Design of 50KVA Single Phase Static Inverter

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Abstract-- This paper gives the design and implementation of a 50KVA single phase static inverter that uses insulated gate Bi-polar Transistors (IGBTs) to produce an alternating current square wave at a frequency determined by a crystal controlled oscillator. The output is filtered by a ferroresonant regulator, which creates a low distortion sine wave output from the square wave input and regulates with a minimum amount of components. In addition, it has a built-in current limiting feature for inverter protection. A DC to AC voltage converter consists of four bidirectional switches that is used to convert the voltage. Single phase static inverters are true on-line ferroresonant transformer-based designs intended for use in UPS systems or in stand-alone applications. The control circuit has a small size for the single phase bridge inverter and it is low cost. The driver circuit isolates the control circuit from power circuit. The output for variable AC voltages are discussed.

Keywords-- single phase, static inverter, Gate Bi-polar Transistors (IGBT's), ferroresonant regulator.

I. INTRODUCTION

A wide range of inverters has been designed to follow rigorous mains compatibility and erratic power supply. The technology associated with efficient conversion, control and conditioning of electric power by static means from its available input form into the desired output form is Power Electronics and it can be found wherever there is a need to modify the electrical energy form (i.e., modify its voltage, current or frequency). The single phase static inverter uses Insulated Gate Bi-polar Transistors (IGBTs) to produce an alternating current square wave at a frequency determined by a crystal controlled oscillator. The output is filtered by a ferroresonant regulator, which creates a low distortion sine wave output from the square wave input and regulates with a minimum amount of components. In addition, it has a built-in current limiting feature for inverter protection. Inverters are used in a wide range of applications, from small switching power supplies in computers, to large electric utility applications that transport bulk power. Static inverter can be built and installed in modules of 3 to 50KVA up to the load capacity.

II. BACKGROUND OF SINGLE PHASE INVERTER

There are two types of single phase inverters namely:

(a) Half- Bridge inverter: This is the most common single-phase inverter as shown in figure 1.

Since most loads contain inductance, feedback rectifiers or antiparallel diodes are often connected across each semiconductor switch to provide a path for the peak inductive load current when the semiconductor is turned off. The antiparallel diodes are somewhat similar to the freewheeling diodes used in AC/DC converter circuits. The H-bridge inverter consists of four switches. When switches T₁ and T₂ are turned on simultaneously, the input voltage Vₛₐₚₐₜ appears across the load. If switches T₃ and T₄ are turned on at the same time, the voltage across the load is reversed and is -Vₛₐₚₐₜ [4].

(b) Full Bridge Single Phase Inverter: The DC to AC converter, also known as inverter converts dc power to ac power at desired output voltage and frequency [3]. The output voltage of an inverter has a periodic waveform that is not sinusoidal but can be made to closely approximate this desired waveform. Figure 2 shows the circuit topology for a full bridge inverter. It is an electronic power converter that is necessary as an interface between the power input and the load. The full bridge single phase inverter consists of the DC voltage source, four switching elements S1, S2, S3 and S4 and load. The switching element available nowadays, such as bipolar junction transistor (BJTs), gate turn off thyristor (GTOs), metal oxide semiconductor field effect transistors (MOSFETs), insulated gate bipolar transistors (IGBTs), metal oxide semiconductor controlled thyristor (MCT’s) and static induction transistors (SIT’s) can be used as a switch. They are substituting the relays, magnetic switches and other magnetic components as the inverter switching devices. This makes use of microcontroller becomes more significant. The full bridge single phase inverter has two legs, left or right or ‘A’ phase leg and ‘B’ phase leg. Each leg consists of two power devices (here MOSFET) connect in series. The load is connected between the midpoints of the two phase legs.
Each power control device has a diode connected in anti-parallel to it. The diodes provide an alternative path for the load current if the power switches are turned OFF. For example, if lower MOSFET in the ‘A’ phase leg is conducting and carrying current towards the negative DC bus, this current would ‘commutate’ into the diode across the upper MOSFET of the ‘A’ phase leg, if the lower MOSFET is turned OFF. Control of the circuit is accomplished by varying the turn on time of the upper and lower MOSFET of each inverter leg with the provision of never turning ON both at the same time, to avoid a short circuit of DC bus.

III. INVERTER ARCHITECTURE

When designing an inverter there are three basic schemes to convert the fuel cell plus boost module’s DC energy into AC. For example, this AC may then be fed into the grid or can be used for stand-alone operation of 220-240V appliances.

There are three types of inverters

(a) Step-up and chop: This type converts the low voltage into a high voltage first with a square-wave step-up converter and then converts the high-voltage DC into the wanted AC waveform (Fig.4).

(b) High voltage in, only chop: This type requires the input voltage to be higher than the output voltage and converts it directly into the wanted AC waveform (fig.5). The advantage of this is the high efficiency of the inverter, typical 96%. The main disadvantage is the lack of insulation between the solar modules and the grid voltages. Also the input voltages always require a large number of modules.[2]

(c) Chop and transform: This type converts the low voltage DC into a low voltage AC first and then converts the low-voltage AC into the wanted AC voltage (fig.6).
The advantages are the low-voltage (safe) operation, the insulation from the grid after the inverter, the ease with which it makes sine wave which feeds into the transformer and the most important in many aspects, reliability due to the low number of semiconductors in the power path. Disadvantage is the slightly lower efficiency of the inverter, typically 92%. Also some hum can be generated by the transformer under load. [2]

There are several types of power inverter available in two categories-the true sine wave power inverter produces utility grade power. These inverters are very expensive and can power almost anything including laser printers fax machines, fans, television set, computers etc. A sine wave inverter is recommended to operate higher electronic equipment.

Modified sine wave type of inverter can adequately power most household appliances and power tools. It is more economical, but may present certain compromises with some loads such as microwave ovens, laser printers, clocks and cordless tool chargers. Simple inverters make use of oscillators driving a transistor to create a square wave, which in turn is fed through a transformer to produce the required output voltage, while advanced inverters have started using more advanced forms of transistors of similar devices such as thyristors.

The main objective is to design and construct 50KV A single phase static inverter having low audible noise, high efficiency transistor bridge, high reliability exceeding 100,000 hours, harmonic filter for distributed control systems, microprocessor based alarms and industrial grade built to operate in extreme environments.

IV. SINGLE PHASE STATIC INVERTER PROCESS

The block (Fig.7) and circuit (Fig.8) diagrams of a 50KVA single phase static inverter are presented below.

The inverter’s basic function is to convert DC power from a rectifier/charger or battery to an extremely accurate, regulated AC output for powering the critical AC load. Each inverter includes a static transfer switch and manual bypass switch. The Static Switch is isolated using high voltage reed relays and automatically transfers a critical load from the output of a failed or overloaded inverter to a bypass source of power without interruption.

The Manual Bypass Switch is a two-position manual make before-break switch used to bypass the inverter and static transfer switch for maintenance purposes.

Phase Inverter- What It Does And How It Works?

Of all the circuits in a tube amplifier, the Phase Inverter, also known as the Phase Splitter, is the most difficult to understand by even some experienced technicians. It’s function is to take a signal input, and create two outputs, one that is identical (e.g. in-phase) to the original, and another that is a mirror-image (phase-inverted or flipped phase). Each signal feeds a power tube (or bank of power tubes) that is connected to each side of the Output Transformer’s primary winding in the typical Push-Pull configuration. Single-ended power amp, like those contained in the Fender Champ, which sport only one power tube, do not require this additional step, and need only a driver before the power tube to boost the preamp signal to a level usable by the lone power tube. So, why is the Push-Pull method of power amplification used when it is inherently more complex and costly? Several reasons. First of all, it enables us to use a more efficient amplifier class called Class AB.
Whereas single-ended audio amplifiers always run in the Class A mode, which runs the tube constantly at maximum power (thereby shortening its lifespan), Class AB runs each tube only slightly above the lowest operational point (called “idle”), and each one is called on as needed to deliver power when necessary. No signal in, no power use, therefore the tubes remain relatively cool until pushed. The second reason for using Push-Pull is that unwanted sonic artifacts, such as hum and odd-harmonic distortion (this is the nasty, raspy kind), are naturally cancelled in the Output Transformer. Even-order harmonic distortion (the kind that sounds cool), remains relatively untouched. There are two designs that dominate guitar amps. One is the “Cathodyne”, also known as the “Split-Load” (Fig. 9), and the other is the “Long-Tailed Pair”, derived from a circuit called the Schmitt Inverter (Fig. 10).

Common-Cathode (where the cathode is grounded and signal is fed to the grid, the most common type of triode amplifier), Common-Grid (where the grid is grounded and signal is fed to the cathode), and Common-Anode (where the plate is “grounded”, not to 0V, but directly to the power supply, which is a “virtual ground”, also called a “Cathode Follower” and, rarely, a “Buffer”). Since the Cathode Follower does not provide signal voltage gain but. It does deliver current gain, which is good for circuits like tone stacks that tend to hog current. However the other two amplifier arrangements, Common-Cathode and Common-Grid do provide voltage gain, though the Common-Grid amplifier isn’t quite as effective as the Common-Cathode amplifier in doing this. The gain for a given signal input is less than that of the Common-Cathode circuit. What the “Long-Tailed Pair” does is to use two triodes, one in a Common-Cathode arrangement, the other as a Common-Grid amp. The signal enters the first stage (Common-Cathode) in the usual way, through the grid. This produces a voltage swing on the plate and the cathode of this stage, as described earlier. The second-stage, which has a common (grounded) grid, has it’s output at the plate, like the first stage. Feeding signal into and tying the cathode of the first stage to the cathode of the second stage, the variation in current of the first stage is superimposed on the cathodes of the second stage. Here is the circuit again, redrawn and simplified in Fig 11. Basically, the plate circuit, which has voltage gain, sends it’s signal to the power tubes. The cathode circuit, which is essentially a cathode follower, since there is no voltage gain, the second stage Common-Grid amp provides the gain. This is the key element missing in the Cathodyne Phase Inverter (Fig.9). After voltage gain is applied, the signal then travels to the power tubes as well. The Common-Cathode amp has higher voltage gain than that of a Common-Grid amp.
In an attempt to balance this out, the plate resistor of the Common-Cathode circuit is slightly reduced, reducing the gain of that stage. In many tube amps, it will be reduced to 82K against 100K for the second stage. All else remaining equal, lowering the plate resistor value also lowers the gain of the stage. The secondary effect of this is that the actual signal is not balanced on both sides, making the output somewhat asymmetrical (i.e. the positive signal swing is not equal to the negative signal swing).

The static inverter is designed for AC output voltage of 220VAC. Load power factor is 0.8 (harmonic power factor). This gives the inverter output power of 176Watts.

The block diagram has three modules.

- Power Circuit Module
- Control Circuit Module
- Driver Circuit Module

Fig.3 shows the booster required signal

V. EXPERIMENTAL RESULTS

After programming the PIC, they were tested in order to show the output signals. Fig.13 shows the booster required signal which was generated by the PIC and displayed using the oscilloscope.

Fig.13 shows the booster required signal

VI. CONCLUSION

The design and implementation of a single-phase inverter that produces a symmetric ac output voltage of desired magnitude and frequency. The digital signal Peripheral Interface Controller of Microchip Technology is used for the implementation of the inverter. The Inverter consists of four bidirectional switches that is used to convert the voltage. Sinusoidal Pulse Width Modulation is used for triggering the gates of IGBTs. The control circuit consists of the PIC controller that is used to produce required PWM signal. The voltage and the frequency can be varied by connecting the controller to the computer. The simulation of the circuit is done using Simulink of Matlab. The outputs for variable AC voltages are observed in the CRO with comparison of the standard values against those of Simulation waveforms and the output waveforms.

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