International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 9 ‖ September 2023 ‖ PP. 05-10

Impact of Voltage Fluctuation and Power Quality on the Performance of Cold Chain Equipment used in Immunization Supply Chain

[1]Er. Shivley Sageer, [2]Mr. Nadeem Ahmad
*[*1]Er. Shivley Sageer, Training Coordinator, NCCVMRC-NIHFW*
[2]Mr. Nadeem Ahmad, Junior Technician, NCCVMRC-NIHFW

Abstract
Electrical Cold Chain equipment require a smooth and steady flow of electric supply. Diminishing voltage can cause great disappointment. Voltage Fluctuation is one of the most important problem. In simple terms, voltage fluctuation is a continuous change in the voltage when devices or appliances that require a higher load are extensively used. Extreme cases of voltage fluctuation can cause heavy damage to the life and Cold chain Equipment. Power surges can damage or destroy Electrical Cold Chain Equipment. A voltage stabilizer will protect them from sudden spikes in power, which can occur when the electrical system has been overloaded. It can also help Electrical Cold Chain Equipment to operate at peak efficiency when they are not plugged into a wall outlet.
Keywords: *voltage fluctuation, power quality, voltage protection device, cold chain equipment, voltage stabilizer, voltage regulators*

Date of Submission: 25-08.2023 Date of acceptance: 06-09-2023

I. INTRODUCTION

In many countries, the mains power supply is erratic with voltage fluctuating in both directions (high and low) frequently. These voltage fluctuations can damage Cold Chain equipment. When the supply voltage goes down, electric current in the equipment increases, which can result in burning the compressor motor and other components of refrigeration equipment. Using voltage regulators and stabilizers is therefore recommended[1].

WHO recommends that wherever supply voltage fluctuations exceed 7% of the nominal voltage, up or down, regulators or stabilizers should be used (Section E001.3 WHO PQS Manual). This applies to all refrigeration equipment, including refrigerators and Cold Rooms.

The voltage of electrical cold chain equipment should be 220 V, but it is common that the voltage cannot keep on 220V all the time, especially in those rural areas.

Under normal circumstances, the electrical cold chain equipment can work on within 187 ~ 242 V voltage. However, the performance of electrical cold chain equipment will be impacted if the voltage fluctuation is too big. In general, the larger the range, the greater the cold chain equipment will be impacted. If the voltage is lower than 187 V, the equipment can work on and even burn down the compressor. If the voltage is higher than 242V, the compressor and other electric parts are easy to be burnt out.

Moreover, if the voltage fluctuation range is less than 10 V, a regulator is not necessary. However, if the voltage fluctuation is big, such as more than 20 V, installing a regulator is very necessary. Especially for those areas where the voltage is always less than 200V or higher than 230V. In this condition, we should match a regulator (AVR). Of course, this means the voltage is often low or high. If only individually comes, it is not necessary to match a regulator. A regulator of above 750 W will be suitable for most of the Cold Chain Equipment[2].

High Voltage Surge was the leading cause of peril to Cold Chain Equipment assessed by Strike Check. When there is an increase in voltage from a power surge, it causes an inrush of electrical current within the Cold Chain

Equipment. This surge generates an excessive amount of heat, which can damage multiple parts of the Cold Chain equipment (CCE).

Most sensitive component in a Cold Chain equipment (CCE) is Control board. Control board can be easily damaged due to excessive heat produced by a surge of electrical current.

1. Impact of Unstable Voltage (Too Low or too High) on the Cold Chain Equipment-

(a)-**Do Not Start** – Cause the machine to not work normally and affect the performance.

(b)-**Short Lifetime** – Too low or too high voltage will easily damage the electronic components of the Cold Chain equipment (CCE), including compressors, fans, thermostats, and lamp power supplies.

Electrical power quality plays an important role in supplying electricity effectively to consumers. As power becomes a more essential and valuable resource for the entire world, it is important to maintain its quality at all levels of usage for the reliable working of the equipment[3].

Due to the usage of nonlinear loads and power electronic equipment in power system transmission, distribution and utilization sectors leads to distortion in voltage and current waveforms. We are already aware of the total harmonic distortion by phase control and integral control of AC power.

Nowadays power distribution companies are showing competitive nature to improve power quality by increasing concern over it to get the profitability and customer satisfaction.

2. Electrical Power Quality

If the power supplied to devices or equipment is deficient, it results in poor performance. Good power quality makes the equipment function properly without affecting performance or life expectancy.

IEEE standard defines electrical power quality as “the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment with precise wiring system and other connected equipment”. It is the deviation of voltage and currents from the ideal or actual waveforms.

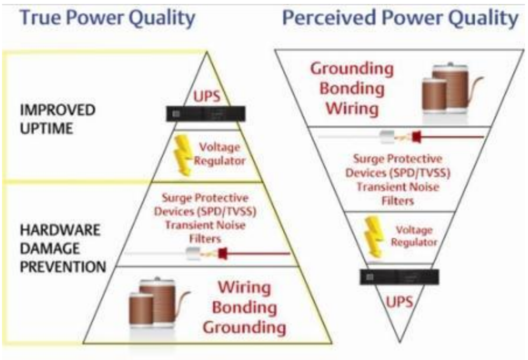

Figure 1 Electrical Power Quality

3. Power Quality Issues

The quality of the power is decided by the end-users. If the power equipment works satisfactorily for given supply then power is at good quality. If it does not function well or fails to work, then power quality is bad. Reasons for bad power quality or power quality issues are discussed below.

3.1 Power frequency disturbances

3.1.1 Voltage sags and swells:

Voltage sag or dip is the decrease of voltage levels from nominal values at power frequency. It lasts from about half of a cycle to several seconds. Low voltages are due to several factors like electrical motors, arc furnaces, utility problems, flickering, etc.

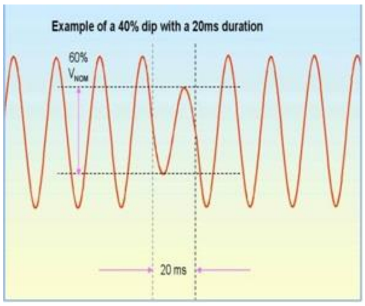

Figure 3 Voltage Sags

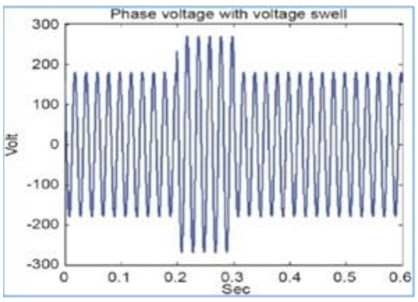

Figure 2 Voltage Swells

Motors like different types of induction motors during starting take a very large current, which results in a drastic voltage drop.
Also, arc furnaces initially take large amperes to produce high temperatures. Utilities drop the voltages by some of the factors like lightning, contact of trees, birds, and animals to power supply lines, switching operations, insulation failures, etc.

Voltage swells occur due to the transfer of loads from one source to another, sudden rejection and application loads. Flickering is a low-frequency problem that occurs mainly at starting or low voltage conditions.

Flickering is due to low voltages or frequency that can be observed by the human eye.

Voltage sags and swells result in a malfunction of equipment, loss of efficiency of motors, insulation failures, fluctuation of light illumination, tripping of relays and contractors, etc.

Power frequency disturbances are not easily cured if they arise at source level because it deals with high powers. However, these can be reduced if occurred internally due to loads by separating off end loads from the sensitive loads.

3.1.2 Electrical Transients

Transients are sub-cycle disturbances that last for less than one cycle of AC waveforms. Due to limited frequency response or sampling rate, detection and measurement of transients are very difficult.

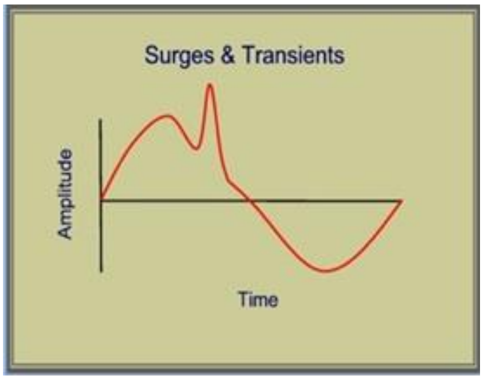

Figure 4 Electrical transient

These are also sometimes called as spikes, surges, power pulses, etc. These occur due to atmospheric disturbances like lighting and solar flares, fault current interruptions, switching the loads, switching capacitor banks, switching power lines, etc.

Some of the devices are designed with transients in mind but most of the devices can handle few transients depends on the severity of the transient and life of the equipment. These transients are limited by surge protection suppressors, filters and other transient suppressors as shown in the figure.

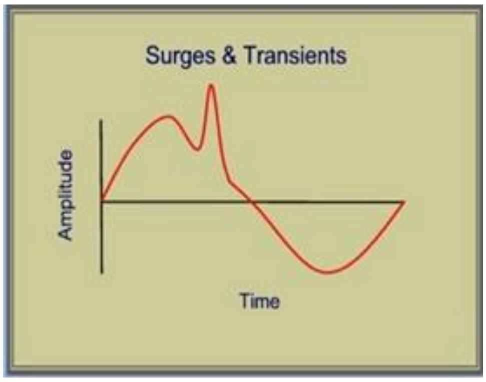

Figure 5 Electrical transient suppression

3.1.3 Harmonics

The harmonic nature of voltage and currents is the deviation from the original or pure sine waves. Harmonic frequencies are integral multiples of the fundamental frequency and are very common in electric power systems.

Order of harmonics differentiates these as even (2, 4, 6, 8, 10) and odd types (3, 5, 7, 9, 11). Major nonlinear loads produce odd harmonics and even harmonics are produced due to uneven operations of the electrical devices like transformer magnetizing currents contains even harmonic components.

The frequency of these harmonics depends on the order of harmonics as 2nd harmonic frequency is 2 times the fundamental frequency. These are generated due to nonlinear loads, arc furnaces, electric motors, UPS systems, different battery types, welding equipment, etc.

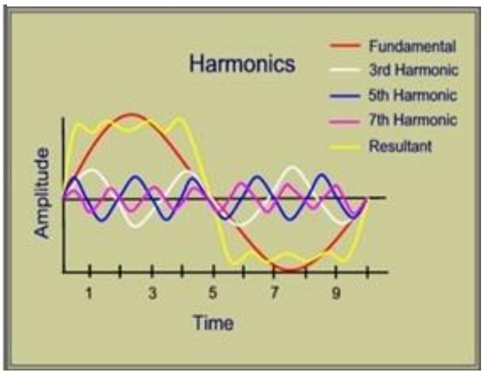

Figure 6 Harmonics

The fundamental waveform is superimposed by odd harmonics, which results in the distorted waveforms. These harmonics have serious effects on various electrical equipment such as overheating of cables and equipment, interference with communication lines, errors while indicating electrical parameters, the probability to produce resonant conditions, etc.

These can be easily measured by harmonic analyzers and reduced by using various harmonic filters like active and passive types.

3.2 Power Factor

The power factor is another main factor that affects the electrical power quality. Low power factor causes several problems like overheating motors and poor lightening. It also leads to the users being penalized to meet electric demands. The power factor is the ratio of active power to apparent power and determines the amount of electrical power utilization.

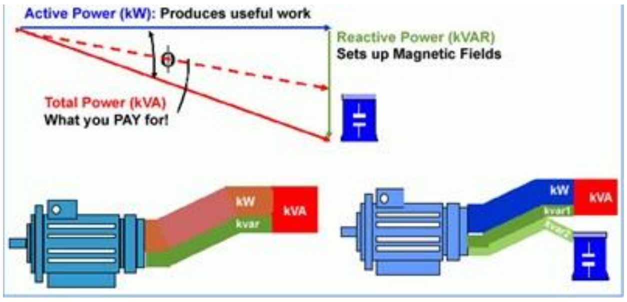

Figure 7 Power factor improvement by capacitor.

Suppose if the power factor is 0.8, it tells that 80 percent of the power is utilized and the remaining energy is wasted as losses. The low power factor is due to induction motors, apparent power elements in the electrical power system network, etc.

The low power factor is improved by using power factors correction devices such as capacitor filter banks, synchronous condensers, and other compensation equipment.

Power factor improvement, with the use of capacitors, results in a reduction of electric bills. Here apparent power drawn from the supply is reduced by capacitors which offer leading power in nature.

3.3 Grounding

Good power quality includes safety to the appliances as well as to operators. Grounding provides system protection as well as equipment protection. Earth serves as constant reference potential with another potential that is going to be measured.

If the equipment body is not properly grounded it results in a severe shock to individuals. System ground protects various equipment against fault conditions and other abnormal conditions occurring at electrical power systems.

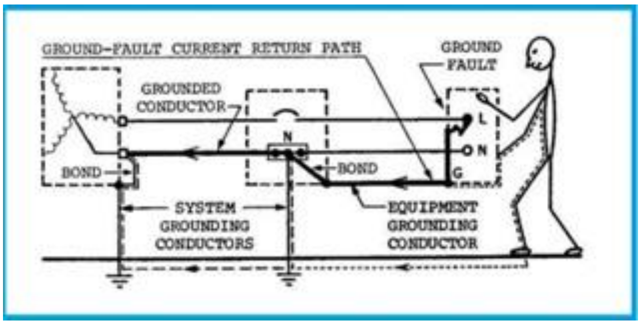

Figure 8 Equipment and system groundings

Signal reference ground is entirely different from normal grounding since it does not provide any protection to equipment or individuals. But it is necessary for the proper working of electronic components or devices to provide low impedance path or reference.

4. Need of Quality Power

In the emerging surplus power scenario, the characteristics of loads and the requirements of electrical systems have changed significantly. The electrical cold chain equipment used presently in Immunization Programme are more sensitive to supply variations than equipment used in the past. It is due to increased use of power electronics and microprocessor-based technologies in these equipment. The increasing penetration of Renewable sources of energy, semiconductor based electronic equipment, non-linear loads, data centres, industries running on adjustable speed drives and arc furnaces, etc. distort voltage/current waveforms in non-conformity to their desired form. This brings challenges to maintain the quality of power to ideal one and ensuring efficacy[4].

In India, various sectors are prone to both generation of higher power quality pollution as well as susceptible to power quality disturbances. The losses due to power quality issues are economic as well as technical. Both utilities as well as consumers are heavily impacted due to the techno-economic losses arising out of poor power quality. Poor power quality not only causes performance degradation and premature failure of electrical equipment but also results in increased system losses, financial loss etc. Optimum power quality can enhance productivity and reduce losses.

5. Solutions for Voltage Protection for Cold Chain Equipment-

There are two ways for Voltage Protection of Cold Chain Equipment i.e..; Digital Controller XR02CX and Stabilizer.

5.1 Use of Different Digital Controller XR02CX

It has a built-in voltage protection mechanism. We can set the lowest voltage VL and the highest voltage VU. When the voltage is lower than the minimum voltage or higher than the maximum voltage we set the thermostat such that, the thermostat will alarm and cut off the power to protect other electrical components of the cold Chain Equipment (such as compressors, and fans) from being burned out. Once the voltage has returned to the normal value, then the thermostat deducts it, the machine will clear the alarm and the refrigeration will be started automatically. This solution is suitable for scenarios: the frequency of voltage instability is preferably lower than 1 time/week. If the frequency is greater than 1 time/week, then directly using a voltage regulator to ensure long-term stable operation of the Cold Chain Equipment is suggested.

5.2 Use of Stabilizer

As the name suggests, voltage stabilizers stabilize the voltage, which means that when the supply voltage fluctuates, it keeps the supply to the equipment within a desired range. A common type of stabilizer uses electromagnetic regulators with so-called tap changers and autotransformers. In the event that the output voltage is out-of-range, a mechanism switches the tap and changes the transformer setting to an acceptable range. It may not give a constant voltage output, but it ensures a safe voltage range[5].

Servo voltage stabilizers use an advanced electronic controlled servomotor to govern a motorized variable transformer. Because of the mechanics involved, there is a short delay in voltage correction. Output voltage accuracy is usually ±1% with input voltage changes of up to ±50%. This type of technology tends to be very effective when considering large three phase applications, such as Cold Room.

A distinction is made between single- and three-phase voltage stabilizers. A three-phase voltage stabilizer is required when voltage stabilization is needed for a three-phase motor, or for stabilizing voltage for a full three-phase setup.

Smaller appliances such as refrigerators or freezers work on a single-phase voltage regulator, while a three phase voltage stabilizer is normally used for Cold Rooms and Freezer Rooms.

When determining the size of a stabilizer it is, first of all, important to know the total load to be connected to the stabilizer. Stabilizers are usually rated in VA (Volt Ampere) or kVA (Kilo Volt Ampere, which is equal to 1000 Volt Ampere).

Because of the surge power requirement when starting a compressor, it is recommended that the stabilizer is rated at least 3 times the load value. For example, when the Cold Room has a power requirement of 5kVA, choose a stabilizer of at least 15kVA.

6. Functions of Stabilizers:

6.1 Increase Efficiency- By reducing energy loss across numerous cycles of power use, a voltage stabilizer can aid appliances in operating at maximum efficiency. Additionally, it will keep your appliances in top shape longer by extending their lifespan.

6.2 Increase Safety- By keeping the circuit breaker on the lower cycle, it also lessens the possibility of overloading it. By doing so, short circuits and depleted shocks that could start a fire or even electrocute a person are avoided.

6.3 Provide Protection against- Under or Over-voltage, Electrical Withstand, Impulsive Transient overload Protection, Short Circuits, and Input Frequency Fluctuations etc.

6.4 Nominal input and output voltage and frequency

Stabilizers provides one or more of the following output voltage and frequency combinations when connected to an electric supply with one or more of the following nominal supply frequencies and voltage ranges. "230/50-60: Extended" type is required to correct a wider range of input voltages. This type is recommended for countries like India with wider input voltage fluctuations.[6]

Type	Nominal Supply (Input)	Nominal output voltage and frequency (standalone)
120/50-60	110, 115, 120, 127 Volt | 50-60 Hz	120 Volt | 50-60 Hz
230/50-60	220, 230, 240 Volt | 50-60 Hz	230 Volt | 50-60 Hz
230/50-60:Extended	220, 230, 240 Volt | 50-60 Hz	230 Volt | 50-60 Hz

6.5 Input voltage fluctuations: Stabilizers continue supplying acceptable output voltages as mentioned below:

Type Input	Minimum input voltage regulation range
120/50-60	82-159 Volt
230/50-60	173-278 Volt
230/50-60: Extended	110-278 Volt

7. CONCLUSION

Excessive voltage fluctuation and poor power quality always result in degradation and premature failure of an electrical cold chain equipment, if runs without a voltage protection device or voltage stabilizer.

As voltage stabilizer is an electrical device, which automatically maintains a constant voltage level. It provides a stable output to the output terminals of Cold Chain equipment irrespective of any variations in the input. Both analog and digital automatic voltage stabilizers can be used with a Cold chain Equipment.

When the supply voltage decreases, electric current in the Cold Chain equipment increases, which can result in burning the compressor motor and other components of the equipment. Therefore, use of Voltage stabilizer is recommended with every Cold Chain Equipment so as to protect them with over voltages, over load, short circuit etc., and to increase their efficiency & safety.

REFERENCES

[1] https://www.unicef.org/supply/media/4416/file/E007-cold-chain-accessories.pdf
[2] https://www.haier.com/in/service-support/self-service/20140625_102137.shtml
[3] https://www.elprocus.com/3-important-factors-affecting-electrical-power-quality
[4] https://www.electricalindia.in/which-factors-affect-the-power-supply-quality
[5] https://www.unicef.org/supply/media/4416/file/E007-cold-chain-accessories.pdf
[6] https://extranet.who.int/pqweb/sites/default/files/documents/WHO_PQS_E07_VS01.5.pdf