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Study of Inverter Design and Topologies for Photovoltaic System

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***Abstract*— The growing demand on energy, high oil prices and concerns of environmental impacts has increased the development of renewable energy such as wind, solar, ocean, biomass and geothermal power. Solar energy is amongst the highest development of renewable resources. With the rapid progress of the power electronic techniques, solar energy as an alternative energy source has been put to use such as photovoltaic (PV) module. In any PV based system, the inverter is a critical component responsible for the control of electricity flow between the modules, battery and loads. This paper presents the theoretical operation of inverter topologies which are Push-Pull and H-Bridge.**

***Keywords*—solar energy, power electronic, photovoltaic system, inverter, Push-Pull,H-Bridge.**

I. INTRODUCTION

The development of renewable energy such as sun, geothermal, biomass and wind have become important contribution to the total energy consumed in the world. These alternative sources of energy can never be exhausted. They cause less emission and therefore stand out as a potentially feasible source of clean and limitless energy. These resources do not cause any significant environmental pollution or substantial health hazards and apparently available as natural abundant resources. Solar energy is amongst the highest development of renewable resources. Malaysia is one of the countries that receive abundant of sun light in average mostly in northern side of Peninsular Malaysia. Perlis, Kedah and Penang have high potential in applying solar energy. With the rapid progress of the power electronic techniques, solar energy as an alternative energy source has been put to use such as photovoltaic (PV) module. The basic concept for PV module is to collect solar energy in space and transfer it for distribution as electrical power [1]. However this renewable source energy requires rather sophisticated conversion techniques to make them usable to the end user. The output of PV is essentially direct current (DC) form. Therefore, it needs to be converted to alternating current (AC) for it to be commercially feasible. This is necessary because the power utilisation is mostly in AC form [2]. This conversion can be done by using inverter. In any PV based system, the inverter is a critical component responsible for the control of electricity flow between the modules, battery and loads. Inverters are essentially DC-AC converters. It converts DC input into AC output. It can be designed to be used with different voltage ranges and topologies for varying applications [3].

II. PHOTOVOLTAIC SYSTEM

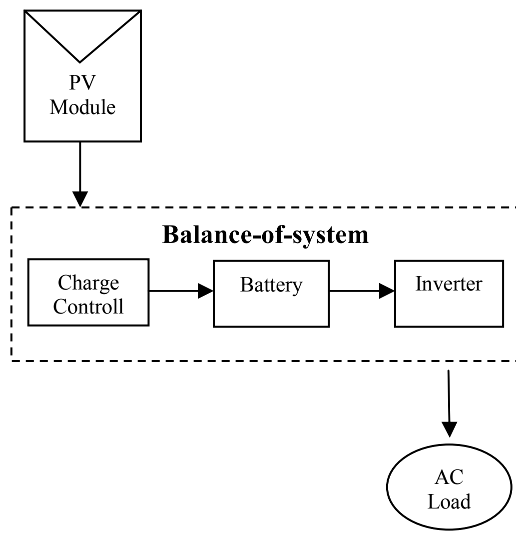

Figure 1. Block diagram representation of Photovoltaic System.

A photovoltaic system is a system which uses solar cells to convert the energy of sunlight into electricity. Photovoltaic-based systems are generally classified according to function, operation requirements, component configurations and the equipment connection to other power sources and electrical loads. This photovoltaic system consists of three main parts which are photovoltaic modules or array, a set of devices and structures that enable the PV electricity to be properly applied to the load known as Balance of System (BOS) components and the last part is load. The major BOS components in this system are charger, battery and inverter.

PV modules convert sunlight instantly into DC electric power. The function of charge controller is protecting the battery from overcharging by monitoring the battery. If the battery is fully charged, the controller interrupts the flow of electricity from PV modules. This can prolong the battery life of the PV system. In PV system, the battery is uses for energy storage. It acts as energy back-up during cloudy days and at night. The PV modules continue to re-charge batteries each day to maintain the battery charge. This system need an inverter to convert the DC output of PV modules into standard AC power for use in the home, synchronizing with utility power whenever the electrical grid is distributing electricity.

III. INVERTER DESIGN AND TOPOLOGY

There are many topologies or circuit designs for creating higher power AC from low voltage DC sources. Two common topologies are the Push-Pull and H-Bridge. The Push-Pull topology is suitable for producing square and modified square wave inverter while the H-Bridge is useful for producing modified square wave and sine wave inverter.

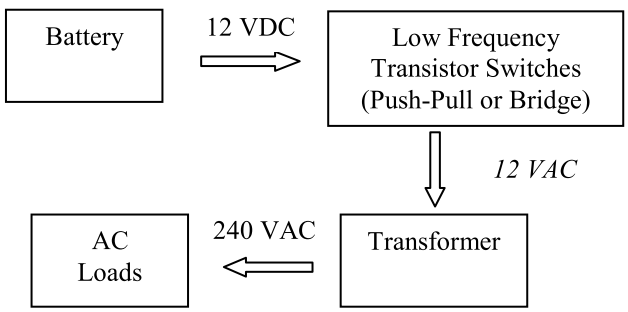

Figure 2. General flow of an inverter.

A. *Push-pull Topology*

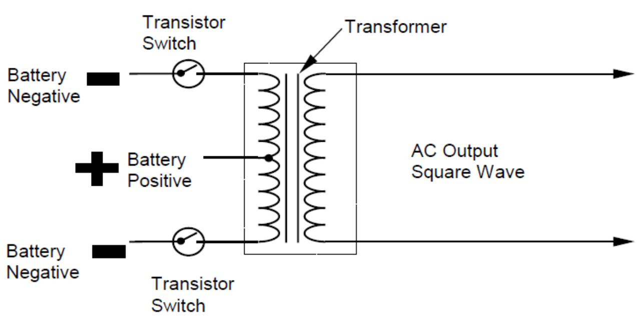

Figure 3. Push-Pull Topology for Square Wave Output.

The basic theory of Push-Pull topology is shown in Fig. 3. There are two transistor switches in this design. If the top switch closes, it will cause current to flow from the battery negative through the transformer primary to the battery positive. This induces a voltage in the secondary side of the transformer that is equal to the battery voltage times the turns ratio of the transformer. This phenomena flow is shown in Fig. 4(a). Only one switch is closed at a time. The switches flip-flop after a period of approximately 8ms which is one-half of 60Hz AC cycle. The top switch opens and then the bottom switch closes allowing current to flow in the opposite direction as illustrate in Fig. 4(b). The continuing of closes and opens switch will produce a square wave output waveform which is higher voltage AC power [4].

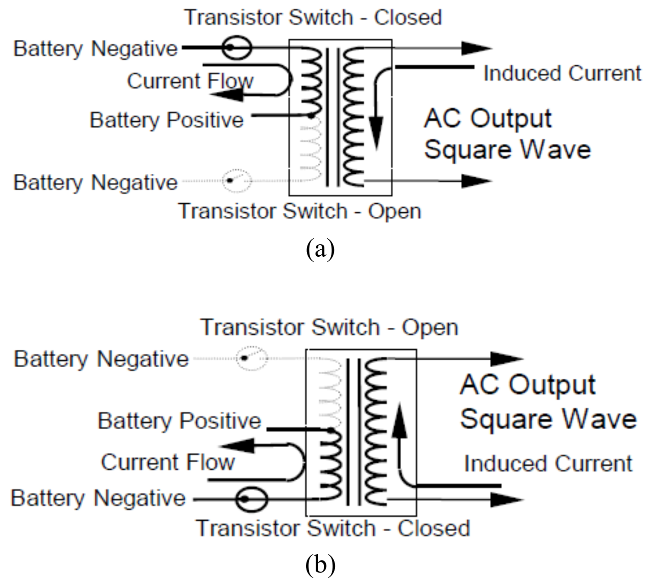

Figure 4. (a) Top switch close state, (b) Bottom switch close state.

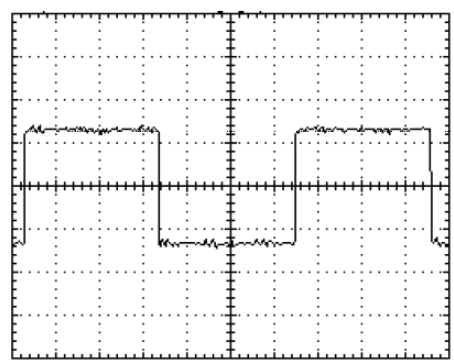

Figure 5. Square Wave Output.

The addition of an extra winding in the transformer along with a few other parts allows output of a Modified Square Wave.

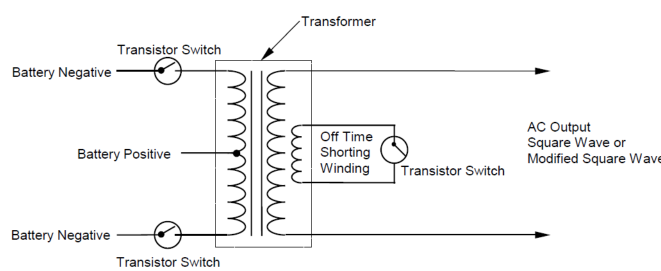

Figure 6. Push-Pull Topology with Shorting Winding.

In the switching cycle, another step is added which is clears out the transformer reducing the problems associated with the sudden change in current direction. This is accomplished by the off time shorting winding shown in Fig. 6. As one switch opens and before the second switch closes, the switch across the shorting winding closes. This is effectively removing the current from the transformer. Off time shorting provides a better zero crossing of the waveform, which equates to better ability to operate electronic devices. Another benefit is improved efficiency and lower total harmonic distortion of the waveform [4].

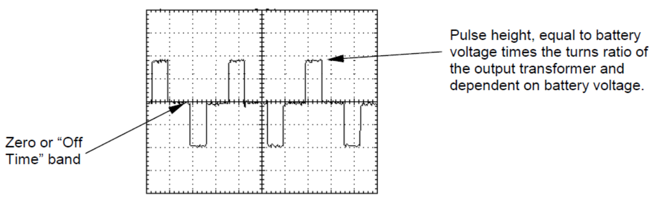

Figure 7. Modified Square Wave and Off Time.

B. *H-Bridge Topology*

The operation of H-Bridge topology is similar to Push-Pull topology. The term H-Bridge is derived from the typical graphical representation of such a circuit. An H-Bridge is built with four transistor switches. The transistors are divided into four groups with the transformer primary connected across the middle of the bridge as illustrate in Fig.8.

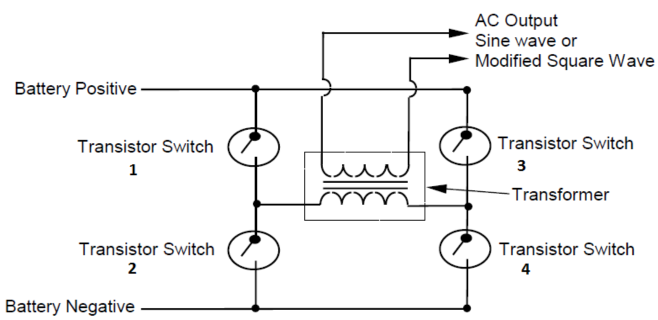

Figure 8. H-Bridge Topology.

The transistors are switched on and off in a specific pattern to produce each part of the waveform. If the switch 1 and 4 are closed, current will flow from the battery negative through transformer primary to the positive terminal of the battery as shown in Fig. 9(a). This current induces a current flow in the secondary of the transformer, which has a peak voltage equal to the battery voltage times the turn ratio of the transformer. The switch 1 and 4 open after a period of time and the switch 2 and 4 close providing off time shorting like in Fig.9(b). The length of the on and off time is determined according to the Pulse Width Modulation (PWM) controller.

Then, the switch 2 and 3 are close and allow current flow through the transformer in a direction opposite to the current flow in Fig.9 (a). This state is shown in Fig.9(c). The switch 2 and 4 are close after this cycle is complete for off time shorting. This cycle will continuous to produce AC power [4].

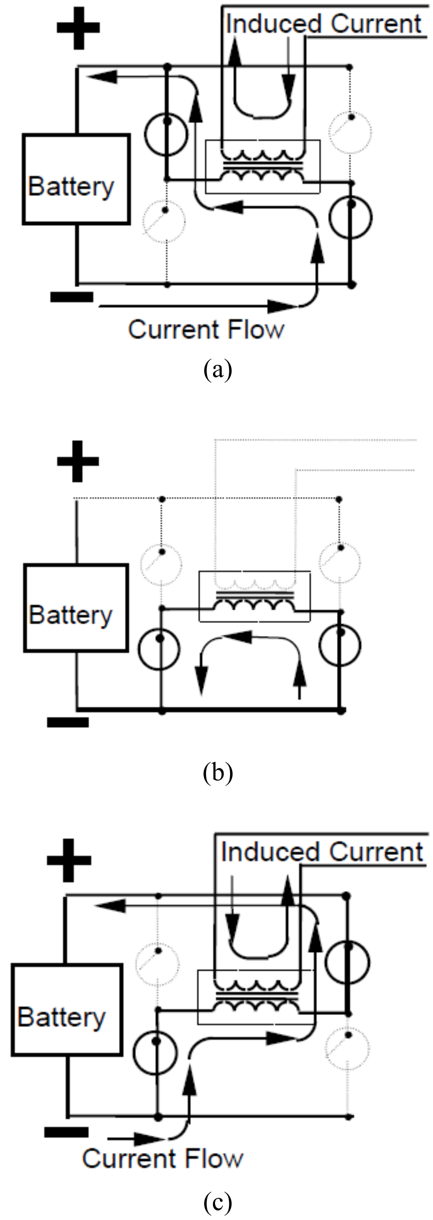

Figure 9. The State Diagram of H-Bridge.

IV. DISCUSSION

The Push-Pull topology was the first step in electronic inverter technology. The advantage of this topology is the simplicity of the overall circuit design and cost effective in manufacturing. But, the major problem is the current in the transformer has to suddenly reverse directions. This will causes a large reduction in efficiency. The disadvantages of this topology are complexity of the transformer design and higher transformer losses in square wave design.

The square wave inverter is the simplest and cheapest form of inverter. But, the output waveform of square wave inverter has high total harmonic distortion (THD). Motor will generate excess heat and most of electronic equipment will not operate well from square wave inverter. Modified square wave inverters have better improvement over square wave types. It has good voltage regulation, lower total harmonic distortion and better overall efficiency. The operation of electric motor is better from a modified square wave and most electronic component will operate without problems.

The advantage of H-Bridge topology is the simplicity of needing only one primary winding on the transformer. The efficiency of this design based on the quality of the transistors used and the number of transistors in parallel. Mostly, the losses in this topology are at the transistor switches. The performance of this design will improve as transistors improve and become available.

For small load applications in PV system, the inverter can be design by using the Push-Pull topologies. This topology is simple and easy to design. This kind of inverter can run the lamp and fan. However some modification of the design is needed for this topology. The next step will continue with further improvement in the circuit design and simulation of this topology in order to improve and modify the circuit design.

V. CONCLUSION

This paper presents the theoretical operational principles of two inverter topologies. As discussed, the Push-Pull and H-Bridge topology of the inverters have advantages and disadvantages. The design of the inverter in PV system is based on the load apply for this system. These theoretical operations are important in designing the inverter to make the solar technology more feasible. The Push-Pull topology is choosing to design the inverter for a small load application in PV system.

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REFERENCES

[1] G. Saravana Ilango, P. Srinivasa Rao, A. Karthikeyan and C. Nagamani, “Single-stage Sine-wave Inverter for an Autonomous Operation of Solar Photovoltaic Energy Conversion System”, Renewable Energy, July 2000.

[2] Assoc. Prof. Dr. Zainal Salam, “Design and Development of a Stand-Alone Multilevel Inverter for Photovoltaiv Applications”, Reseacrh Report, Malaysia, September 2003.

[3] Emmanuel Sambuis and Sangmin Chon, “TMS320C2000TM DSP Controllers: A Perfect Fit for Solar Power Inverters”, Application Report, Texas Instruments, May 2006, pp. 1-8.

[4] Trace Engineering, “A Review of Inverter Design and Topologies”, Trace Engineering Company, Arlington, WA, 1999.

[5] http://en.wikipedia.org/wiki/H-bridge, Retrieved January 12,2011.