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Automation Components

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White paper

NRG Digital solid state relays

Now enable prediction of machine failures, maximizing plant efficiency

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Digital solid state relays now enable prediction of machine failures, maximizing plant efficiency

INTRODUCTION

Unplanned machine downtime costs organizations considerable amounts of money in lost revenue, bad quality products and penalties for delayed shipments.

Maintenance, which was an activity to be undertaken only in case of a breakdown, became much more important in the second and third wave of the Industrial Revolution. Preventive maintenance schedules were devised to reduce unplanned downtimes. However, these schedules carry a high maintenance cost as machines must be stopped for the planned maintenance and replacement parts are an added cost.

With the fourth wave of the Industrial Revolution, also known as Industrial Internet of Things (IIoT) or Industry 4.0, there is a greater focus on maximizing overall equipment efficiency (OEE), reducing operational costs and improving productivity. One of the most cited applications for the IIoT is predictive maintenance.

Predictive maintenance attempts to keep costs low by reducing the frequency of maintenance tasks, reducing unplanned breakdowns and eliminating unnecessary preventive maintenance. It is the ability to predict when a machine failure could occur so that necessary corrective actions are taken before the breakdown occurs. With predictive maintenance, machine critical components are continuously monitored in real time. Data from these components is collected so that predictive patterns could be built from the analysis of historical data.

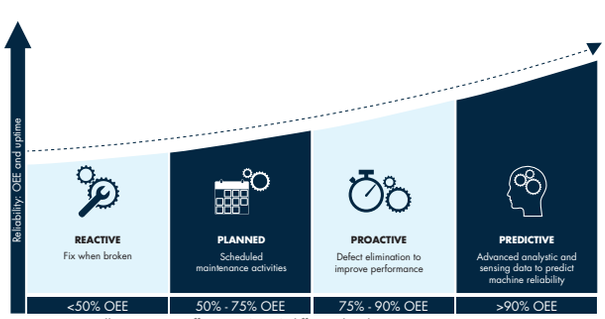


Figure 1: Overall Equipment Efficiency (OEE) different levels.

Carlo Gavazzi, a leading manufacturer of solid state relays (SSRs), has developed a new range of intelligent solid state relays, the NRG series, that integrates monitoring and can exchange status and diagnostic data with the machine controller in real time through an industrial communication interface.

This paper explains the NRG concept and how it fits into today's changing market, the importance of real-time monitoring, how data from the NRG can reduce unplanned machine downtime and concludes by comparing the NRG to an alternative monitoring solution.

THE EVOLUTION OF THE SOLID STATE RELAY AND ITS TRANSFORMATION TO FIT IN AN IIoT ENVIRONMENT

Solid state relays are switching components recognized for their ability to perform millions of cycles without breaking down. They became very popular in the early 1980s following the introduction of Programmable Logic Controllers (PLCs) in control systems for automated processes. A control system compares the value or status of the process variable being controlled with the desired value or setpoint, and applies the difference as a control signal to bring the process variable output to the same value as the setpoint. The control changes very frequently causing the switching component to switch ON and OFF repetitively to ensure a constant process. Because of their trouble-free operation over many cycles, solid state relays took over as the preferred switching component in control systems. This is particularly true for temperature-controlled processes where unacceptable temperature fluctuations can be eliminated with the fast switching provided by solid state relays. Repeatable and stable processes can be guaranteed with the use of solid state relays.

Carlo Gavazzi solid state relays have been evolving over the years to adopt technological advances in materials, processes and technology and keep abreast with latest needs in the automation industry.

The industry is now undergoing another transformation – DIGITALIZATION. We have all been personally affected by this transformation over the past years, but its adaption in industry has taken a more cautious approach as new technology requires in-depth analysis. There's no denying though, that employing digital initiatives is the only way for companies to grow, and the pace is expected to pick up rapidly in the next years.

Digitalization is the process of using digitized information to make established ways of working simpler and more efficient. It is not about changing the way business is done, it is about using data that is instantly accessible in order to make informed decisions. In tomorrow's automation

processes, the solid state relay will keep doing the switching function essential to the control and stability of processes. But is the solid state relay of today ready for the new era?

In this digital transformation, the machine components need to have the ability to exchange data with the machine controller. Sensors and actuators, including the solid state relays, need to evolve to remain an integral part of this digitally interconnected components network. Carlo Gavazzi has hence transformed the traditional solid state relay by adding to it a communication interface to enable real-time monitoring and data exchange thus creating the digital solid state relay for the new era, the NRG.

Figure 2: Through Digitalization, data becomes instantly accessible and plant efficiency can be improved.

THE ADDED VALUE OF REAL-TIME MONITORING

'You can't manage what you can't measure'.
At the root of digitalization is data, data obtained through real-time monitoring and measurements that is in turn used to ensure better machine, process or plant management.

Monitoring is essential to reduce unplanned machine stoppages, to ensure a quick reaction to sudden failures, to improve processes and optimize machine performance, to maximize machine availability and to facilitate troubleshooting.

With the vast choices surrounding us, one of the challenges faced by machine builders is the selection of the most appropriate monitoring solution. It needs to tick all the boxes in terms of functionality, cost, ease of use, all within a compact form factor. Carlo Gavazzi's proposal to this dilemma is the NRG.

THE SOLID STATE RELAY PLATFORM OF THE FUTURE

At its core, the NRG is a solid state switching solution but, in its completeness, it is a digital solid state switching solution suited for the ongoing industrial revolution. In addition to the switching function, the NRG integrates monitoring circuitry that enables measurement and diagnostic information related to the status of the SSR and the load it controls to be exchanged with the machine controller. This data exchange is done over a communication interface provided on the NRG SSR. Real time access to this data enables the machine controller to determine what actions are needed to maintain a healthy machine state and prevent unplanned shutdowns.

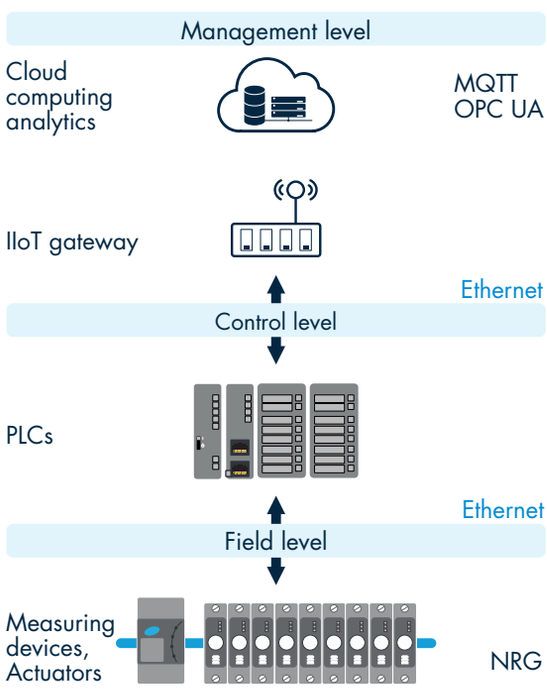


Figure 3: The evolved solid state relay (NRG) for integration in a digitalized platform

REDUCING UNPLANNED DOWNTIME WITH THE NRG

The NRG fits in the same footprint as the traditional solid state relay, hence the additional monitoring functionality and communication interface do not come at the cost of valuable panel space and additional wiring.

In an automated heating process, unplanned downtime related to the solid state relay can be attributed to any of the following factors:

1. Failure of the load connected to the solid state relay
2. Failures related to the solid state relay
3. Failures related to the mains supply or other external factors

When any of the above mentioned failures occur, it may not be possible for the automated process to maintain the set temperature profile. Quality of goods being produced is compromised and the machine must be shut down. Machine downtime related to these failures can be eliminated or reduced by utilizing NRG parameters associated to the status of the solid state relay and other relevant accessible data as explained below.

PREDICTING POTENTIAL LOAD FAILURES

Heaters used in different applications and markets typically have different characteristics. For example, short wave infrared heaters that are more present when radiant heat is required have a very different behavior than nichrome heaters that are more common for contact heating. These different characteristics cause heaters to fail in different ways. Lifetime is another factor that differs from one heater type to another. Heater lifetime depends on the conditions in which it is used in the application. When looking at failing patterns there is no one fit for all. One common factor, however, is the change in resistance from the original value when heaters age. This deviation is an indication of a potential heater failure that if identifiable can be used to prevent an unplanned machine shut down.

With the NRG, this identification is possible. The NRG approach adopted to predict a potential heater failure is to continuously measure the heater resistance by using accessible current and voltage measurements from the solid state relay and alert the machine controller if the measured resistance deviation is out of the set bounds. This abnormality can be displayed on the machine interface or else transmitted digitally to the maintenance people to plan a timely intervention.

The following table is referred to as an explanation of how the NRG predictive heater failure indication functions. This feature is activated through a Teach command and a % value that sets the permissible load (resistance) deviation. The permissible set range is from 5 to 100%.

On this command, each respective NRG solid state relay takes a snapshot and records the current and voltage measurements of that moment as the reference measurements (Iref, Vref). During its operation, the NRG solid state relay continuously monitors the current and voltage and calculates the actual resistance to compare to the set resistance. If the measured resistance compared to the set resistance exceeds the allowed deviation a Load deviation alarm is issued.

Period	Time 0			2 years later		
	NRG SSR 1	NRG SSR 2	NRG SSR 3			
						
Parameter	NRG SSR 1	NRG SSR 2	NRG SSR 3	NRG SSR 1	NRG SSR 2	NRG SSR 3
Iref	1 A	2 A	1 A	1 A	2 A	1 A
Vref	230 V	230 V	230 V	230 V	230 V	230 V
% Load deviation allowed	10%	10%	10%	10%	10%	10%
Allowed resistance deviation to issue alarm	23Ω	11.5Ω	23Ω	23Ω	11.5Ω	23Ω
Ireading	1 A	2 A	1 A	1.1 A	2.3 A	1.1 A
Vreading	230 V	230 V	230 V	230 V	230 V	235 V
Status	No alarm	No alarm	No alarm	No alarm	Alarm*	No alarm
Actual deviation	0%	0%	0%	<10%	>10%	<10%

*Alarm is issued on NRG SSR2 related to a Load deviation 2 years into the installation. The resistance of the load measured 2 years later is 100 Ω vs. 115 Ω of the time 0. The allowed delta for no alarm issue was set to 11.5 Ω and since the deviation was higher an alarm was issued.

Table 1: Behaviour of the Load deviation alarm for predicting load failures

All the computations are invisible and are handled by the NRG solid state relay. The only output of the Teach command is an indication through a Load deviation alarm when it happens.

SUDDEN UNPREDICTABLE FAILURES

Heaters may fail suddenly before showing any sign of aging either because of a malfunction, a premature failure or misuse. In the case of a sudden failure, the Load deviation alarm explained above would not issue any error before the failure occurs. The NRG would notify such an occurrence once the fault happens. A Load loss alarm is issued as soon as the heater fails. This immediate detection and intervention ensures that the quality of goods being produced is not comprised and material just produced is not scrapped or re-worked. This immediate detection is especially important in control systems were output variables are either not very accurate, for example in radiant heating, or when they are measured with a delay.

The diagnostic features integrated in the NRG contribute

to the reduction of unplanned downtime by facilitating troubleshooting in guiding maintenance people to where the fault resides and the cause of the failure. Dedicated help menus indicate the alarm type and provide a readily accessible troubleshooting guide.

Aside from the heater, the upstream protection as well as the solid state relay may be subject to sudden failures. For any such failure, the NRG would indicate the occurrence through an alarm condition indicating the specific failure and guide of how the issue can be resolved.

NRG PARAMETERS FOR COST EFFECTIVE PREVENTIVE MAINTENANCE

Each NRG solid state relay is equipped with parameters that indicate the SSR running hours and the Load running hours. These registers provide the actual hours that the heater and the SSR have been in use. Costs can be reduced by replacing either according to their lifetime in actual use rather than the number of years in the field.

Through data collection of these parameters machine builders can optimize predictive patterns related to heater or SSR failures. Predicting potential failures at the correct time ensures that the purchasing of replacement parts is done just in time minimizing inventory costs.

THE NRG PLATFORM

The NRG is not a single component but a system that may consist of multiple NRG bus chains. An NRG bus chain consists of at least 1 NRG controller and a number of NRG solid state relays, maximum 32, daisy chained via an internal bus.

Figure 4: The NRG bus chain consisting of an NRG controller and maximum 32 NRG solid state relays

The NRG controller is the facilitator of the communication between the PLC and the NRG solid state relays. The main function of the NRG controller is to perform internal operations related to the setup and maintenance of the NRG bus chain. It must communicate the same language as the PLC and is available with a Modbus RTU interface for serial networks or PROFINET for ethernet based networks.

In a Modbus serial network, it is possible to have a maximum of 247 NRG bus chains.

For a PROFINET network, the only limitation is the PLC. One NRG bus chain is considered as one IO, or node. NRG PROFINET bus chains can be configured in line, star, ring or a mix of such topologies. Multiple NRG PROFINET bus chains will occupy only one ethernet port when in a line configuration.

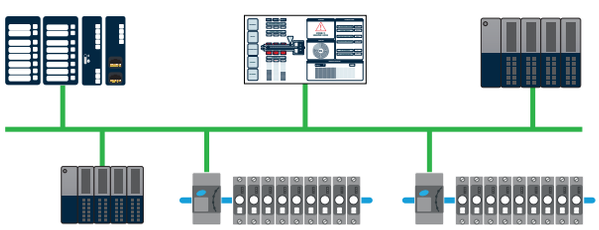


Figure 5: The NRG in a PROFINET network. One NRG bus chain occupies one IO

The NRG solid state relays are the switching devices that integrate monitoring circuitry and a communication interface through which measurement data and diagnostics can be exchanged with the machine controller. Each NRG solid state relay on the bus chain is uniquely identified. Upon start-up, each NRG solid state relay is automatically given an address based on the sequential order in which it is located on the NRG bus chain.

Each NRG SSR can provide the following measurements: Current (A), Voltage (V), Frequency (Hz), Power (kW and VA), Energy consumption (kWh), SSR running hours and Load running hours.

The monitoring circuit on the NRG solid state relay provides diagnostic information to identify faults related to Load deviation, Mains loss, Load loss, SSR open circuit, SSR short circuit, SSR over-heat and SSR out of range if operation is outside of set limits of voltage, current or frequency.

The communication interface used for measurements and diagnostics is also used by the machine controller to regulate the switching of the NRG solid state relay. Control signals through digital outputs are replaced by switching commands that are communicated directly by the PLC to each NRG solid state relay. Apart from the ON/OFF command, that replicates the function of the digital output modules, with the NRG it is possible to control the SSR output switching with a power mode. The desired % output power value is communicated to the specific NRG SSR and the addressed NRG SSR will determine the needed switching pattern to ensure that the desired output power is delivered to the load. The power control mode frees up memory in the PLC as the computation to convert the %

output power to PWM is not required since the NRG SSR can directly interpret a % power value.

The power control mode enables the NRG solid state relay to be controlled in different modes. The switching mode is selectable amongst ON/OFF and Burst, Distributed full cycle or Advanced full cycle for power control. The lowest resolution for the power mode is 1%.

A COST-EFFECTIVE MONITORING SOLUTION WITH THE NRG

Real-time monitoring is crucial for a better machine management. It provides constant up-to-date information that allows informed decisions both locally and remotely (through digitalization), permits monitoring of trends as they develop and enables quick reaction to momentary events. Different heater monitoring solutions exist, the most typical uses add-on current transformers (CTs) targeting primarily a timely detection of a heater break.

With the NRG, Carlo Gavazzi is proposing a different and unique cost effective solution for real-time monitoring that in addition to a timely reaction to failures includes features that enable predictive and better preventive maintenance programs. This is all facilitated through a standard industrial communication interface that allows easy and fast integration in automation machinery.

The table below compares the NRG solution to a CT monitoring solution on some aspects, to highlight the additional features and benefits the NRG can provide, that ultimately result in a higher return on investment compared to CTs solution.

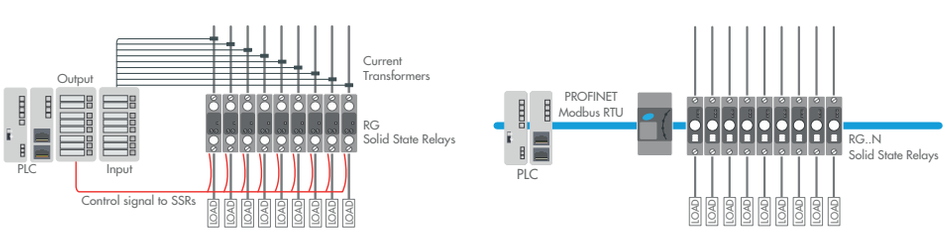
	Traditional SSRs with external CTs solution	The NRG solution
Features		
Versatility and flexibility	Low	High
Diagnostics	Low	High
Panel space occupancy	High	Low
Time labour savings in wiring	Low	High
PLC configuration and flexibility	Complex	Easy
Stock of different components	High	Low
Overall system cost	High	Low
Ready for IIoT	No	Yes

Table 2: Comparison of a control loop using a traditional SSR and additional components vs. the NRG solution

VERSATILITY AND FLEXIBILITY

With external CTs the only data available (through an analog signal) is Current, whereas the NRG readily provides additional data related to Voltage, Power, Energy consumption and Running hours. With current readings from CTs, some theoretical calculations may be possible to get some of the data that is provided by the NRG (for example, power or a normalized current) but apart from being inaccurate if based on assumptions instead of actual measurements, it consumes additional PLC computational power. With the NRG all data is readily available at no added cost.

Most CTs are not suitable for a wide operating range. For this reason, different heater sizes in one machine may need different CT models. The NRG solid state relay measurement is not affected by the heater size and remains valid across the specified operational range of the SSR. Users have the flexibility to adjust the limits in which they want the NRG SSR to operate. An error indication is issued if the SSR operates outside the set range.

The NRG can provide a much more complete system status than other monitoring systems. The only possible measurement with CTs is Current. Basic CTs do not offer diagnostics and it is up to the machine controller to identify an error presence and the error type. With the NRG, the alarm indication is provided by the SSR as a descriptive fault. The NRG SSR distinguishes several failure modes to facilitate and reduce troubleshooting time.

DIAGNOSTICS

The NRG Load deviation alarm, that is an important parameter related to the prediction of a potential failure, cannot be replicated by CTs since it is based on resistance rather than current. SSR related data such as Running hours and SSR over-temperature pre-warning, can only be provided by the NRG.

PANEL SPACE OCCUPANCY

For the setup using external CTs in addition to traditional solid state relays, the following components are required: PLC, digital outputs to control the SSRs, SSRs, current transformers and analogue input modules.

Comparatively, the NRG solution requires far fewer components: PLC with a communication interface and NRG SSRs including the NRG controller.

The NRG SSRs occupy the same footprint as the traditional SSRs so the elimination of CTs, input and output PLC cards give rise to significant space savings. The NRG solution occupies much less panel space compared to other monitoring solutions.

TIME LABOUR SAVINGS IN WIRING

The communication bus on the NRG is utilized for the switching in addition to measurement of data and diagnostics. Wiring of CTs to input cards and from output PLC cards to SSR is eliminated with the NRG considerably reducing the installation time.

PLC CONFIGURATION AND FLEXIBILITY

The industry standard interface of the NRG makes configuration and setup very easy. With the engineering tools in use by machine software designers it's a matter of drag and drop.

STOCK OF THE DIFFERENT COMPONENTS

The traditional setup requires much more hardware than the NRG setup. Apart from managing a larger stock inventory, different suppliers must be managed with higher probabilities of delivery issues.

Different applications may necessitate different SSR switching modes and so different traditional SSR models suited to the specific application have to be stocked. With the NRG its only necessary to stock one model and change the switching mode as required.

OVERALL SYSTEM COST

The hardware components required with the CTs monitoring setup become redundant when the NRG is used. This cost saving together with lower installation costs and reduced panel space result in a lower overall system cost for machine builders.

READY FOR IIoT

Through digitalization, machines can be accessed from any remote location. The communication interface on the NRG enables remote access down to the solid state relay level. This additional functionality enables the vendor to perform remote diagnostics.

CONCLUSION

While Industry 4.0 is still evolving and most do not have a complete picture, there is no denying that the digital era is impacting every industry. Businesses that do not take measures to apply digitalization as part of their competitive edge will struggle to survive.

In tomorrow's smart factory everything that can be connected will be connected. Data is a valuable resource to achieve the goal of cost savings and maximized efficiency that will ensure global competitiveness.

With the NRG platform, Carlo Gavazzi's solid state relays have undergone the transformation to become digital in preparation for the next industrial revolution.

BENEFITS AT A GLANCE

FOR MACHINE BUILDERS

- Connectivity and data access make the NRG ready for an Industry 4.0 environment
- Lower system costs compared to other monitoring solutions
- Dynamic process improvements and optimized energy consumption
- Panel space savings
- Identification of alarms to simplify troubleshooting guides
- Remote customer support can access SSR data
- Optimization of own processes through collection of accessible data and analysis

FOR END USERS (having NRG in their machines)

- Higher ROI – reduced unplanned downtime by real time monitoring
- Reduction of scrap by timely failure detection
- Predictive and better preventive maintenance plans minimize inventory costs for spare parts and maximize machine availability
- Reduced troubleshooting time

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