HYBRID AC VOLTAGE REGULATOR USING TAP CHANGING TRANSFORMER

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ABSTRACT

A step-up/down AC voltage regulator is proposed, in which a tap-changing transformer and a pulse width modulation (PWM) AC chopper are combined. The proposed regulator can step up or down the output voltage to input voltage. Also, the proposed regulator restrains more harmonics of output voltage compared to the conventional PWM regulator. The input current flows continuously in the proposed regulator, while it flows discontinuously in the conventional PWM regulator. Through digital simulation, several characteristics are investigated theoretically and then compared with those of conventional schemes. Practical verification of the theoretical predictions is presented to confirm the capabilities of the proposed regulator.

Keywords: *Voltage regulator, PWM, AC Chopper.*

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1. INTRODUCTION

Usually AC Choppers are used for the reduced voltage output. But the AC choppers also called as AC voltage regulators are bound to more voltage losses due to harmonics. This is rectified by using some PWM techniques.

Usual regulators that have PWM techniques for reduced voltage some additional features for enhancing the voltage input. That is done here using the tap changing transformer. Step up as we have discussed before can be done using the tap changing transformer .But we need both step up and step down. So we have to go for a hybrid construction.

The Hybrid construction has both tap changing transformer and the voltage chopper. The use of a practical SCR voltage controller results in considerable harmonic distortion and substantial additional losses which reduce the net energy saving.

The use of PWM AC Chopper eliminates partially this drawback. By proper choice of different PWM combination we can go for reduced harmonic content in the circuit. We are adding both the step down and the tap changer ac voltage regulator to get both step up and step down accordingly.

Microcontrollers are used for the tap changing connection selection with the help of relays and in the PWM generation. For the analysis, Changes in harmonics of output voltage, total harmonic distortion at source and load and experimental results are taken.

2. LITERATURE SURVEY

1. E. El-Bidweihy, K. Al-Badwaihy, M. S. Metwally, and M. El-Eedweihy, "Power factor of AC controllers for inductive loads,":

A general relationship for the input power factor of ac controllers with inductive loads is derived in this paper. Its simplified form is given for the phase angle, integral cycle, and symmetrical pulse width modulated controllers. The latter may or may not have a freewheeling path for the load

2. G. N. Revankar and D. S. Trasi, "Symmetrical pulse width modulated ac chopper,":

Output voltage, output current and line current waveforms in a symmetrically pulse width modulated (SPWM) ac chopper are analyzed for harmonic content, displacement factor, distortion factor, power factor and efficiency. The results are compared with those of phase controlled ac chopper circuit to assess the superiority of SPWM ac chopper. A novel SPWM ac chopper with minimum number of active components is presented. The circuit operation and the design considerations are discussed

3. B. W. Williams, “Asymmetrically modulated AC chopper,”:

A new circuit is presented for three-phase voltage controller (AC chopper) constructed from IGBTs .Traditionally such an equipment contains thyristors as switching elements. All drawbacks of this solution come from its only possible control method: firing control. The new circuit allows Pulse Width Modulation (PWM) control, providing much better properties. A new and advantageous control method is presented, including the protections also. Many application fields can be found, all require AC voltage control. The examined ones are: Energy-saving control of induction motor drive; Compensation of an unbalanced supply; Active filtering of the upper harmonics; Excitation system of brushless motor.

4. A. Mozder, Jr. and B. K. Bose, “Three-phase ac power control using power transistor,”:

PWM rectifier inverter system using insulated gate-bipolar-transistors (IBGT’s), capable of switching at 20kHz is reported. The base drive circuit for the IGBT, incorporating short circuit protection is presented. The inverter uses snubber together with a simple energy recovery circuit, which ensures reliable and efficient operation even for 20 kHz switching. The front end for the system is a regenerative single phase full-bridge IGBT inverter along with an ac reactor. Steady-state design considerations are explained and control techniques, for unity power factor operation and fast current control of the front end converter, in a rotating as well as a stationary reference frame, are discussed and compared. Results from computer simulations as well as experimental results, for a 1.5-kW prototype system using GE IGBT’s Type6E20, are presented.

3. CONVENTIONAL AC VOLTAGE REGULATOR

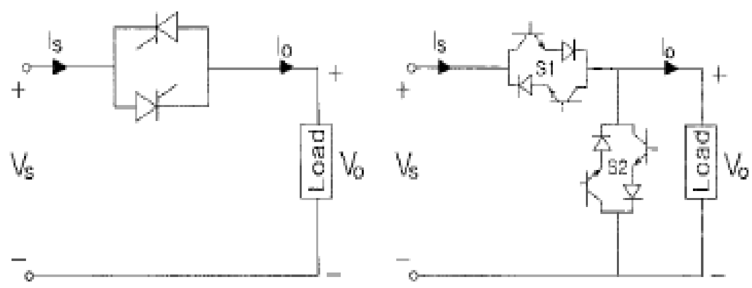


Fig 3(a) PAC ,(b) PWM

Fig. 1(a) shows the power circuit of PAC which does not require the freewheeling path. Fig. 1(b) shows the power circuit of the PWM voltage regulator, which is composed of two pairs of inverse parallel power switches, one connected in series and the other in parallel with load. The series-connected transistors regulate the power delivered to the load, and the parallel ones provide the freewheeling path to discharge the stored energy when the series ones are turned off.

3.1 LINEAR REGULATORS

Linear regulators are based on devices that operate in their linear region (in contrast, a switching regulator is based on a device forced to act as an on/off switch). In the past, one or more vacuum tubes were commonly used as the variable resistance. Modern designs use one or more transistors instead. Linear designs have the advantage of very "clean" output with little noise introduced into their DC output, but are less efficient and unable to step-up or invert the input voltage like switched supplies. Entire linear regulators are available as integrated circuits. These chips come in either fixed or adjustable voltage types.

3.2 SWITCHING REGULATORS

Switching regulators rapidly switch a series device on and off. The duty cycle of the switch sets how much charge is transferred to the load. This is controlled by a similar feedback mechanism as in a linear regulator. Because the series element is either fully conducting, or switched off, it dissipates almost no power; this is what gives the switching design its efficiency. Switching regulators are also able to generate output voltages which are higher than the input, or of opposite polarity — something not possible with a linear design.

Like linear regulators, nearly-complete switching regulators are also available as integrated circuits. Unlike linear regulators, these usually require one external component: an inductor that acts as the energy storage element. (Large-valued inductors tend to be physically large relative to almost all other kinds of component, so they are rarely fabricated within integrated circuits and IC regulators — with some exceptions

4. PROPOSED AC VOLTAGE REGULATOR

4.1 Block Diagram

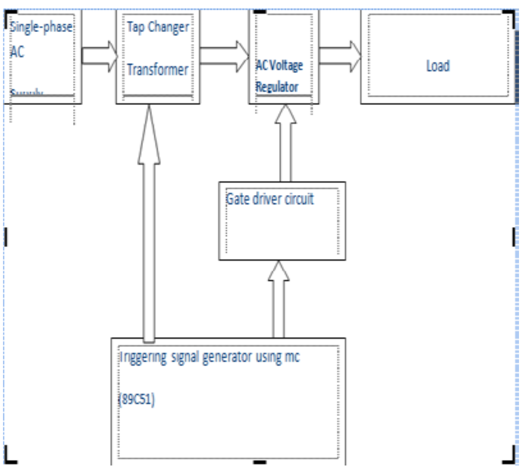


Fig 4.1 Block diagram of proposed AC voltage regulator

4.2 Proposed power circuit of AC voltage regulator

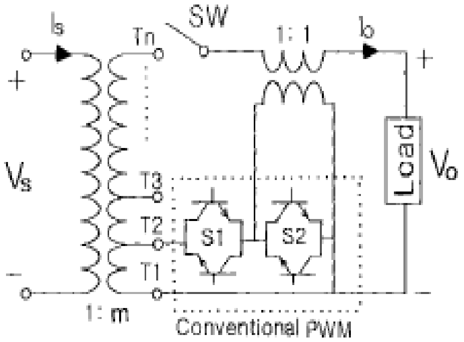


Fig 4.2 Proposed power circuit of AC voltage regulator

4.3 Hybrid Regulators

Usually AC Choppers are used for the reduced voltage output. But the AC choppers also called as AC voltage regulators are bound to more voltage losses due to harmonics. This is rectified by using some PWM techniques. Usual regulators that have PWM techniques for reduced voltage some additional features for enhancing the voltage input. That is done here using the tap changing transformer. Step up as we have discussed before can be done using the tap changing transformer .But we need both step up and step down. So we have to go for a hybrid construction.

The Hybrid constructions have both tap changing transformer and the voltage chopper. The use of a practical SCR voltage controller results in considerable harmonic distortion and substantial additional losses which reduce the net energy saving. The use of PWM AC Chopper eliminates partially this drawback. By proper choice of different PWM combination we can go for reduced harmonic content in the circuit. We are adding both the step down and the tap changer ac voltage regulator to get both step up and step down accordingly.

Microcontrollers are used for the tap changing connection selection with the help of relays and in the PWM generation. For the analysis, Changes in harmonics of output voltage, total harmonic distortion at source and load and experimental results are taken.

Many power supplies use more than one regulation method in series. For example, the output from a switching regulator can be further regulated by a linear regulator. The switching regulator accepts a wide range of input voltages and efficiently generates a (somewhat noisy) voltage slightly above the ultimately desired output. That is followed by a linear regulator that generates exactly the desired voltage and eliminates nearly all the noise generated by the switching regulator. Other designs may use an SCR regulator as the "pre-regulator", followed by another type of regulator. An efficient way of creating a variable-voltage, accurate output power supply is to combine a multi-tapped transformer with an adjustable linear post-regulator.

Voltage controllers are increasingly applied as motor soft starters and sometimes as energy savers, reducing the flux level in the connected induction motor in accordance with the load. However, the use of a practical SCR voltage controller results in considerable harmonic distortion and substantial additional losses which reduce the net energy saving. The use of PWMAC chopper eliminates partially this drawback. Nowadays the applied bi-directional switches may consist of two IGBTs and diodes connected to each other in opposite direction. For proper control, the short-circuit of the supply and breaking the motor current must be avoided.

In the case of proper control, the on and off periods occur in the three phases simultaneously, and the number of chopping periods during one cycle of the line voltage is assumed to be an integer multiple of six (i.e. $6n$). The locus of the voltage Park-vector is assumed to be symmetrical with respect to the three phase axes for the sake of simplicity of calculations.

4.4 MECHANICAL TAP CHANGERS

A mechanical tap changer physically makes the new connection before releasing the old, but avoids the high current from the short-circuited turns by temporarily placing a large diverter resistor (sometimes an inductor) in series with the short-circuited turns before breaking the original connection. This technique overcomes the problems with open or short circuit taps. The changeover nevertheless must be made rapidly to avoid overheating of the diverter. That is why OLTCs are usually comprised of a diverter switch and a tap selector. In the diverter switch powerful springs are wound up, usually by a low power motor (motor drive unit (MDU)), and then rapidly released to effect the tap changing operation. To avoid arcing at the contacts, the tap changers operates in a filled with insulating transformer oil or SF_6 vessel. While the tap selector is usually in the main transformer tank, the diverter switch takes place in a separate compartment to the main transformer tank to prevent contamination of its oil.

One possible design (flag type) of on-load mechanical tap changer is shown to the right. It commences operation at tap position 2, with load supplied directly via the right hand connection. Diverter resistor A is short-circuited; diverter B is unused.

4.5 SOLID STATE (THYRISTOR) TAP CHANGERS

These are relatively recent developments which use thyristors both to switch the load current and to pass the load current in the steady state. Their disadvantage is that all of the non-conducting thyristors connected to the unselected taps still dissipate power due to their leakage current and they have smaller short circuit withstand capacity. This power can add up to a few kilowatts which has to be removed as heat and leads to a reduction in the overall efficiency of the transformer. They are therefore only employed on smaller power transformers.

Switching logic is defined for a single-phase transformer tap changer using thyristor switching. A laboratory model validates the theory and shows that tap changing is possible in less than one cycle over the whole power-factor spectrum. Waveform sampling and the use of a microprocessor based control system provides improved control and additional features such as data logging etc. Two schemes are considered for the application of thyristor tap changing to three-phase transformers. Economic viability is strongly dependent on the associated power system and its abnormal operating features, namely system fault currents and especially the degree of exposure of the transformer to lightning surges.

5. SOFTWARE IMPLEMENTATION

The proposed AC voltage regulator circuit is constructed using MATLAB software. The simulation circuit and output waveforms of step up and step down are shown.

5.1 SIMULATION CIRCUIT

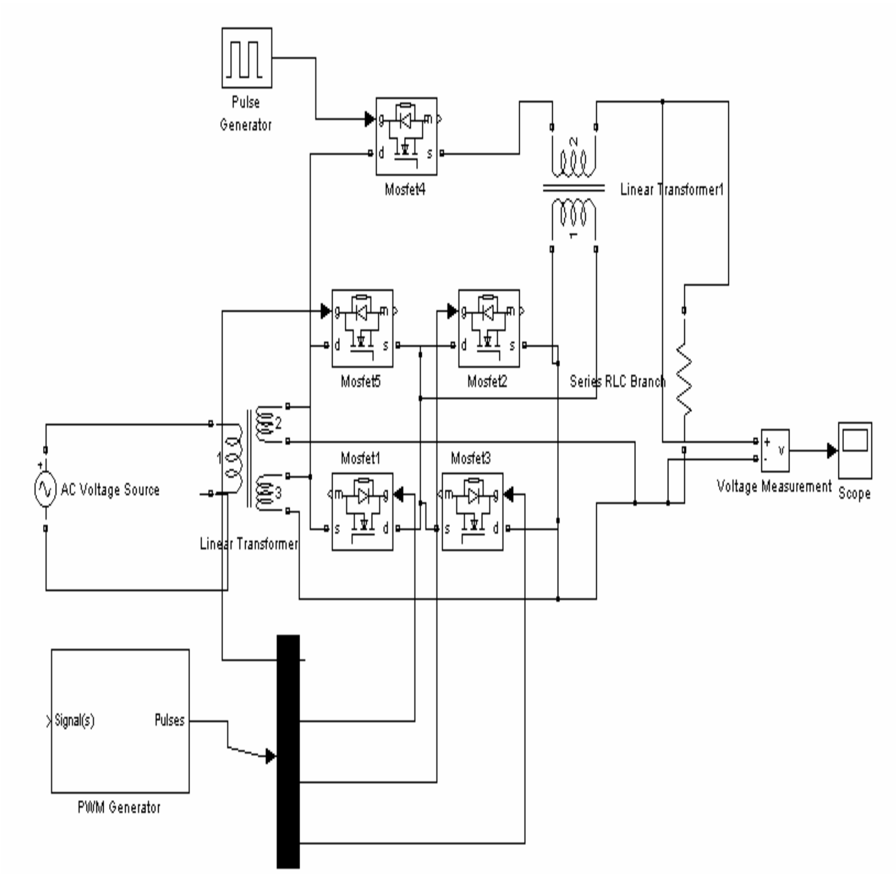


Fig 5.3 Proposed AC voltage regulator simulation circuit

5.1.1simulation output waveform

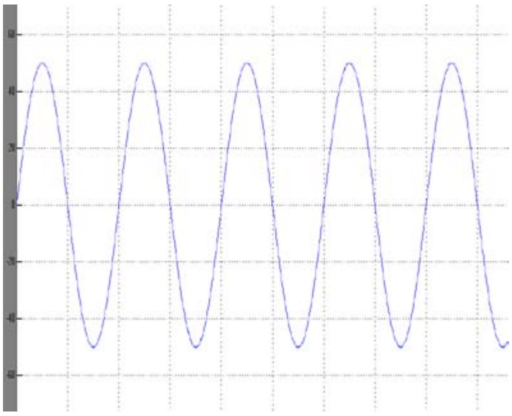


Fig 5.1 Simulation Output before PWM

<u>Scale</u>

X axis Time in seconds

Y axis voltage in volts

5.1.2 Simulation Output after PWM

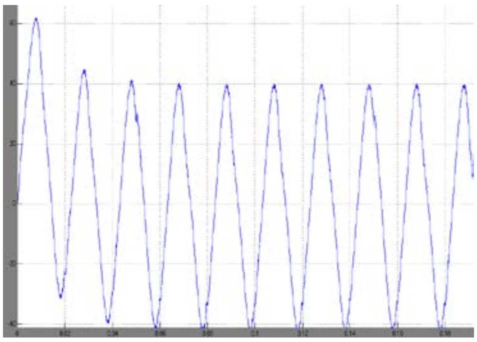


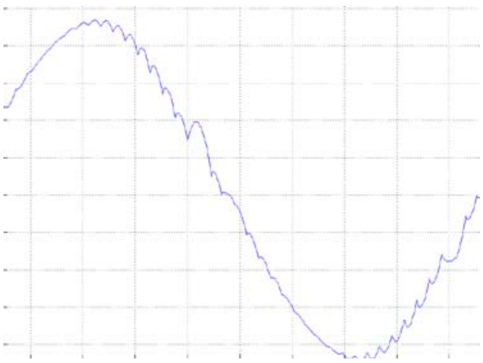
Fig 5..2 Simulation Output after PWM

<u>Scale</u>

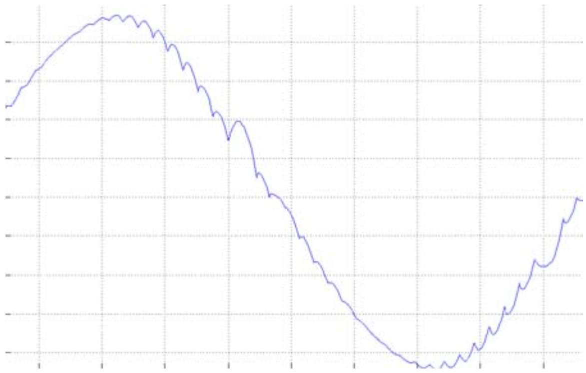
X axis Time in seconds

Y axis voltage in volts

Voltage waveform



Current waveform

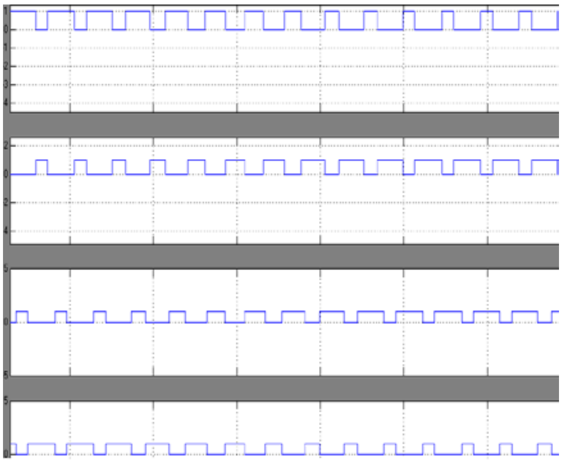


Scale

X axis Time in seconds

Y axis voltage in volts

Gate pulses to switches



Scale

X axis Time in seconds

Y axis voltage in volts

6. CONCLUSION

A step-up/down ac voltage regulator has been proposed, in which the transformer with tap changer and the PWM ac chopper are combined. The proposed regulator can step up or step down the output voltage to input voltage and restrains more harmonics of the output voltage compared to the conventional regulators. Input current of the proposed regulator flows continuously except for connecting Tap T1, while in the conventional PWM, it flows discontinuously. We are simulating the circuit with MATLAB simulink block set and it is inferred to be correct. Further implementation of hardware is to be done.

7. BIBLIOGRAPHY

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