A Survey Paper on 'Methods for Mitigation of Harmonics Due to SMPS'

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Abstract

The harmonic currents generated by the modern power supply equipment cause power system heating and also add to user power bills. Personal computers are the major equipments which use the modern power supply ie switched mode power supply (SMPS).These SMPS draw non-sinusoidal currents from the supply which results in generation of harmonics. Power quality of the distribution network is been disturbed by these harmonics during the operation of the electronic load. The switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. This paper presents comparison study of different methods to control the SMPS operation to minimise the harmonics generated and also the disadvantages of these methods and how they can be overcome by sigma-delta modulation technique.

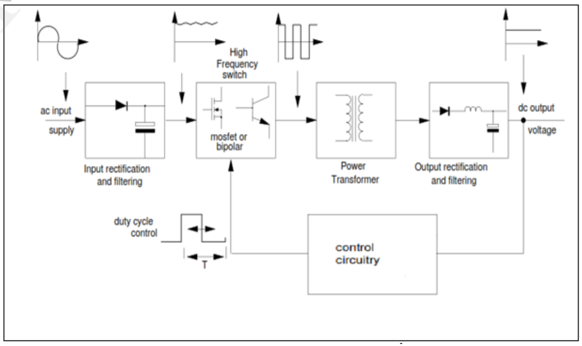
***Keywords**-harmonics, power supply, power quality, switch mode power supply.*

1. Introduction

A) What is switched mode power supply?

Switch-mode power supplies (SMPS) are a popular and sometimes necessary choice for DC-DC power conversion.[1] These circuits offer distinct benefits and tradeoffs when compared to alternative methods of converting DC power. A switched-mode power supply is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a source, like mains power, to a load, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass MOSFET of a SMPS continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a SMPS dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass MOSFET. This higher power conversion efficiency is an important advantage of a SMPS. SMPS's may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight. Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required.

B) Basic model of an switch mode power supply.



In an SMPS, ac supply is first rectified, and then filtered by the input reservoir capacitor to produce a rough dc input supply. This level can fluctuate widely due to variations in the mains. In addition the capacitance on the input has to be fairly large to hold up the supply in case of a severe drop in the mains. (The SMPS can also be configured to operate from any suitable dc input, in this case the supply is called a dc to dc converter.) The unregulated dc is fed directly to the central block of the supply, the high frequency power switching section. Fast switching power semiconductor devices such as MOSFETs and Bipolars are driven on and off, and switch the input voltage across the primary of the power transformer. The drive pulses are normally fixed frequency (20 to 200 kHz) and variable duty cycle. Hence, a voltage pulse train of suitable magnitude and duty ratio appears on the transformer secondaries. This voltage pulse train is appropriately rectified, and then smoothed by the output filter, which is either a capacitor or capacitor/inductor arrangement, depending upon the topology used. This transfer of power has to be carried out with the lowest losses possible, to maintain efficiency. Thus, optimum design of the passive and magnetic components, and selection of the correct power semiconductors is critical.

Regulation of the output to provide a stabilized dc supply is carried out by the control feedback block. Generally, most SMPS systems operate on a fixed frequency pulse width modulation basis, where the duration of the on time of the drive to the power switch is varied on a cycle by cycle basis. This compensates for changes in the input supply and output load. The output voltage is compared to an accurate reference supply, and the error voltage produced by the comparator is used by dedicated control logic to terminate the drive pulse to the main power switch/switches at the correct instance. Correctly designed, this will provide a very stable dc output supply. It is essential that delays in the control loop are kept to a minimum, otherwise stability problems would occur. Hence, very high speed components must be selected for the loop. In transformer-coupled supplies, in order to keep the isolation barrier intact, some type of electronic isolation is required in the feedback. This is usually achieved by using a small pulse transformer or an opto-isolator, hence adding to the component count.

In most applications, the SMPS topology contains a power transformer. This provides isolation, voltage scaling through the turns ratio, and the ability to provide multiple outputs. However, there are non-isolated topologies (without transformers) such as the buck and the boost converters, where the power processing is achieved by inductive energy transfer alone. All of the more complex arrangements are based on these non-isolated types.

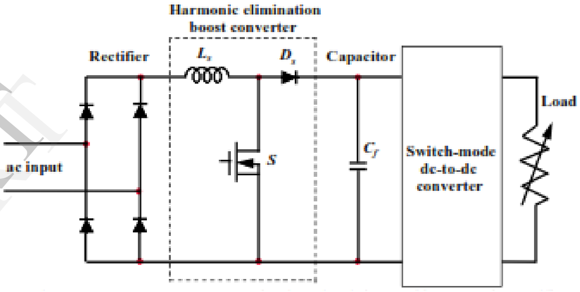
C) What are harmonics?

A harmonic of a wave is a component frequency of the signal that is an integer multiple of the fundamental frequency, i.e. if the fundamental frequency is *f*, the harmonics have frequencies 2*f*, 3*f*, 4*f*, 5*f*. . . etc. The harmonics have the property that they are all periodic at the fundamental frequency, therefore the sum of harmonics is also periodic at that frequency. Harmonics are electric voltages and currents that appear on the electric power system as a result of non-linear electric loads. When a non-linear load, such as a rectifier, is connected to the system, it draws a current that is not necessarily sinusoidal. The current waveform can become quite complex, depending on the type of load and its interaction with other components of the system. Regardless of how complex the current waveform becomes, as described through Fourier series analysis, it is possible to decompose it into a series of simple sinusoids, which start at the power system fundamental frequency and occur at integer multiples of the fundamental frequency

2. Literature Survey

In literature survey we are goin to discuss some methods of reducing harmonics due to SMPS.

a) Thomas Key, Jih Sheng lai [4].In this paper an active-type harmonic-elimination circuit is built into the common electronic equipment ie SMPS which is cost-effective based on energy loss considerations.



Fog 2.1: SMPS with active-type harmonic-elimination circuit

A series inductor at the input to a power supply prevents sudden current changes (di/dt) and acts as a simple filter component. The rectifier circuit operates in the same way except the harmonic content and the peak current are reduced. It is possible to manipulate the inductor value to suit IEC, but the cost and size increment could be excessive. For example, a 200-W power supply requires a 10-mH series inductor to meet IEC 1000-3-2. The boost converter is also called "step-up converter" which converts low dc voltage to high dc voltage. The supply contains a front-end boost converter. The switch *S* controls energy flow. When *S* turns on, a current builds upon the inductor *L*, meanwhile the diode *D* remains in the reverse blocking mode because the on-state of *S* means zero voltage across. When *S* turns off, the energy stored in the inductor charges through the diode *D* to the capacitor *C*. The inductor current can be controlled to follow a desired wave shape. Here the inductor current is normally controlled to follow the rectified voltage, and the ac-side current will be in phase with the ac voltage. The current is nearly sinusoidal with almost invisible high frequency (70 kHz) switching ripples. The size of the boost converter is significantly less than any passive filters, but the performance is much better.

b) A.N.Malleswara Rao, Dr. K. Ramesh Reddy, Dr. B.V.Sanker Ram[5]. In this paper an resistor and an inductor is used to reduce the harmonic.

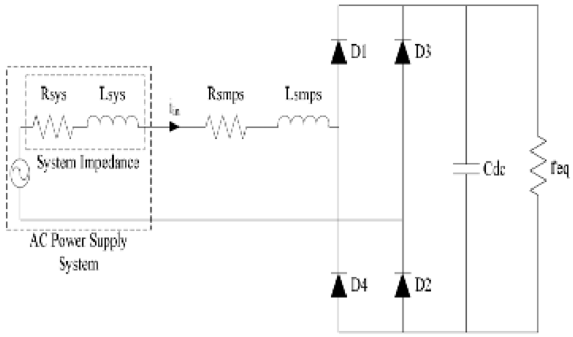


Fig2.2: SMPS with RSMPS and LSMPS

The resistance of the SMPS (RSMPS) is dominated by the resistance of the negative temperature coefficient (NTC) thermistor used for inrush current protection. Although resistors generally have a much smaller tolerance range, typically around ±1 %, the range applied in the analysis in this paper is taken as ±20 %, in order to correctly represent different types of components and different operating temperature regions. A uniform distribution is taken for RSMPS to allow for a more random variance in this parameter. The influence of RSMPS on harmonic emission of low power SMPS load is small, but still more significant than in case of high-power SMPS', This is because the large inductor present in high-power SMPS with passive power factor correction (p-PFC) will dominate the high-power device input impedance.

The inductance (LSMPS) of the SMPS device is dominated by the value of the PFC inductor selected to satisfy harmonic mitigation. Accordingly, this model parameter is only present in high-power SMPS load. To determine the value of LSMPS inductor to satisfy harmonic mitigation, the inductor size was adjusted until the harmonic limits were just met at each rated power using a detailed full-circuit SMPS model.

c) Siew-Chong Tan,Y. M. Lai,Chi K. Tse,Martin K. H. Cheung[6]. This paper presents that the switch is controlled by the pulse width modulation (PWM) technique.

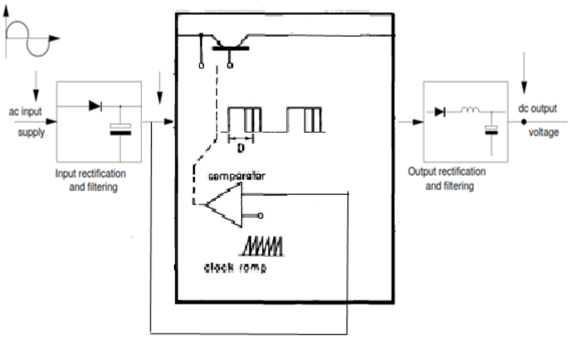


Fig2.3: SMPS with PWM control technique

The PWM technique comprises of an comparator which compares the modulating signal and the carrier signal to give the PWM signal, it gives an high output when the modulating signal is higher than the carrier signal and it gives an lower output when carrier signal is higher than the modulating signal. And in this way an pulse width modulated signal is been generated which is been used in the control circuit of SMPS. When the pulse goes high in the PWM signal, the fast operating switch is been turned on and when the pulse goes low the fast operating switch is been turned off.

d) Clemens M. Zierhofer[7]. This paper presents that at the rectifier output of an SMPS an boost converter is been used. The switch of this boost converter is been controlled by the delta modulation (DM) technique. DM is an analog to digital converter.

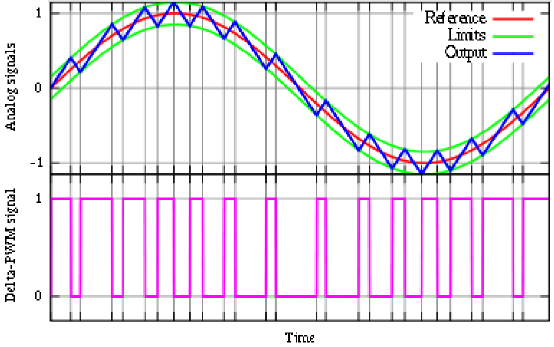


Fig2.4: Output of DM

Here the analog signal is the sinusoidal input which is converted to digital pulses and fed to the switch of the boost converter, which acts according to the duty cycle. These pulse frequency are almost equal to the input sinusoidal frequency ie the input frequency is followed and hence harmonics are minimized. In DM rather than quantizing the absolute value of the input analog waveform, DM quantizes the difference between the current and the previous step. The modulator is made by a quantizer which converts the difference between the input signal and the average of the previous steps. In its simplest form, the quantizer can be realized with a comparator referenced to 0 (two levels quantizer), whose output is *1* or *0* if the input signal is positive or negative. It is also a bit-quantizer as it quantizes only a bit at a time. In delta modulation, the present sample value x(t) is compared with the previous sample value x'(t) and the result of this comparison is transmitted. The DM can also be replaced by Adaptive delta modulation (ADM) technique[7]. Here the pulse height adapts to the amplitude of the input signal, which is a better method to reach the frequency of the input signal. So harmonic mitigation is more effective than DM.

3. Disadvantages of Existing Method

- The first method increases the cost due to install a boost converter-type harmonic elimination circuit in a switch-mode power supply.
- PWM has constant switching frequency irrespective of the input.
- Since DM depends on a discrete number of bytes to sample the input signal, the sampling rate imposes a limit on how closely it can approximate the shape of the input current wave, this creates infidelity known as slope overload distortion.
- In adaptive delta modulation, due to variable step size, the slope overload distortion is solved but the granular noise still remains since the step size will be still larger for small or constant amplitude input signals.
- DM and ADM are unable to meet the frequency of input signal therefore other frequency components are still present.

4. Proposed new solution

In the literature study we have seen many methods for reducing the total harmonic distortion, however most methods failed to achieve the efficient results. To provide the best solution for the problems imposed by existing methods, recently the new method was presented called Sigma-delta modulation (SDM)[9] schemes are presented as a powerful approach to attain sinusoidal input current in a boost-type rectifier (BTR). The SDM schemes generate long on-state duration of the switch at the start of each half-cycle in a BTR. They also have harmonic-spreading effects. By virtue of these advantages, the dominant low-frequency harmonics in the input current are effectively reduced. The difference between the sinusoidal reference and the actual input current in a BTR is estimated after voltage zero crossings. The input current waveforms are compared in cases of SDM and the DM methods and found that the switch operates at a high frequency in SDM than in DM ie SDM is very close to the input current waveform and hence the total harmonic distortion is minimizes by SDM than the other methods.

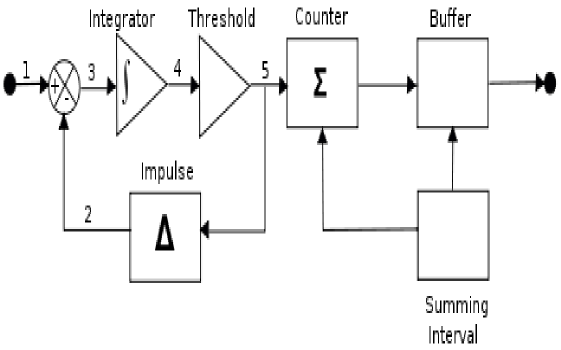


Fig4.1: Circuit diagram for SDM

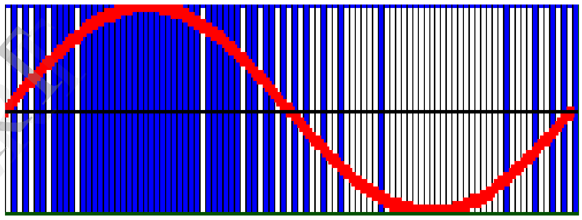


Fig4.2: Output of SDM

5. Conclusion

This paper gives a survey of different methods to minimize the harmonics due to SMPS and concludes that SDM overcomes the disadvantages of the existing methods. SDM operates with a very high frequency than DM and ADM. Therefore SDM method helps in getting pulses of certain frequency which is same as that of the input signal ie it follows the input signal and helps in reducing harmonics. Hence the switch operated with SDM gives more sinusoidal current and reduced THD.

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