SET DVR: POWER QUALITY IMPROVEMENT FOR INDUSTRIAL APPLICATION

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ABSTRACT

Driven from the necessity of industry to reduce the cost of unavoidable voltage dips/sags Iberdrola Distribución Eléctrica SAU., in collaboration with Corporación Zigor SA, has developed the SET DVR (Surge EliminaTor Dynamic Voltage Restorer).
The SET DVR energy store-less topology (no battery, nor u-cap , nor other energy storage components is used) described in this paper, additionally to compensate 30 seconds 50% dips, it also mitigates other power quality problems, namely: flicker, slow and fast regulation problems, voltage distortion problems and some level of transient over voltages. The SET DVR dips/sags mitigation equipment has been specifically designed for high power demanding industries.

THE VOLTAGE DIP PROBLEM

Although utilities keep on trying to improve the reliability of the grid, sensitivity of industrial equipment to power quality disturbances increases as automation and electronics become more ubiquitous in industry.
There are real possibilities to reach 100% availability of power supply with both DC and AC for many industrial critical applications [1]. There is, nonetheless, a gap when facing 100 % availability for high power industrial demand mainly due to investment or long term return on investment [2]. When immunizing against disturbances, purchasing cost, return on investment versus saving, maintenance cost, efficiency, size, reliability or availability are the key decision criteria to industrial decision makers.

Whenever mitigation equipment is economically unaffordable (battery or rotary UPS, etc) to guarantee the immunity from interruptions, industry try to evaluate to mitigate, at least, the voltage dips which should normally represent over 2/3 of the power quality events causing industrial process incidents.

A voltage dip can be defined as a short-term reduction in RMS voltage. The dip is normally specified by the time this disturbance last and by the percentage of voltage drop over the nominal value.

Most existing equipment in industry comply with the sensitivity curve defined by IEEE 446 standard as shown in figure 1.
Unfortunately, electrical networks cannot guarantee being always above the lower line of figure 1.

The problem that dips cause to industry can therefore be represented by the area created between the lower line of the IEEE 466 standard and the distributions of the dips duration and percentage voltage drop of the network.

Typical values of dip that most frequently cause industrial problems range form 0 to 500 ms in time and 10 to 40% in voltage drop, although severe dips can reach 60% or longer periods. Network faults might produce series of dips due to automatic reclosers acting after a failure in clearing the fault. This series of dips often requires that the voltage compensation equipment needs to be capable to operate several seconds.

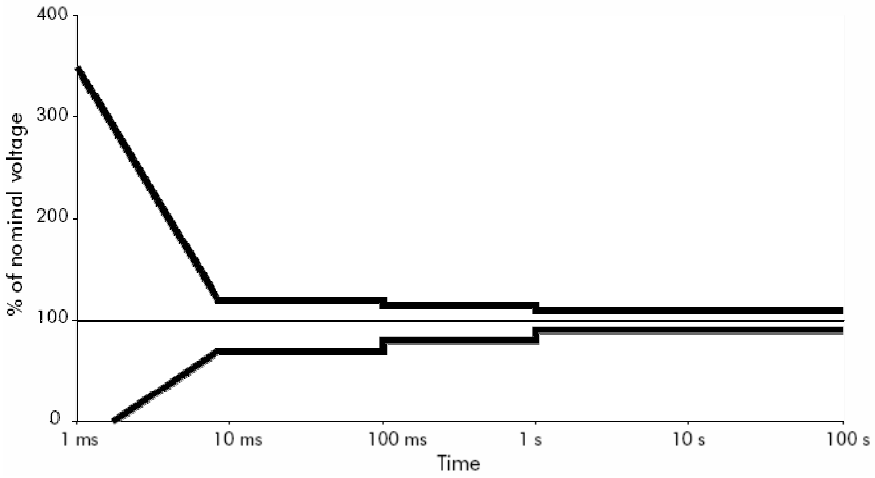

Figure 1 – IEEE 466 standard for equipment sensitivity

STATE OF THE ART OF VOLTAGE RESTORERS

So far, different topologies and products have been developed and tested in the industry to solve fast voltage regulation problems since many of the traditional technologies are not adequate for the time frame and time response required for dips as defined above. Some of the products do use u-caps or batteries as energy back-up to compensate the dips.
Most topologies do use stand-by strategy, that is, the active compensation components of the electronics do operate only during the dip.

The design target for the SET DVR was to solve some limitations of existing topologies, namely:

a) Not use of batteries or other energy storage components
b) Provide a longer time frame for repetitive dips scenarios
c) Allow continuous operation to offer very high stabilization accuracy
d) Allow bi-directional energy flow
e) Improve time response to allow permanent voltage distortion filtering

MAXIMIZE THE PERCENTAGE OF DIP COMPENSATION CAPABILITY SET DVR TOPOLOGY AND ARCHITECTURE

As shown in figure 2, based on a booster transformer plus a set of a reversible rectifier, plus an inverter the SET DVR builds up a flexible energy injection/absorber compensator capable to correct (+/-) the input voltage deviations to offer an extremely stable output voltage with a very fast response.
The first deployed units have demonstrated to be successful in real industrial sites. An n-paralleled 300 kVA unit has been developed for 3x400V.

SET DVR ADVANTAGES

SET DVR offers the following disturbance compensation capabilities:

a) Voltage dips and swells
b) Voltage variations,
c) Voltage distortion,
d) Voltage flicker,
e) Voltage unbalance,
f) Some level of transient overvoltages

The Master Unit (300kVA) is shown in figure 3:
Higher power units can be built by paralleling slave units to the master one up to 10 or more units.

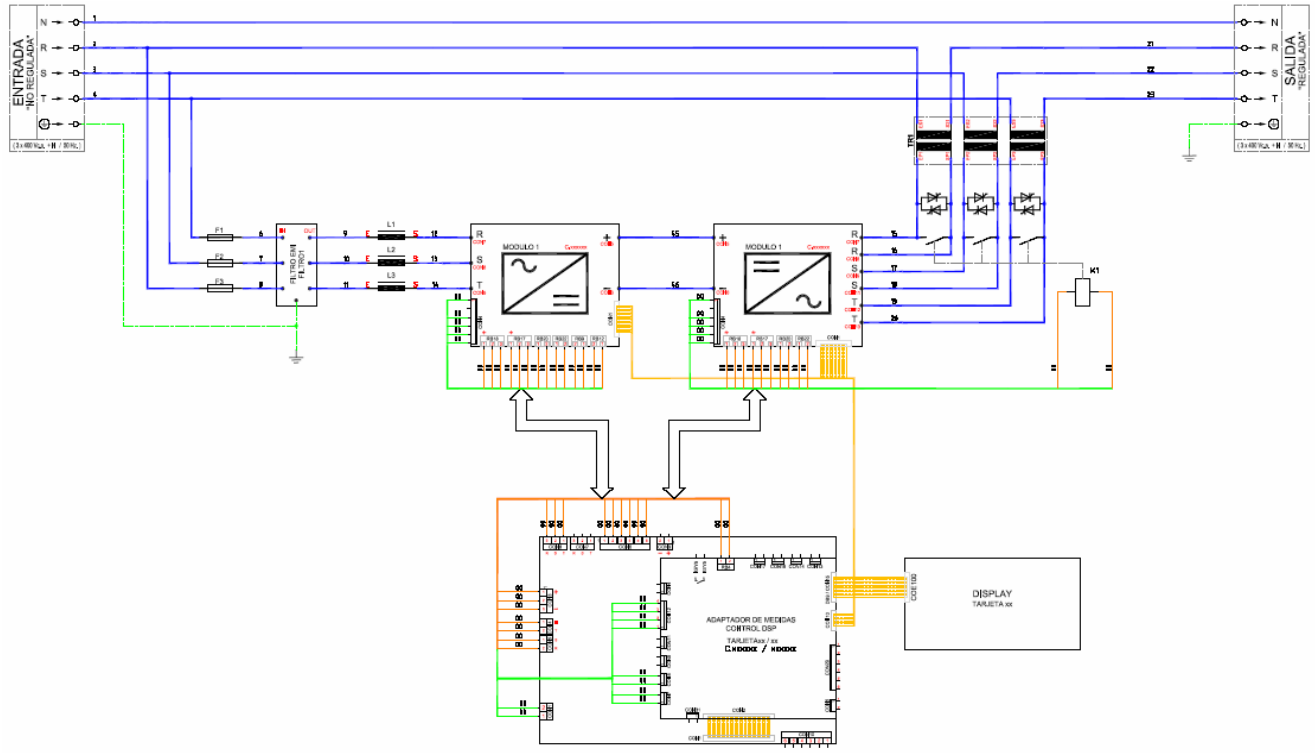

Figure 2 - Topology of the SET DVR

Figure 3 - 300kVA Master SET DVR 3x400V unit

Additionally, the proposed topology allows building the SET DVR for medium voltage level by changing the booster transformer.

The SET DVR has the following main features:

a. No battery or alternative energy storage is required, minimizing the maintenance cost and increasing the reliability
b. Continuous voltage regulation within the ± 0.5%.
c. Compensation of long lasting dips (-50% up to 30 seconds)
d. Avoids relays and brushes
e. Time response less than 3 milliseconds
f. Capable to operate with industrial regenerative loads (four-quadrant converter, …)
g. Improves the voltage distortion.
h. Flicker compensation.
i. Non stop of process operation in case of failure.
j. Easy to parallel additional equipment
k. Independent phase compensation
l. Voltage balancing capability
m. Balanced and unbalanced dip compensation
n. Automatic Bypass
o. Efficiency 97.5% for low voltage and 98.5% for medium voltage.
p. Overload capacity: 150% during 1 second
q. Dips logging and system monitoring

SET DVR OPERATION

We herein describe the SET DVR compensation capabilities.

Voltage Dips Compensation Capability

Figure 4 shows the compensation capabilities of the SET DVR. A sample dip compensation is presented in figure 5 during 5 cycles.

Voltage Regulation

The designed topology looked also at the possibility to mitigate other power quality problems at the same time, namely flicker, slow and fast regulation problems, voltage distortion and some level of transient overvoltages. Finally the SET DVR (Dynamic Voltage Restorers) has demonstrated to become effective for all these problems with a high stabilization accuracy and very fast response, typically less than 3 ms.

Voltage Unbalance Compensation

Due to the independent phase compensation capability as well as the bidirectional energy flow control operation, the SET DVR can balance and equalize three phase unbalanced systems, both during transients and continuously.

Voltage Flicker

Due to the continuous operation and its accuracy and fast response the SET DVR also solves the flicker problem.

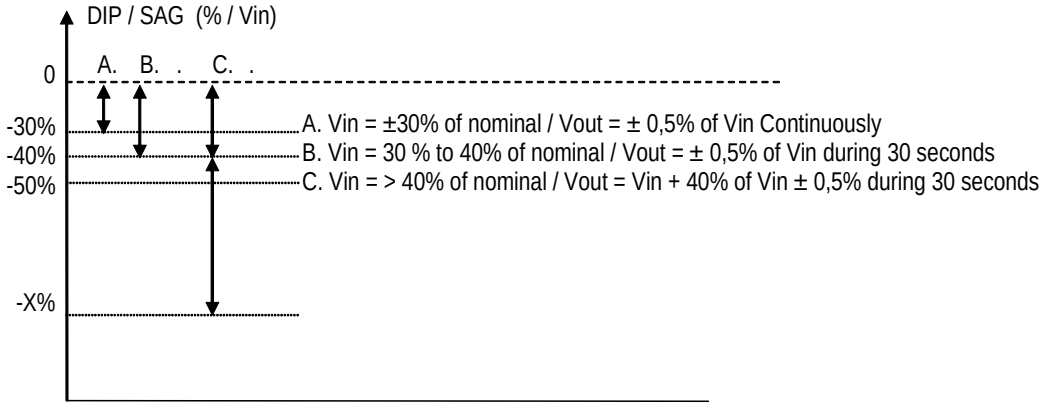

Figure 4 - SET DVR dips/sags compensation capabilities

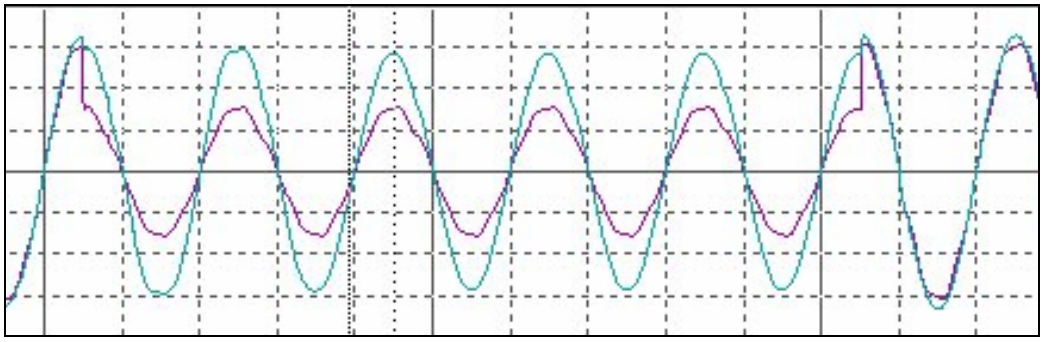

Figure 5 - Compensation Sample for a –40% dip Vin

Overvoltage

Its capability to respond to 2 to 3 ms sub-cycle transients together with complementary MOV equipped as standard offers a high level of overvoltage protection both for very fast and fast transients.
The overvoltages caused by bank capacitor switching is another disturbance that is eliminated by the SET DVR

MONITORING

The SET DVR has both system monitoring and voltage dip events logging based on user friendly interface using web server technology. Figure 6 shows the appearance of the alarm logging function.

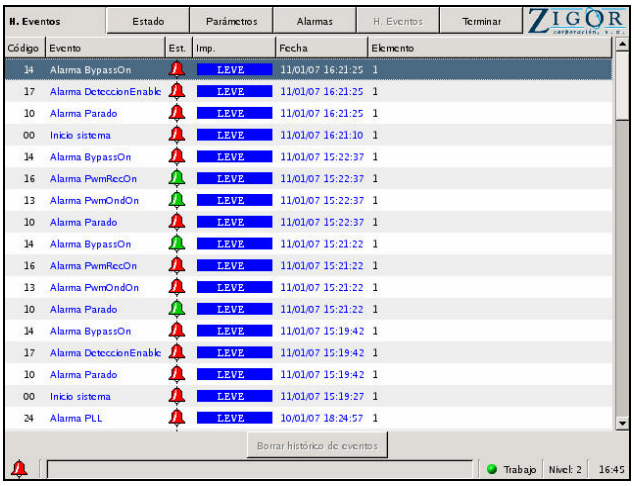

Figure 6 – Monitoring System

CONCLUSIONS

The innovation introduced into the SET DVR offer lower levels of investment and higher level of disturbance immunization since the same equipment covers more disturbances than to date existing commercial DVR systems, namely:

a) Voltage dips/Swells,
b) Highly accurate voltage regulation,
c) Voltage distortion,
d) Voltage flicker,
e) Voltage unbalance,
f) Transient overvoltages

Its Master-Slave scalability based design is also a very valuable feature to modulate the investment as power requirements increase.

Another important advantage of the proposed systems is the lack of energy storage components eliminating the cost of maintenance and their influence on the reliability of the complete system.

Because the energy flow could be reversed throughout the booster transformer the SET DVR achieves a high efficiency as well as overvoltage protection capability.

Finally the proposed topology allows building the SET DVR for any voltage level.

The first installed units have demonstrated to be successful in real industrial sites. A n-paralleled 300 kVA unit has been developed for 3x400V.

REFERENCES

[1] Voltage-Sag Solutions for Industrial Customers, EPRI, Palo Alto, CA California Energy Commission, Sacramento, CA: 2003. 1007485

[2] F. Romualdo Pascual, V. Fuster Roig, A. Quijano López, 1999, *Las Plantas Industriales ante las perturbaciones eléctricas*, AVEN, Valencia, Spain, 122-127.