RENEWABLE ENERGY SOURCES AND HARMONIC POLUTION OF THE NETWORK

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Abstract

Recently the range of types and the number of units of power electronic systems and other equipments causing harmonics and interharmonics rise sharply. This paper describes how and why harmonics and interharmonics are generated, how their presence affects the electrical system and equipment and how to minimise these effects. The relations between the renewable energy sources and harmonic - interharmonic polution are mentioned.

Keywords

Harmonics, interharmonics, renewable energy sources.

1. Introduction

Harmonics are voltages or currents with a frequency that is an integral multiple of the fundamental supply frequency. Interharmonics are voltages or currents with a frequency that is a non-integral multiple of the fundamental supply frequency. Subharmonics are a particular case of interharmonics of a frequency less than the fundamental frequency.

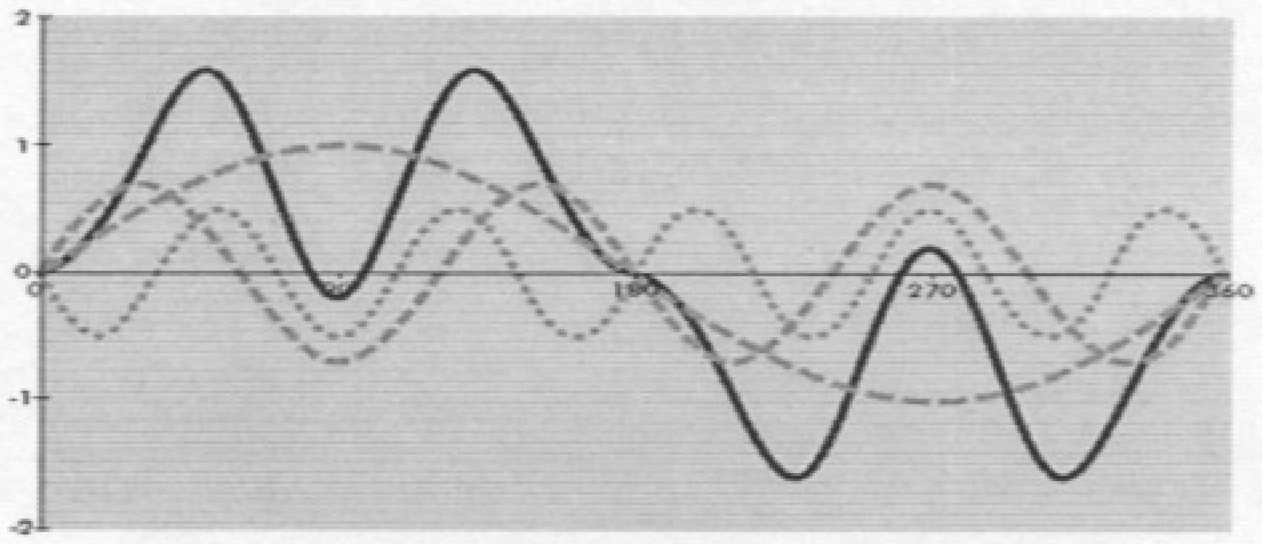

Figure 1: An example of a distorted current waveform

This waveform is not a sinewave and normal measurement equipment, such as averaging reading rms-calibrated multimeters, will give inaccurate readings. Note also that there are six zero crossing points per cycle instead of two, so any equipment that uses zero crossing as a reference will malfunction. The harmonics originate as currents and most of the ill effects are due to these currents. No useful conclusions can be drawn without knowledge of the spectrum of the current harmonics but it is still common to find only the total harmonic distortion (THD) figures quoted.

2. How harmonics are generated

In a circuit containing only linear elements the current is proportional to the voltage. If the load is not linear, the waveform is distorted, although either the current or voltage is pure sinusoidal.

Any cyclical waveform can be deconstructed into a sinusoid at the fundamental frequency plus a number of sinusoids at harmonic frequencies. For symmetrical waveforms, i.e. where the positive and negative half cycles are the same shape and magnitude, all the even numbered harmonics are zero. Any non-linear load can be modelled as a linear load in parallel with a number of current sources, one source for each harmonic frequency (Figure 2).

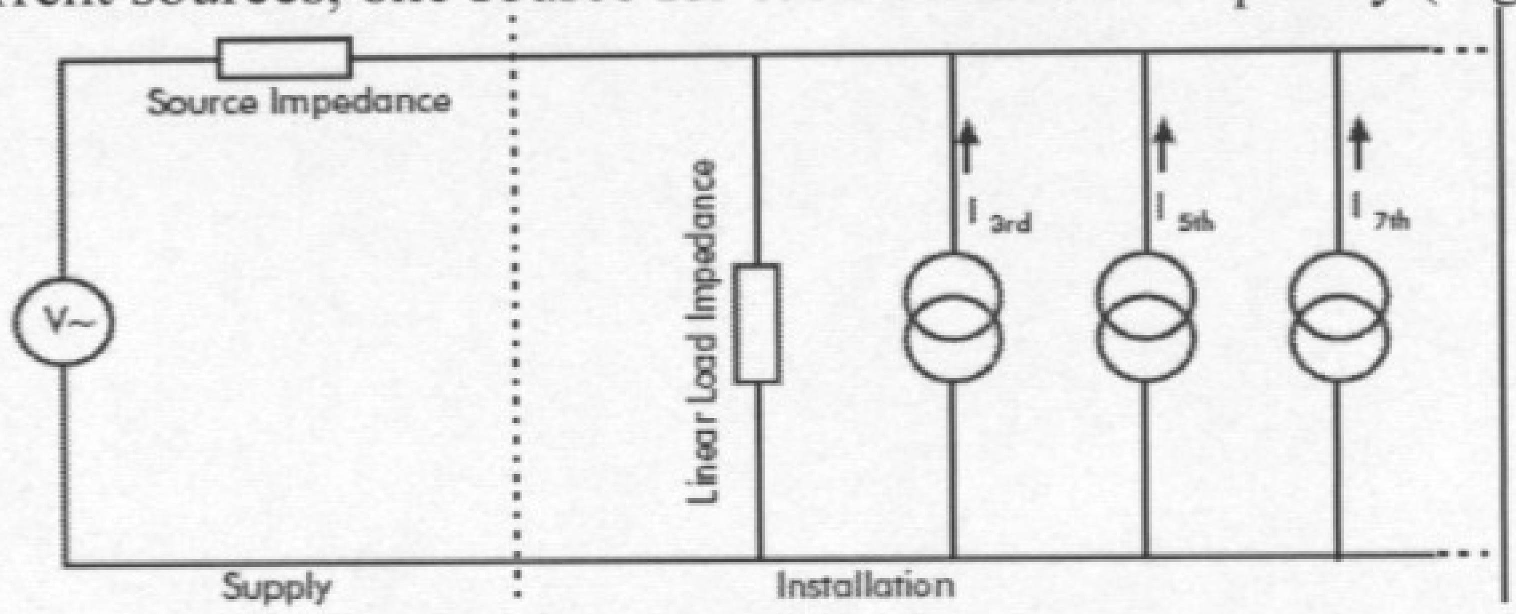

Figure 2: Equivalent circuit of a non-linear load

3. Sources of harmonics

Harmonic load currents are generated by all non-linear loads:
Single phase loads:
- Switched mode power supplies (SMPS)
- Electronic fluorescent lighting ballasts
- Small uninterruptible power supplies (UPS) units

Three phase loads:
- Variable speed drives
- Large UPS units

Switched mode power supplies (SMPS)

The power supply unit draws pulses of current which contain large amounts of third and higher harmonics (Figure 3).

Single phase UPS units exhibit very similar characteristics to SMPS.

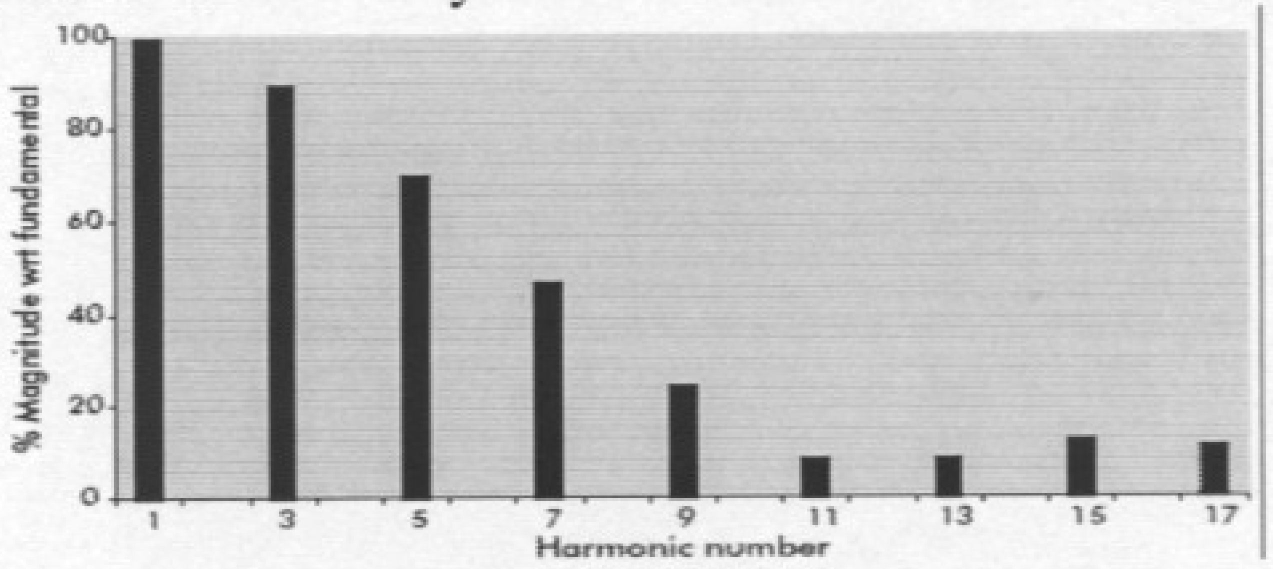

Figure 3: Harmonic spectrum of a typical PC

Three phase loads

Variable speed controllers, UPS units and DC converters in general are usually based on the six-pulse bridge. The six pulse bridge produces harmonics at 6n +/- 1.
The magnitude of the harmonics is significantly reduced by the use of a twelve-pulse bridge. The 6n harmonics are theoretically removed. The 12n harmonics remain.

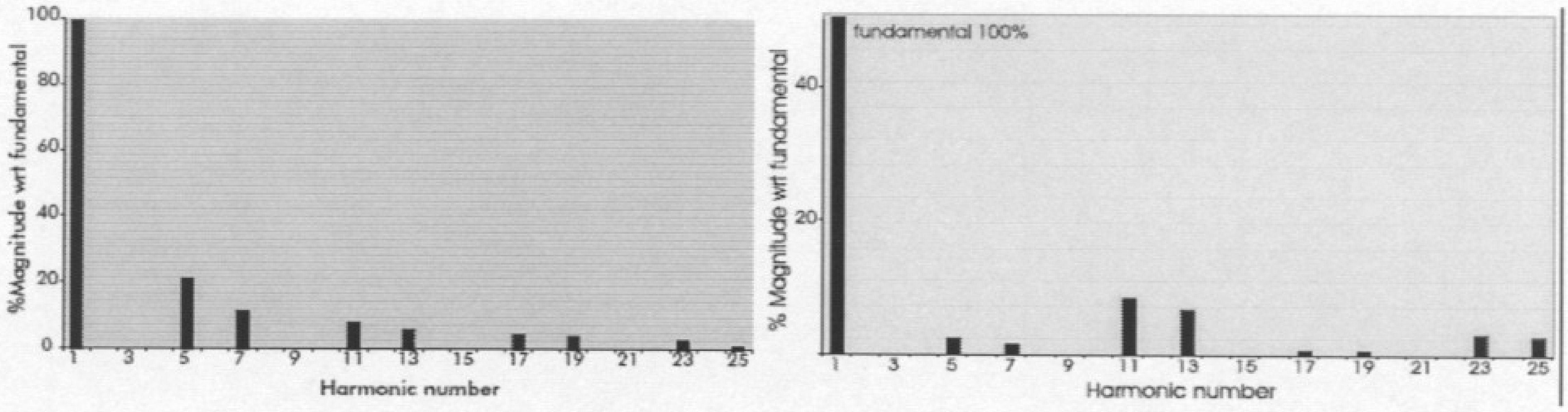

Figure 4: Typical harmonic spectrum of 6-pulse bridge and 12-pulse bridge

4. Problems caused by harmonics

Harmonic problems within the installation

Problems caused by harmonic currents:

-overloading of neutrals (fundamental currents cancel out, harmonic currents do not)
-overheating of transformers (increased eddy current losses, shorter life)
-nuisance tripping of circuit breakers
-over-stressing of power factor correction capacitors
-skin effect (above about 350 Hz, additional losses and heating)

Problems caused by harmonic voltages:

-voltage distortion (The resultant distorted voltage waveform is applied to all other loads connected to the same circuit, causing harmonic currents to flow in them - even if they are linear loads.)

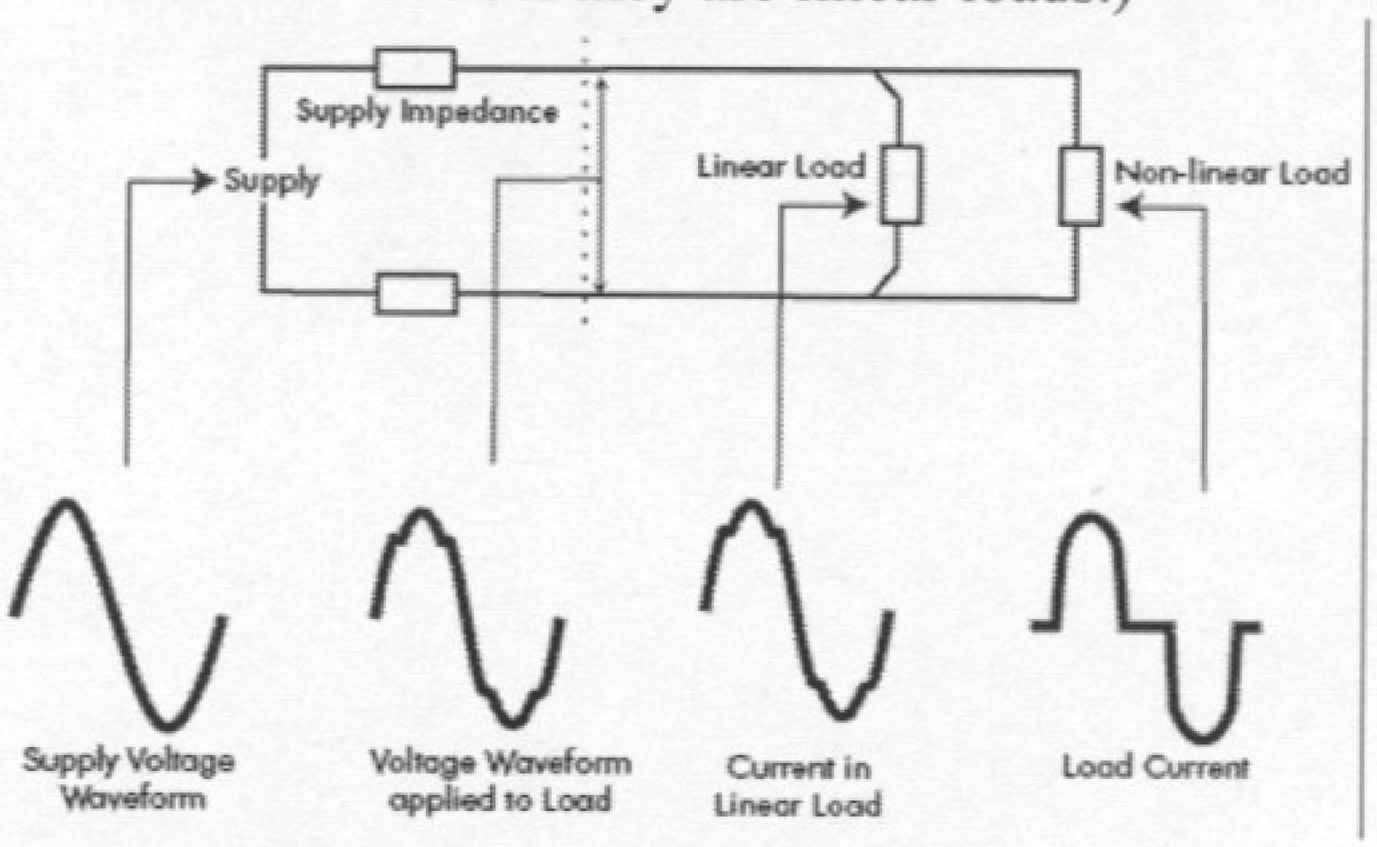

Figure 5: Voltage distortion caused by a non-linear load

-induction motors (increased eddy current losses)
-zero-crossing noise (switching at zero voltage)

Problems caused when harmonic currents reach the supply

When a harmonic current is drawn from the supply it gives rise to a harmonic voltage drop proportional to the source impedance at the point of common coupling (PCC) and the current. The voltage at the PCC is already distorted by the harmonic currents drawn by other consumers and by the distortion inherent in transformers, and each consumer makes an additional contribution.

5. How interharmonics are generated

There are two basic mechanisms for the generation of interharmonics. The first is the generation of components in the sidebands of the supply voltage frequency and its harmonics as a result of changes in their magnitudes and/or phase angles. These are caused by rapid changes of current in equipment and installations, which can also be a source of voltage fluctuations. Disturbances are generated by loads operating in a transient state, either continuously or temporarily, or, in many more cases, when an amplitude modulation of currents and voltages occurs. The second mechanism is the asynchronous switching (not synchronised with the power system frequency) of semiconductor devices in static converters.

6. Sources of interharmonics

- **-Arcing loads**

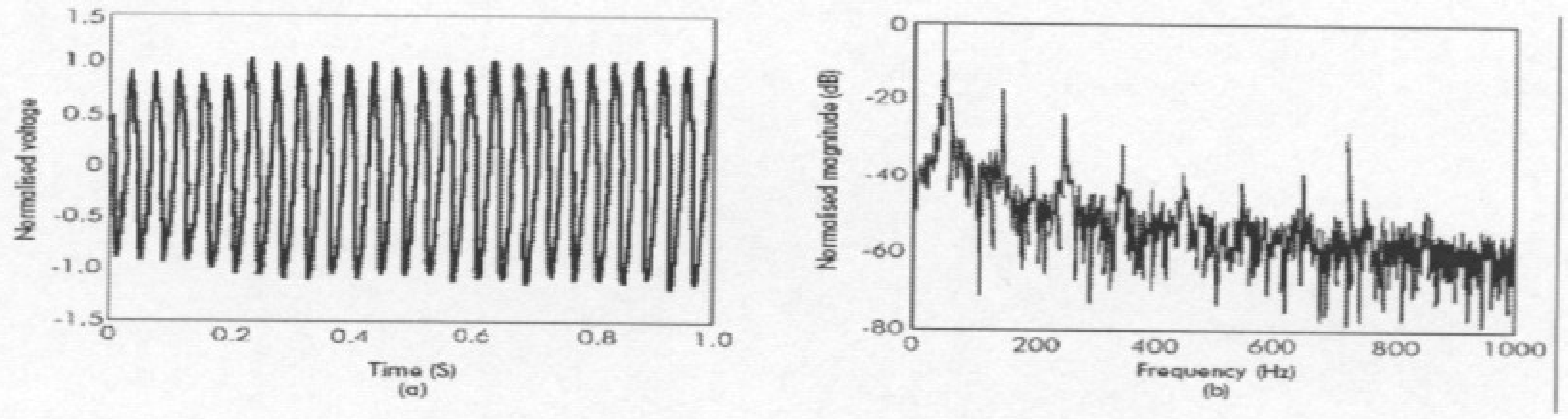

Figure 6: Typical arc furnace voltage flicker measured at the supply transformer a) fluctuation of voltage, b) spectrum of harmonics (spikes) and interharmonics

- **-Variable-load electric drives**

Induction motors can be sources of interharmonics because of the slots in the stator and rotor iron, saturation of the magnetic circuit, asymmetry of the motor (rotor misalignment), etc. Motors with variable-torque loading, can also be sources of subharmonics. The effect of variable load is also seen in adjustable-speed drives powered by static converters. In wind power plants the effect of the variation in turbine driving torque results for example from the “shadow effect” of the pylon.

.-Static converters, direct and indirect frequency converters

Indirect frequency converters contain a dc-link circuit with an input converter on the supply network side and an output converter on the load side. The dc-link contains a filter which decouples the supply and load systems, but there is always a certain degree of coupling. As a result, current components associated with the load are present in the dc-link, and components of these are present on the supply side. These components are subharmonic and interharmonic.

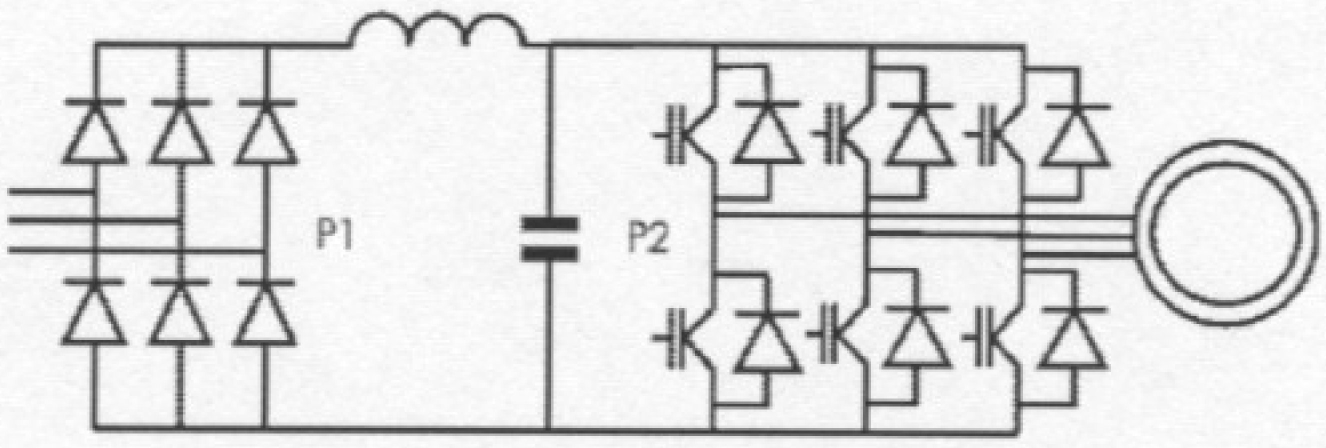

Figure 7: Frequency converter with the voltage source dc-link

-Ripple control

The ripple control is a sinusoidal signal in the range 110-2 200 (3 000) Hz. Magnitude of the voltage is in the range 2-5% of the nominal voltage. Figure 10 shows an example of the voltage spectrum for a system using data transmission at a frequency 175 Hz.

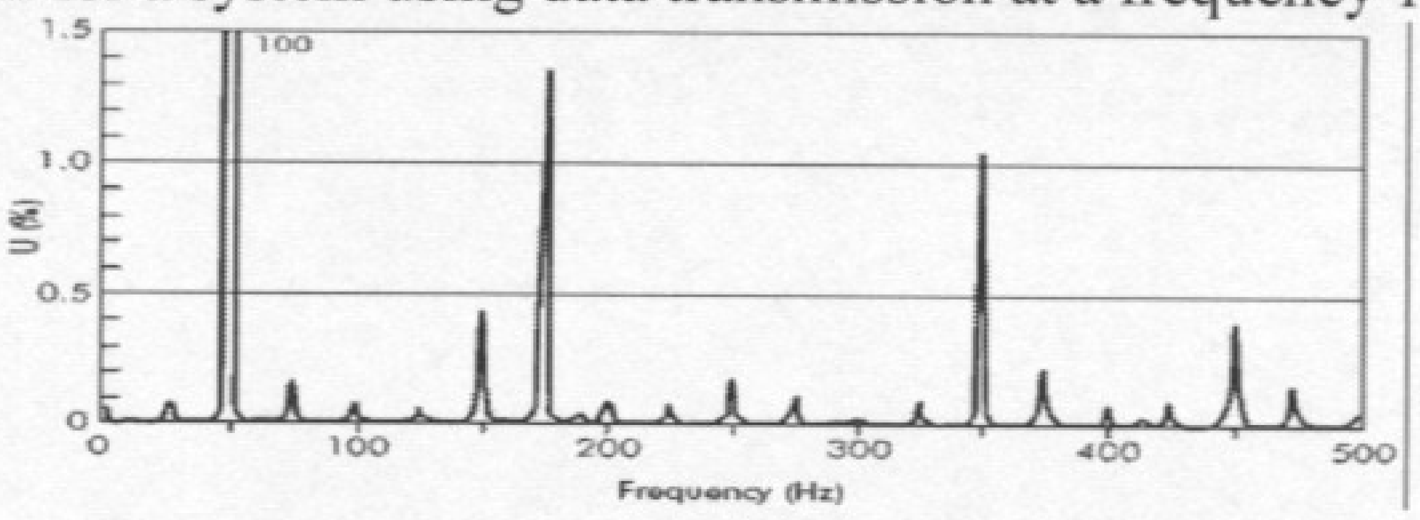

Figure 8: FFT results for the voltage during emission of data

7. Effects of the presence of interharmonics

Interharmonic currents cause interharmonic distortion of the voltage. The most common, direct, effects of interharmonics are:

-Thermal effects
-Low-frequency oscillations in mechanical systems
-Disturbances in fluorescent lamps and electronic equipment operation
-Interference with control and protection signals in power supply lines. (main harmful)
-Overloading passive parallel filters for high order harmonics
-Telecommunication interference
-Acoustic disturbance
-Saturation of current transformers

The most common effects of the presence of interharmonics are variations in rms voltage magnitude and flicker.

8. Harmonics and interharmonics mitigation methods

-reducing the emission level
-reducing the sensitivity of loads and
-reducing coupling between power generating equipment and loads

Passive filters

Passive filters are used to provide a low impedance path for harmonic currents. The filter may be designed for a single harmonic or for a broad band depending on requirements.

Isolation transformers

Triple-N currents circulate in the delta windings of transformers, it isolates triple-N harmonics from the supply. The same effect can be obtained by using a 'zig-zag' wound transformer.

Active Filters

A current transformer measures the harmonic content of the load current, and controls a current generator to produce an exact replica that is fed back onto the supply on the next cycle.

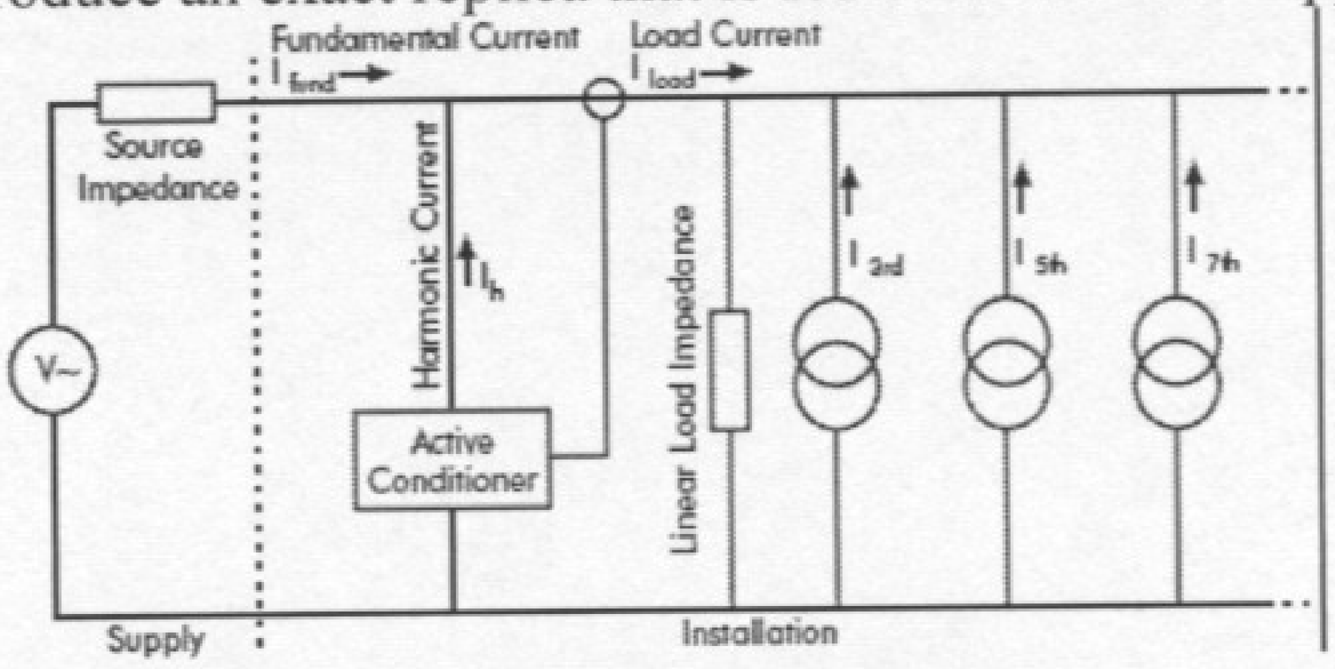

Figure 9: Active harmonic conditioner

9. Conclusions

Virtually all modern electrical and electronic equipment contains a SMPS or involves some form of power control and so is a non-linear load. In 2010 the 8% share of renewable energy sources is required in the Czech Republic. The main part will be covered by the wind turbines, biomass generators, hydro power plants and photovoltaic cells. All types may produce harmonic or interharmonic distortion, because they usualy consist of some type of electronic power control and an electric drive (induction or synchronous motor).

Negative influences of renewable energy utilisation must be prevented. It is useful to design mathematical models of the equipment and to calculate the possible distortion before the instalation. Although the harmonic emission of the device may be small, the number of the installed units may cause serious problems. The location of the RES may cause some problem areas.

References

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