

Study of Power Quality in Power Supplies Using Matlab/Simulink

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Abstract: Power Supplies are extensively used in various electrical and electronic applications. It requires AC to DC rectification and filtering action, having advantages of high efficiency and power density. The main problem associated with these types of power supplies are injection of harmonic current in supply, which adversely affect the performance of system and more importantly causes poor power factor. Research in improved power quality utility interface has gained importance due to stringent power quality regulation and strict limits on total harmonic distortion (THD) of supply current, regulated by standards V, 2 IEC 61000-3-2 and IEEE 519-1992. In this paper, the power quality of Power Supplies is analyzed by simulate it and measuring the Total Harmonic Distortion and Power Factor. Analysis of various power supplies has been carried out using MATLAB SIMULINK environment [12].

Key-Words: - Power Quality, THD, Regulation

1 INTRODUCTION

The electrical energy not normally used in the form in which it was produced or distributed. Practically all electronic systems require some form of energy conversion. A device that transfer electrical energy from a source to a given load using electronic circuits is referred to as power supply. Now days, in most of the power supply unit, the energy flow is controlled with power semiconductor devices.

These devices continuously switching ON and OFF with high frequency (referred to as switch mode power supply) due to which harmonics are created in the supply. Hence all equipment which are built with switching devices or with internal loads with non-linear voltage/current characteristics created harmonics. Now a day, harmonics are the major causes for a power quality distortion. As the technology is increasing, the demand of good power quality is increasing. However, The Power quality means maintaining the voltage at its rated rms value with negligible amount of harmonics and maintaining frequency with statutory limit and least amount of interruption. There are various power quality issues such as Power surges, High voltage spikes, Transients, Frequency variation, Power sag, Electrical line noise, Blackouts, Harmonic distortion etc. The major cause for a power quality distortion is the Harmonics. Harmonics are currents or voltages with frequencies that are integer multiples of the fundamental power frequency [1].

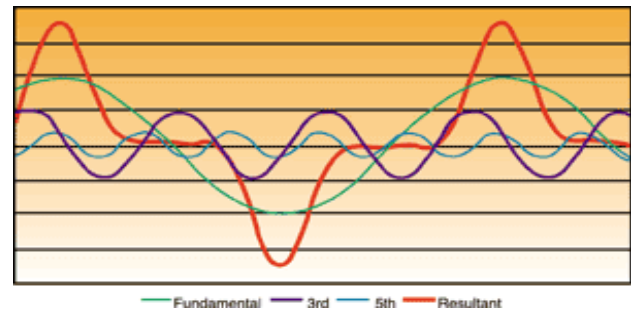


Fig:1 Harmonic distortion waveform

Harmonic disturbances are generally caused by equipment with nonlinear voltage/current characteristic and are mainly the result of modern electronic controlled power consumption [2].

2 PREVIOUS TECHNIQUES USED

Various research papers, books and literature on power quality and power supplies have been studied. There are various techniques are used to analyze or mitigate the power quality problems. A brief introduction to some papers is described below.

2.1. *Power Quality Improvement in Switched Mode Power Supplies Using Autoconnected Transformer Based 9-Phase ac-dc Converters* Kalpana, G Bhuvaneswari, Bhim Singh, 2010

This paper describes the, different auto connected transformer-based 9-phase ac-dc converter configurations, which are designed, modeled and simulated to feed such medium capacity SMPS for improving the power quality indices at the point of common coupling (PCC).

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The auto connected transformer is designed suitable for producing 9-phase voltages of same magnitude and having equal phase shift. A set of power quality indices on input ac mains and magnetic ratings for various auto connected transformer configurations for this SMPS are also presented so that the best converter configuration can be chosen according to the requirements for a particular application.

2.2 Modeling and Simulation of Series Compensator to Mitigate Power Quality Problems, S.Sadaiappan, Dr.P.Renuga, D.Kavitha, 2010

In this paper, a series compensator is proposed and a method of harmonic compensation is described and a method to mitigate voltage sag is investigated. The proposed series compensator consists of Energy Storage System (ESS) and Voltage Source Inverter (VSI), Injection Transformer. The modeling and simulation of the proposed series compensator was implemented in Matlab Simulink work space. Simulation results showed that the proposed series compensator was efficient in mitigating voltage sags and harmonics and thus improve the power quality of the isolated power system.

2.3 Modeling, Controller Design and Simulation of Power System Friendly Power Supply, A.P.N.Tekwani, B.G.N. Khanduja,2010

This paper describes the two methods named Unity Modulus (Magnitude Optimum) method and Ziegler- Nichols method. The parameters obtained from both the methods are compared by the mathematical model for forward and reverse power flow mode of operation. The model is generated in Simulink toolbox of MATLAB.

It is observed that the unity power factor is maintained during all the conditions for various loads. Drastic reduction in %THD of input current waveform is obtained in proposed power supply.

3. PROPOSED METHODOLOGY

In this paper, the Power Quality will analyzed by determining the value of Total harmonic distortion of various power supplies. This may be achieved by simulink of power supplies and take an harmonic spectrum and THD measurement of each power supply. However this method to analyze the power quality is most efficient method either to go for an real practical work. The simulation method is easy to implement any device and so we can practically analyze it. Hence, in this paper the focusing part is to simulate the power supplies and to take an evaluation about power quality by measuring the Total Harmonic Distortion. However, The total harmonic distortion, or THD, of a signal is a

measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.

4. POWER SUPPLIES

The perfect power supply would be one that is always available, always within voltage and frequency tolerances and has a pure noise-free sinusoidal wave shape. In this paper there are various types of power supplies are introducing for analyzing the power quality. Such power supplies are as follows: [12].

- 4.1) Linear Power Supply.
- 4.2) Zener Regulated Power Supply.
- 4.3) Series Regulated Power Supply.
- 4.4) Switch Mode Power Supply.
- 4.5) Zero Current Switching Power Supply.
- 4.6) Zero Voltage Switching Power Supply.

4.1) LINEAR POWER SUPPLY:

In electronics, a Linear Regulator is a component used to maintain a steady voltage.

The voltage produced by an unregulated power supply will vary depending on the load and on variations in the AC supply voltage. For critical electronics applications a linear regulator may be used to set the voltage to a precise value, stabilized against fluctuations in input voltage and load. The regulator also greatly reduces the ripple and noise in the output direct current. Linear regulators often provide current limiting, protecting the power supply and attached circuit from over current [12].

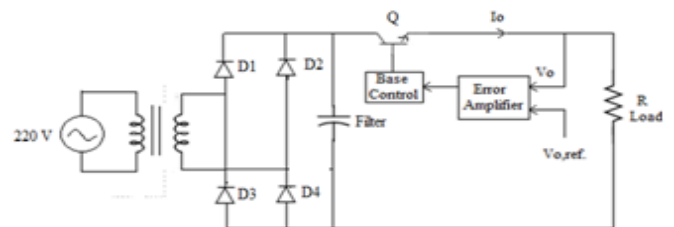


Fig.4.1 Electric circuit diagram of Linear Power Supply

The purpose of the regulator is to maintain V_o at a constant value when the input voltage V_i or the output current or both vary.

4.2) Zener Regulated Power Supply:

The Zener Regulated Power Supply is used for very simple low power applications where the currents involved are very small and the load is permanently

connected across the Zener diode (such as voltage reference or voltage source circuits). The constant reverse voltage V_Z of the zener diode makes it a valuable component for the regulation of the output voltage against both variations in the input voltage from an unregulated power supply or variations in the load resistance. To regulate small amounts of current the cheapest approach is to use a Zener Diode.

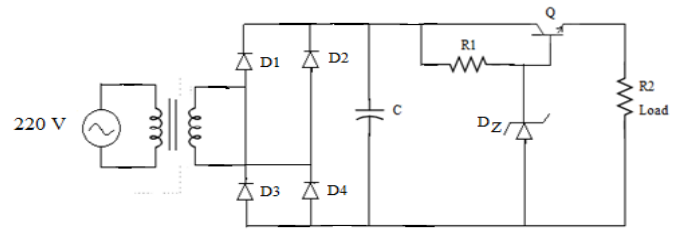


Fig.4.3 Electric Circuit Diagram of Series Regulated Power Supply

Here, the load current I_{R2} is supplied by the transistor whose base is now connected to the Zener diode. Thus the transistor's base current (I_B) forms the load current for the Zener diode and is much smaller than the current through $R2$. This regulator is classified as "series" because the regulating element, viz., the transistor, appears in series with the load. $R1$ sets the Zener current (I_Z) and is determined as -

$$R1 = \frac{V_S - V_Z}{I_Z + K \cdot I_B}$$

Where, V_Z is the Zener voltage, I_B is the transistor's base current and $K = 1.2$ to 2 (to ensure that $R1$ is low enough for adequate I_B).

$$I_B = \frac{I_{R2}}{h_{FE(min)}}$$

Where, I_{R2} is the required load current and is also the transistor's emitter current (assumed to be equal to the collector current) and $h_{FE(min)}$ is the minimum acceptable DC current gain for the transistor.

This circuit has much better regulation than the simple Zener regulator, since the base current of the transistor forms a very light load on the Zener, thereby minimizing variation in Zener voltage due to variation in the load. Note that the output voltage will always be about $0.65V$ less than the Zener due to the transistor's V_{BE} drop. Although this circuit has good regulation, it is still sensitive to the load and supply variation. This can be resolved by incorporating negative feedback circuitry into it. This regulator is often used as a "pre-regulator" in more advanced series voltage regulator circuits.

4.4) Switch Mode Power Supply:

A Switch Mode Power Supply is an electronic power supply that incorporates a switching regulator to convert

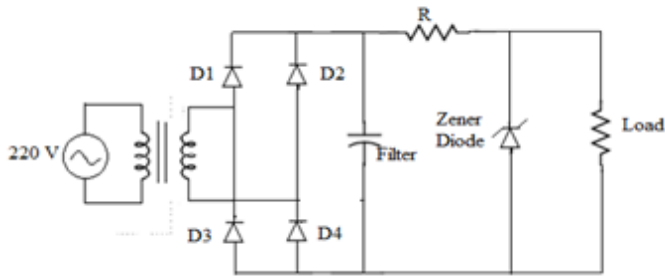


Fig.4.2 Electric Circuit Diagram of Zener Regulated Power supply

The figure shows a simple Zener voltage regulator. It operates by way of the Zener diode's action of maintaining a constant voltage across itself when the current through it is sufficient to take it into the Zener breakdown region. The resistor $R1$ supplies the Zener current I_Z as well as the load current I_{R2} ($R2$ is the load). $R1$ can be calculated as -

$$R1 = \frac{V_S - V_Z}{I_Z + I_{R2}}$$

Where, V_Z is the Zener voltage, and I_{R2} is the required load current.

The voltage from a half-wave power supply is applied to a resistor R and a Zener diode connected in series. In normal operation, the Zener diode operates in the "reverse-breakdown" mode, in which the reverse voltage is equal to the nominal Zener voltage and is independent of the current (as long as the current is non-zero). The resistor R helps regulate the current through the Zener diode. As the load current is increased, some of the current that was flowing through the Zener diode is bypassed into the load device, reducing the Zener current, but the voltage remains constant.

4.3) Series Regulated Power Supply:

Adding an emitter follower stage to the simple Zener regulator forms a simple series voltage regulator and substantially improves the regulation of the circuit.

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. An SMPS is usually employed to efficiently provide a regulated output voltage, typically at a level different from the input voltage.

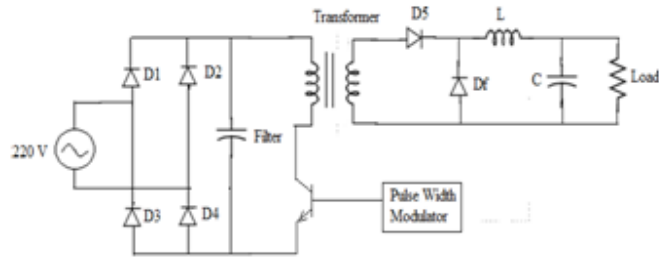


Fig.4.4 Electric Circuit Diagram of Switch Mode Power Supply

The pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions.

Switch-mode power supplies convert commercial AC power into the required high-frequency DC power using the high-speed switching of semiconductors. Switch-mode power supplies are so compact, light, and efficient that they are used as power supplies by most electronic devices.

4.5) Zero Current Switching Power Supply:

In Zero Current Switching Topology, the switch turns on and turns off at zero current. The peak resonant current flows through the switch but the peak switch voltage remains the same as in its switch mode counterpart. Such a topology is shown in the following figure.

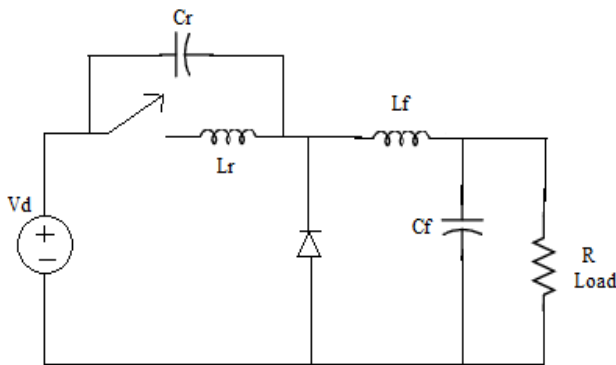


Fig.4.5 Electric Circuit Diagram of Zero Current Switching Power Supply

Here L_r and C_r are the resonance inductor and capacitor and the L_f and C_f are the filter inductor and capacitor. The inductor L_r limits the di/dt of the switch current, and L_r and C_r constitute a series-resonant circuit. In such converters the current produced by LC resonance flows through the switch, thus causing it to turn on and turn off at zero current [12].

The main function of these converters is to reduce switching losses of the devices (MOSFETs, IGBTs, etc) by operating them either in zero voltage or in zero current switching mode. In the ZCS, the switch is required to conduct a peak current that is higher than the load current I_o by an amount V_d/Z_o . The turning on and turning off of a switch at a zero current and zero voltage resulting in an essentially lossless switch.

4.6) Zero Voltage Switching Power Supply:

In Zero Voltage Switching Topology, the switch turns on and turns off at zero voltage. The peak resonant voltage flows through the switch but the peak switch current remains the same as in its switch mode counterpart. Such a topology is shown in the following figure.

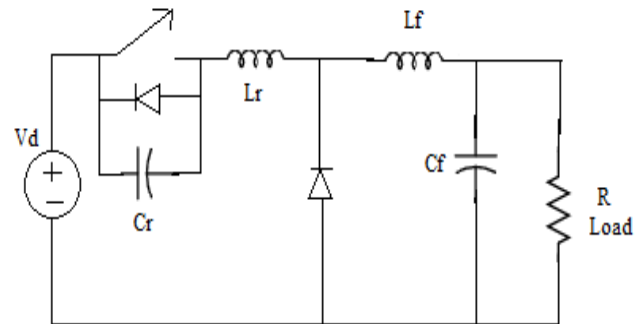


Fig.4.6 Electric Circuit Diagram of Zero Voltage Switching Power Supply

To achieve ZVS, capacitor C_r is connected in parallel with the switch. With the capacitor, C_r , the internal switch capacitance C_j is added and it affects the resonant frequency only. It is not contributing power dissipation in the switch.

In the zero voltage switching topology, the switch is required to withstand a forward voltage that is higher than V_d by an amount $Z_o I_o$. For zero voltage (lossless) turn-on of the switch, the load current I_o must be greater than V_d/Z_o . With the ZVS, the switching losses in semiconductor devices are zero. The EMI is also reduced during transition.

However, the ZVS is preferable for high switching frequencies. The ZVS can also be either of half-wave or full-wave type [12].

5. RESULTS

Simulation was carried out in MATLAB environment using simulink and power system block set (PSB) toolboxes. The simulation results of various types of power supplies has been observed and the power quality parameters namely Total Harmonic Distortion (THD) have been calculated. The results of the following power supplies simulation is as follows:

5.1 Linear Power Supply:

The simulation of Linear Power Supply has been done in MATLAB software and gets the Total Harmonic Distortion as a result with its Harmonic Spectrum Graph as shown below:

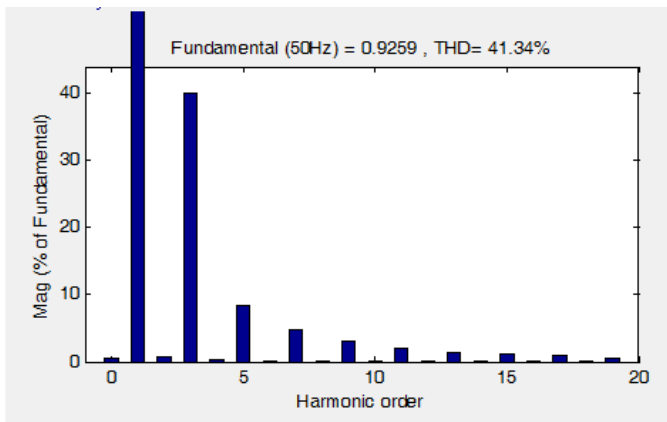


Fig.5.1(a) Harmonic Spectrum of Linear Regulated Power Supply

The supply current THD are observed to be 70.13 %, which is more than limit specified by IEEE-519. The Ripple content are quite high and the calculate power factor is found to be 0.5.

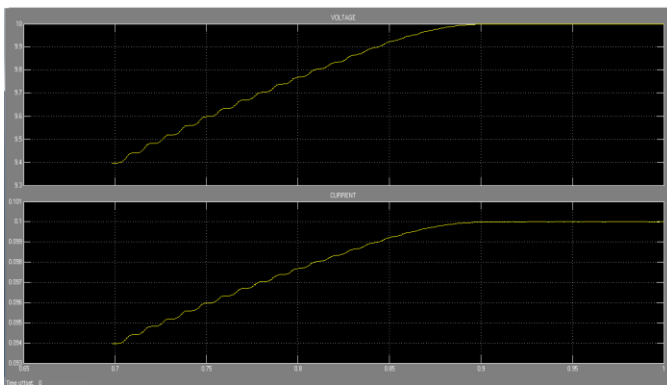


Fig.5.1(b) Output Voltage and Current Waveform of Linear Regulated Power Supply

5.2) Zener Regulated Power Supply:

The simulation of Zener Regulated Power Supply has been done in MATLAB software and gets the Total Harmonic Distortion as a result with its Harmonic Spectrum Graph as shown below:

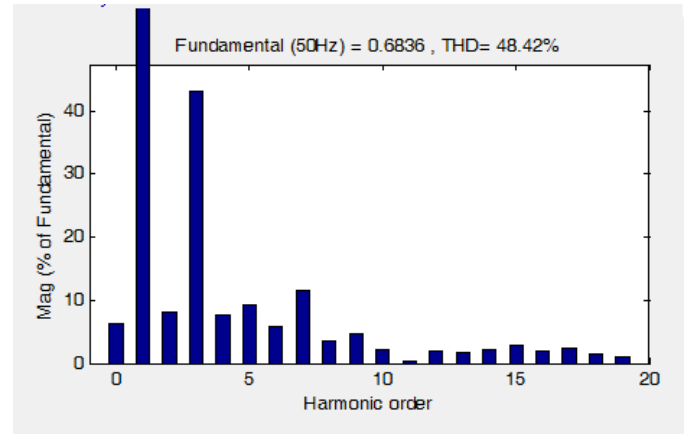


Fig.5.2(a) Harmonic Spectrum of Zener Regulated Power Supply

The supply current harmonics are observed to be 41.33 %, which is more than limit specified by IEEE-519 and the calculate power factor is found to be 0.5 and the ripple content are also high.

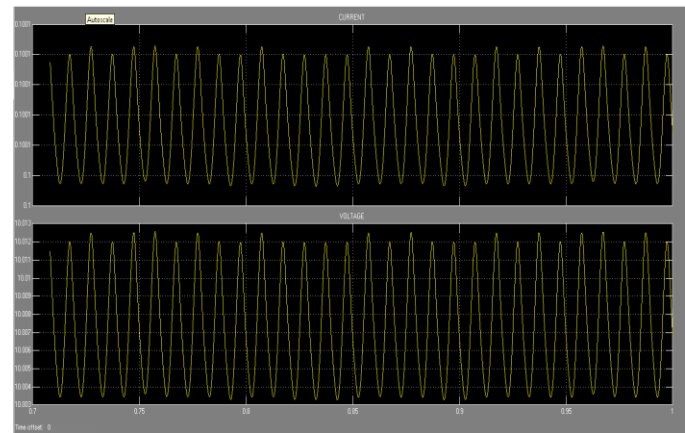


Fig.5.2(b) Output Voltage and Current Waveform of Zener Regulated Power Supply

5.3) Series Regulated Power Supply:

The simulation of Series Regulated Power Supply has been done in MATLAB software and gets the Total Harmonic Distortion as a result with its Harmonic Spectrum Graph as shown below:

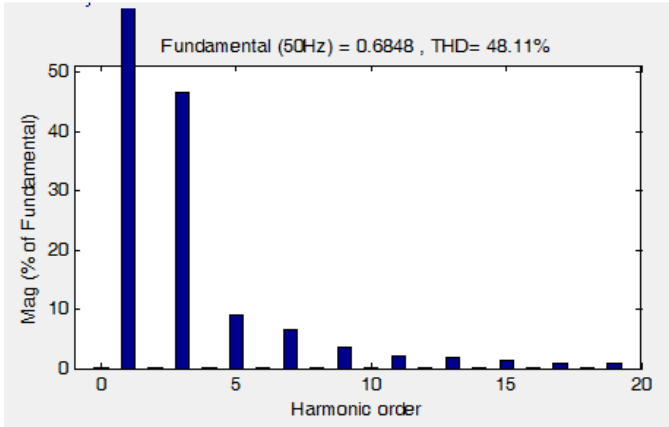


Fig.5.3(a) Harmonic Spectrum of Series Regulated Power Supply

The supply current harmonics are observed to be 29.62%, which is more than limit specified by IEEE-519. Ripple content are quite high and power factor measured to be is 0.5

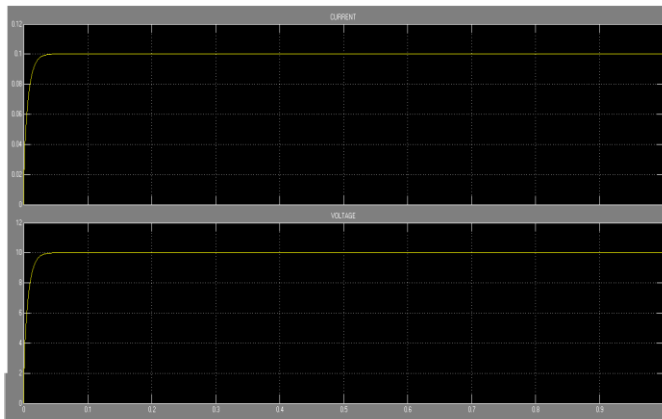


Fig.5.3(b) Output Voltage and Current Waveform of Series Regulated Power Supply

Distortion as a result with its Harmonic Spectrum Graph as shown below:

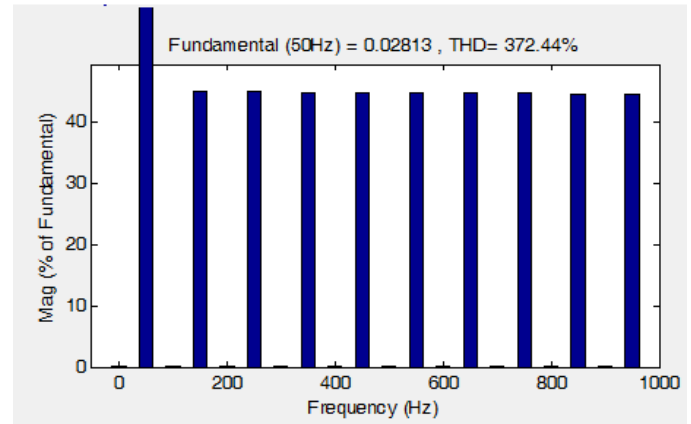


Fig.5.4(a) Harmonic Spectrum of Switch Mode Power Supply

The supply current harmonics are observed to be 448.41%, which is more than limit specified by IEEE-519. Ripple content are quite high and the power factor measured to be is 0.5

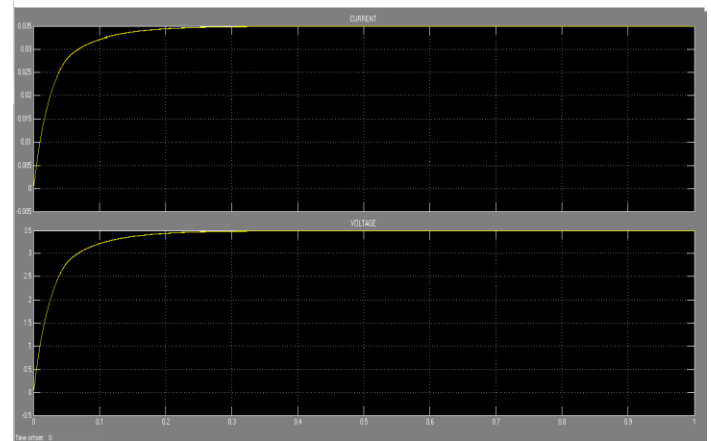


Fig.5.4(b) Output Voltage and Current Waveform of Switch Mode Power Supply

5.4) Switch Mode Power Supply:

The simulation of Switch Mode Power Supply has been done in MATLAB software and gets the Total Harmonic

5.5) Zero Current Switching Power Supply:

The simulation of Zero Current Switching Power Supply has been done in MATLAB software and gets the Total Harmonic Distortion as a result with its Harmonic Spectrum Graph as shown below:

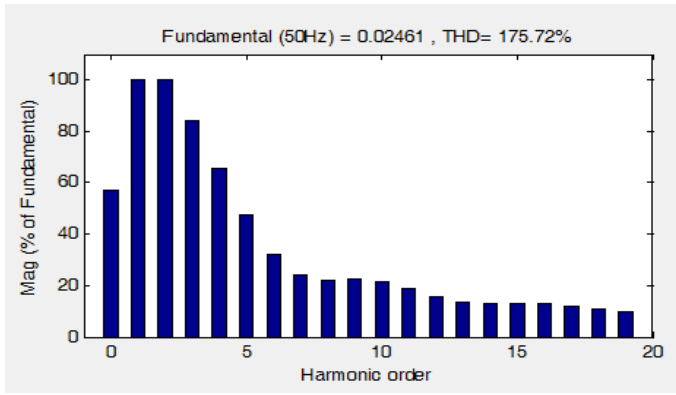


Fig .5.5(a)Harmonic Spectrum of Zero Current Switching Power Supply

The supply current harmonics are observed to be 55.39%, which is more than limit specified by IEEE-519. The calculated power factor is obtained to be 0.5 and The Ripple content are high.

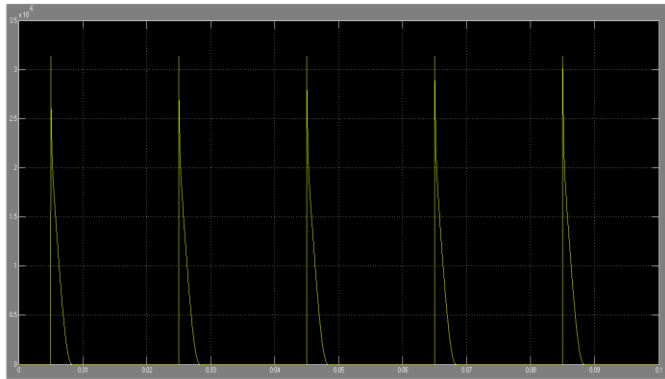


Fig.5.5 (b) Waveform of Power Loss in ZCS

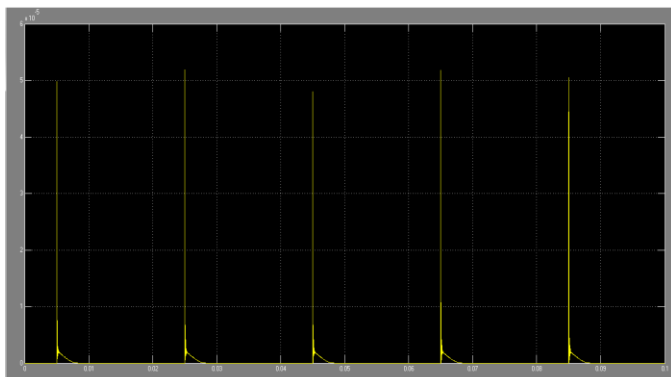


Fig.5.5 (c) Waveform of Reduction of Power Loss With ZCS Mode

5.6) Zero Voltage Switching Power Supply:

The simulation of Zero Voltage Switching Power Supply has been done in MATLAB software and gets the Total Harmonic Distortion as a result with its Harmonic Spectrum Graph as shown below:

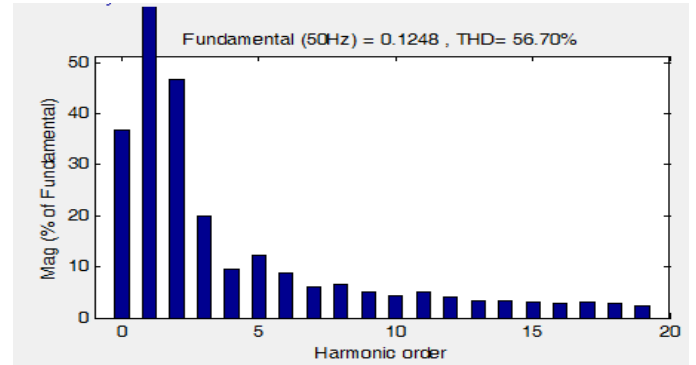


Fig .5.6(a)Harmonic Spectrum of Zero Voltage Switching Power Supply

The supply current harmonics are observed to be 56.53%, which is more than limit specified by IEEE-519. Ripple content are high and the power factor measured to be 0.5

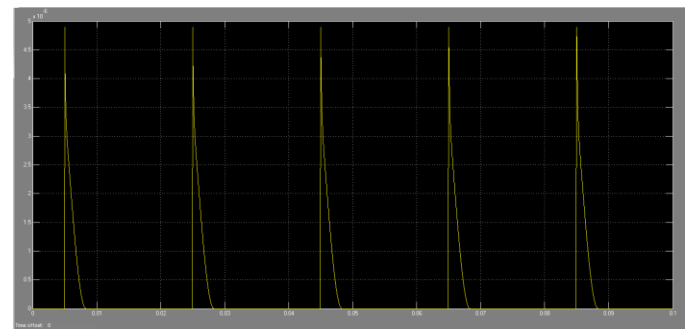


Fig.5.6 (b) Waveform of Power Loss in ZVS

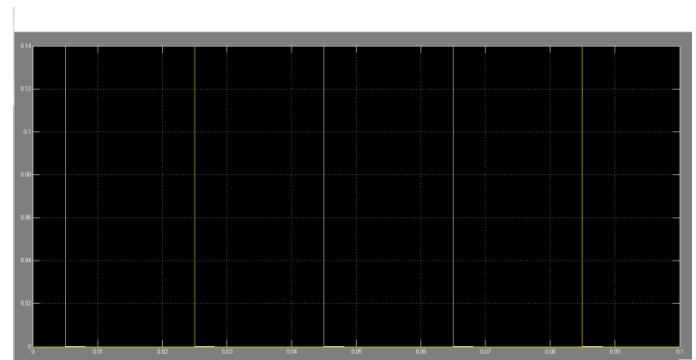


Fig.5.6 (c) Waveform of Reduction of Power Loss With ZVS Model

Comparison Table of Power supplies

Power Supplies	THD	Power Factor
1)Linear Power Supply	41.34%	0.8
2)Zener Regulated Power Supply	48.42%	0.8
3)Series Regulated Power Supply	48.11%	0.8
4)Switch Mode Power Supply	372.44%	0.8
5)Zero Current Switching Power Supply	175.72%	0.8
6)Zero Voltage Switching Power Supply	56.70%	0.8

6. CONCLUSIONS

The simulink is a matlab software package for multi-domain simulation and model -based design of dynamic systems. Since due to the use of power electronic devices, the supply quality is deteriorating day by day, if the supply quality is poor, it may harm the whole system. Hence Matlab/Simulink is a recommended technique before going on to the real time implementation. With this software the user becomes enabling to model, simulate and analyze the most significant signals. Hence, various types of power supplies has been simulated and the related THD and power factor has been calculated which is showing out with the high percentage of harmonic distortion as the power quality issue. Hence, Harmonic Distortion and Power Factor can be improved by using the latest harmonic reduction techniques.

Harmonic distortion is increasing day by day at a faster rate and is a matter of concern to the utility, customer and manufactures of different equipment. To keep the harmonic distortion to low value, following actions are necessary.

1. In India it is necessary first to create awareness regarding harmonic problems, their effects and elimination techniques among the utility, consumers and manufactures of different equipments to make power system less polluted.

2. The harmonic Standards should be imposed on the equipment and should be made mandatory to the manufactures and consumers. The equipment should strictly comply to the harmonic standards before selling it in open market.

3. The utility should monitor the installation of high tension consumers periodically, regarding the harmonic distortion and penalties should be imposed on customers using equipments crossing specified limits.

4. Filters should make compulsory to H.T. consumers.

Harmonic currents & voltage distortion are becoming the most severe and complex electrical challenge for the electrical industry. So by designing and giving complete solutions in the form of detuned and tuned harmonic filter systems, Active filters and other protection systems for industrial installation that can ensure the trouble free operation of electrical installation for industries. By defining and implementing these solutions users will be provided with the right quality of power supply for their requirements .

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