Impact of ASD settings in its LVRT behaviour

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***Abstract*-- A common matter of concern in industrial installations is that adjustable-speed drives (ASD) trip due to voltage sags. ASD manufacturers are including more and more in these devices settings related to control strategies (e.g. allowable DC voltage levels, etc) in order to improve their Low Voltage Ride Through (LVRT). These settings must be carefully adjusted in each installation in order to prevent any interference with the process where ASDs are used.**

In this paper, a method to establish the setting values to achieve a determined LVRT level has been done. A voltage sag generator developed by the part of the authors has been used to test several setting values and its impact on the process.

Two commercial ASD installed in a factory were used during tests.

***Index Terms*-- Adjustable Speed Drives, Power quality, Voltage sag, Low Voltage Ride Through.**

I. INTRODUCTION

Voltage sags, see Fig. 1, are short-duration reductions in the rms voltage, with duration between 0.5 cycles and 1 min [1]. One of the most common reasons for voltage dips are the faults in the transmission network, mostly provoked by storms [2]. The spread of voltage sag over the network is high due to their interconnection, so this kind of phenomenon can hardly be avoided. The depth of the sags also depends on the proximity of the electric devices to the fault.

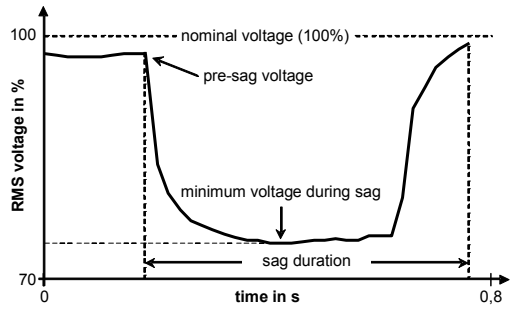


Fig. 1: Voltage sag

Adjustable-speed drives (ASD) are widely used in both industrial and commercial applications as the most versatile and efficient means of achieving motion control, nevertheless, since ASD are electronically based, they are very sensitive to voltage dips, especially unsymmetrical, and power disturbances causing unexpected protection trip in the drive. These trips may be related to [3,4]:

- Failure of low voltage dc bus (see Fig. 2).
- Significant voltage ripple in dc bus.
- High transient currents.
- Reductions in speed or torque supplied.

In the industrial sector, these events may provoke a significant loss in revenue and costly downtime. For example, in continuous process systems, such as metal casters, paper machines, winders, extruders, etc., any interruptions to that process can halt the entire manufacturing flow, with extremely costly implications. [5].

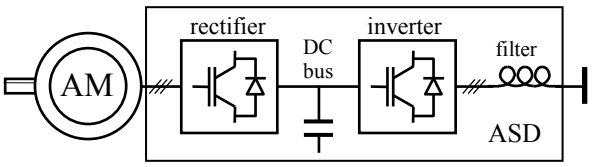


Fig. 2: Typical ASD scheme.

The objective of this work is to study and analyse the behaviour of ASDs during voltage sags and to evaluate how they have to be configured in order to improve their LVRT level in terms of their dynamical behaviour. In this way, the study has been conducted in three phases:

- Analysis of the causes of trip or failure of an ASD during voltage sag.
- Analysis of settings related to failure or trip to voltage dips.
- Study of variation of ASD settings to increase the immunity of the drive in the selected application.

Two commercial ASD installed in a factory have been selected for the Low Voltage Ride Through (LVRT) study presented in this article. Some tests under different voltage sag conditions and with different sets of parameters have been carried out.

For testing purposes, a voltage sag generator developed by the part of the authors has been used [6]. International standards related to voltage sag testing and immunity [7,8] have been considered for its design. Duration and depth of voltage sags can be selected during the tests; voltage sag trains can be programmed as well. An example of voltage sag generated by the equipment can be seen in Fig. 3 and its main characteristics are shown in Table 1.

Table 1: Main characteristics of voltage sag generator

Nominal voltage	3 × 400 V
Voltage during sag	0 – 400 V
Transient voltage*	1200 V
Nominal current	30 A
Transient current**	300 A
Sag duration	1 ms – 37 s
** Limited by IGBT capacity*	
*** Limited by fuse*	

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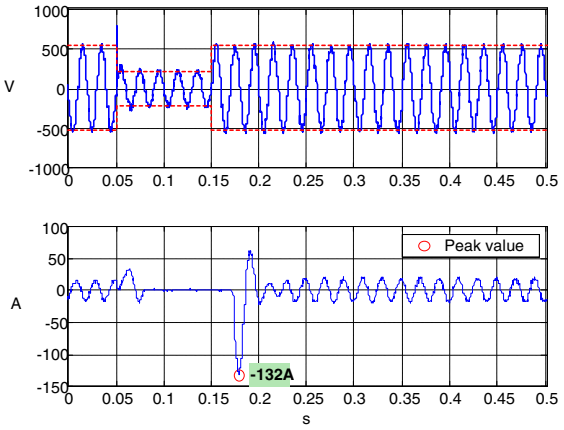


Fig. 3: Voltage and current waveform at the output of voltage sag generator during a three phase sag (duration: 100 ms, depth: 60%)

II. STANDARDS RELATED TO EQUIPMENT IMMUNITY AGAINST VOLTAGE SAGS

In this paper, an analysis of standards related to equipment immunity against voltage sags has been done in order to establish the desired immunity level during the tests [7,8,9,10]. The standard taken as a reference is the SEMI F47 due to its high immunity level when compared to other standards [9].

The immunity curve (see Fig. 4) is represented in duration versus voltage curve, where voltage represents the minimum voltage achieved during voltage sag, and duration represents the time until the nominal voltage is restored (see Fig. 1). The equipment fulfills the standard when it continues working normally during voltage sags in the immunity zone, i.e., when it achieves the required LVRT level.

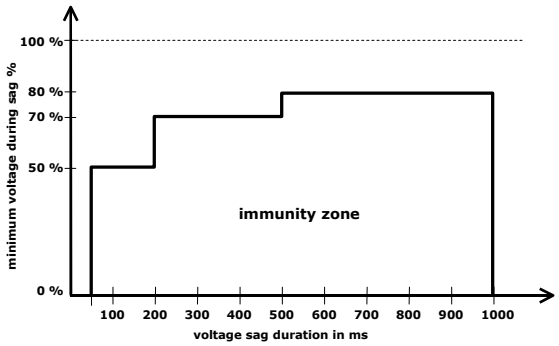


Fig. 4: Immunity levels defined in SEMI-F47

A power quality meter was set up for a year, from July 2003 to May 2004, in the factory where the ASD drivers were installed with the aim of registering the voltage sag events. As a result, 72 voltage sags were detected. Unexpected stops and malfunctioning of equipments were also registered, during the above mentioned period, in order to establish a relationship between voltage sag and equipment behaviour. As a result, 17 voltage sags were detected and classified as shown in Fig. 5, where each cell represents the voltage sag occurrence related to equipment trips for different ranges of duration and minimum voltage

This graphic shows that the 59% of the problems could be avoided if all the equipments fulfilled a proposed immunity curve (see shadowed zone in Fig. 5) similar to the SEMI F47.

The lower levels of SEMI F47 are not considered in the proposed immunity curve because of their low level of occurrence and their difficulty to be achieved during the tests.

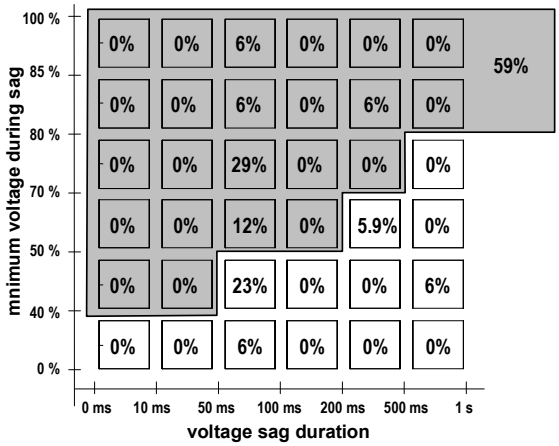


Fig. 5: Voltage sag histogram and proposed immunity level (shadowed zone) for sags related to equipment trips in the factory

III. ASD SETTINGS RELATED TO VOLTAGE SAGS

There are different ASD topologies that could be modified in order to achieve a higher level of immunity to disturbances with different ability to provide full-power ride-through.

The commercial ASDs tested have the following main strategies to increase its immunity against voltage sags:

- Flying Start. During voltage sag the ASD control disconnects the motor (power to keep control is taken from DC bus) and waits until the voltage recovers. During the disconnection, the motor speed decreases. Once the voltage sag is finished, the ASD detects the motor speed and starts controlling the motor gradually (as a ramp) from this speed to the set-point speed. This technique makes the motor decrease its inrush currents preventing the trip of drive protections.
- DC storage. The ASDs are configured to increase the energy stored in their capacitors connected at the DC bus. This energy can be used during voltage sag to keep the motor running.
- Load inertia. The load (especially in applications with high inertia) is used as a flywheel, so, during voltage sags the power for ASD controls is obtained by decelerating the load. Therefore, the inverter will adjust to operate at a frequency slightly below the motor frequency, causing the motor to act like a generator to regenerate power into the drive, contributing to the maintenance of the DC bus [11].

Commercial ASD can use any of the strategies shown above or similar systems. The election of the correct strategy and its settings has been taken by testing the ASD with the help of the voltage sag generator.

IV. ASD TESTS AND RESULTS

Two ADS devices, called ASD A (5,5kW) and ASD B (3kW), used in a factory have been tested to analyse their behaviour under voltage sag and the effect of settings on LVRT level. In a first step, a test with the default setting of ASD has been done. The ASD behaviours extracted from all the tests are classified in three stages:

- Normal. ASD keeps running during voltage sag and the effect in load behaviour is negligible.
- Stop+auto start. ASD stops running during voltage sag but it starts working when voltage sag finishes.
- Stop. ASD stops working when voltage sag occurs and it needs an external order to re-start working.

Results for ASD A and ASD B are shown in Fig. 6 and Fig. 7. As can be seen, the proposed immunity level is not achieved.

After this first test, some setting variations were made, and the tests were repeated until the proposed immunity level was achieved. The settings that were adjusted are:

- Disable of errors related to DC voltage levels.
- Minimum and maximum voltage DC levels.
- Enable "load inertia" mode (ASD A).
- Enable "flying start" mode (ASD B).

As a result, by means of adjusting the settings, the immunity level achieved is clearly much better than the one achieved by the proposed immunity curve, as shown in Fig. 8 and Fig. 9.

During tests, peak current values have also been registered (see Fig. 10) in order to evaluate the impact of setting variations on ASD's in the inrush currents. High peak values have been detected that could be related to the charge of the capacitor bank in the DC bus. For example, in ASD A tests, peak values up to 50A where detected when the nominal current is lower than 10A. Protection devices settings have to be adjusted in order to avoid trips during these peaks.

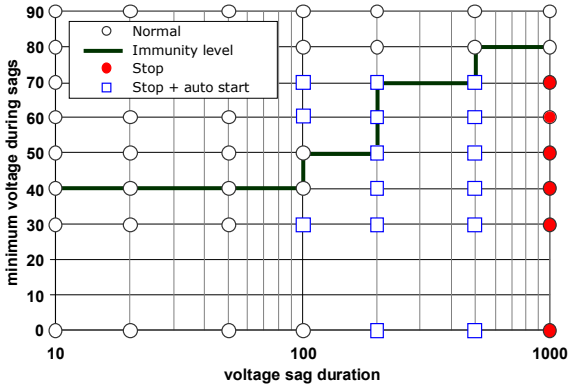


Fig. 6: ASD A: Test results with default settings.

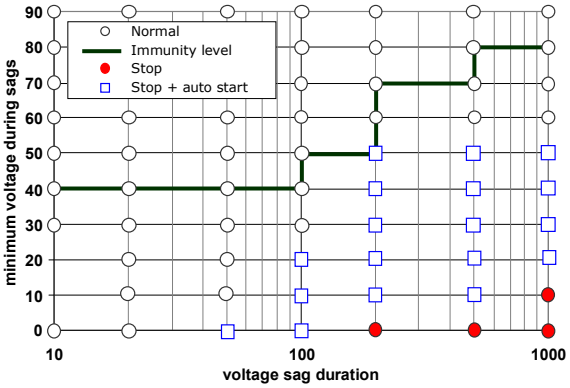


Fig. 7: ASD B: Test results with default settings.

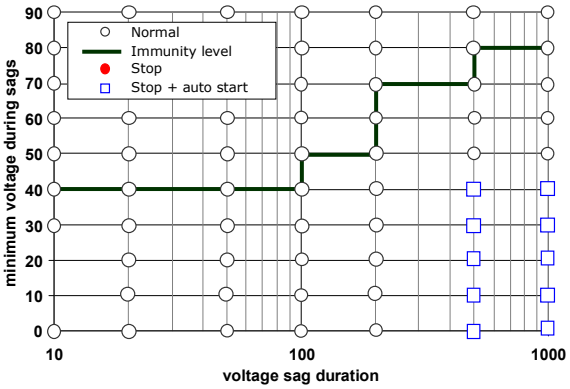


Fig. 8: ASD A: Test results with new settings.

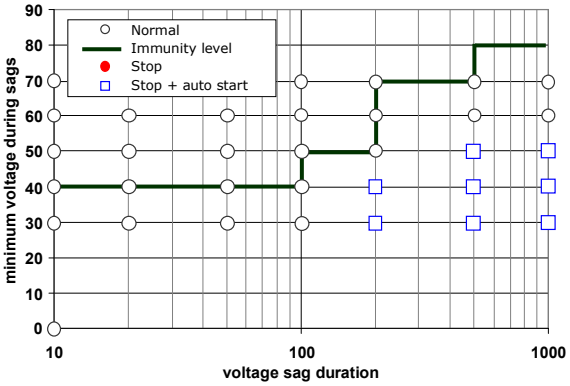


Fig. 9: ASD B: Test results with new settings.

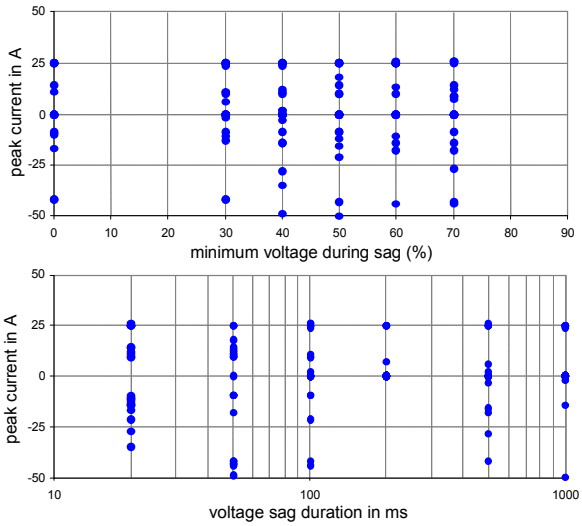


Fig. 10: ASD A: Peak current during test.

V. Conclusions

In this article, the LVRT behaviour of two commercial ASD's installed in a factory has been analysed. Firstly, an analysis of international standards has been carried out in order to get a reference to establish a LVRT level. These standards have been compared with voltage sag measurements and its impact in the factory equipment; thus, a proposed immunity curve that could avoid the 59% of unexpected trips is presented.

Once the objective LVRT level was defined, several tests with a voltage sag generator have been done. The adequate setting values to increase the immunity have been determined with these tests. Moreover, these settings not only improve the immunity of the ASDs to voltage sags but also reduce the transient currents during these dips.

The results of these tests can be used by end-users to determine the effect of voltage dips on different commercial ASD's, and also by drive manufacturers to improve the voltage dip performance of their equipment.

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