

¹K.Samidurai,
²K.Thanushkodi,

An Improved Power Quality Scheme Using High Frequency Link AC/AC Converter



Abstract—This Paper deals with the digital simulation of an electronic transformer based voltage regulator which improves the quality of power supplied by the utility. The regulator proposed is simulated using MATLAB / SIMULINK. It is found that the proposed scheme has superior operating and performance characteristics, particularly on the aspects of power quality, energy saving and efficiency unlike the conventional triac based schemes. Simulation results show that the improvement in performance with respect to input power factor and reduction of total harmonic distortion in output voltage resulting in improved power quality. The discontinuity caused by the conventional regulators in the load voltage to obtain variable AC voltage can be reduced to an appreciable extent using the proposed scheme.

Keywords – electronic voltage regulator (EVR), input power factor (PF), total harmonic distortion (THD), power quality (PQ)

I.INTRODUCTION

The conventional triac based schemes used to obtain variable AC voltage from single phase AC supply are simple, reliable, and cost effective [1-3]. However, it suffers from various drawbacks such as increased harmonic content, low input power factor and power loss especially at lower output voltages [4-6].

This paper suggests a new scheme which improves power quality and energy saving. The proposed electronic voltage regulator, EVR makes use of amplitude modulation and phase shifting technique for achieving a variable AC output voltage. The circuit comprises of standard H-bridge, one on either side of the high-frequency transformer is termed as an electronic transformer [7, 8].

In this study an isolated high frequency link AC/AC converter analyzed. The high frequency link AC/AC converter has the cost and size advantages because of high frequency operation of the magnetic core. Low cost and easy availability of ferrite core material have helped the implementation of high-frequency link power transformation [9].

The use of high frequency link AC/AC converter to achieve variable AC voltage results in improved power factor PF, reduction of THD in output voltage, and improved power quality, PQ as compared to the conventional triac based schemes [10]. Simulation results are presented to validate the proposed scheme.

II. PRINCIPLE OF OPERATION OF THE PROPOSED SCHEME

The principle of operation of the high frequency AC to AC link electronic transformer is based on amplitude modulation and phase shifting technique. In this method, a

low-frequency sine wave of supply frequency is modulated by a high-frequency square wave. The high-frequency square wave is the gate signal to the IGBTs. The voltage output can be obtained by multiplying these two waveforms. Hence this voltage can be transformed with a high-frequency transformer since it is a high frequency modulated sine wave of supply frequency [8].

The circuit diagram for the proposed scheme is shown in Fig.1 (a). In this circuit, a center tapped transformer suitable for high frequency is used for isolation and two pairs of bidirectional switches one each, on primary and secondary side of the transformer are used. Each bidirectional switch consists of four diodes in a bridge configuration and an IGBT to facilitate bidirectional flow of current.

To control the AC output voltage, the phase shifting technique is employed. As depicted in Fig.2, in this technique the high frequency square waves (10 kHz) are applied as the gate signals to the IGBTs. The gate signals to the IGBTs S_3 and S_4 are delayed by ' α ' seconds with respect to the gate signals of IGBTs S_1 and S_2 on the primary side of the transformer. The amplitude modulated voltage wave waveform (Fig.3) across terminals 'a' and 'b' of the transformer is obtained by switching of S_1 and S_2 with a 50% duty ratio signals shown in Fig. 2.

Thus a high frequency modulated voltage is obtained across the primary terminals (a, b) of the transformer. Fig 2 shows that the switches S_3 and S_4 are also turned on with 50% duty cycle but are shifted (in time) from the gate signals for S_1 and S_2 respectively by ' α ', where ' α ' is given by

$$\alpha = \theta \cdot \frac{T}{180} \text{ in seconds.}$$

and θ varies from 0° to 180°

T: switching ON time ($T = 1/(2f_{sw})$) in seconds

f_{sw} : switching frequency considering the ratio of the transformer as 1:1 and the internal resistance of the converter is negligible; the fundamental output voltage is obtained as follows [8]:

¹K. Samidurai is with Karpagam College of Engineering, Coimbatore, India. He can be reached at swami_la@yahoo.co.in.

²K. Thanushkodi is with Akshaya College of Engineering and Technology, Coimbatore, India. He can be reached at thanush12@gmail.com.

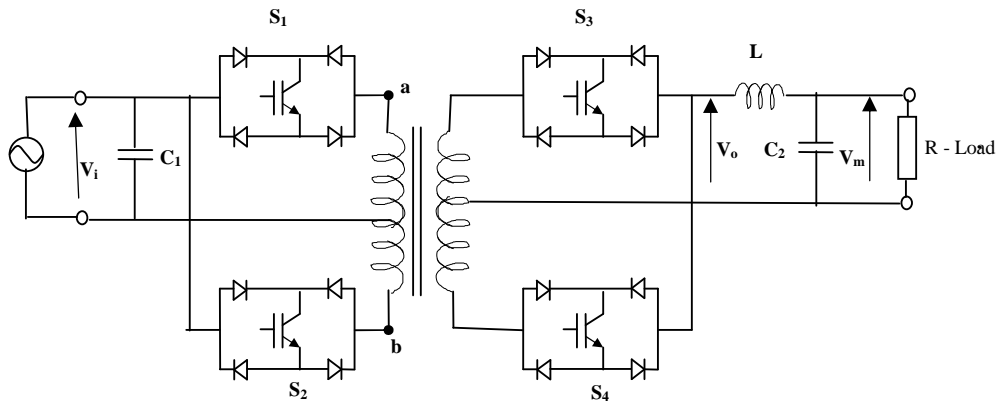


Fig.1.(a) Circuit diagram of the proposed scheme

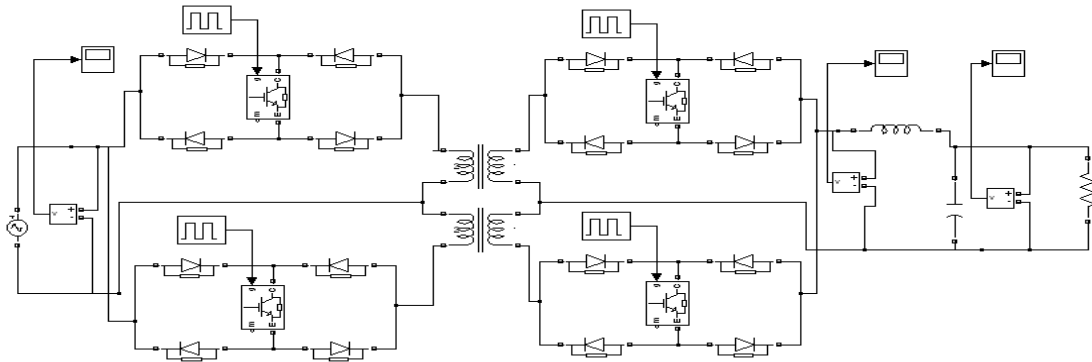


Fig.1.(b) Simulink model of the proposed scheme

$$V_o = (1 - 2t_0)V_i, \quad \text{where } t_0 = \frac{\alpha}{T}$$

V_o : rms output voltage

V_i : rms input voltage

By raising the switching frequency the time integral of the voltage applied to the transformer can be made smaller. Therefore the volume of the transformer can be made smaller. Because the output voltage and power flow are the maximum values under a given input voltage and a given switching frequency, it is important that the transformer should be designed for the condition $\theta = 0^\circ$ at any switching frequency. The range of θ from 0° to 90° is used, as the output is zero when $\theta = 90^\circ$ [8].

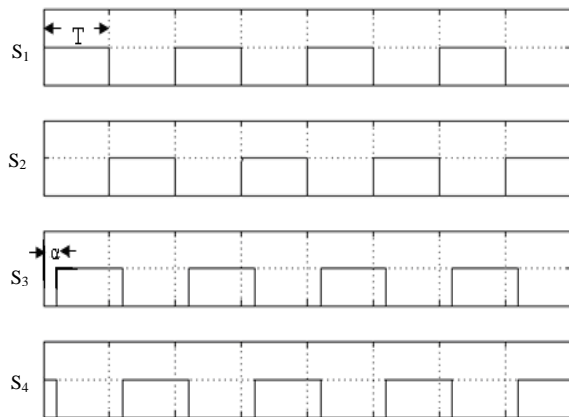
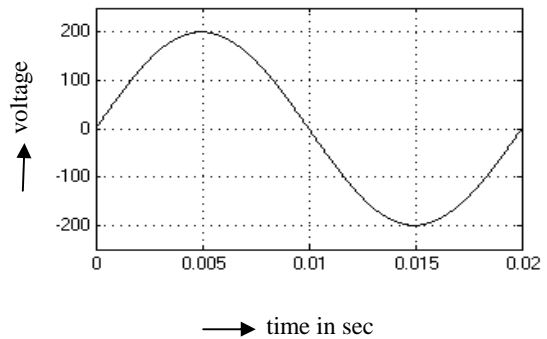
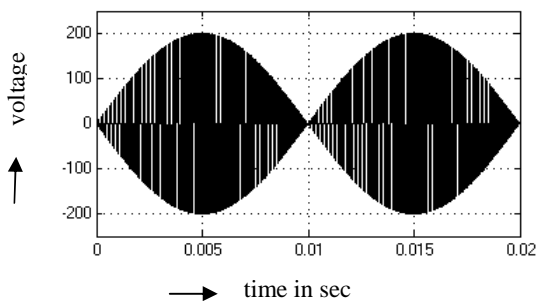


Fig 2. Pulse pattern

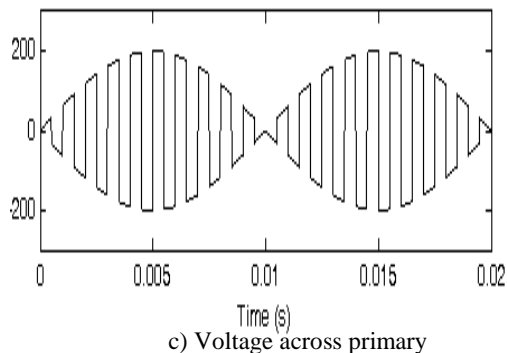


(a)

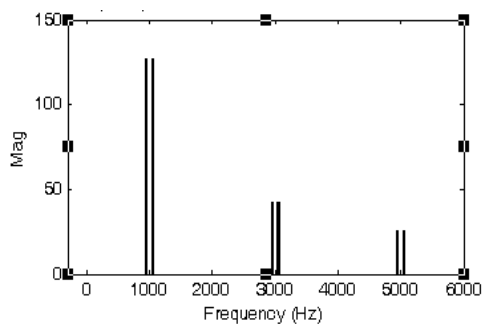


(b)

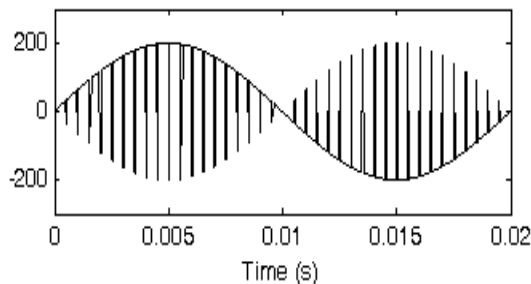
Fig.3. Waveforms illustrating amplitude modulation
 (a) Input voltage waveform
 (b) Amplitude modulated voltage waveform across transformer terminals a & b



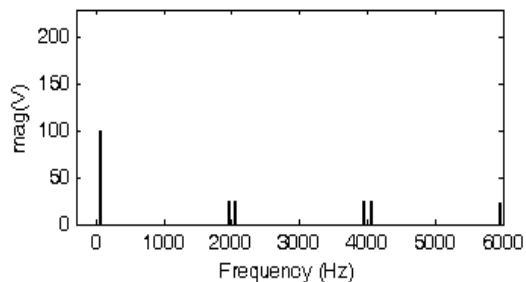
c) Voltage across primary



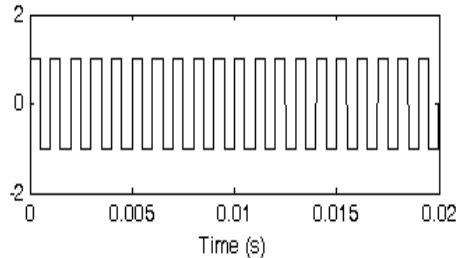
d) Fourier spectrum of primary voltage



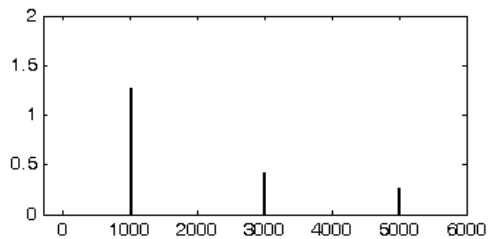
e) Unfiltered output voltage



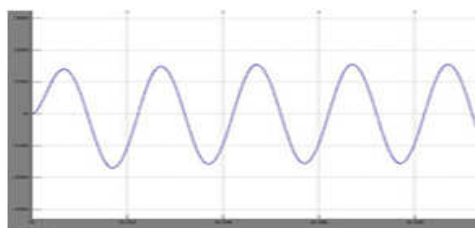
f) Fourier spectrum of unfiltered output voltage



a) Switching signal



b) Fourier spectrum of switching signal



g) Load voltage

Fig.4. Waveforms and harmonic spectra of the Primary / output voltages

III. SIMULATION RESULTS

The proposed scheme is simulated using MATLAB/SIMULINK as shown in (Fig.1.b) consists of four bi-directional switches each of which consists of four diodes in a bridge configuration with an IGBT at the DC terminals. The IGBTs used are rated for medium operating frequency (1 to 10 kHz). The switching frequency of the IGBTs is fixed at 10 kHz, so as to miniaturize the isolation transformer. Fig (4) gives the waveforms of primary / output voltages and switching signals. The sinusoidal voltage across primary shown in Fig.4.c ensures appreciable reduction in total harmonic distortion, THD and input power factor, PF close to unity. The harmonics present in the output voltage does not have any significance as the lowest harmonics starts at 2 kHz as shown in Fig.4.f. It is known that these types of higher order harmonics can easily be filtered out. Fig.4.g depicts the load voltage of the proposed scheme, which is very close to sinusoidal unlike triac based schemes.

TABLE I validates the significant reduction in THD of the proposed scheme over the conventional triac based scheme even at very low output voltages. It is known that the reduction in THD implies improvement in input power factor, PF and hence energy saving [10].

TABLE I
COMPARISON ON THD BETWEEN THE
SCHEMES (PROPOSED AND TRIAC BASED)

S.No	load Voltage (V)	Total Harmonic Distortion(THD)	
		Proposed	Triac Based
1	50	0.269	1.486
2	60	0.196	1.343
3	70	0.273	1.233
4	80	0.126	1.137
5	90	0.259	1.058
6	100	0.275	0.982
7	110	0.256	0.914
8	120	0.258	0.853
9	130	0.254	0.792

IV.CONCLUSION

In this paper a new scheme of electronic voltage regulator i.e. isolated high frequency link AC/AC converter is analyzed. Simulation results depicts that there is an appreciable reduction of THD in output voltage and improvement in input power factor, PF close to unity. Unlike the triac based schemes, the proposed regulator does not pollute the input power and output power to the load to a great extent while manipulating the given input supply. Owing to this reason, it can be used wherever variable ac voltage for the single phase loads is required. The quality of power is improved with the use of this scheme as it reduces the THD of the system. As the proposed scheme is energy efficient, it can be used for residential lamp dimmers, heat control, speed control of ceiling fans and other fractional horse power single-phase capacitor- run motors.

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VI.BIBLIOGRAPHIES



K. Samidurai received his B.E degree in Electrical & Electronics Engineering from Bharathiar University, Coimbatore, India in 1992 and M. Tech degree in Power Systems from National Institute of Technology, Tiruchirapalli, India in 2005. Since 2005, he has been an Assistant Professor in Department of Electrical & Electronics Engineering, Karpagam College of Engineering, Coimbatore, India. His research interests are in the areas of power

quality(PQ), energy conservation and power electronics. He is currently working towards his PhD degree at Anna University, Chennai, India.



Dr. K. Thanushkodi received his B.E degree in Electrical & Engineering and the M.Sc (Engg) degree from Madras University, Chennai, India in 1972 and 1976 respectively, and the PhD degree in Electrical & Electronics Engineering from Bharathiar University, Coimbatore, India in 1991. He is currently the director of Akshaya College of Engineering and Technology, Coimbatore, India. His research interests include computer modeling

and simulation, computer networking, power systems and power electronics.