Design and Simulation of Novel Integral Switching Cycle Control for Heating Load

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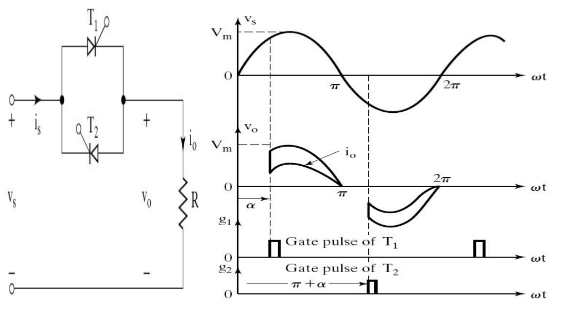
***Abstract*: The Class of ac power controllers consists of Solid State Power Controller (SSPC) which connects and disconnects the load to the supply according to the required power. Two important voltage control techniques are commonly used for heating power control in ac power controller are Phase Control Switching (PCS) and Integral Cycle Control (ICC). In case that PCS is used for resistive load, it can produce higher order harmonics and heavy inrush current while switching on in a cold start. In ICC frequency contained is variable and smooth voltage control is not possible and output voltage control is not continuous. To remove the disadvantage of both the method and have advantage of both methods author proposed new method termed as Integral Switching Cycle Control(ISCC) for heating application. In this paper authors have reported design and simulated results of ISCC method for heating application for resistive load along with the abilities and deficiencies of the proposed method.**

***Keywords*: Integral Switching Cycle Control, Heating Application, Interharmonics, Total Harmonic Distortion**

I. INTRODUCTION

Most of the load needs variable or regulated ac power like welding, heating furnace requires variable ac supply. Ac voltage controllers are used to drive such loads. Usually it takes main supply as the inputs and provides variable ac to the load. Basically two types of ac-to-ac conversion are in use direct conversion and indirect conversion. In indirect ac-ac conversion involves an intermediate dc stage, called the dc link or dc bus and the converter are called dc link converter. During direct conversion the ac input waveforms are directly converted into the desired output waveforms.

Phase Controlled Switching (PCS) is one of the methods of the direct conversion which is extensively used for adjustable ac-to-ac and ac-to-dc power conversion [1]. In case of heat controllers of resistive load (R), phase control circuits cause higher order harmonics and generate Radio Frequency Interference (RFI) and heavy inrush currents while switching on from cold. At large power levels, it requires bulky and expensive line filters to minimize RFI [2].



(a) (b)

Fig. 1 (a) Switching arrangement of phase control circuit
(b) Waveforms of phase control circuit

Fig. 1 (a) shows the switching arrangement of phase control circuit. In the case of PCS, the rms value of output voltage is given by

$$V_0 = V\,[1/\pi\ \{(\pi - \alpha) - ½ \sin 2\alpha\}]^{1/2} \quad \dots (1)$$

$$P\,F = V_0/V \quad \dots (2)$$

Where input supply voltage v(t) = Vm sinωt; Vm and V are maximum and rms values of the supply voltage and α is the switching angle of the circuit, as shown in fig. 1(b). The expression of Total Harmonic Distortion (THD) is given by [3]

$$THD = \frac{\sqrt[2]{\sum_2^\infty I_i}}{I_1} \quad \dots (3)$$

When α varies between 60 and 120, the supply voltage is close to its peak value (86.7% to 100%) and the corresponding voltage control range is from 44.2% to 89.7%. At the switching instant (ωt = α), the line current jumps from zero to almost its peak value, as shown in fig. 1 (b). Thus, di/dt is high over a wide range of control.

Integral cycle control is another method of direct conversion. It is also known as on-off control, zero switching or cycle selection. There are several applications in which mechanical time constant or thermal time constant is of order of several seconds for such application almost no variation in temperature is noticed if control is achieved by connecting the load to source for some on cycle and then disconnecting the load for some off cycles. So it consists of switching on supply to load for an integral number of cycles and then switching off the supply for a further number of integral cycles. It is repeated cyclically. The duty cycle is controlled for changing the output power basically it is an on-off control similar to the obtained through thermostatic switches except that here an integral number of cycles are passed. Due to zero voltage and zero current switching of thyristors, the harmonic generated by switching actions are reduced.

Fig. 2 shows the output voltage waveform of ICC. When the power is ON, during n cycle the temperature or speed increases exponentially from a minimum value and reaches a maximum at the end of n^{th} cycle. If n is the number of full cycles passed per M cycles of the source voltage then it is said to have a duty cycle of D= n/M. The difference between maximum of temperature and the minimum temperature is called the differential. Harmonic frequency present in ICC is lowest and low switching losses are produced so EMI and RFI problem will be less. Inrush current will also be less due to ZVS but smooth voltage control is not possible and frequency contained in ICC is variable.

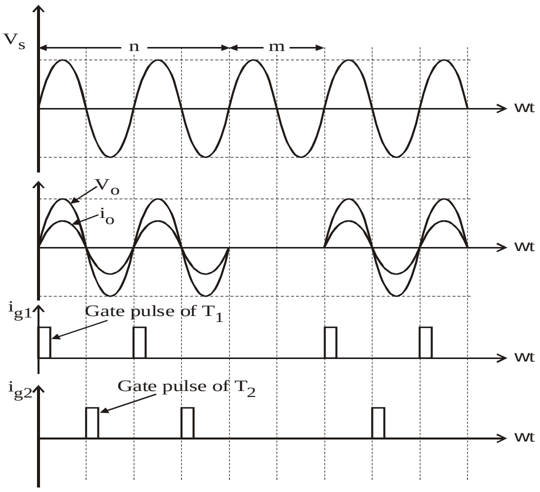


Fig. 2 Output of Integral Cycle Controller

II. PRINCIPLE OF OPERATION

To remove the disadvantage of both the methods and have advantages of both the methods PCS and ICC authors' proposed novel method termed as Integral Switching Cycle Control (ISCC) for the control of heating load. In this method phase angle α or duty cycle D can be varied. As shown in figure.3 duty cycle is kept 0.2 and firing angle α is 50˚.

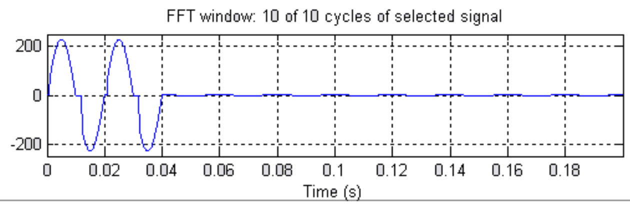


Fig. 3 Output waveform of ISCC with D = 0.2 and α = 10˚

III.PERFORMANCE CHARATERISTIC

SSPC is modelled as an ac voltage source or current source connected to a load through a network of switches. Switches including diode are assumed to be ideal and unidirectional, zero on state losses and unrestricted voltage or current carrying capabilities for a simplified analysis and the criteria for measuring the performance of the converter operation.

Its operation consists of two phases: *Transient Phase* in which voltage and current waveforms are unstable and vary from period to period and *Steady State Phase* in which all waveform are stabilized. .

The Transient State Performance measures includes Transient Current from the source, Short circuit current from the source and surge protection

VTR: The forward voltage transfer ratio is defined as the ratio of the rms voltage output voltage to the rms input voltage.

CRR: The reflective characteristic gives the effect of load current on the current drawn by from the source. The CRR is defined as the ratio of the input current to the rms load current.

Harmonic Profile: The output voltage and source current wave form are non sinusoidal. The lowest undesired harmonic frequency in the voltage and input power factor are the measures used for the undesirable Fourier Component.

Component Stresses: Voltage and current in the switch may consist of high transient which may be considering higher than the normal operating voltage. These transients voltage dictate the selection of switching devices and hence determine the cost. The component stress is measured as the ratio of the peak Voltage (Current) to the rms value of the components

IV.SYSTEM DESIGN

A. Block Diagram :

Block Diagram of ISCC circuit involves the basic three Sections. First section comprises of a power supply stage to drive all internal amplifier and feed the gate energy to the power semiconductor devices. In second section a zero voltage detecting stage, which sense the instant of zero supply voltage and delay angle to provide the phase delay α. This stage releases the power amplifier for a short duration pulse this cross over point so that they may trigger the power semiconductor if required or separate some other more continuous drive circuit. Finally in third section an amplifier stage is required which magnifies the control signal to provide the drive needed to turn on the power switch on. As shown in the block diagram, the control block consist of control circuit for ISCC, firing circuit and power amplifier (FCPA) and power supply for controlling the load.

FCPA consist of gate driver for thyristor and triac is used as power devices in the proposed design.

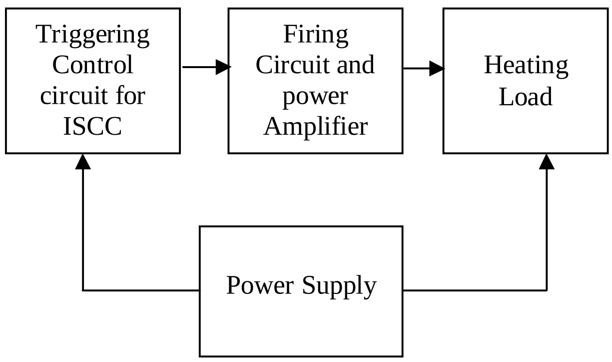


Fig. 4 (a) Block diagram of the ISCC

B. SIMULATION

Simulation of ISCC using MATLAB Simulink has been carried out by the authors and results are discussed for various duty cycle and phase angle. Fig. 4(b) shows the simulation results for ISCC with D=0.2 and α = 30˚ for the circuit topology discussed in fig. 4(a) and in figure 4(c) duty cycle and phase angle both has been changed. duty cycle is D = 0.6 and α = 90˚ Simulation is carried out in MATLAB R2007 with simulation parameter configuration of fixed step type ODE 4 type (Runge-Kutta) with unconstrained Periodic Sample time of fixed step size of 1e-6.

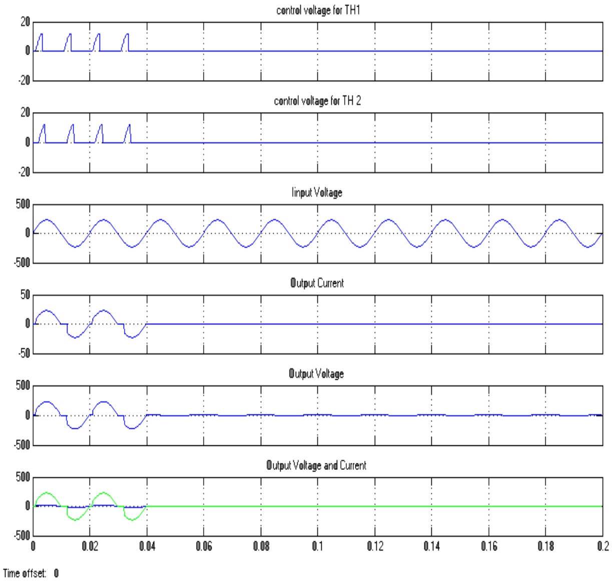


Fig. 4 (b) Simulation result for the control Topology of ISCC with D = 0.2 and α = 30˚

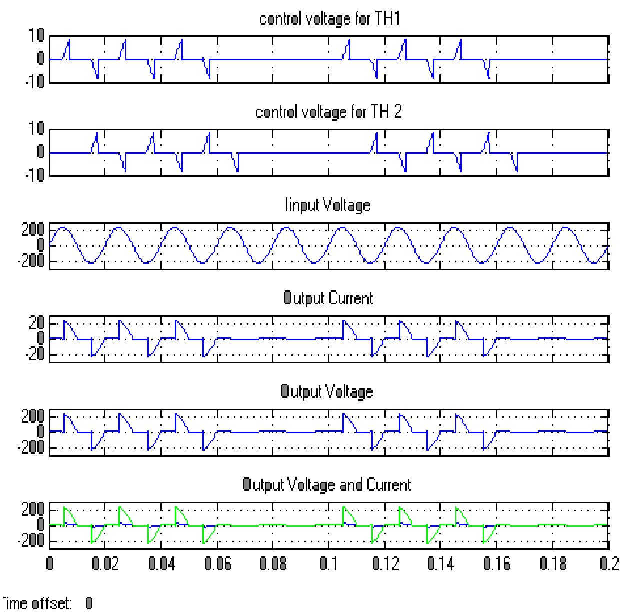


Fig. 4 (b) Simulation result for the control Topology of ISCC with D = 0.6 and α = 90˚

V. ANALYSIS

Fig. 5(a) shows the variation in output voltage with variation in duty cycle by keeping α = 10˚ constant. Output voltage increases with increase in duty cycle. In Fig. 5(b) duty cycle is kept constant to 0.1 and α is varied from 0 to 180˚ and it is observed that as firing angle α increases value of output voltage decrases. And fig. 5(c) shows the variation in output voltage and THD with variation in firing angle α and keeping the duty cycle constant to 0.1. it is observed that output voltage is decreases with increase in α and total harmonic distortion (THD) is maximum when α = 170˚ and THD is minimum when α = 10˚ for D=0.1.

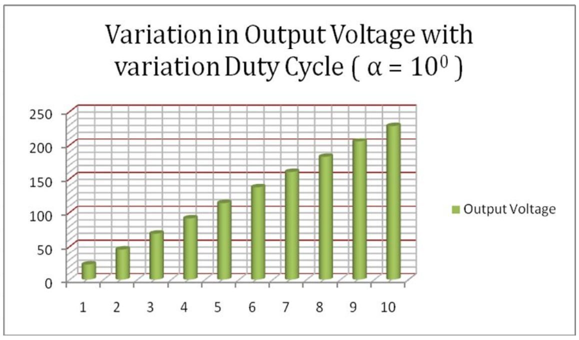


Fig. 5(a) Variation in Output voltage with duty cycle

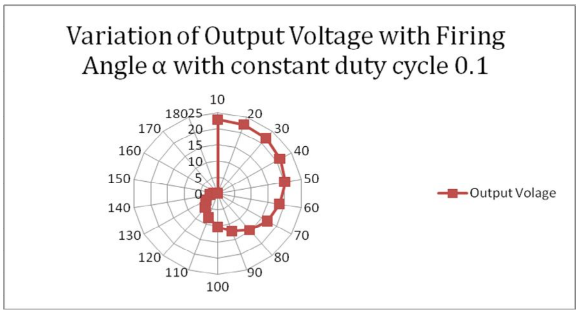


Fig. 5(b) Variation in Output voltage with firing angle

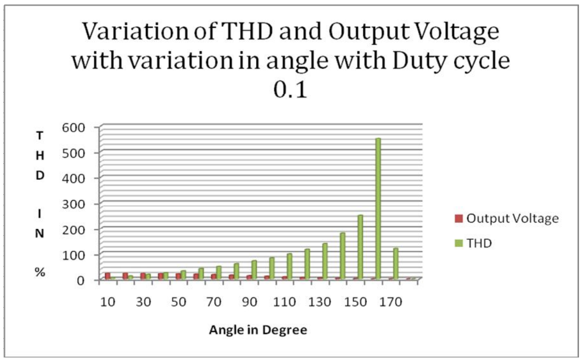


Fig. 5(c) Variation in THD and Output voltage with variation in firing angle (D=0.1)

VI. CONCLUSION

ISCC has been simulated, variation in output voltage with variation in duty cycle and phase angle control is observed and it is found that as duty cycle increases output voltage increases and as α increases output voltage decreases. Value of THD is maximum around the angle 160˚ to 170˚.

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