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Dual- Tap Chopping Stabilizer with Subcyclic AC Soft Switching

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ABSTRACT: The ac voltage controllers with thyristor technology can be replaced by pulse width modulated (PWM) ac chopper, which has important advantages. A dual-tap chopping stabilizer with a compensating transformer, with a pulse width-modulation frequency of about 5 kHz and a new soft-switching technique is presented in this paper. It is based on the zero-current switch-off attainable several times in a half cycle under any combination of the current and voltage signs in the main taps. Consequently, the circuit combines high speed & low switching losses. The need for detecting the current zero crossing is eliminated in this project by applying a specific switch activation schedule for each combination of the current and voltage signs of the main taps. The new method reduces the electrical stress in the switches and the electromagnetic emission.

KEYWORDS*:* chopper, on-load tap changer (OLTC),pulse width-modulation, voltage controller

I. INTRODUCTION

AC voltage controllers are the devices which convert fixed alternating voltage into variable alternating voltage without change in supply frequency. It is also called as ac voltage regulator.AC voltage controllers using thyristors are quite common. The load voltage is controlled by controlling the firing angle of the thyristors. Single phase ac controllers operate with single phase ac supply voltage of 230V RMS at 50Hz in our country. Three phase ac controllers operate with 3 phase ac supply of 400V RMS at 50Hz supply frequency. The appearance of the power semiconductors in the fifties and the steadily increasing rates and speed since then led to the replacement of mechanical switches by solid-state counterparts, eliminating the need for frequent and costly maintenance revisions and allowing faster operation. Nowadays, most OLTCs for low-voltage stabilization in the range of 300 VA–300 kVA 230 V single-phase. Thyristor-based OLTCs are also applied to phase regulation in long high-voltage electric lines. In dual-tap chopping solutions, it is important to achieve low commutation losses, since the usual switching pattern frequency is in the range of 1–10 kHz.

II. CONVENTIONAL METHOD-DUAL TAP CHOPPING STABILIZER WITH COMPENSATING TRANSFORMER

In conventional method, a dual- tap chopping stabilizer with a compensating transformer ,with a pulse width-modulation frequency of about 5KHz and a new soft switching technique achieved by two auxiliary small power branches [1]. Unlike other super cyclic ac soft switching solutions ,the new commutating method allows zero current turn off, several times in a half cycle, for any sign combination of voltages and current, thus reducing the electric stress and the electromagnetic emission. In conventional method the need of detecting the current zero crossing is eliminated by applying a specific switch activation schedule for each combination of the current and voltage signs of the main taps [2]. Power circuit topology of dual tap chopping stabilizer with compensating transformer is shown in fig 1.

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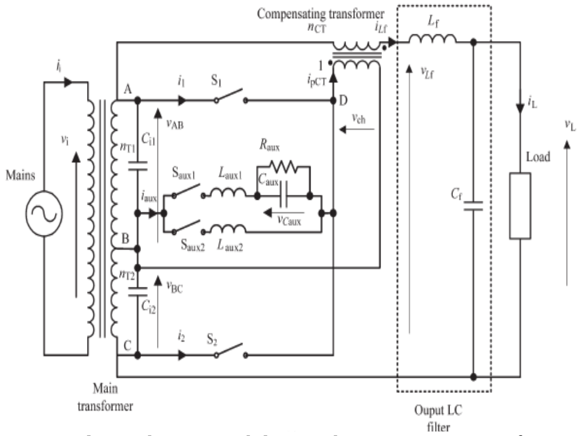

Fig1: Dual-Tap chopping stabilizer with compensating transformer

The compensating transformer add to or subtracts from the output of the main transformer $V_{AC}=V_1\ (n_{T1}+n_{T2})$, a voltage $V_{ch}n_{CT}$ obtained by chopping the voltage at the secondary of the main transformer with the main switches S_1 and S_2 [4]. The capacitors C_{i1} and C_{i2} between taps are used to limit voltage variations in the secondary of the main transformer due to the effect of the commutation on its leakage inductance.The drawbacks in conventional methods are Free wheeling path cannot be provided and Output voltage is reduced due to compensating transformer. The above disadvantages are overridden by the new proposed topology, the dual tap chopping stabilizer with sub cyclic ac soft switching [3].

III. PRPOSED METHOD-DUAL- TAP CHOPPING STABILIZER WITH SUBCYCLIC AC SOFT SWITCHING

The circuit for dual tap chopping stabilizer with subcyclic ac soft switching can be divded into two circuits as power circuit and control circuit. The block diagram of proposed method is as shown in fig 2

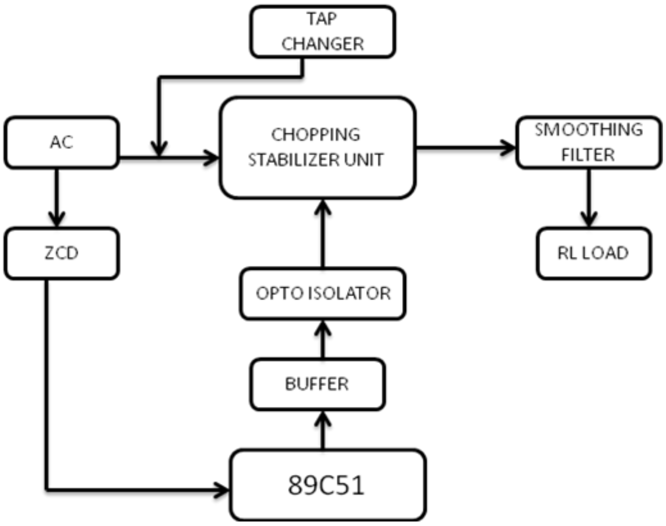

Fig 2 Block diagram of proposed method

The description of block diagram components is given below

A. Power MOSFET

The IRF-840 provides fast switching, ruggedized device design, low on-resistance and cost effectiveness. The TO-660 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-660 contribute to its wide acceptance throughout

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the industry.Features are Ultra Low On-Resistance, 175°C Operating Temperature, Fully Avalanche Rated, 8A, 500V, rDS(ON) = 0.850W,Single Pulse Avalanche Energy Rated.

B. Opto Isolator (MCT6E)

An opto isolator, also known as an optical coupler or opto coupler, is a semiconductor device that allows signals to be transferred between circuits or systems, while keeping those circuits or systems electrically isolated from each other [9]. The opto-isolator is simply a package that contains both an infrared light-emitting diode (LED) and a photo detector such as a photosensitive silicon diode, transistor Darlington pair. The MCT6/ MCTE family is an Industry Standard Single Channel Phototransistor [5]. Each opto coupler consists of gallium arsenide infrared LED and a silicon NPN phototransistor. These couplers are Underwriters Laboratories (UL) listed to comply with a 5300 VRMS isolation test voltage. SO9001 quality program results in the highest isolation performance available for a commercial plastic phototransistor opto coupler [6-7]. The functional diagram of opto coupler is shown in fig 3.The devices are available in lead formed configuration suitable for surface mounting and are available either on tape or reel, or in standard tube shipping containers.

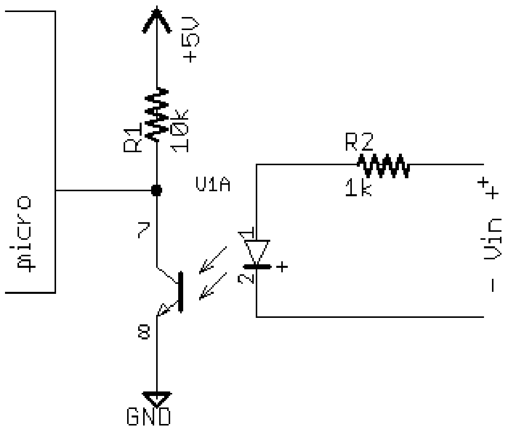

Fig 3Functional diagram of opto coupler

C. Voltage Regulator

A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level. It may use an electromechanical mechanism, or passive or active electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages [8]. With the exception of shunt regulators, all voltage regulators operate by comparing the actual output voltage to some internal fixed reference voltage. Any difference is amplified and used to control the regulation element. This forms a negative feedback servo control loop. If the output voltage is too low, the regulation element is commanded to produce a higher voltage. If the output voltage is too high, the regulation element is commanded to produce a lower voltage.

D. Current Buffer

A buffer amplifier (sometimes simply called a buffer) is one that provides electrical impedance transformation from one circuit to another. Two main types of buffer exist, the voltage buffer and the current buffer [10]. Typically a current buffer amplifier is used to transfer a current from a first circuit, having a low output impedance level, to a second circuit with a high input impedance level. The interposed buffer amplifier prevents the second circuit from loading the first circuit unacceptably and interfering with its desired operation.

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IV. MODES OF OPERATION

A .Mode 1: Positive Mode (First Tap)

In the positive mode of first tap change M1 conducts along with the diodes on the opposite legs i.e. D1 & D4 [11]. Simultaneously D9 & D12 conducts in the chopper unit along with M3.After reaching near the load the current branches and flow through C1 and R1.Here the current flow is from the source to the load. This mode of operation is shown in fig 4

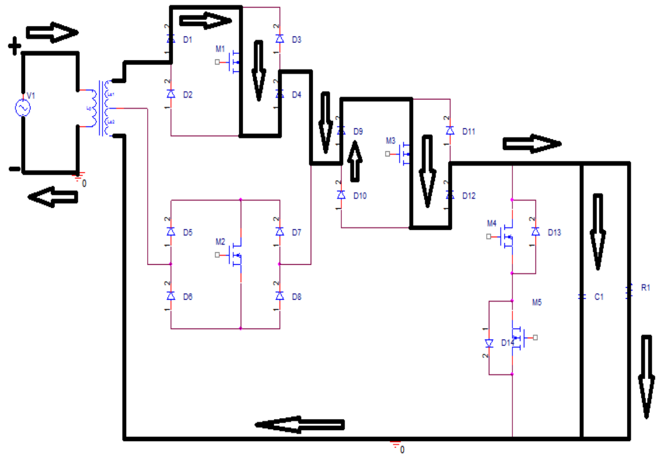

Fig 4. Positive Mode (First Tap)

B. Mode 2: Negative Mode (First Tap)

In the negative mode of first tap M1 conducts along with the diodes on the opposite legs i.e. D2 & D3. Simultaneously D10 & D11 conducts in the chopper unit along with M3. After reaching near the load the current branches and flow through C1 and R1 in the opposite direction to that of the positive mode

Here the current flow is from the load to the source [12]. This mode diagrammatic representation is shown in fig 5

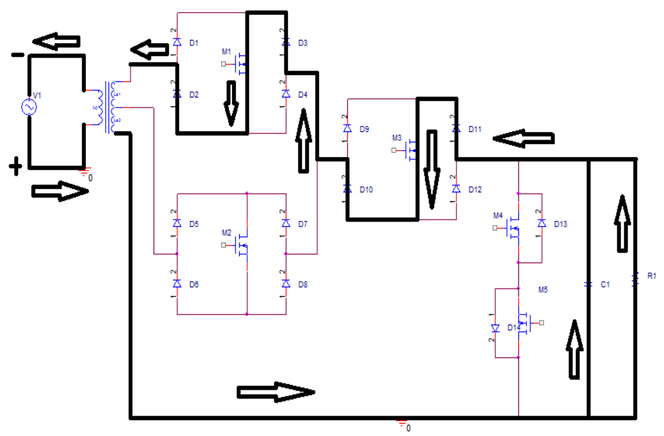

Fig 5 Negative Mode (First Tap)

C. Mode 3: Positive Mode (Second Tap)

In the second tap there is the reduction in the voltage level. With the reduced voltage the conduction of the switches takes place. In the positive mode of the second tap the second tap changer is switched on where M2 conducts along with the diodes in the opposite legs i.e. D5 & D8. Whereas M3 along with the respective diodes D9 & D12 starts conducting in the chopper unit [13]. Here also the current flow takes place from the source to the load as in case of the first tap.The mode 3 operation is shown in fig 6

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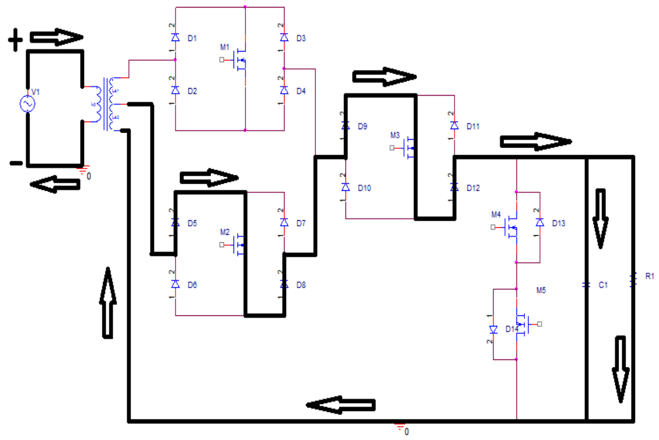

Fig 6 Positive Mode (Second Tap)

D. Mode 4: Negative Mode (Second Tap)

In the negative mode of operation of the second tap D6 & D7 conducts along with the switch M2 and also M3 conducts with the respective diodes D10 & D11. Current flow is from the load to the source. The fig 7 describes mode 4 operation.

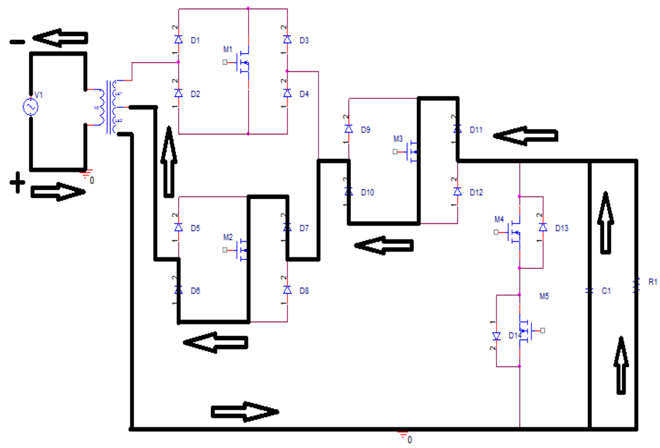

Fig 7 Negative Mode (Second Tap)

Free wheeling paths are provided to prevent the sudden switching changes when the circuit changes over from one tap to other or from one mode to other. The free wheeling path provides the continuity in the power flow in the load. The same free wheeling path works for both the tap settings. When there is change over of the switch from one mode to other the is small disturbance in the power flow across the load [14]. This disturbance across the load is compensated by the free wheeling circuit. The free wheeling circuit circulates the energy stored in the load there by the small disturbance is eliminated.

V. SIMULATION RESULTS

The simulation of proposed circuit diagram has been done by using PSPICE. It allows various types of analysis. Each analysis is invoked by including its command statement. The simulation waveform for compensative transformer control chopper is shown in fig 8.

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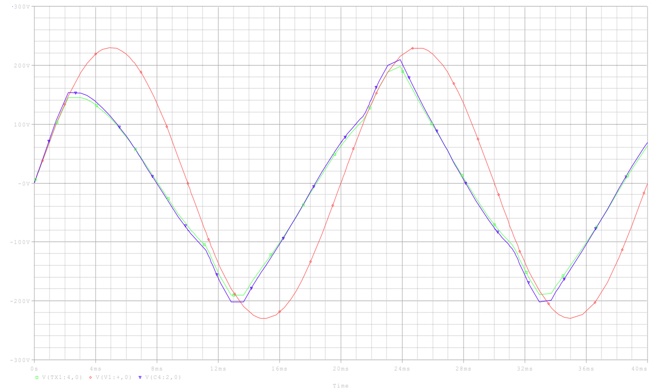

Fig 8 output waveform of chopper with compensative transformer

The simulation circuit and output waveform of dual tap chopping stabilizer with sub cyclic ac soft switching is shown in fig 9 and 10 respectively.

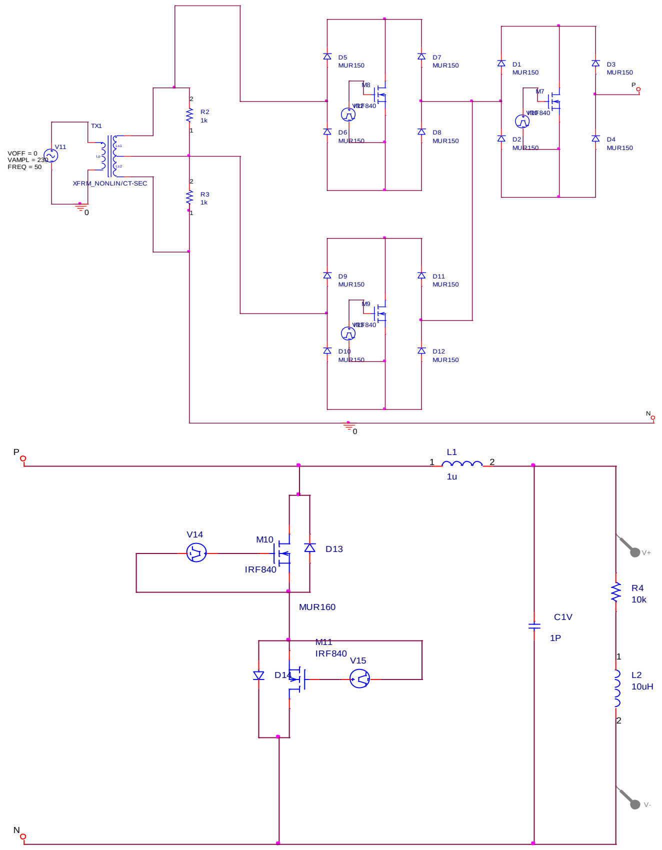

Fig 9: Simulation circuit of dual tap chopping stabilizer

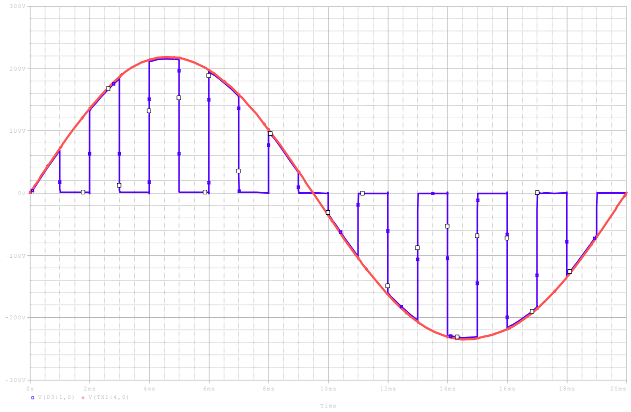

Fig 10 output waveform of dual tap chopping stabilizer with sucyclic AC soft switching

VI. CONCLUSION

In this paper dual-tap chopping stabilizer, with a pulse width-modulation frequency of about 5 kHz and a new soft-switching technique is presented. The circuit combines high speed & low switching losses. Experimental results show that the proposed topologies give good performance for AC choppers .The AC chopper has sinusoidal current waveforms, better power factor, faster dynamics, and smaller input/output filter. This new method reduces the electrical stress in the switches and the electromagnetic emission. The simulation output of the designed circuit and the output of the hardware circuit are the same and hence verified.

VII. FUTURE SCOPE

The scope of this system can be extended to further areas with simultaneous advancement in its performance by further improving the power factor hence the performance of regulators and drives will also be improved. A technical study and an evaluation of the power of the required components are done on the commutation techniques that extend the application field of tap changers to the reduction of the fast perturbations of the mains as flicker, voltage harmonics, voltage oscillations, etc. Experimental results with insulated-gate bipolar transistor switches are obtained in a 1 kVA prototype. Further this circuit can be modified such that this circuit can be used for the house hold requirements at various taps according to the requirements. We hope that this system will be definitely useful to many people involved in various fields. With commercialization of this system it can be made more affordable

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