Scope International Journal of Science, Humanities, Management and Technology. ISSN : 2455-068X
Vol.3 Issue 2 (2017) 7 - 13. Submitted 20/04/2017. Published 29/04/2017

SOFTSWITCHED CYCLOINVERTER BASED ON ZCS

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Abstract

A ZCS and ZVS based cycloinverter is used to convert voltage at main frequency to a voltage at higher frequency with reduced switching losses and total harmonic distortion factor .The switching of IGBT takes place at ZCS and ZVS with the help of an auxiliary switch along with an inductor. Here we are designing and simulating this soft switched cycloinverter and it is being compared with the conventional hard switched cycloinverter. Using the proposed cycloinverter, losses are reduced by 50% than that of the conventional one and the efficiency is increased significantly .

Index Terms: ZCS, ZVS, IGBT, AC-AC conversion.

1. INTRODUCTION

The increased need for high power density in industries led to the need of high speed high frequency motors. Now a days high frequency ac/ac converters are used for high torque ac machines in the place of dc/ac inverters. Cycloinverter is such an ac to ac converter which converts voltage at main frequency to a voltage at higher frequency without any intermediate dc link. Single phase centre tapped cycloinverter is a conventional one which uses hard switching for switching on and off transitions.The switching losses and harmonic contents of this type of switching is overcome by using soft switched cycloinverers. They are also called resonant cycloinverters as zero current or zero voltage points are achieved, by the sinusoidal waveform obtained at resonance condition. This can be achieved by the inductor along with the auxiliary switch and the capacitor provided across the load where this capacitor is used to smoothen the output also. Other than total harmonic distortion factor ZCS can reduce switching losses caused by IGBT current tailing and stray inductances.

2. HARD SWITCHED CYCLOINVERTER

Power semiconductor devices like IGBT when used as switching devices can operate under two main switching configurations – hardswitching and softswitching. In hard switching the device turns - on and turns - off during the voltage and current peaks of input, that is the device requires to turn-on and off the entire load current during each transient. The circuit diagram for the hardswitching implementation is given in fig(1). It consists of a single phase centretapped transformer and four IGBTs, namely - T1M , T2M , T3M and T4M which are connected in antiparallel . T1M and T2M forms the positive part of converter whereas T3M and T4M makes negative group. The load is connected across transformer midpoint terminal and terminal A. During the positive half cycle of supply voltage , IGBTs T1M and

T4M are forward biased and T1M begins conduction at ωt=T0. Thus the load voltage follows the positive envelope of the supply voltage till it reaches the supply peak. At this point T1M is commutated and T4M gets turned on. Hence the load voltage follows the negative envelope of supply till ωt=T1.Then during the negative half of supply voltage IGBTs T2M and T3M is forward biasedand the above cycle repeats. Hence the desired output waveform , as shown in fig(2) , is obtained by the proper conduction of IGBTs.

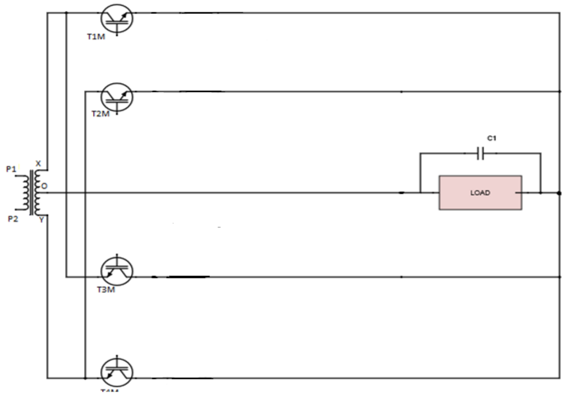


Fig (1).Hardswitchedcycloinverter

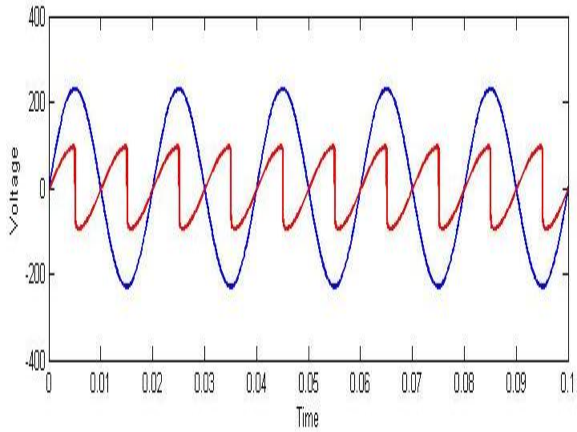


Fig (2). Waveforms of hardswitchedcycloinverter

But it is observed that the circuit operation in above manner causes an overlap between voltage and current during each switching cycle. This overlap may results in energy loss and increased switching stresses on device. This power losses can be reduced by increasing $\frac{di}{dt}$ and $\frac{dv}{dt}$ across the switch. But EMI tends to be generated due to sudden variation in these parameters and it affects the converter control circuit .Though hardswitching seems to be the simplest switching configuration, it has some more disadvantages to be incorporated .With this the converter losses increases and hence itsefficiency decreases at high switching frequencies. But for the harmonic losses to be reduced, this switching frequency needs to be optimised to a feasible high value. Incorporating these, the switching frequency value is to be designed with utter care. Another major disadvantage of hardswitching is it burdens the cooling system with increased losses .Coming to the practical implementation, where hardswitchedcycloinverter is connected to the machine input, there occurs an overvoltage at machine terminal. This is due to the increased $\frac{dv}{dt}$ at the inverter output which results in the generation of travelling wave and hence machine insulation is damaged .From all the above facts it is evident that the device reliability needs to be compromised due to prolonged hardswitching operation .So another efficient switching configuration, that is softswitching is implemented in the proposed circuit inorder to eliminate all the disadvantages to an extend.

3. SOFTSWITCHED CYCLOINVERTER

The circuit of softswitchedcycloinverter is shown in the fig .There are positive and negative converters .Two groups of switches used are main IGBTs [T1M-T2M-T3M-T4M] and auxiliary IGBTs [T1A-T2A-T3A-T4A].The main IGBTs conducts current from the ac supply to the given load while energy in the inductor is conducted to the given load via auxiliary IGBTs .

For this cycloinverter, output frequency,f0=fi*Nr.

Where, Nr is an integer which decides how many times the input frequency must be multiplied and fi is source frequency.

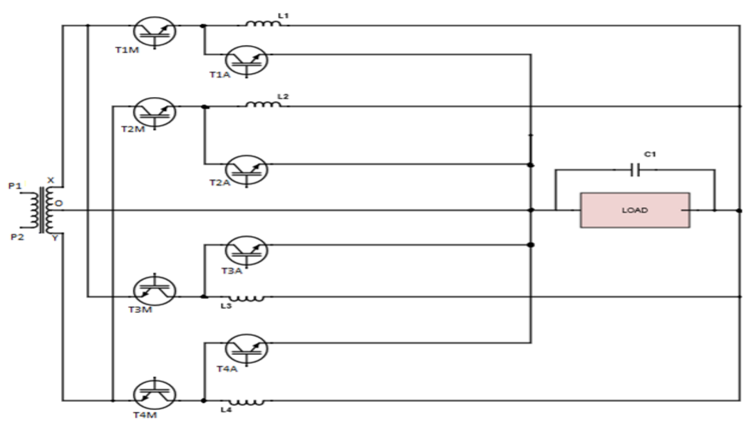


Fig (3).Softswitchedcycloinverter

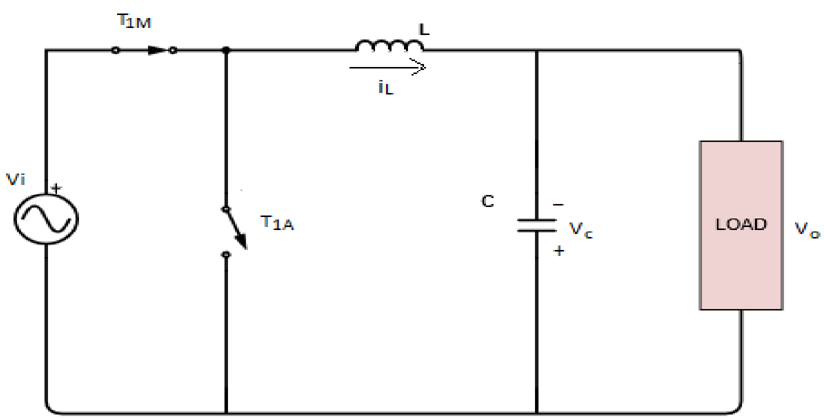
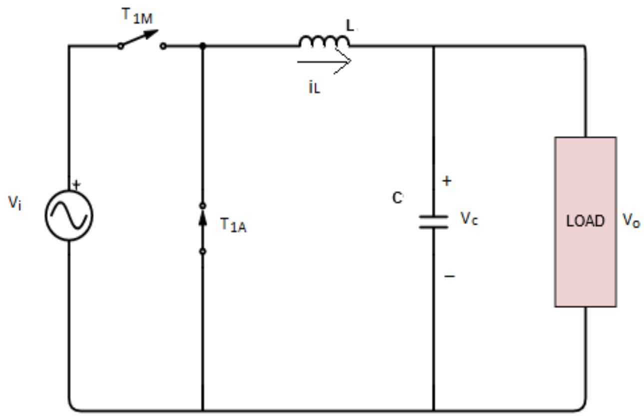


Fig (4). Charging circuit

The output wave form of cycloinverter is shown in fig(3). At the instant T0,switch T1M begins to conduct and continues to conduct till T1'.At this time the inductor gets charged till the inductor current builds up to its maximum value ie; it is fully charged .Then at the instant T1' the switch T1M gets turned off by transferring its current to T1A and this switch gets turned on. At time T1 switch T1A is off and T4M of negative converter gets ON and next half cycle starts .The sequence of the conduction is T1M,T1A,T4M,T4A,T2M,T2A,T3M,T3A for an input cycle having Nr as 2.



Fig(5).Discharging circuit

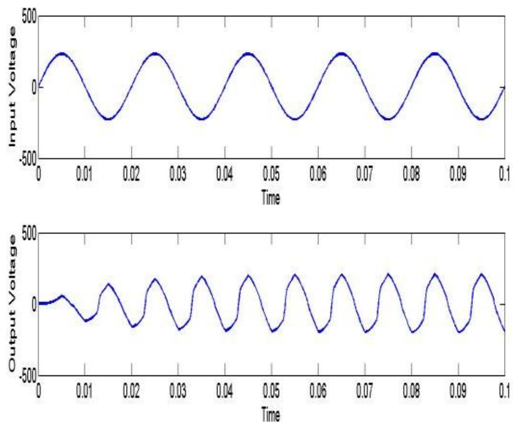


Fig (6). Waveforms of softswitchedcycloinverter

Capacitor and inductor values should be designed so as to favour for the occurance of resonance condition .From [1] the equations for capacitor and inductor value design are given below.

At resonance ,when,

$$X_L = Xc//R$$

$$X_L = \frac{X_C \times R}{X_C + R}$$

$$2\pi f L = \frac{R}{2\pi f RC + 1}$$

$$L = \frac{R}{4\pi^2 f^2 RC + 2\pi f}$$

Charging and discharging of inductor should takes place resonance. But the current stress in the converter increases with increase in capacitance value. So the selected value of capacitance should be optimum and it is given by the equation $C = \frac{1}{\omega^2 L} - \frac{1}{\omega R}$ Saturation of inductor core increases the stress across the switches and cause damages .This can be avoided by making magnetic field generated less than 0.39 wb/m² also using materials for core made of Manganese Zinc Ferrite and temperature which is less than 100ºC.Issues related to skin effect can be reduced by using litz wire.

By the introduction of a small airgap in the core, the magnetic flux will decrease .Effective permeability of the core is given by

$$\mu_e = \frac{\mu_i}{1 + \mu_i(\frac{g}{mL})}$$

where μ_i = initial permeability
g = gap
mL = magnetic path length.

The above mentioned equation holds good for magnetic circuits which are closed regardless of its shape. To make core characteristics independent of permeability at initial stage, the air gap is needed .Thus gap prevent the saturation with large ac signals. But as gap reduces permeability more number of turns will be needed which results in more copper loss.

4. THD ANALYSIS

THD is the sum total of harmonic distortion in a signal.It is the ratio of sum powers of harmonic components to that of the fundamental component.

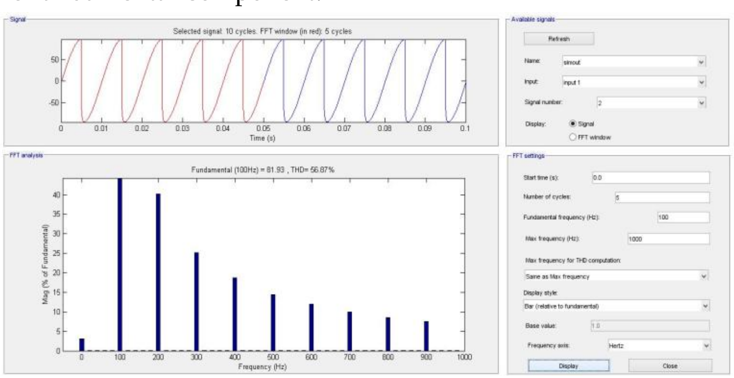


Fig (7).THD of hardswitchedcycloinverter

Here,five cycles of the output waveform of the hardswitchedcycloinverter is compared with that of the fundamental waveform having zero THD.It's THD is observed to be 56%.

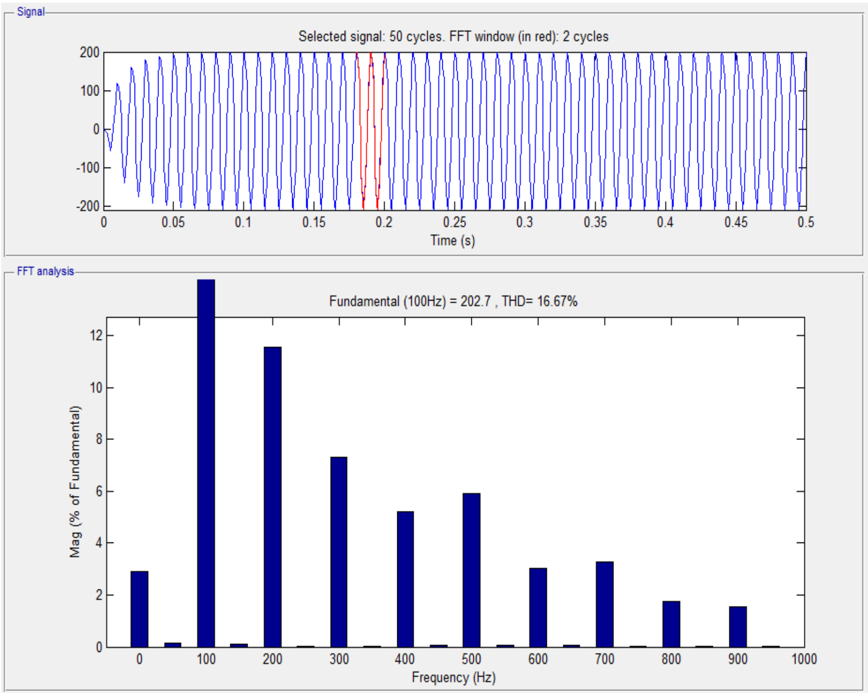


Fig (8). THD of switched cycloinverter

Fig (8) shows the THD of softswitchedcycloinverter.Two cycles of output waveform of softswitchedcycloinverter is compared with that of the fundamental waveform .It is analyzed that the THD is 16.67%.ie;THD has reduced by a considerable amount. Thus it can be concluded that the THD has reduced nearly by 50% incase of softswitchedcycloinverter when compared with hardswitched one.

5. RESULTS

The simulation circuit of the softswitchedcycloinverter andconventionlhardswitchedcycloinverter was designed and implemented.It was observed that the the frequency of output voltage was increased than that of input frequency with reduced switching losses and THD leading to an increased efficiency.The THD is reduced to 16.67% which is a considerable amount.

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