# Electromagnetic Compatibility Requirement for Semiconductor Plants

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## 1.0 INTRODUCTION

Power utility designs and builds power systems to generate, transmit and distribute electrical power to customers. Originally, customers only demand reliable and continuous electrical power for their operations. But electronic equipment, which is integral to industrial and commercial power systems, can fail or malfunction if subjected to a minor voltage, current or frequency deviation.

Before the era of solid-state electronics, power quality was not discussed because it had little or no effect on most loads connected to electrical distribution systems. When an induction motor suffered a voltage sag, it didn't shut itself down but simply 'spun out' fewer horsepower until the sag ended. The same was true for incandescent or fluorescent lighting systems in a facility - the lumen output just decreased temporarily.

But today, as sensitive equipment and processes become more complex and downtime costs increase, contractors and engineers have to specify and install specialised equipment to fight off danger.

The ideal power supply voltage for sensitive electronic equipment is an uninterrupted sinusoidal waveform of constant amplitude. Any event that reduces this condition is called a power quality disturbance. Power quality disturbances as brief as one-half cycle can affect the operation of sensitive electronic equipments.

There are many ways in which power supply to an industrial plant can be poor in quality. Some of the main causes contributing to these problems are atmospheric activity, theft cases of the utility network components, use of non-linear loads, etc.

In the case of external faults to the power system, such as a lightning strike or a third party damaging the underground cable system, the network protection schemes (relays) will immediately isolate the faults and thus give rise to a power quality event called voltage sag. This event can damage or disrupt sensitive electronic devices in industrial plants connected to the same substation with the faulty feeder. The impact of the voltage sag event, however, can be minimised if the industrial plants are designed to be immune to this power quality event.

In this article, the recommended minimum immunity requirement for semiconductor plants against voltage sag will be presented in brief. These requirements are based on the semiconductor industrial standards (SEMI F47, SEMI F49, SEMI F50) and Malaysian Standards (MS IEC 61000-2-4, MS IEC 61000-4-34).

## 2.0 UNDERSTANDING EMC

According to IEC standards (IEC 61000-2-1 and IEC 61000-2-4), power quality is actually an electromagnetic compatibility (EMC) problem. Is the equipment connected to the power grid compatible with the events on the grid, and is the power delivered by the grid, including the events, compatible with the equipment that is connected? Compatibility problems always have at least two solutions: in this case, either clean up the power, or make the equipment tougher.

Ideally, electric power would be supplied as a sine wave with the amplitude and frequency given by national standards (in the case of mains) or system specifications (in the case of a power feed not directly attached to the mains) with an impedance of zero ohms at all frequencies.

However, no real life power feed will ever meet this ideal condition. It can deviate in the following ways:

- Variations in the peak or RMS voltage. When the RMS voltage exceeds the nominal voltage by a certain margin, the event is called a 'swell'. A 'dip' (in British English) or a 'sag' (in American English - the two terms are equivalent) is the opposite situation: the RMS voltage is below the nominal voltage by a certain margin.
- An 'undervoltage' or brownout occurs when the low voltage persists over a longer time period.
- Variations in the frequency.
- Variations in the wave shape - usually described as harmonics.
- Quick and repetitive variations in the RMS voltage. This produces flicker in lighting equipment.
- Abrupt, very brief increases in voltage, called 'spikes', 'impulses' or 'surges', generally caused by large inductive loads being turned off, or more severely, by lightning.
- Nonzero low-frequency impedance (when a load draws more power, the voltage drops).
- Nonzero high-frequency impedance (when a load demands a large amount of current, then stops demanding it suddenly, there will be a dip or spike in the voltage due to the inductances in the power supply line).

Electromagnetic Compatibility (EMC) is a branch of electrical sciences which studies the unintentional generation, propagation and reception of electromagnetic energy with reference to the unwanted effects that such an energy may induce. To this purpose, the goal of EMC is the correct operation, in the same electromagnetic environment, of different equipments which involve electromagnetic phenomena in their operation.

For all electrotechnical equipments, EMC must be considered right from the initial design phase and the various principles and rules carried on through to manufacture and installation.

This means that all those involved, from the engineers and architects that design a building to the technicians that wire the electrical cabinets, including the specialists that design the various building networks and the crews that install them, must be concerned with EMC - a discipline aimed at achieving the 'peaceful' coexistence of equipment sensitive to electromagnetic disturbances (which may be considered as the 'victim') alongside equipment emitting such disturbances (in other words, the 'source' of the disturbances).

EMC is now becoming a discipline aimed at improving the coexistence of equipments or systems; which may emit electromagnetic disturbance and/or be sensitive to them.

## 3. VOLTAGE SAG AND EMC

Voltage sags is one of the electromagnetic phenomena that exists in the electromagnetic environment that affects sensitive equipments. The MS IEC 61000 series define voltage sag as a sudden reduction in voltage to a value between 10% and 90% of nominal voltage for a duration of 10 ms (1/2 cycle) to 60 seconds.

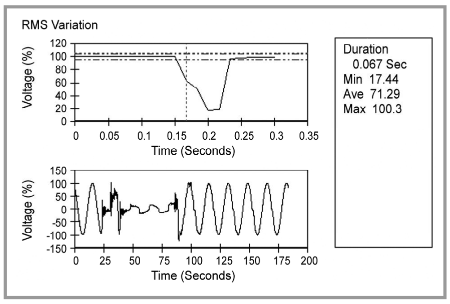


*Figure 1: Voltage sag due to external fault*

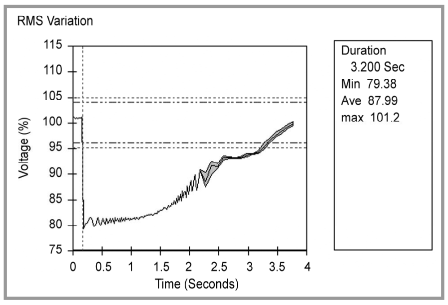


*Figure 2: Temporary voltage sag caused by motor starting*

When the voltage sags, it means that the required energy is not being delivered to the load and this can have serious consequences depending on the type of load involved.

The primary source of voltage sags observed in the supply network is an electrical short circuit occurring at any point on the electricity supply system. Many short circuits are caused by over voltages, which stress the insulation beyond its capacity. Atmospheric lightning is a notable cause of such over voltages. Alternatively, the insulation can be weakened, damaged or bridged as a result of other weather effects, by the impact or contact of animals, vehicles, excavating equipment, etc, and as a result of deterioration.

The switching of large loads, energising of transformers, starting of large motors and the fluctuations of great magnitudes that are characteristic of some loads can all produce large changes in current which is similar in effect to a short circuit current. Although the effect is generally less severe at the point of occurrence, the resulting changes in voltage observed at certain locations can be indistinguishable from those arising from short circuits. In such a case, they are also categorised as voltage sags.

## 4. IMPACT OF VOLTAGE SAGS TO EQUIPMENT

In this article, three voltage sag immunity standards: MS IEC 61000-4-11, MS IEC 61000-4-34 and SEMI F47 are discussed for EMC analysis for semiconductor plants. However, there are also many other voltage sag immunity standards, including CBEMA, ITIC, etc.

MS IEC 61000-4-11 and MS IEC 61000-4-34 are a closely related pair of standards. They both cover voltage dip immunity. MS IEC 61000-4-11 covers equipment rated at 16 amps per phase or less. MS IEC 61000-4-34 covers equipment rated at more than 16 amps per phase. SIRIM

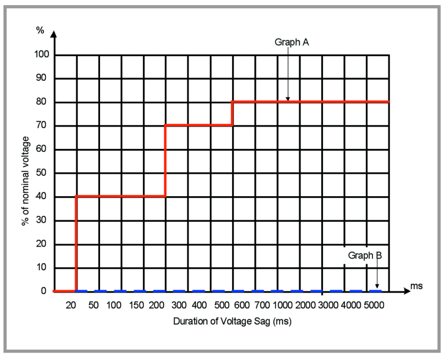


*Figure 3: MS IEC 61000-4-11/4-34 (Class 3)*

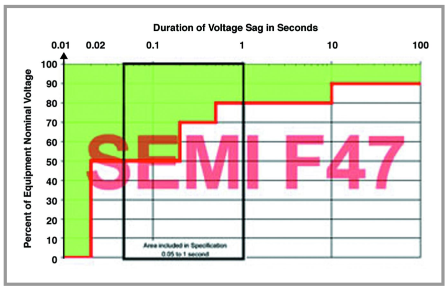


*Figure 4: SEMI F47*

Malaysia has adopted both standards as Malaysia Standards.

SEMI F47 is the other voltage sag immunity standard used in the semiconductor manufacturing industry. It is used both for semiconductor equipment, and for components and subsystems in that equipment.

All the three standards specify voltage sags with certain depth and duration, for example, 70% of nominal for 500 milliseconds. The percentage is the amount of voltage remaining, not the amount that is missing. These sags are applied to the Device Under Test (DUT). Each standard specifies the pass-fail criteria for DUT when a voltage sag is applied. The IEC standards have a range of pass-fail criteria, but the SEMI F47 standard is more explicit.

## 5. STANDARDS FOR VOLTAGE SAG IMMUNITY

The first step in identifying a suitable solution for improvement to voltage sags is to identify the components that frequently fail during a voltage sag event.

These components are commonly known as the 'Weak Links' of the system. For a chiller, it has been found that the controller circuit is the weak link that gave way whenever a voltage sag event happens. The rest of the chiller circuit will typically behave normally during these voltage sag event. In general, we can conclude that if the controller circuit of the chiller can be hardened, the chiller will be able to function properly when a voltage sag event happens.

*Figure 5: Voltage sag immunity testing*

### 5.1 Voltage sag immunity testing

After identifying the weak link in the chiller, a suitable voltage sag mitigation need to be selected to harden the

*Figure 5: Flywheel UPS*


*Figure 6: Dynamic Voltage Restorer (DVR)*

system. The mitigation selected shall be able to provide voltage sag protection according to the industry standards. A voltage sag immunity testing is necessary to verify the equipment's sensitivity and choice of solution.

A voltage sag generator is a piece of test equipment that is inserted between the AC mains and the DUT. It generates voltage sags of any required depth and duration.

The standards for equipment testing standards are SEMI F42 and MS IEC 61000-4-11/4-34. These standards define the test procedure and parameters used to characterise the susceptibility of equipment to voltage sags.

After the testing is done, the types of suitable solutions for improving the equipment's susceptibility to voltage sags can be identified and justified.

**5.2 Approaches to improve EMC**

Some of the common approaches to improve the equipment sensitivity to voltage sags are:

- Harden the control circuit for selected equipments, for example, chillers, compressors, etc, to voltage sags by installing single phase power conditioner such as the Dynamic Sag Corrector (DySC), Voltage Dip Compensator (VDC), Dynamic Compensator (Dynacom) or Dip Proofing Inverter (DPI). These measures will protect the microprocessor's power supply, relay circuits and other instrumentation to be more robust during voltage sags.
- Adjust the settings on the motor protection circuit to make the parameters less sensitive to voltage sags and voltage unbalance. The proposed delay settings for the voltage and current relay are at least two seconds. The proposed unbalance current setting is between 20% and 30%, and the voltage unbalance to at least 3% (for motors with service factors of 1.15 or greater). It is also important to disable any feature that will make the chiller shutdown on the dropout of a single cycle of voltage.
- Built-in software programming within the sensitive device. Several small adjustable speed drive models have user programmable automatic restart. Typically, they wait 30 to 60 seconds for the circuit to stabilise before trying to restart. The number of retries can be programmed, typically it is set at five retries. This strategy is commonly used by HVAC fans and pumps in an unattended environment. This applies to both sags and momentar interruptions.
- Install three-phase low voltage power conditioners to protect the overall supply schemes for the sensitive process. Examples are DySC, Dynacom, Active Voltage Conditioner, Flywheel UPS, etc.
- A newly installed three-phase medium voltage power conditioners to protect the whole plant from voltage sags. An example is the Dynamic Voltage Restorer (DVR). ■

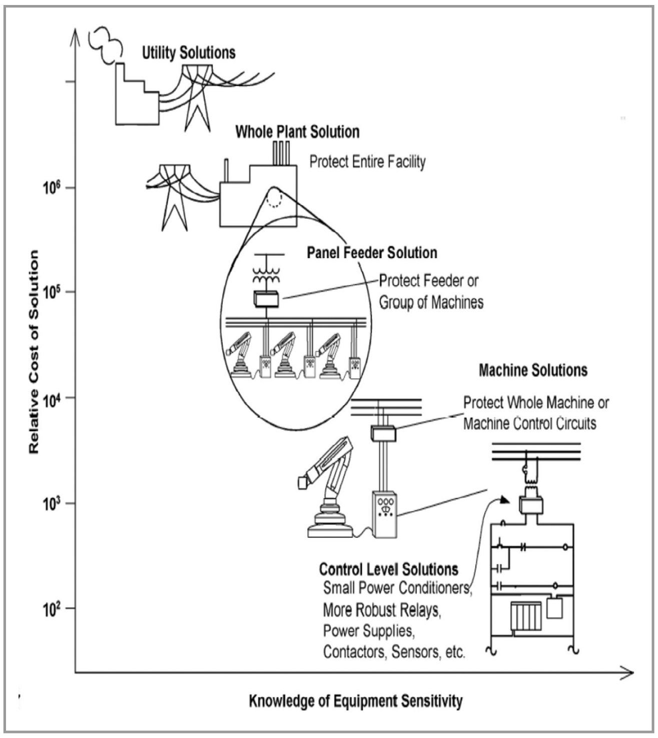


*Figure 7: Levels for voltage sag immunity*