ESAVPRO SYSTEM

ENERGY SAVING AND PROTECTION SYSTEM

CONTENTS

1.GENERAL DESCRIPTION – THEORY OF OPERATION

1.1. ESAVPRO SYSTEM

ESAVPRO system can be described as a Power Quality Supply Device for a three/single phase power supply electrical system (400V/230V AC +/-10%, 50 Hz), with Maximum rated current 1600 Amperes. Its purpose is to supply Power Quality to all electrical and electronic equipment, for increasing their life expectancy and at the same time to reduce their Energy Consumption.

1.2. TECHNICAL CHARACTERISTICS

1.2.1. Esavpro System Design

Single Phase Device

ESAVPRO unit can make the energy reliable by the manipulation of all electrical parameters in order to supply the best power quality for having better utilization of energy for maximum efficiencies, reduction in Energy losses and consumption but as well to protect and increase the life expectancy of all single phase electrical equipment.

It can be used as a central Power supply unit for three / single phase Loads with Nominal Voltage 400V/230V AC +/-10%, 50 Hz, for maximum load of 1600 amperes. It can accept primary voltages from 400V/230V AC +/-10%.

Single Phase Device

It can be used as well separately for different three / single phase loads with the same above Power Supply up to above amperage.

ESAVPRO unit can be designed for different three / single phase loads with Nominal Voltage 400V/230V AC +/-10%, 50Hz by taking actual measurements during load conditions before its installation.

Its size is depended upon the actual taken measurements and the main fuses of Main breaker switch for each installation.

1.2.2. Voltage Optimization

Three Phase Device

ESAVPRO unit helps the voltage to be at reasonable levels from supplying voltage, with an energy saving Optimization transformer, according to the design of each installation with or not combination of very high quality of capacitors. It can accept primary voltages from 400V/230V AC +/-10%, 50 Hz, for loads with nominal voltage 400V/230V AC +/-10%, 50 Hz.

1.2.3. Absorption of Surge Currents, Transients & Spikes

Three Phase Device

The load site MOVs are designed to absorb Transient and Spikes next to Fundamental Voltage in order the ESAVPRO unit to act as a filter as well for not allowing the high frequency signals to travel in the electrical installation system.

1.2.4. Harmonics and Power Factor

After actual measurements for each case the ESAVPRO system is being designed to be a filter and Power Factor corrector at the same time, for increasing cosφ (Power Factor) for better utilization of energy and reduction of line losses.

1.3. THEORY

1.3.1. Energy Saving & Power Quality

Power (electrical power) has many parameters which influence the quality of energy which is needed for all electrical equipment and appliances to work with their maximum possible efficiency for reducing / minimizing energy losses and consumption.

If the parameters of power quality can be manipulated to be as possible reliable then the result of a very good power quality is the energy saving in KW or KWh reduction in Demand KWD/KVAD and also the increasing of the life of all electrical and electronic equipment.

Power Quality is very important for all kind of load, Inductive and Resistive.

Inductive loads are that kind of load which have magnetic mass and can receive electrical energy in order to transform it in kinetic energy or work done. Motors, compressors e.t.c.

Resistive loads like elements, florescent lights or any kind of lights a factor which is responsible for their consumption in KWh is voltage and its stability.

Power can have the following power quality factors or parameters.

Voltage & its Stability.

Surge Currents Transient – Spikes

Harmonics

Power Factor

Above power quality factors are affecting energy losses which are increasing the energy consumption (KWh) and the life expectancy of all electrical and electronic equipment.

1.4. VOLTAGE & ITS STABILITY

For 3Φ equipment this factor (voltage, voltage imbalance) is very important. Voltage imbalance can cause many problems in 3Φ machinery.

1.4.1. Problems

Under Voltage, over voltage and voltage imbalance have the following adverse effects:

- Overheating of motors lead to insulation breakdown.
- Imbalanced currents.
- Negative voltage sequence.
- Motor bearings failure.
- Speed variation in motors.
- Reduced motor efficiency.
- Wasted energy which leads to higher KWD/KVAD, KWH.
- Increased noise and vibration.
- Increased maintenance of equipment and machinery.

According to NEMA (National Electrical Manufacturer Association USA), after years of studies for 3Φ motors it can be said that not only these equipment's life is getting lower, but their consumption in KWh is higher, as imbalance in voltage is in existence, please see below fig.1, fig.2 and voltage imbalance table.

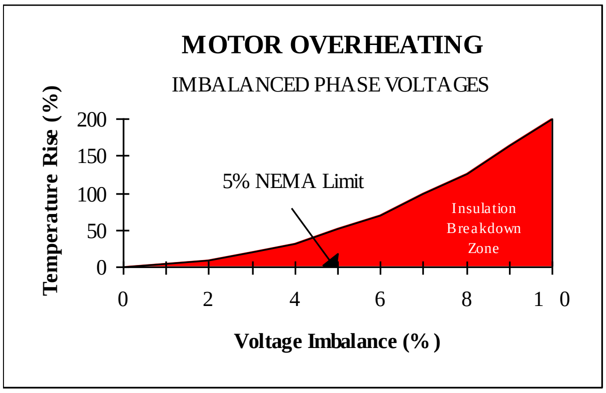


Fig.1

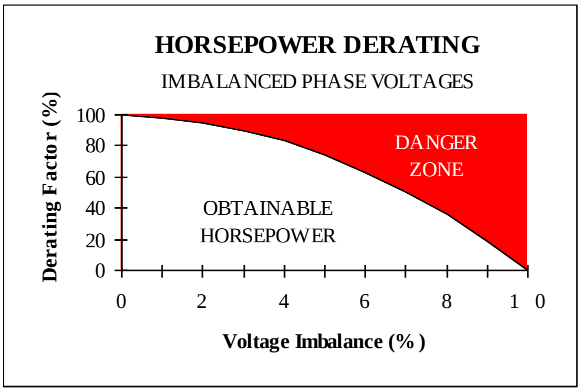


Fig.2

VOLTAGE IMBALANCE TABLES FOR 3Φ MOTORS

% voltage Imbalance	% Rise temper $2xdv^2$	% Losses Kwh
3	18	15
4	32	25
5	50	35

Temp. increase °C	Reduction life of equipment %
10	50
20	75

1.5. VOLTAGE STANDARDS

NEMA standards publication MG 1-2003 for Motors and Generators, states that: Motors meeting the criteria contained in the NEMA standard will operate satisfactory within plus or minus 10% of the rated voltage.

The NEMA standard for voltage unbalance states that a motor will operate satisfactorily at its rated load with a voltage unbalance up to one percent (1%) at the motor terminals.

The American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE) C84.1 Standard for nominal voltages, implies that an adequately designed power system can have up to a 3% inherent voltage unbalance. However, if measurements at the motor terminals indicate more that a 1% voltage unbalance, the motor should be derated according to derating factor for motors imbalance voltages.

Voltage unbalance %	Derating Factor %
1	98
2	95
3	88
4	82
5	75

1.6. EUROPEAN VOLTAGE HARMONIZATION

The IEE recommended in 1996 all electrical equipment should be tested at 230V – 14% to +10%.

Equipment manufacturers have now had 11 years to ensure their appliances will operate within the Harmonised levels.

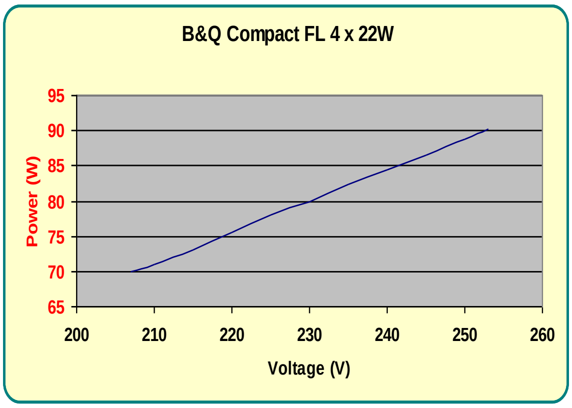
The network suppliers have not made any changes to the existing 1995 voltage levels.

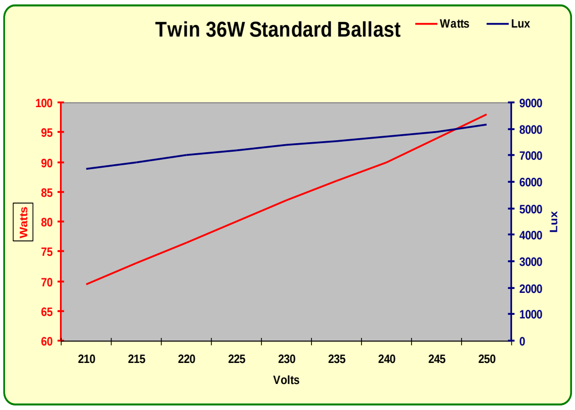
The average supply voltages remain from 220V to 245V through Europe.

Pre 1995	**240V ± 6%**	**225.6 to 254.4V**
1 /1/ 1995	**230V -6% +10%**	**216.2 to 253.0V**
31 /1/ 2003*	**230V ± 10%**	**207.0 to 253.0V**

A 230V linear appliance operated on a 240V supply will consume 9% more energy than necessary.

A 230V rated lamp operated at 240V will achieve only 55% of its life.





1.7. SURGE CURRENTS TRANSIENTS-SPIKES

Surge Currents, Transient & spikes usually are high frequency signals or sudden increasing of voltage above the fundamental level, with high speeds (sometimes less than 1 nanosecond) which actually affect motor windings by increasing their hysteresis losses & eddy current losses.

Also they are increasing equipment temperature (electrical energy which is transformed to thermal energy) or increasing vibration (electrical energy which is transform to kinetic energy). Thermal or kinetic energy can be characterized as an extra energy losses.

Sometimes surge currents are responsible for the distraction of any equipment due to high voltage levels. As an example which is very common is the failure of power supply of computers due to above reason.

Moreover transients and spikes due to their nature as high frequency signals with high speed, they can travel in all equipment and electrical installation to all direction (kirkoff's low), with their destroying results. This (traveling in wires and cables) has a result in increasing the skin effect losses.

Skin effect is a tendency for alternating current (AC) to flow mostly near the outer surface of a solid electrical conductor, such as metal wire, with the existence of high frequencies. The effect becomes more and more apparent as the frequency increases.

The main problem with skin effect is that it increases the effective resistance of a wire for AC at moderate to high frequencies, compared with the resistance of the same wire at direct current (DC) and low AC frequencies.

It is a phenomenon and energy loss due to the ability of electrons when traveling in wires or cables as electrons are traveling at the outer surface. In the existence of high frequencies the quantity of electrons is increasing at this point. The result is the creation of turbulence with their movement and this creates increasing of heat (energy loss) and line losses in the cables.

Also another factor which magnify this phenomenon in electrical distribution and all kinds of installation system is kickoff's low.

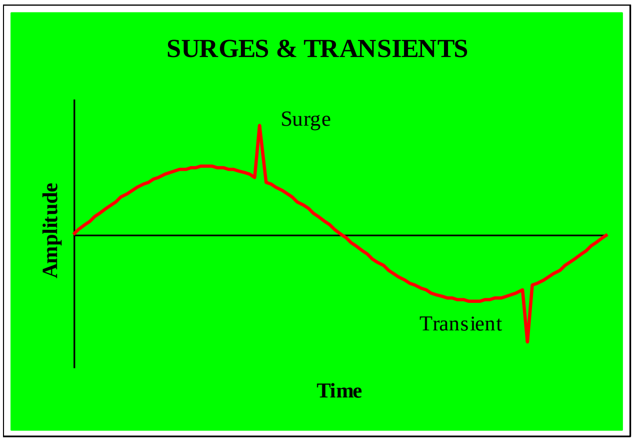
Kickoff's low says that current (electrons) move to least way path. So if an electrical system has low impedance then is more sensible and susceptible to surges, transients and harmonics from outside. If this system has low impedance and already suffers from all above high frequency signals then its problem becomes higher in the respect of line losses and skin effect losses.

1.7.1. Problems

Surges transients and spices have the following adverse effects:

- Increase maintenance and downtime.
- Reduce lifetime of equipment.
- Cause computers to stop execution of programs.
- Create false data in computers.
- Erase data in computer memory.
- Result in hardware damage.

- Cause damage to insulation in transformers and motors.
- Cause nuisance tripping of adjustable-speed drives.
- Increasing Demand and Consumption (KW, KVA, KWh).



1.8. LOSSES FOR MOTORS

1.8.1. Losses

Every Motor will experience losses, which results in a temperature increase. The maximum allowed temperature is limited by the magnets, the oil in the bearings and the mechanical behavior of the brushes.

1.8.2. Electric Dissipation

All motor coils have resistance and will therefore generate heat.

1.8.3. Hysteresis Losses

In all motors except from hollow rotor motors, the magnets move with respect to the iron core of the motor. This results in a reversing magnetic field in the iron which leads to hysteresis.

Each rotation produces an energy loss proportional to the area of the hysteresis curve (B/H). The power loss due to hysteresis is proportional to the motor speed and can therefore be represented as a friction torque. Due to this friction torque the motor can produce less output torque.

1.8.4. Eddy Current Losses

An eddy current is a phenomenon caused by a moving magnetic field intersecting a conductor or vice-versa. The relative motion causes a circulating flow of electrons, or currents within the conductor. These circulating eddies of current create electromagnets with magnetic fields that oppose the change in the external magnetic field (Lenz's Law). The stronger the magnetic field, or greater the electrical conductivity of the conductor, the greater the currents developed and the greater the opposing force.

Eddy currents are also the root cause of skin effect in conductors carrying AC current.

Eddy currents create losses through Joule heating, and they reduce the efficiency of many devices that use changing magnetic fields such as iron core transformers and alternating current motors.

A reversing magnetic field in iron also leads to an induce voltage. The resistance of the iron determines the resulting currents in the iron and these currents are the eddy currents.

Eddy currents heat up the iron because of its resistance. If a massive iron return is used large eddy currents will be induced with high power losses.

The power loss due to eddy currents is proportional to the square of the motor speed and can therefore be modeled as mechanical damping. Damping will decrease the performance of the motor.

1.9. HARMONICS

1.9.1. What is a Harmonic?

The typical definition for a harmonic is “a sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency.”

Electrical generators try to produce electric power where the voltage waveform has only one frequency associated with it, the fundamental frequency. In the North America, this frequency is 60Hz, or cycles per second. In European countries and other parts of the world, this frequency is usually 50Hz. Aircraft often uses 400 Hz as the fundamental frequency.

At 50Hz this means that fifty times a second, the voltage waveform increases to a maximum positive value, then decreases to zero, further decreasing to a maximum negative value, and then back to zero. The rate at which these changes occur is the trigometric function called a sine wave, as shown in figure1. Is the mathematical expression of the movement of the electrons in the wires or cables, in an alternative electrical distribution system. The electrons in other words they change their polarity (50 for 50 HZ or 60 for 60 HZ frequencies) times per second from positive to negative as they are traveling in the cables.

Some references refer to “clean” or “pure” power as those without any harmonics. But such clean waveforms typically only exist in a laboratory. Harmonics have been around for a long time and will continue to do so.

The frequency of the harmonics is different, depending on the fundamental frequency. For example, the 3rd harmonic on a 50Hz system is 3*50 or 150 Hz. At 60Hz, the 5th harmonic is 5*60 or 300Hz. The 7th harmonic in a 50Hz system, is 350 Hz. Figure 2 shows how Harmonics can distort the fundamental signal and how would appear on an oscilloscope-type display.

1.9.2. Why Worry About Them?

The presence of harmonics does not mean that the factory or office cannot run properly. Like other power quality phenomena, it depends on the “stiffness” of the power distribution system and the susceptibility of the equipment. There are a number of different types of equipment that can have misoperations or failures due to high harmonic voltage and / or current levels. In addition, one factory may be the source of high harmonics but able to run properly. This harmonic pollution is often carried back onto the electric utility distribution system, and may affect facilities on the same system which are more susceptible.

Some typical types of equipment susceptible to harmonic pollution include:

Excessive neutral current, resulting in overheated neutrals. The odd triplen harmonics in three phase wye circuits are actually additive in the neutral. This is because the harmonic number multiplied by the 120 degree phase shift between phases is an integer multiple of 360 degrees. This puts the harmonics from each of the three phase legs “in-phase” with each other in the neutral. This harmonic is being created by single phase machinery like photocopy machines, computers, UPS, florescent lights, fax machines e.t.c.

Studies shown that the last 15 years Harmonics and especially , the 3rd and triplen harmonic level in distribution systems is higher than ever before due to the fact that nowadays all buildings, homes, factories, offices etc they cannot operate without single phase and especially these kind of equipment.

Incorrect reading meters, including induction discW-hr meters and averaging type current meters.

Harmonics as high frequency signals affect and cause the following side effects for all equipment as follows:

– Overheating of transformers (K-Factor), and rotating equipment.

– Increased Hysteresis and Skin effect losses losses.

– Neutral overloading/unacceptable neutral-to-ground voltages (straight voltage loss).

– Distorted voltage and current waveforms.

– Breakers and fuses tripping.

– Unreliable operation of electronic equipment,

– Wasted capacity - Inefficient distribution of power.

– Increased maintenance of equipment and machinery.

-- Reduced true PF, where PF=Watts/VA.

– Erroneous register of electric meters.

– Wasted energy / higher KWD & KWH.

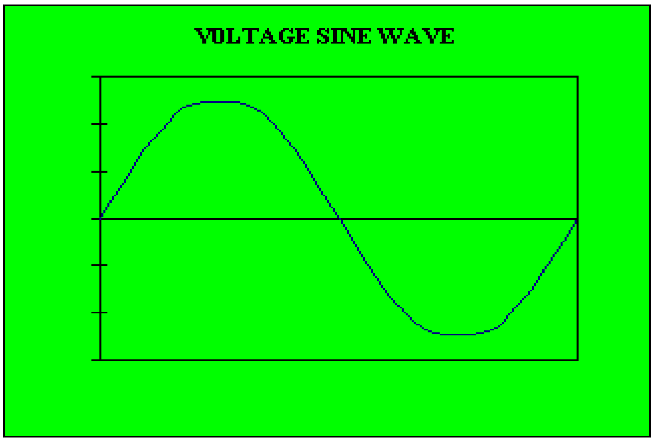


fig.1

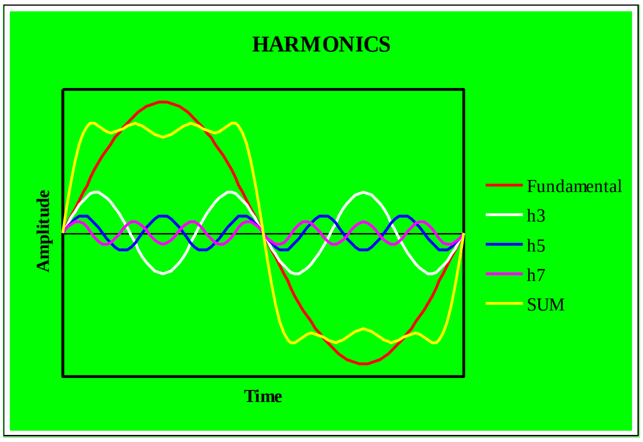


fig.2

1.10. POWER FACTOR

Power Factor is the ratio of working/Real power or energy (kilowatts or KW) to apparent or total power (kilovolt-amperes or KVA) delivered. It measures how effectively total delivered power is being used. A high power factor, signals effective utilization of electrical power, while a low power factor indicates poor utilization of electrical power.

However, this is not to be confused with energy efficiency or conservation which applies only to energy or KW. Improving the efficiency of electrical equipment reduces energy consumption but does not improve the power factor.

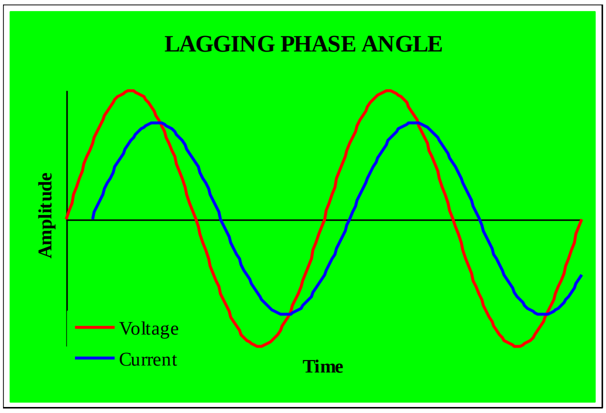
The basic formula for Power Factor is the mathematical ratio of real power to total power. This ratio is an effective measure of system electrical efficiency and is represented as a percentage or decimal (e.g., 90% or 0.9).

Real Power (measured in kilowatts KW) is the part of the triangle which results in real work done, in the form of heat energy. This is the power that drives the world.

Apparent Power (measured in KVA) is that portion of the power triangle that we actually measure and is a combination of real power and reactive power.

And Reactive power (measured in KVA) generates the magnetic field for inductive loads such as motors, transformers, lighting, ballasts, etc. Reactive power is measured in kilovars (KVAR), serves no real function at all.

Power Factor can be described by the Energy Triangle as the COSΦ of the triangle which is equal to



$$PF = \cos\phi = \frac{\text{RealPower(KW)}}{\text{ApparentPower(KVA)}}$$

If cosΦ can be increased almost to unity but not beyond unity then lines loses I^2R can be reduced.

In three phase machinery this is getting a lit of beat complicate for the reason that in a 3 phase power supply system is impossible to have stable balance 3Φ system for all the 3 phase (voltage and current balances). The asymmetrical components of power should be taken in consideration. For 1Φ Machinery is easier to manipulating it because only one phase is in existence.

1.10.1. Problems

Low P.F. causes the following adverse effects:

- Increased line losses - I2R.
- Wasted generation capacity (KVA).
- Wasted distribution / transformer capacity (KVA).
- Wasted system capacity (KVA).
- Reduced system efficiency (KW).
- Increased maximum demand (KVA), and related charges.
- Possible power factor charges.
- Increased Maintenance of equipment and machinery.
- Wasted energy / higher electric bills - KWD & KWH.