Power quality improvement

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Abstract – This paper explaining some solutions to the power quality. There are just as many solutions to power quality problems as there are configurations that produce poor power quality. Many various methods can not have ability to address the problem in a unified approach.
For this reason, in order to improve the power quality the engineer must work closely with the user and equipment manufacturer in order to determine the need for a proper equipment sollutions and the proper conditioner if needed to improve the power quality.

Way the clean sinusoidal power is needed?

As the technology change the older forms of power conversions are being replaced, especially with the introduction of the solid state switching devices. Drawers and static rectifiers have replaced the old ac-to-dc motor-generator sets. Very little maintenance is requiring for the new adjustable speed drives. From the another side the motor generator sets has high maintenance pieces of equipment and physically are too large. After resolving the one set of problems in the industry the another problems has been introduced.

The factors that characterize loads, which are insensitive to power quality, are those in which electrical energy is being used from the AC bus, and no timing or data is involved. For example, an AC arc furnace uses the energy supplies just for that: energy supply. On the another hand, loads which take more than simply bulk energy from the bus, for example devices which utilize the accuracy of the power frequency, or loads which take carrier current communications data from the AC bus, or loads which employ controls-perhaps sensitive controls, are indeed to power quality. For such loads, it may be possible to calculate the level of power quality, which is needed to maintain proper operation. Electronic loads frequently produce current wave shapes with electronic loads frequently produce current wave shapes with total harmonic distortion in the 70% to 100% ranges.

Installing the shunt capacitor the power factor will be corrected, because the poor power factor caused by the increasing converter loads is one of the problems. To bring power system harmonic problems into focus capacitors and other system devices are combined.

The use of microprocessor-based controllers, computers, and other related electronic equipment has accelerated the use of electronic loads in our factories, businesses and homes. A source of low voltage dc to normal operation is requiring for the circuitry in these devices. Therefore, virtually every modern computer or electronic device has a small static power converter as part of it composition.

Comparison to the total industrial size's load, each power supply is a small load. When compared to the entire power system grid, this one power supply is an even smaller percentage of the total load. However, these small static power converters have proliferated to the point that have become a substantial portion of the total commercial load.

Each non-linear device produces its own distorted waveform composed of varying harmonic components. Each device allows current to pass during a portion of the voltage sine wave and blocks the flow of current during other portions of the sine wave.

As a result of load changes, phase controlled devices such as adjustable speed drives generate harmonic currents with amplitudes varying.

Fig. 1, illustrated a typical switching-mode power supply.

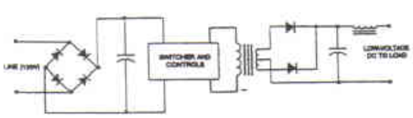

Fig. 1. Typical switching-mode power supply

Fig. 2, illustrated a normal power system voltage sine wave along with the resulting current waveform caused by the power supply.

When the voltage drops below the nominal voltage for several cycles, sag, the sensitive electronics suffer. Fault condition in a neighboring power network, utility switching, and a fault condition in a neighboring power network or many other power system incidences can cause this condition. The power supply may shut down during a sag condition. The load of the power supply may then experience a power outage for the duration of the sag.

When the differing power quality problems from each device are summed within one power system, the result may manifest it self in many different ways: nuisance tripping of circuit breakers and adjustable speed drives, deterioration of electronic equipment performance continuous or sporadic computer malfunctions, overheating and premature failure of transformer even when the transformer nameplate rating seems adequate, telephone interference, overheating of motors by operation on a power system with distorted voltage waveform, capacitor fuse blowing, overheating of neutral - possibly causing neutral burnout resulting on equipment, being over vol.

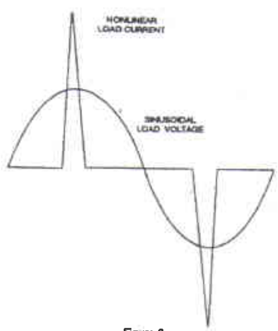

Fig. 2. Voltage sine wave along with the current waveform

Problems solutions

Problems with voltage regulation can be corrected to varying degrees with Uninterruptable Power Supplies (UPS), Active Harmonic Filters, Passive Harmonic Filters, Phase Multiplication, Constant Voltage Transformers, Power Line Conditioners (PLC), Line Voltage Conditioners (LVC), Surge Suppressors, Static Var Compensators and Static Watt Compensators. One way to limit the problems in power systems caused by those harmonics is that isolating susceptible loads from loads that generates the harmonics. Additional inductance can be introduced into the power circuit and attenuate the harmonics that are injected into the power system by putting the harmonic producing loads on isolation transformer. Using the large neutral conductors on the loads that generating the harmonic the above approach is usually accompanied. The transformers supplying the power to these harmonic-generating loads should also be evaluated for possible derating.

Passive filters

Historically, passive filters have been the preferred method of controlling harmonics. Also passive filters are the most common to the Electromagnetic Interference (EMI) reduction problem. Passive filters for EMI signals are installed on power feeders between distribution transformers and the loads requiring protection.

There are two techniques that can be used that can be used for preventing the power systems from harmonic currents:

1. Low impedance shunt filter
2. High impedance series filter

The shunt filter must carry only a fraction of the system load current. These factors tend to make the series filter more costly than a shunt filter. An added feature of the shunt filter is that it also supplies reactive power at the fundamental frequency, therefore, helping the system's power factor. However, the series filters must carry full system load current and be insulated for full line voltage.

Harmonics are absorbed at the source by adding a parallel filter, for example: inductor-capacitor combination to the power system. Based on the load configurations, passive filters are tuned to specific frequencies. The parallel filter acts as a short circuit to ground for the frequencies of harmonic current to which it is tuned. Fig. 3 is a typical tuned passive filter. Change in the loads or the power system may change the required power handling capability of the filter elements.

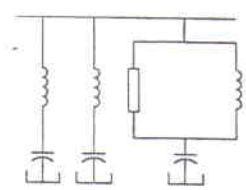

Figure 3

Fig. 3. Passive filter

These filters are usually tuned and sized for only a few frequencies. This results in the need to periodically re-tune the filter. It is extremely difficult to know and predict all future system change. A load or source change could result in system ability problems with detrimental effects on the power system and loads. Passive filters also take some time to settle following a change in the level of harmonics in the system. The duration of this time settling is inversely proportional to the quality factor of the inductive and reactance components in the filter. The better filtering will be achieving components with a high quality factor and lower losses. However, higher quality factors value result in longer times for the system to settle after the harmonic levels have changed. This will result in a "ringing" effect and long periods of unfiltered harmonics entering the power system.

Constant Voltage Transformers (CVT)

The term CVT was originally applied only to transformers of special design, which are used at low voltage and power to provide a voltage-regulated bus for the load. There are commercially available electronic CVT whose main element is not a transformer but a back-to-back rectifier/inverter whose controls are designed to regulate the voltage at the load bus.

For voltages with a small amount of distortion, only the fundamental components of the voltages are used in the formula. For an ideal voltage regulator, the regulation characteristic would be at 100% for a wide range of input voltages. If the input voltage range is restricted to +80% to +120% of rated, an ideal CVT characteristic is shown in Fig. 4.

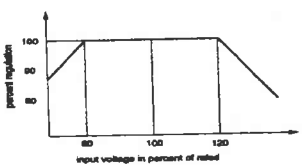

Fig. 4. Regulation characteristic of an ideal CVT

A stepping transformer will sense a change in the system voltage and compensate for it by automatically changing taps. This is a method that attempts to keep the system voltage from going too high or dropping so low that the sensitive electronics are effected. However this method can take up to 1/2 cycle to compensate for any voltage fluctuations. The tap changer on the transformer will usually not change settings until the load current waveform makes a zero crossing.

Uninterruptable Power Sources (UPS)

UPS are devices, which are used to supply electrical loads from the commercial power mains during normal operation, and, as a backup, from a standby source during standby operation. Installing an UPS to supply power to critical loads is another common solution to power quality problems. The standby mode is also called the "emergency" or "backup" mode. Another words, UPS provide standby capacity for powerfails and short outages and provide constant frequency.

The off-line UPS are normally in the stand-by mode. The critical load is supplied by the normal power system until there is a problem. When the off-line UPS senses a problem it will pick-up the load. These UPS's may protect sensitive loads from voltage dips, sags and outages due to the solid state switching in the UPS. While in the standby mode, an off-line UPS does not protect the load from the power sources voltage harmonics. As batteries are recharged following an outage, all the non-linear rectifiers performing the recharging operation induce significant harmonics on the power network.

With an on-line UPS the load is always connected to the UPS. An on-line UPS supplies clean power to load by using an inverter to reconstruct a sinusoidal voltage for the load from energy stored in batteries. The batteries are kept charged by a dc rectifier that is connected to the power system. This rectifier isolates the UPS load from most power quality problems found in the distribution system.

Even though the UPS supplies clean power to the load, it is still a non-linear load to the source. The rectifier input to the UPS, causes harmonic currents to be absorbed from the power source. Power quality on the source power system worsens with the UPS as a load and could have a detrimental effect on other sensitive loads that are on the same circuit.

The costs of UPS's are high relative to other solutions. However, an UPS may be the only choice when long-term outages are anticipated.

Active Power Line Conditioning (APLC)

The same marriage of digital control devices, strategies, and power switches that causes power quality problems can also provide a cost-effective solution to power quality problems. The APLC is active, broadband power line filter, which provide an adaptive solution to many power quality problems. Benefits provided by an APLC are:

1. Load Current Harmonic Cancellation
2. Passive Noise Filtering
3. Continuous Voltage Regulation
4. Source Voltage Harmonic Compensation
5. Spike Protection

The two filters (one in series with the load and one in parallel with the load) share a common dc-link, Fig. 5. Both filters are dynamically controlled through high speed switching using a pulse width modulation control strategy.

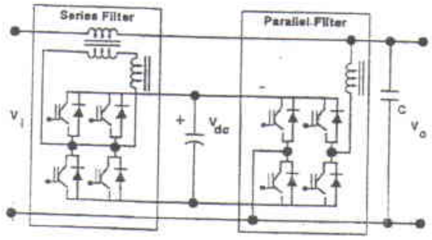

Fig. 5. APLC filters

1. The series active filter provides instantaneous voltage regulation and input voltage harmonic compensation. The following parameters exceed the requirements of the most sensitive loads. The APLC input voltage may be as much as 15% high or low and may have as much as 10% harmonic distortion. The APLC output voltage to the load will hold the output to within 1% of normal voltage with less than 1% harmonic distortion. The response time to a step change in the input voltage is less than one millisecond with no ringing.

2. The parallel filter generates all of the harmonic current drawn by the load. Loads with current total harmonic distortions of greater than 100% and crest factors on the order of two and half are readily accommodated.

The basic operation of the parallel filter current compensation is shown in Fig. 6. The current is shown for a typical non-linear load, such as a capacitor load on a full wavebridge rectifier.

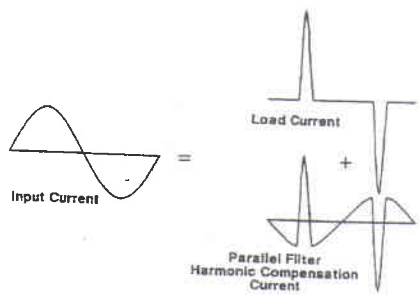

Fig. 6. Parallel filter current compensation

The input current flows in the parallel filter, when no current flows in the load. The non-fundamental component is supplied from the filter when the load current turns on. From the parallel filter is supplied the large peak harmonic current, larger than the fundamental. This process continues through both the positive and negative half-cycles. The result is that the load current harmonics are compensated by the parallel filter-while only fundamental current is absorbed from the power distribution system.

APLC performance

To produce unexpected and potentially damaging resonance the APLÇ does not interact with other filters or source impedance. To provide the data to design an optimum harmonic filter, no detailed analysis of the facility's distribution system is needed. Ringing in passive filters in response to step changes in loads does not occur.

The active power line conditioner includes an active parallel filter, which automatically cancels these harmonic components. Fig. 7 illustrated the total harmonic distortion presented to the distribution system.

The active power line conditioner provides a combination of features and functions unique in the power quality industry.

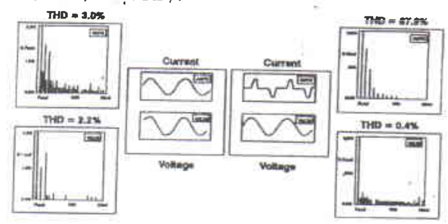

Fig. 7. APLC performance

It automatically and instantaneously adapts to changes in the distribution and load characteristics to provide clean, trouble free electric power.

Application

The interaction of the current with the line impedance results in the distorted voltage on the distribution system, Fig. 8.

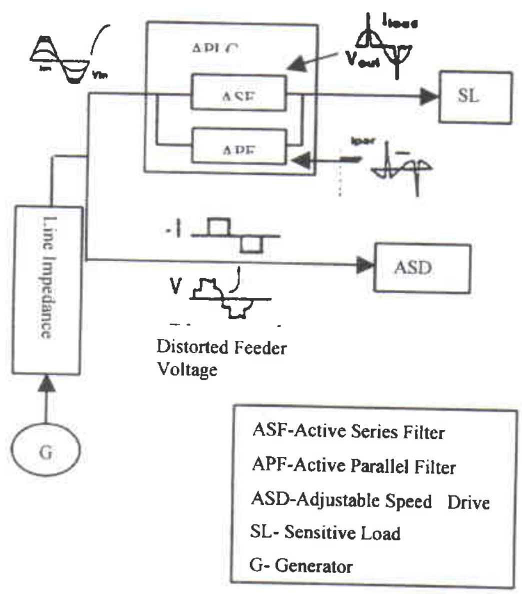

Fig. 8. Application

The APLC is connected in series between polluted distribution system and the sensitive load. The APLC is represented here as an Active Series Filter and an Active Parallel Filter.

The unregulated, distorted voltage supply is represented by non-sinusoidal waveform with various amplitudes. The non-linear current drawn by the load is represented by the haversine-shaped curve. The APLC regulates the voltage and compensates for harmonics, effectively isolating the sensitive load from the polluted distribution system.

The sensitive load also generates harmonics, which, if not canceled, would further distort the power distribution system. The active parallel filter supplies all of the non-fundamental current to the load, resulting in the cancellation of harmonics.

Therefore, the APLC works both ways. It provides regulated, harmonic compensated voltage to load and, simultaneously, shields the distribution system from the load-induced harmonics. The UPS provide only one way protection.

Conclusions

Of all the above stated various methods of dealing with power quality problems only one solution has the ability to address the problem in a unified approach.

1. The APLC eliminates load harmonics, reduces source harmonics, and adjusts for source voltage variations instantaneously.
2. The insulation transformers do not eliminate load harmonics, do not reduce source harmonics, and do not adjust for source voltage variations instantaneously.
3. The stepping transformers do not eliminate load harmonics, do not reduce source harmonics, and adjusts for source voltage variations instantaneously.
4. The UPS eliminates load harmonics, do not reduce source harmonics, and adjusts for source voltage variations instantaneously.
5. The passive filters eliminate load harmonics, reduce source harmonics, and do not adjust for source voltage variations instantaneously.

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