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A DSP Based On-Line UPS

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Abstract: Many facilities such as patient health care centers , data processing systems, critical telecommunication links, LAN servers, offices etc rely on uninterruptible power supplies (UPS) to maintain a continuous supply of power in case of line outage. In addition to requiring continuous power, many critical nonlinear loads are sensitive to the incoming line transients and input harmonic voltage distortion. Conventional UPS systems operate to protect against such disturbances using complex filtering schemes, often employing large passive components. Among the various UPS systems online UPS provides maximum protection to such loads against any power problems. Because of multiple power conversion stages, online UPSs have been the most complex and expensive type of systems. Today's low cost, high performance Digital Signal Processors(DSPs) provide an improved and cost- effective solution for online UPS design, making them software controllable, adding some facilities like remote configuration and monitoring and other network management facilities.

This paper presents the basic design and merits of using real time digital signal processing (DSP) control of UPS systems.

Keywords: UPS, pulse width modulation, digital signal processors

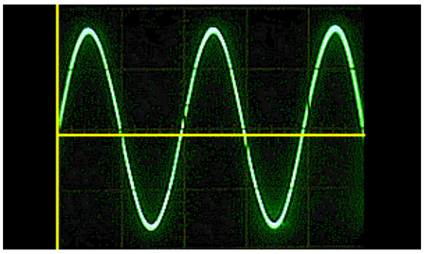

Fig. 1: Sine wave

1. Introduction

Un-interruptible power supplies (UPS) play an important role in interfacing critical loads such as computers, tele-communication links, data-processing systems, life supporting systems and industrial controls, e.t.c to the power grid .Among the various UPS topologies, on–line UPSs provides maximum protection to such loads against any utility power problem, as it protects against power blackout. However, because of multiple power conversion stages, on-line UPSs have been most complex and expensive type of systems. Today's low cost, high performance Digital Signal Processors (DSPs) provide an improved and cost- effective solution for online UPS design.

2. Typical On-Line UPS:

A typical UPS consists of a rectifier supplied battery bank & a static inverter-filter system to convert a dc voltage to a sinusoidal ac output. Modern UPS systems minimize the harmonic content of the inverter output voltage through the use of complex filtering schemes employing large passive components.

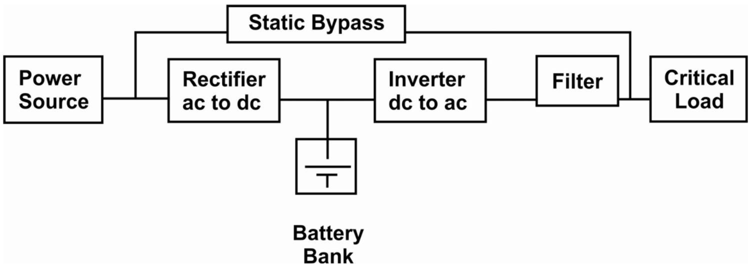

Fig. 2: Block diagram of typical on-line UPS

3. Need for Pulse Width Modulation:

PWM is nothing but the control of UPS inverter switching, under feedback control to realize the desired output waveform and also to minimize the harmonic content of the output voltage. Pulses are generated whenever a carrier signal & modulating signal crosses each other. These pulses are given to thyristors and pulsating output is generated. Depending on the number of output pulses generated, switching frequency of inverter is determined. Width of the pulses is proportional to magnitude of the output sine wave and if the number of pulses per half cycle is more, lower order harmonics will be eliminated.

4. General PWM Techniques for UPS:

4.1Using analog devices

Analog PWM uses natural sampling technique, which compares a sinusoidal modulating wave form with a triangular wave (from a time-base generator) to generate pulses.

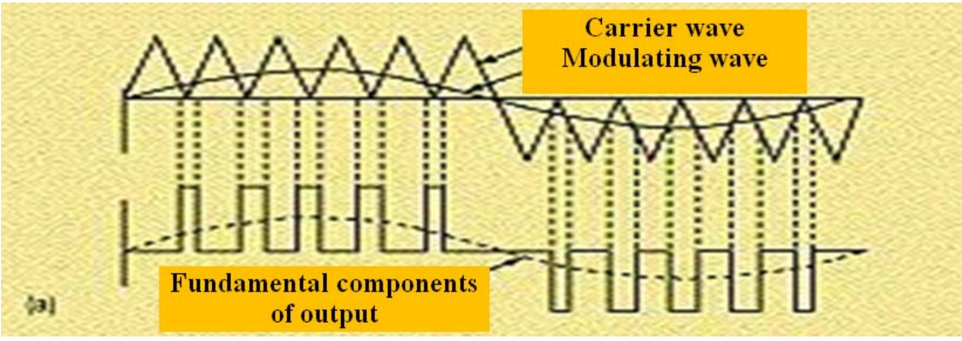

Fig. 3: Pulses generated by time base generator

4.2 Using microprocessors

A digital PWM signal generator is interfaced with a microprocessor. It calculates the pulse width at every sampling instant. According to this calculated width, the pulse generator generates the pulses with a constant switching frequency.

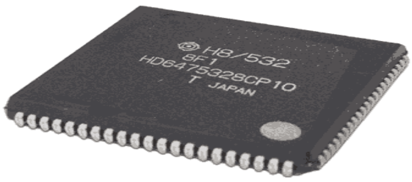

Fig. 4: Microprocessor

5. Then, Why DSP?

Most of the Microprocessor –aided UPS systems continue to depend on the analog op-amp controls and they lack speed required for high frequency inverter control. Therefore, harmonics are not eliminated in the output wave form, insisting on the large output LC-filter circuit. With the availability of low cost- high performance DSP chips characterized by the execution of most instructions in one instruction cycle, complicated control algorithms can be executed with speed, making very high sampling rate possible for digitally controlled inverters. High speed DSPs are now capable of executing over 30 million instructions per second (MIPS).

5.1 More reasons for using DSPs:

- No analog circuitry. Thus no offsets(i.e. installation & maintenance cost saved)
- High speed DSP control allows for real time harmonic cancellation.
- Flexible configuration for many power sizes.
- Sophisticated switching algorithm saving overall system costs.
- Features may be upgraded in the same hardware, to fulfill different incoming needs.

6. DSP Control of UPS systems

Most electronic loads served by UPS systems are non-linear and thus generate harmonic currents that must be filtered at the inverter output to reduce the distortion to acceptable levels. The DSP controlled UPS systems employs software controlled harmonic conditioners with the ability to dynamically adopt to changing load conditions for compensating load harmonics without manual intervention. The functional block diagram is as shown below:

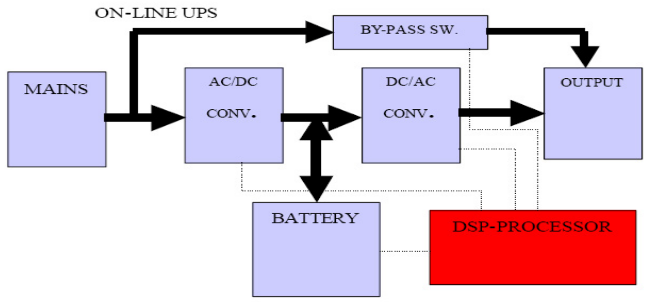

Fig. 5: Functional block diagram of DSP control of UPS system

Thus, the application of advanced signal processing using a DSP operates to provide sinusoidal load voltages even under varying load situations, while eliminating the need of large passive filters.

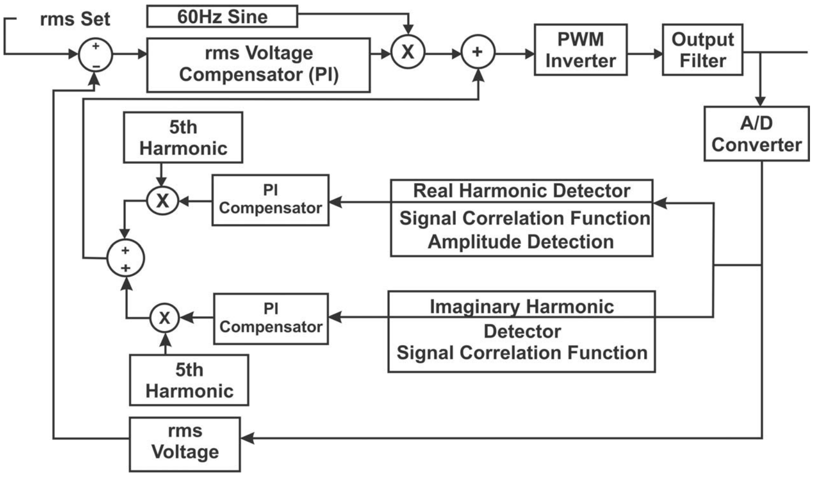

Fig. 6: Block diagram of DSP control with PWM inverter control circuit

6.1 Description:

The output of the UPS PWM inverter is sampled and converted to an rms voltage that is processed in a negative feedback loop. The actual inverter output is compared to a software rms reference value to determine the error voltage. The error voltage is then passed through a proportional integral (PI) control to eliminate any steady state errors present. The result is the necessary error compensation signal. A harmonic distortion correction signal is then subtracted from the error compensation signal and the result is applied to the input of PWM inverter. The above mentioned harmonic distortion correction signal is generated in the negative feedback loop. The Digital Signal Processor detects the harmonic distortion signal within the output voltage waveform and determines the amplitude of real and imaginary parts of the harmonic components. This process will be described for the cancellation of the 5^{th} harmonic, however, any harmonic whose frequency is below half the sampling frequency can be cancelled in the same manner.

Each frame of the converted digital output from the A/D converter passes to a real and imaginary component harmonic detectors for phases a, b and c. For example, the harmonic distortion waveform (A_{a5}) is processed by a signal correlation function in order to detect the real and imaginary values of the 5^{th} harmonic. This function can be written for phase 'a' as,

$$\Lambda a5 \quad = \quad \sum_{n=0}^{N-1} va(n) * \cos \frac{5*2\pi n}{N} - j\sum_{n=0}^{N-1} va(n) * \sin \frac{5*2\pi n}{N} \tag{1}$$

Where $v_{a\,(n)}$ is the output voltage of phase a for sometime n. The distortion signal may be represented more simply as

$$\Lambda a5 \quad = \quad \lambda_{a5r} + j * \lambda_{a5i} \tag{2}$$

Where λ_{a5r} is the real component of A_{a5}, and λ_{a5i} is the imaginary component of A_{a5}.

Once the harmonic distortion signal (A_{a5}, A_{b5} and A_{c5}) is detected by the signal correlation function, the amplitudes of the real and imaginary components of the 5^{th} harmonic are computed by averaging the amplitude components of the three phases as shown below.

$$\overline{V}_{5r} \quad = \quad \frac{\mathrm{Re}(\Lambda_{a5}) + \mathrm{Re}\left(\Lambda_{b5e}^{-j\frac{2\pi}{3}}\right) + \mathrm{Re}\left(\Lambda_{c5}e^{j\frac{2\pi}{3}}\right)}{3} \tag{3}$$

$$\overline{V}_{5i} \quad = \quad \frac{\mathrm{Im}(\Lambda_{a5}) + \mathrm{Im}\left(\Lambda_{b5e}^{-j\frac{2\pi}{3}}\right) + \mathrm{Im}\left(\Lambda_{c5}e^{j\frac{2\pi}{3}}\right)}{3} \tag{4}$$

The amplitude components are then applied to a PI compensator to generate the harmonic distortion correction signal necessary to cancel harmonic distortion from the output voltage. The resulting harmonic distortion correction signal is then subtracted from the error compensation signal and applied to the input of the PWM inverter to produce an output voltage waveform free of harmonic distortion. The same technique can be applied to eliminate still higher harmonics like 7^{th}, 9^{th} etc, Below figure shows the operation of UPS without harmonic conditioner

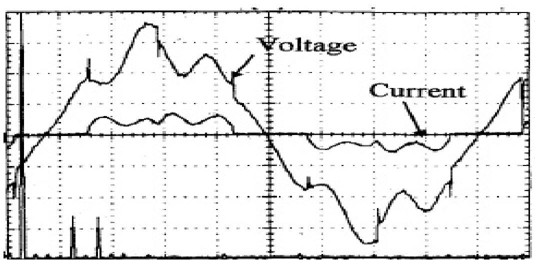

Fig. 7: Voltage current relationship without harmonic conditioners

But with all-harmonic conditioners enabled, the output voltage wave is like below:

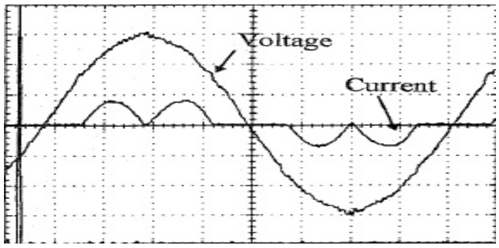

Fig. 8: Voltage current relationship with all harmonic conditioners enabled

Hence, the DSP controlled inverter and harmonic conditioners operate to provide Sinusoidal load voltages even under varying non-linear load conditions while preventing higher operating temperatures due to additional harmonic currents.

6.2 Advantages of using DSP in UPSs:

- High reliability and low dimensions**:** With the DSP, the number of electronic components is halved, thereby reducing processing time and failure probability and increasing reliability and eliminating the use of redundant current and voltage sensors.
- Precision: The DSP controls the electrical values directly, guaranteeing extreme precision and stability of output voltage and avoidance of noise due to distorting loads.
- Interactive communication**:** DSP controls the UPS in its entirety and outputs on a serial interface all the supervision reports, for automatic shutdown of servers, for communication on a LAN network, the Internet and Intranet and for IT maintenance which is carried out without switching the equipment off.
- Knowing the history**:** The control software provides users with operating and historical data in the form of clear read-out monitors, aiding them in taking any decisions.

Moreover the control system upgrade can be implemented in software, making the latest features available to any compatible UPS without changes to the hardware.

7. Conclusion

The conventional methods of UPS control and with using DSP, how the UPS control can be made more users friendly, its advantages are discussed in the paper. No doubt, DSPs are going to lead the market of control inverters in near future and already big players in the market like Texas Instruments, Eaton group, Intel etc are in the arena to make use the technology in a full swing.

8. Acknowledgement

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9. References

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