VOLTAGE DIPS IN INDUSTRIAL PLANTS: IDENTIFICATION METHODOLOGY, EFFECTS AND SOLUTIONS. IMMUNIZATION CASES

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SUMMARY

This paper presents the methodology developed to identify the production problems and the available solutions due to the dip voltages in industrial plants. It’s the result of a long-term collaboration between CITCEA (Technological Innovation Centre) and ENDESA. The main aim of the collaboration is to select one or more paradigmatic companies of different productive branches and to analyse the general problems and solutions for each branch.

As the process becomes more automated, the sensitivity to dips will increase. The automation chain acts a propagation stream. Only with one element in fault due to the dip (sensors, static converters, bus controllers, remote racks…) the production is stopped. Sometimes with very difficult process to start again due to the materials accumulation, sometimes with easy start. In any case there are production losses. The proposed method takes account of quantity and quality aspects, as well as the heterogeneity between the productive branches or different technologies involved. Depending on the technologies involved, different actions are needed to correct the sensitivity to dip voltages.

The steps to characterize the problems and, when it’s possible, to solve them, are:
1) To analyze the process
2) To identify the critical parts
3) To choose the immunization technique
4) Theoretical estimation of the attainable immunity level
5) Simulation and/or test of the proposed actions
6) Project for the concrete case
7) Cost estimation
8) Decision of doing the changes

Basically, there are two families of immunization techniques: to left the plant with a controlled stop and try to restart after the dip, or to keep the plant working during the dip.

Two cases are presented in detail: Constant speed drive and Variable speed drive.

PROCESS ANALYSIS

This activity has technical and management components. The technical component is the basis to identify the origin and streaming of dip disturbances. The management component is the basis to evaluate the economical impact of the disturbance.
very low, especially if there is a separated feed system for
controls in the plant.
At same time, the “brains” must know the dip presence, so
detection must be done, e.g. under voltage relays. In many
cases the programs must be different during dip presence. In
modern static converters these functions are provided together
under the name “ride through” or similar.
In some cases, currents during the dip can be greater than in
normal operation. The set points of protection relays must be
changed to allow this, but sustaining the correct protection.

To implement any one of the two immunization techniques
we need to combine in a coherent form a set of the following
immunization tools:
• Timed under voltage relays
• UPS “process brains” feed
• Time and level protection sets
• Especial programs in “brains”
• “Ride through” features in static converters

THEORETICAL ESTIMATION OF THE
ATTAINABLE IMMUNITY LEVEL

In the cases that parameters for a good plant characterization
are well known, it is possible to know the attainable immunity
level. This is done by direct calculation, or more often by
using simulation tools.

SIMULATION AND/OR TEST OF THE PORPOSES
ACTION

If a correct simulation is possible, in addition to the attainable
immunity level, other useful information can be obtained like
relay protection set points, speed changes, temperature
changes, peak torques, etc.
Sometimes, due the plant complexity or due the unknown
parameter values the simulation can became unreliable. In this
case, some test must be done in order to assure the coherency
of future immunization actions.

PROJECT

As result of the previous steps, a project for every case can be
done. It includes the wiring adds or changes, the new
programs and the new set points.

COST ESTIMATION

Execution cost, operation cost and maintenance cost must be
estimated.

DECISION OF DOING THE CHANGES

The plant staff, attending at cost estimation and future
benefits due to fewer production losses, decides wheter to do
the changes.
The final decision of making changes to immunize the plant
and what strategy will be applied is always taken according
with economical parameters like payback time.

IMMUNIZATION GENERAL TECHNIQUE

Fig. 1 depicts the block diagram for a general plant
immunization. In normal operation the UPS feeds all the
control circuits or “brains” (PLCs, temperature regulators,
network controllers, relays ...). For constant speed drives or
temperature process these brains should be PLCs and relays,
these are the subsystems 1 to n. For variable speed drives, the
control circuits of static converters 1 to n are also feed from
UPS.

Fig. 1 Block diagram for a general plant immunization

Under voltage relay UVR1 switch the control feed off if the
dip is too severe. Under voltage relay UVR2 detect the dip
presence. With this information, the restart subsystem can
order the controlled stop and restart or the maintenance of
working in dip conditions. If the converters have “ride
through” or “flying start” capabilities they do the actions by
themselves.

In order to maintain the system working properly, protections and programs must be coherent with dip presence.

**CASE 1: IMMUNIZATION OF A CONSTANT SPEED DRIVE**

As a part of a cement furnace there are two fans to maintain temperature profiles mixing a variable air flux. The fans are working at constant speed and the air flux is regulated by impulsion valves. There are two induction, wounded rotor motors, 530 kW at 3kV, with power factor capacitors. The capacitors are always connected over the motor. Starting method is by liquid rotor resistors. Control circuits are a mix of PLC and relay. The two motors are feed from a dedicated transformer. The protections are under voltage relays and over current relays (time dependent, symmetry…) classical type.

**Analysis & Identification**

This part had been identified as one of the three critical parts of the plant. In this part there are no severe restrictions in the immunization due to the fact that there is no relationship with combustion system. Actually, the dip activates the under voltage relay and the motors are turned off. The stream propagation is the security contact that stops whole plant if fans are not working. With the proposed immunization the motors will stand on losing speed and air flow. Due the big thermal inertia of the system and shot dip duration, the lost air flow will not reduce the quality of production.

**Immunization Technique & Simulation**

Due the high starting time of motors, the stand working technique had been selected. During a voltage dip the motor current increases. The maximum safety current will limit the attainable immunity level. As the motor and transformer are well identified an electrical simulation is possible.

Fig. 2 shows the simulation results: the over current as function of dip severity.

**Immunization Project**

Fig. 3 presents the power circuits for one motor. Fig. 4 is the actual control circuit and Fig. 5 is the proposed control circuit with voltage dip immunization.

Actual control is very simple. PLC activates M3, if there is correct power voltage, the under voltage relay MIA activates K3 and the motor runs. Other NC contacts are protection and plant security loops.

With the proposed circuit, the actual protection functions are still working. But the UPS supply guarantee the function of PLC in case of dip voltage.

Under voltage relay UVR1 detects non immunized (severe) voltage dips. The threshold point is set to 50% depth and 1 second duration. In this case the system acts like before the modification. Under voltage relay UVR2 detects voltage dip presence informing to the PLC. The actual relay MIA is maintained only by practical layout reasons.
The over current actual set values are 4xIr and will be set to 6xIr to allow the new current conditions during the dip. Where Ir is the motor rated current.

With the new system immunized dips are 50% depth and 1 second duration, so the immunization level attained is very high. In the area of this plant, more than 80% of voltage dips are less severe than this. The production incidences might be reduced at less than 20% of actual value.

**Immunization Technique & Simulation**

With the proposed immunization the rectifier will be turned on every time the under voltage protection turns it off. The fan will lose speed and air flow will be reduced. There is a limit of this reduction to avoid CO presence. In case of a very severe voltage dip, the rectifier will be stopped.

As there is no good parameter to modelling the combustion system, it is not possible to simulate with accuracy the behaviour during the dip, and as a consequence, is not possible to predict the attainable immunity level. It will be compulsory to make some tests over the plant to know it. One proposed test is to turn on and off the rectifier during short times with normal process but with the anti-dust electrostatic filters off to skip the explosion risk. This will be done with a specially designed PLC program for test proposes.

**Immunization Project**

In this case, the main actions are over PLC and rectifier programs. Minor changes are done over the control circuits. Fig. 6 is the actual control circuit. Fig 7 is the proposed new control circuit.

![Fig. 5 Proposed control circuit](image_url)

**CASE 2: IMMUNIZATION OF A VARIABLE SPEED DRIVE**

As a part of the same cement furnace there is one fan carrying the combustion air. Air flux is regulated in function of fuel flux to obtain correct combustion so there is no CO presence in the exhausted gas. If CO appears, exhausted gas can explode when is passing by the anti-dust electrostatic filters. The fan is driven by a DC motor 1000 kW at 520 V. The speed regulation is done by a six pulse full controlled rectifier feed from a three phase 400 V AC 50 Hz. The rectifier and accessories are controlled from a PLC. The rectifier control is last generation micro-controller based. The control and the power have separated feed circuits.

**Analysis & Identification**

This part had been identified as one of the three critical parts of the plant. In this part there are restrictions in the immunization because there is a direct relationship with the combustion system. Actually, the dip activates the under voltage alarm of controlled rectifier and it will rest in stop error mode. The stream propagation is the security contact that stops all the combustion process and, in an indirect way the whole plant.
The new program has three working modes: If KUV1 is active the rectifier stops by means of P1. If KUV1 and KUV2 are not active, so normal voltage is present, the program acts like before the modification. In case of KUV2 active and not KUV1, so immunized dip voltage, a special sequence over P1 is done.

When P1 (RUN of the rectifier) has a positive edge all the (programmed) internal alarms are cleared and the rectifier is put in RUN mode. In case of voltage dip, when KAL is active by internal under voltage alarm and KUV2 is also active, the program makes an OFF position for P1, wait 20 ms in this state and passes to ON position again. The process is repeated as many times as necessary, until the voltage normalizes or KUV1 decides it is a too severe dip. Fig. 8 to 10 illustrates the timing diagrams corresponding to the new PLC program in dip presence.

**OTHER CASES**

**Plastic Extruder**

Variable speed drive: One DC motor 100 kW 460 V driving the main axe of a plastic-extruder. The control of the motor is a controlled rectifier. After identifying the critical part, the control unit is powered from an UPS system. Two minimum voltage relays disconnect or stand the operation of the converter as result of dip severity. Other parts of the installation are powered from UPS to avoid un-controlled response from sensors during dip voltages. Similar to case2.

**Compressor in a drinks plant**

Variable speed drive: One induction motor 150 kW 380 V driving the main air compressor. The speed is regulated by a voltage source inverter with voltage/frequency constant law. Due the high restart time of this old generation converter the partial immunization had been only to program the “ride through” capabilities.

**CONCLUSION**

As automation degree in the plants grows, the dip voltage sensitivity is higher. Different immunization techniques are available. Most of them have a very short pay-back time. But the easiest way to immunize the plants against voltage dips is to take care of voltage dips during the plant project. Trying to feed the “brains” from a UPS and programming the control system in front of dip effects.