A Novel Simple Reliability Enhancement Switching Topology for Single Phase Buck-Boost Inverter

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Abstract: The buck-boost inverter provides boosting and inversion function in a single power processing stage based on the front end buck-boost converter characteristics. The static stabilizer offers a reasonable slow servo controlled as well as other static tap changing facility. The basic topology is with buck-boost transformer with high primary to secondary ratio for voltage correction of 25%. The control voltage is imposed on the primary side of the buck-boost transformer. The voltage regulation of this topology is achieved electronically with the step changes in voltage. This task is accomplished through a feedback and control system implemented. The system uses IGBTs as power switches. Direct AC-AC converter circuit improves the overall system response and fast voltage correction. Number of storage capacitor usage will increase the life of the system. 20 KHz PWM control operation using Microcontroller Atmega16 to achieve time of 1 to 1.5 cycles. Simulation results vividly validate the proposed idea of single phase buck-boost inverter.

IndexTerms - buck-boost inverter, PWM, IGBT Chopper.

I. INTRODUCTION

The smooth functioning of the majority of electrical and electronic equipment depends on the supply voltage correctness and steadiness. Nowadays, many industries and private users are subjected to long-lasting fluctuations that can be inconvenient or even dangerous. AC voltage stabilizers are used for obtaining a steady AC supply with very close tolerances from fluctuating mains. They find application in a very wide variety of fields. Static Voltage Stabilizer is an IGBT based PWM type buck-boost voltage stabilizer which has tight regulation and fast correction speed which is impossible to obtain conventional methods. In this topology there is no need to convert the AC input to DC and again convert it back to regulated AC output. This simplifies the design, reduces the component count and improves the efficiency and reliability. The power stage is an IGBT chopper control.

The chopping frequency is around 20 KHz which ensures absolutely silent operation and pure sine wave output (no waveform distortion). The control section is based on micro controller which ensures quick correction of output which is not possible in conventional relay type stabilizer or servo controlled stabilizers. Since the circuit is fully solid state (no mechanical or moving parts) there will not be any wear and tear like the brush tear in servo stabilizer or relay degrading in relay based stabilizer. This is especially useful in places where we need very fast correction speed, constant output voltage, overload current limiting and short circuit protection, soft start, high voltage cut-off and low voltage cut-off, automatic bypass, no wear and tear, long life and maintenance free which is impossible with other conventional relay type or servo control stabilizers.

II. BRIEF LITERATURE SURVEY

This paper presents a single phase two-quadrant PWM rectifier to power fixed DC voltage at the input of inverter module will be presented in this paper. The proposed PWM rectifier can be operated as a single phase bridge rectifier to maintain well-regulated and boosted DC-link voltage for Inverter module. The control of this converter is realized using analog type closed loop circuit. A proportional-integral type controller is designed, and the PWM type switching control signal for IGBT is generated by Op-amp circuitry. In idle case, the proposed PWM rectifier can be arranged to act as a single phase full bridge rectifier [1].

This is an SMPS type voltage stabilizer for mains voltage (AC input and AC output). This is a new switching topology where PWM is made directly in AC-to-AC switching, without any harmonic distortion. In this topology there is no need to convert the AC input to DC and again convert it back to regulated AC output. This simplifies the design, reduces the component count and improves the efficiency and reliability [2].

In this the author analyzed that the Voltage stabilizer provides an output voltage with a specified limit for supplying to load irrespective of wide fluctuation in the input voltage, independent of load power factor and without introducing harmonic distortion. The voltage stabilizer adjusts automatically the voltage variation whether high or low to the proper voltage level necessary for the safe operation of equipment’s [3].

This paper proposes the design and implementation of a microcontroller-based single-phase automatic voltage regulator (AVR). The basic building blocks for this design include a PIC 16f 628 microcontroller, a triac, a step-up transformer, a zero crossing circuitry and a load voltage sensing circuitry. This design is based on the principle of phase control of ac voltage using a triac. The trigger pulse for the triac is delayed by the microcontroller to provide the desired regulator terminal voltage. This voltage is always sensed and fed back to the microcontroller via a measuring unit to get a
continuous control system. One of the intensions to develop this AVR is to use it in domestic heating and lighting controls [4].

In this present paper, stress has been laid upon the present scenario of power quality in every grid. With more and more use of nonlinear electrical loads instead of linear loads, we get increased efficiency with reduced power requirements; however this degrades the power quality of whole power system. Power quality is basically determined by the voltage [5].

III. DESIGN OF EXPERIMENTATION

III.I Software Design

The basic building block of this project is as shown below:

![Simulation Diagram of Software Design](image1.png)

As per the simulation diagram shown in figure 1, the details of each block with sub diagram are described in detail:

III.I.I Main Supply

![Schematic Diagram of Main Supply](image2.png)

The 230v AC supply is taken from grid. The pulses are increased or decreased by multiplying 1.2 and 0.85 respectively according to the requirement. Then that pulses are get multiplied in the multiplier box. The output can be recorded at Scope 2. The pulses are required to change the input for another reading. The input which are required is ready at controlled voltage source cvs1. We can change input in simulation by changing the value of Vs.

III.I.II Input Measurement

![Schematic Diagram of Input Measurement](image3.png)

This block shown in Figure 3, is connected for the measurement of voltage and current. Further, it is connected to scope for input waveform of current as well as voltage.
As shown in Figure 4 input voltage 169V, which is given to the system for measurement.

III.III Reference Generator

In this block sinusoidal waveform are generated by providing a simple program.

III.IV Subsystem

In this block PI controller are used for a generation of pulses. Those pulses are given to the inverter circuit for triggering of IGBT. As shown in main simulation Fig. no 5.1 the output of subsystem is given to the scope for the observation of error and gate pulses of inverter. Waveforms are as shown below in Figure 7.

III.V Inverter

In this block IGBT inverter are used to convert DC into AC and again it is converted to AC using inverter.
III.I.VI Coupler

In Figure 8, two signals are present—one directly from the Grid and another from the output of the inverter. In this block, phase shift and magnitude of the two signals are checked. If they are out of phase, it is harmful to the circuit. Therefore, both signals are started from zero firing angles. According to the feedback network, constant output is obtained by adding or subtracting the signals. For adding or subtracting, a transformer is used which is present in the block of the trans couple. Its schematic diagram is as shown below.

III.I.VII Output Measurement

In this block, a constant output is obtained, which is 174V as desired. In this block, only scopes are connected for measuring output voltage and current. Waveforms of output voltage and current are as shown below:

From the above figure 11 of waveform, it is observed that the output voltage is constant though there is variation in input as shown in the figure above.

III.I.VIII Powergui

The Powergui block is necessary for simulating any Simulink model containing Simulink Power System blocks. It is used to store the equivalent Simulink circuit that represents the state-space equations of the Model.[6] The Powergui block allows you to choose one of the following methods to solve your circuit:

- Continuous method, which uses a variable step Simulink solver.
- Discretization of the electrical system for a solution at fixed time steps.
- Phasor solution method

### III.II Hardware Design
The main connection diagram of this project is as shown below:

![Schematic model of Hardware](image)

The above figure shows the schematic diagram of Hardware Model. The various components used in the above model is as Adapter, different types of microcontroller, LCD, relays, voltage regulator, Heat Sink, diode rectifier, snubber circuit, transformer, Isolators and drive circuit etc.

### IV. SPECIFICATIONS OF COMPONENTS USED

<table>
<thead>
<tr>
<th>Table.1</th>
<th>Specifications of Components Used</th>
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<tbody>
<tr>
<td>Serial. No.</td>
<td>Component</td>
</tr>
<tr>
<td>1</td>
<td>Adapter</td>
</tr>
<tr>
<td>2</td>
<td>ATMEGA8 Microcontroller</td>
</tr>
<tr>
<td>3</td>
<td>7805 Regulator</td>
</tr>
<tr>
<td>4</td>
<td>7812 Regulator</td>
</tr>
<tr>
<td>5</td>
<td>Transformer</td>
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<td>6</td>
<td>Relay</td>
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### V. DESIGN CRITERIA

#### V.I Diode Bridge Rectifier

Input line voltage $\equiv 230V_{ac}$
Output DC voltage $\equiv 300V_{dc}$
Load current $\equiv 2$ Amp.

\[
V_m = \sqrt{2} \times 230 = 325 \text{ V}
\]

\[
V_{dc} = 2 \times V_m / \pi = 2 \times 396 / \pi = 210 \text{ (without filter)}
\]

Diode :
- $V_R (\text{max}) > V_m > 396 \text{ Volts}$
- $I_R (\text{max}) > I_0 > 2.2 \text{ A}$
- $I_{\text{surge}} > I_p > 34.15 \text{ A}$

selected diode are $D_1$ to $D_4 = 1N5408$

![Table 2 Specifications of Diode](image)
1. Maximum Average Forward Rectified Current ($I_{av}$) 3 A
2. Maximum Recurrent Peak Reverse Voltage ($V_{rm}$) 400 V
3. Maximum DC Blocking Voltage ($V_{dc}$) 400 V

V.II IGBT
While selecting IGBT

\[ V_{ds} > 0.707 \times V_{dc} \quad \text{[let } m_{a}=1 \text{ (max)]} \]

\[ > 0.707 \times 300 \]

\[ > 212 \text{ volts} \]

\[ V_{gs} > 12 \text{ volts} \]

\[ I_{d} > I_{L} \text{ max} \]

\[ > 2 \text{ Amps} \]

Switching time should be as small as possible selected IGBT is FGA15N120.

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<tbody>
<tr>
<td>1.</td>
<td>Drain-Source Voltage</td>
</tr>
<tr>
<td>2.</td>
<td>Gate-Source Voltage</td>
</tr>
<tr>
<td>3.</td>
<td>Continuous Drain Current</td>
</tr>
<tr>
<td>4.</td>
<td>Turn-Off Delay Time</td>
</tr>
<tr>
<td>5.</td>
<td>Fall Time</td>
</tr>
</tbody>
</table>

Table .3 Specifications of IGBT

V.III Isolator and Drive Circuit
Selected isolator is 4N35 which has got IRED and phototransistor internally.
The maximum forward current for LED = 20mA
Peak output voltage of ATMEGA8 will be = 5 V
Let maximum current for LED to be selected as 0 mA

\[ R = \frac{V_{i}}{I_{f}} \]

\[ = \frac{5}{20} \text{ A} \]

\[ = 250 \Omega \]

Selected \[ R = 270 \Omega \frac{1}{4} \text{ w} \]

With this value,

\[ I_{f} \text{ (max)} = \frac{5}{270\Omega} \]

\[ = 18.5 \text{ mA} \]

Which is acceptable value for 4N35
Selected Resistors are = 270 $\Omega \frac{1}{4}$ w each.

4N35 requires supply voltage = 12 $V_{dc}$
So we design power supply for the rating 100 mA.
Using transformer of 12-0 secondary voltage.

\[ V_{m} \text{ (sec)} = \sqrt{2} \times 12 = 17 \text{ V} \]

Selected ripple voltage $V_{opp} = 0.5 \text{ V}$
For same voltage, at any input range of AC supply we used a regulator IC as 7812.

Selected Opto Coupler is 4N35 which has
Using transformer of 12-0 secondary voltage.

\[ V_{m} \text{ (sec)} = \sqrt{2} \times 12 = 17 \text{ V} \]

got IRED and phototransistor internally.
The maximum forward current for LED = 20 mA
Peak output voltage of ATMEGA8 will be = 5 V
Let maximum current for LED to be selected as 20 mA

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with this value

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Which is acceptable value for 4N35
Selected Resistors are = 270 $\Omega \frac{1}{4}$ w each.
4N35 requires supply voltage $= 12 \, V_{dc}$.
So we design power supply for the rating 100 mA.

Selected ripple voltage $V_{r_{pp}} = 0.5 \, V$
For same voltage, at any input range of AC supply we used a regulator IC as 7812
Hence $V_{dc} = 12 \, V$

<table>
<thead>
<tr>
<th>Table.4 Spécifications of Isolator and Drive Circuits</th>
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</thead>
<tbody>
<tr>
<td>1. Collector emitter breakdown voltage 70 V</td>
</tr>
<tr>
<td>2. Collector current 100 mA</td>
</tr>
<tr>
<td>3. Forward current 20 mA</td>
</tr>
<tr>
<td>4. Reverse voltage 6 V</td>
</tr>
</tbody>
</table>

VI. SOFTWARE REQUIRED
- MATLAB SIMULINK,
- ATMEL STUDIO 6.0,
- PCB ARTIST,
- SINAPROG

VI. RESULT
The ultimate aim of this project is obtain constant output voltage even there is increase or decrease in input voltage. This can observed by combine view of input and output voltage which is as below:

![Waveform of Input and Output Voltage](image)

<table>
<thead>
<tr>
<th>Table.5 Result of Simulation and Hardware Model</th>
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<tbody>
<tr>
<td>Serial No</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>4</td>
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From the above results we can say that, simulation model gives more accurate results than the hardware model. There is a slight difference between both the outputs which is negligible.

VII. CONCLUSION
A single phase buck-boost inverter has been proposed in the paper. The topology is simple, symmetrical and easy to control. The other desirable features include good efficiency due to optimal number of device switching’s and reduced switching issues. The proposed inverter has a number of attractive features, such as covering the low and variable input voltage, low switching losses, boosting and inversion functions, few voltage and current sensors, and finally resulting in a low cost solutions.

REFERENCES