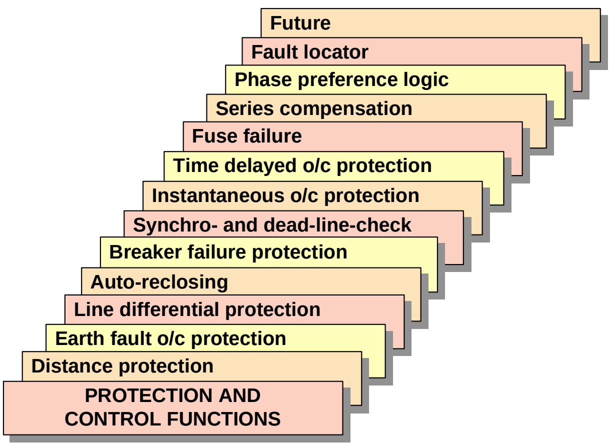

Figure 5. Protection and control functions

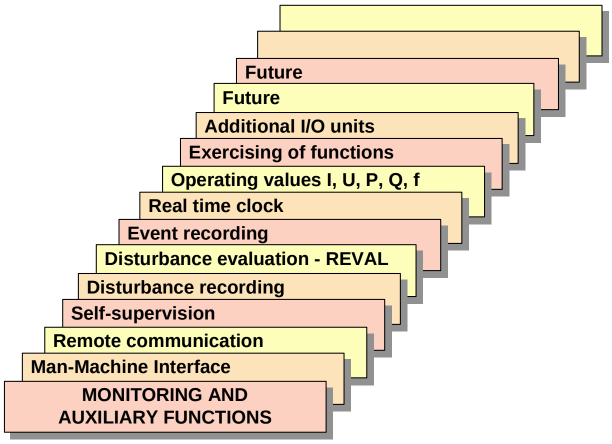

Figure 6. Monitoring and auxiliary functions

4.3 Self-supervision function

REx 5xx has an "intelligent" self-supervision, only faults in the vital measuring parts of the protection block the relay. Any error detected in one of the 12 digital signal processors will only block this particular faulty processor, while the remaining processors will still operate, eventually with decreased functionality if logics are used to connect more than one function, i.e. for the distance function in different communication schemes.

The supervision is divided in two parts, one that is performed at start of the protection and one that is performed continuously during normal service. The main part of the supervision is made by the main processor on the main processor module and another part is made by a signal processor on the A/D converter. A basic function is of course the use of " watch dogs" for all the microprocessors as well as control of the check sums for memories of the programs and settings.

4.3.1 Self supervision at start

The start and shut down of the protection at switching on and off the dc supply voltage is made in sequence. The A/D converter has a lower DC- supply threshold value, to ensure that the A/D converter will start to operate before the measuring unit starts, and continue to operate at shut down after the measuring unit has shut down. In this way correct data will always be available to the measuring elements, ensuring correct function at switch on and switch off of the dc power supply.

After the test, the following text is shown on the HMI.

Self test OK or eventually ERROR

The corresponding error code will be visible on the HMI, see figure 7 (or via SMS)

Event message	Description	Generating signal
Internfail OK	Internal fail status	Int- fail (reset event)
Internfail Error		Int- fail (set event)
Internwarn OK	Internal warning status	Int-warning (reset event)
Internwarn Error		Int-warning (set event)
CPU-fail OK	CPU module fatal error status	Int-CPUfail (reset event)
CPU-fail Error		Int-CPUfail (set event)
CPU-warn OK	CPU module non-fatal error status	Int-CPUwarn (reset event)
CPU-warn Error		Int-CPUwarn (set event)
ADC OK	ADC module status	Int-ADC (reset event)
ADC Error		Int-ADC (reset event)
I/O board OK	I/O Module B status	Int-IOB (reset event)
I/O board Error		Int-IOB (set event)
I/O -1 OK	I/O module 1 status	Int-IO1 (reset event)

Figure 7. Self-supervision, event messages

4.3.2 Self supervision during operation

The error code on the HMI will be the same as for the start- up.

Program execution
The watchdog function supervises that the program execution is performed in correct sequence. If this is not the case a reset is sent to the main processor.
(During start a time-out control is included.) The logic functions are continuously supervised.

A/D converter.
The main processor supervises, that data is received and a check sum control is made for each received set of data every ms. (At start, the check is that data are received.) The watchdog has a time out of 10 ms. In addition the microprocessor on the A/D converter has an internal Power On - check.

Signal processors.
The signal processors perform the various measuring functions in the terminal. Internal control of the processors is made as well as external check that the processors produce data to the main processor. The check sum for the data from the A/D converter is continuously supervised. Read/write control of internal RAM and check that the signal processors produce data are performed continuously every ms.

(At start, internal RAM and registers are checked. A checksum for setting parameters is calculated and the internal communication controlled.

The supervision of the signal processors and other parts on the main CPU module is divided in two groups according to Appendix 1. The faults which can cause unwanted trip are blocked, and the remaining functions are connected for warning

FLASH-PROM.
The setting parameters are stored in non-volatile FLASH PROM. Both the data and the setting procedures are supervised. The parameters are stored in two areas that contain exactly the same information. At start and change of settings, the check sums are calculated for the parameters and the two areas are compared byte by byte. If one area is faulty, a trial reset is performed by utilizing the parallel area.

The comparison of the two areas, byte by byte, is continuously performed. A comparison takes total 1 minute. If an error is detected in one of the areas, the relay automatically switches over to the other area and gives an alarm. The relay will be blocked only if errors are detected in both areas.

Main CPU module
As a summary the CPU provides the following self-supervision functions during both start and continuously. The start check can also be activated via the MMI: (see error code in figure 7.)

The signal structure for the supervision is shown in figure 8.

- Checksum of program memory
- Read/write check of RAM to all locations in the memory. Check time 1 minute.
- Program execution order control. Watchdog detection time 10 ms
- Program lock ups are checked by controlling that the "idle task", i.e. the lowest priority loop in the operative system is executed.
- All I/O nodes are polled for status
- The A/D converter is controlled to produce data with correct time frame as well as the checksum.
- Poll for MMI status
- Checksum for parameters stored in Flash- PROM
- Checksum for actual working parameters
- Poll of signal processor status

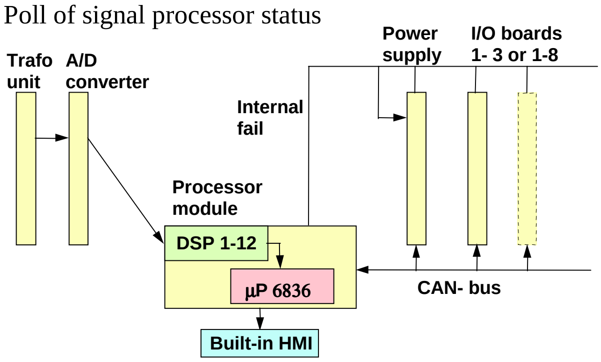

Figure 8 Signal structure for self-supervision

I/O nodes.
The I/O nodes are indirectly supervised from the main CPU. On the I/O boards, the internal communication (CAN bus) is supervised as well as Read/write RAM checks an ROM checksum. A watchdog function is also provided.

Thus most of the electronics is supervised. However, the Binary in opto-coupler circuits and the Binary output relays are not supervised. The probability for a fault was considered to be too low to justify additional circuitry for self-supervision. The final check to activate the I/O circuits cannot be performed, thus limiting the self-supervision possibilities.

Internal communication.
The internal communication between the main CPU module the I/O boards and the power supply is carried out by a Master-Master serial data bus, **CAN bus**. Each I/O module and the CPU module have a special hardware circuit for the communication control. The bus is continuously supervised. As soon as an incorrect message is detected, determined by a single node, the message is repeated. Via different built in facilities in the CAN bus excellent facilities for error detecting and correction is provided. I.e. a faulty node can be identified and disregarded, without disturbing any other node. The error handling is rather sophisticated, with counters for error messages, which can be set to a certain value determined by the maximum load of the bus.

Power supply.
The self-supervision is checking the dc levels. The alarms are provided as signal contacts and to the CPU via the CAN bus.

Transformer module.
The transformer module has no direct self-supervision. However, indirectly the transformer module is supervised via the process signals as specified in the section below.

4.4 Additional supervision via process signals

The process signals can also be utilized for self-supervision connected to a binary output and to the HMI, local or remote via a SMS or SCS system.

- The **unsymmetry current** check can be coupled to an alarm output and detects faulty parts in the current circuits IL1, IL2, IL3.

Eventually also the following functions can be utilized, but the difficulty is to distinguish between relevant and irrelevant information.

- The **low voltage** check can detect faulty parts in the voltage circuits for UL1,UL2, UL3 and be coupled to an output.
- The **disturbance recorder** triggering facilities can detect faults in the analogue inputs (5I, 5 U), <I >I, <U, >U etc. and be connected an output.
- The **overload** function can detect faults in IL1, IL2, IL3 and be connected to an output.

In addition to the process signals, all **phasor values** are available. The phasor values have not (yet) been utilized for self-supervision. However, the acceptable limits for deviation or e.g. comparison between Main 1 and Main 2 can fairly easy be performed via an SMS or SCS system.

5 SECURITY, DEPENDABILITY AND AVAILABILITY

The possibility to improve the protective relay reliability and to reduce the maintenance labour requirement by introducing an automatic test or supervision of the protective relay has been interesting for the power industry during the past few years. The automatic testing or self supervision shall detect component failures in the protective relay and result in an increased reliability together with a greatly reduced or excluded maintenance testing. One important factor is , how to utilize modern technology. Shall the relay be performed in one microprocessor with serial execution of all functions or by parallel execution in different microprocessors. The REx 5xx is a multiprocessor design, which increases both the security and dependability. The structure in REx 5xx is also well suited for a structured self-supervision as shown in figure 9 and figure 10 below.

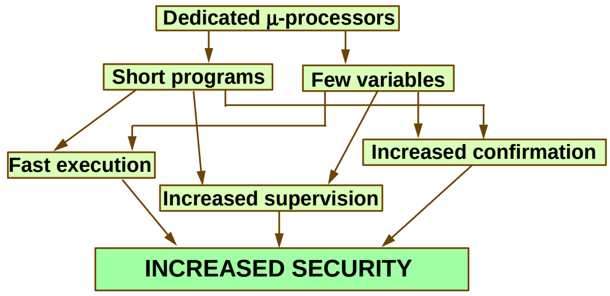

Figure 9. Security

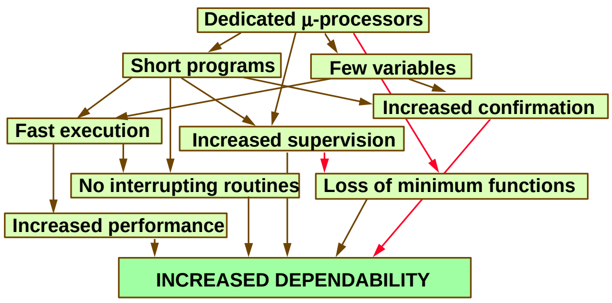

Figure 10 Dependability

Increased **security** and increased **dependability** consequently gives an increased **availability.** However, since an automatic test system or self supervision system does not test or supervise itself and can contain an increased hardware and software complexity in the protective relay, it consequently can give a reduction of the Mean Time To Failure, MTTF, if the design is not optimized.

In conventional schemes, security is enhanced by series connection of protections at the cost of dependability (and availability). On the other hand, dependability may be increased with parallel protections, at the cost of security. A rely with self supervision can be considered to give improvements both in dependability and security according to fig. 11

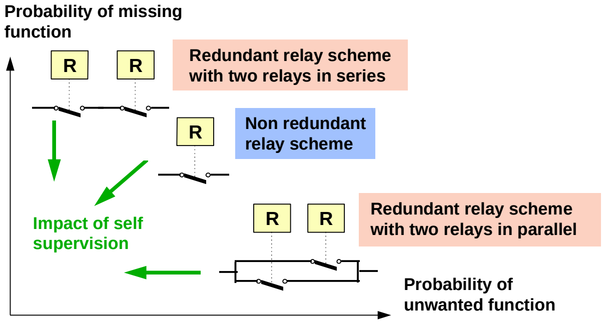

Figure 11 Influence of self-supervision on dependability and security

However, since the whole fault clearing system is not supervised or automatically tested, the automatic test system must be supplemented with a regular manual check with reference to dependability. Thus, it must be stated that the main impact of the self-supervision is on the security, i.e. the risk for unwanted function has been decreased

5.1 Dependability

A study of automatic testing and supervision performed jointly by the Swedish State Power Board and the Swedish Utility Sydkraft AB is described below: The study has been performed with reference to <u>Failure to Operate</u>. The increased security, which can be achieved with numerical self-supervision was not considered. All referred calculations are made with an assumed MTTF of 20 years including the CT- and PT-wiring and the trip circuit wiring. For the redundant protection a MTTF of 20 years is assumed for each of the redundant protections. The assumed MTTF of 20 years (37 % likelihood that the protection is operational after 20 years) is short compared to operational experiences. When a longer MTTF is applied in the calculations, a less favorable result for automatic testing or supervision is achieved. **The MTTF for the 500 series is specified to 70 years from service records of 20000 delivered terminals**

The manual testing is assumed to be carried out every second year. The manual test will take three hours to perform. During this time the protection is out of service. At manual test of redundant protection the testing is made in such a way that only one of the redundant protections is out of service at a time. When a failure to operate is detected either at manual test or by automatic means, it is assumed to be repaired in 48 hours (MTTR 48 h).

The manual testing is assumed to have a fault detection capability of 90 %. The likelihood of failure to operate is detected with 90 % detection ability by the manual test and a detected failure is repaired within 48 hours.

5.1.1 Single protection

In Figure 12 below, the curve "I" shows the resulting probability of failure to operate over the years when the protection is manually tested, as assumed above. The probability of failure to operate can be reduced if the fault detection ability of the manual testing is raised from 90 to 98 % according to figure 2. The test interval every second year is maintained. By assuming that the manual testing is replaced by continuous automatic supervision, the probability of failure to operate will be according to curve II.

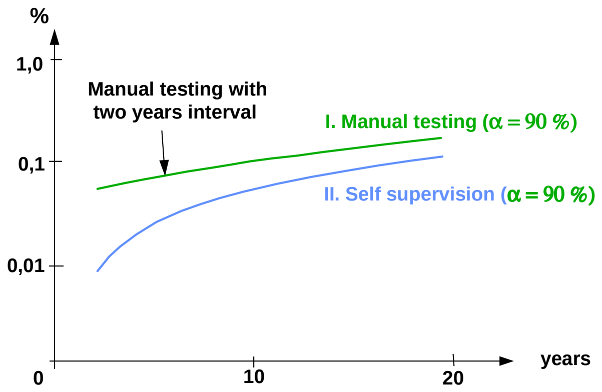

Figure 12. Probability of failure to operate for a single protection.

The reduction in average probability of failure to operate, over a 20 years period, will be 0.04 or one failure to operate out of 25 operations. Curve II will be achieved under the assumption that the fault detection capability of the automatic test or supervision is 90 % and that the additional equipment for the automatic test or supervision does not introduce any new risks for failure to operate by its own.

In practice these two assumptions are not possible to achieve at the same time. A very high fault detection capability can normally only be achieved by introducing additional components and quite complex software with additional risks for failure to operate.

These additional risks reduce the theoretical reduction in probability of failure to operate. When the number of additional components is minimized the fault detection capability is reduced and the probability of failure to operate is increased.

For conventional static (or electro mechanical) equipment, α must be limited to < 50 %, due to the amount of additional components for the automatic self-supervision. Thus automatic self-supervision in conventional protection and control equipment will not increase the dependability and security.

For numerical equipment the self-supervision can be given an α > 85 % with very limited influence on the complexity of the software. Thus, self-supervision in numerical equipment significantly improves both security and dependability.

When the resulting probability of failure to operate of a single protection manually tested cannot be accepted a redundant protective relay has to be used. Only by redundant protective relay's, a substantial increase in the dependability can be achieved.

5.1.2 Redundant protection

In figure 13, the curve I and II shows the resulting probability of failure to operate for a redundant protection, Curve I represents only manual testing every second year and curve II an "ideal" automatic testing or supervision device. The fault detection capability for the testing and supervision associated with curves I and II are 90 %.

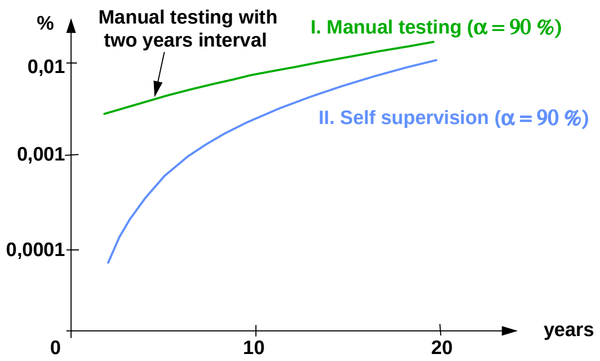

Figure 13. Probability of failure to operate for redundant protection

The "ideal" self-supervision will reduce the average probability of failure to operate over a 20-year period to 0.007. This reduction is equivalent to one failure to operate out of 140 operations.

The reduction is achieved under the assumption that the two self supervision functions in the devices in main 1 and 2 protective relay's, are "ideal", i.e. are not introducing any new risks for failure to operate.

5.2 Security and availability

Self-supervision has the main impact on security and availability. As stated in figure 1 the availability can be increased considerably. However, very little is published from utilities about the practical implication of this new aspect on protection schemes. Perhaps it is too few installations yet, to give an impact on the statistics for unwanted and missing functions. In principle, the new facilities should give much better result for the numerical protection equipment, compared with electromechanical or static protection equipment.

6. CONCLUSIONS

The conclusion by the joint study of two utilities in Sweden was **that automatic testing or supervision cannot replace manual testing** when increased **dependability** is concerned. The main reason is that not the whole fault clearing system can be tested. **Self-supervision** will increase the dependability, security and availability of the protection equipment, but will have the main impact on **security**

The fault detection capability of all manual testing and self-supervision must be high, >90 % respective >70 % to achieve a substantial reduction in the probability of failure to operate. The achievable reduction in the average probability of failure to operate when a single protective relay is equipped with automatic testing is limited. When the probability of failure to operate for a manually tested single protective relay is not acceptable a redundant protection is preferred to automatic testing.

In practice no reduction in probability of failure to operate can be achieved with automatic testing of redundant protection. On the other hand, the security is very much improved, which makes the self-supervision extremely valuable.

The joint study by the Swedish State power Board and the Swedish utility Sydkraft AB has shown that the base to maintain a reliable fault clearing is manual maintenance testing at regular intervals. Therefore, an advanced and well-proven test system like the ABB COMBITEST together with regular manual tests including the whole fault clearing system cannot be replaced with automatic testing or supervision.

However, the experience so far indicates that the interval for manual tests can be significantly prolonged. Also additional methods, e.g. supervision of the performance of the fault clearing including the protection equipment via disturbance recorders and event recorders are new tools to check the fault clearing capability, which can prolong the regular preventive maintenance manual test intervals by directing the repair directly to faulty parts.