University of the Witwatersrand

ELEN4000A

Electrical Engineering Design II

Design Of The Dual-Inverter For Grid-Connection And Islanded Mode

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Abstract: The high-level design for the dual-mode inverter has been proposed. The first stage is required in the design to buck the high input voltage from the PV array to a constant low voltage. The second second stage is for converting DC into AC. The LC filter is introduced to the design to eliminate the harmonic distortions produced by the inverter. IGBT-based switch is proposed to mode transition considering efficiency and response time.

Key words: Hysteresis control, THD - Total Harmonic Distortion, SPWM,

1. INTRODUCTION

Inverter systems are essential for connecting the energy produced using renewable energy sources with the main grid. In order to achieve utility-interaction, it is required that the inverter can be operated in grid-connected mode or the islanded mode, also the inverter system should have a smooth switch between two modes. When the inverter is connected to the main-grid, it is operated as a current source. The current pushed into the grid is monitored to follow the reference (voltage of the grid), the current injected must be in phase with the reference. In the islanded mode, the inverter is used as a voltage source.

2. BACKGROUND

2.1 Literature Review

2.2 Constraints and Assumptions

- The input to the system is 400Vdc ±10% and assumed to be constant at maximum power of 1kW generated from MPPT.
- The output from the system should be a 230Vrms sine wave at 50Hz with with total harmonic distortion within the acceptable range specified by the SANS 62282 (THD less than 5%) and allow inductive loads to be used without damage.
- The system has no earthing issues.
- The system must be simple and robust without the use of the microcontroller.

2.3 Success Criteria

- The presence of smooth transition between modes in the system, operates as the voltage following current source under grid tie, and act as a voltage source under islanded mode.
- The system is able to deliver 230Vrms with a sine wave with THD less than 5% from the filter, since the output from the H-bridge is a square wave which carries higher THD (48.3%).
- The system has functional faults protection (overload and short-circuit).

3. DESIGN OF THE INVERTER SYSTEM

This section highlight the proposed design for the transformerless dual-inverter. Figure 1 shows the block diagram of the dual-inverter system that can operate in islanded mode or grid-connected mode.

The control unit is required for smooth switching between the modes. Under the grid-connected mode, the controller selects the SPWM control to switch the H-bridge. The H-bridge uses the encoded PWM signal and use it to produce high voltage of similar code. Under the grid-tie, the hysteresis control method is used. The LC filter is connected on the output of the H-bridge to filter high frequency harmonics and reduce the harmonic distortions from the H-bridge.

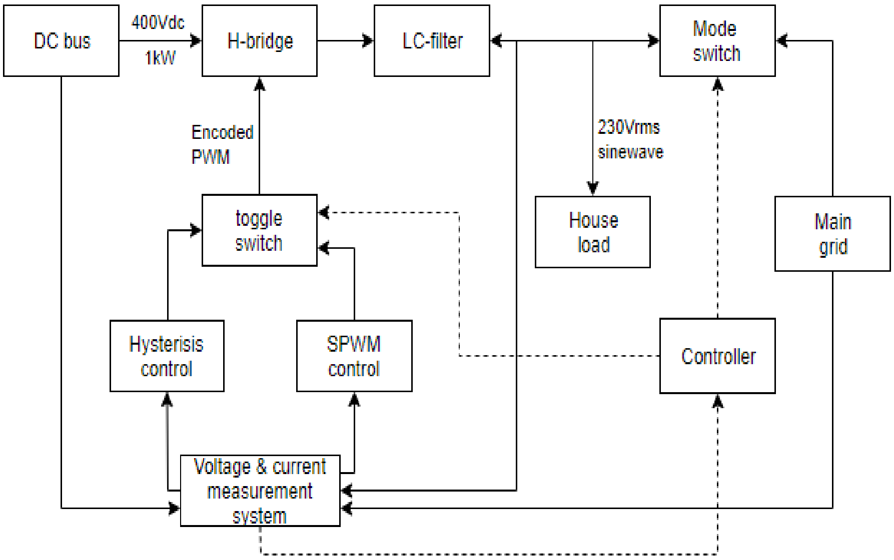

Figure 1: Block diagram of the of the dual-inverter system.

3.1 Inverter Bridge Control

3.1.1 ***SPWM control*** SPWM is a technique used to transform a certain signal into its equivalent form by employing a higher frequency carrier wave. Due to the variation of duty cycle in the PWM, the time voltage span is either increased or decreased. The output voltage will therefore resemble that of the reference of signal. The frequency of the carrier signal should be higher and greater than the reference signal in order correctly sample the reference signal and reduce the effect of distortions on the output of the inverter, the carrier frequency of 20kHz will be used while the reference will be at 50Hz since it is the required frequency as well on the output. Figure 2 below shows the carrier signal (green), reference signal (blue) and the resultant SPWM encoded signal (red).

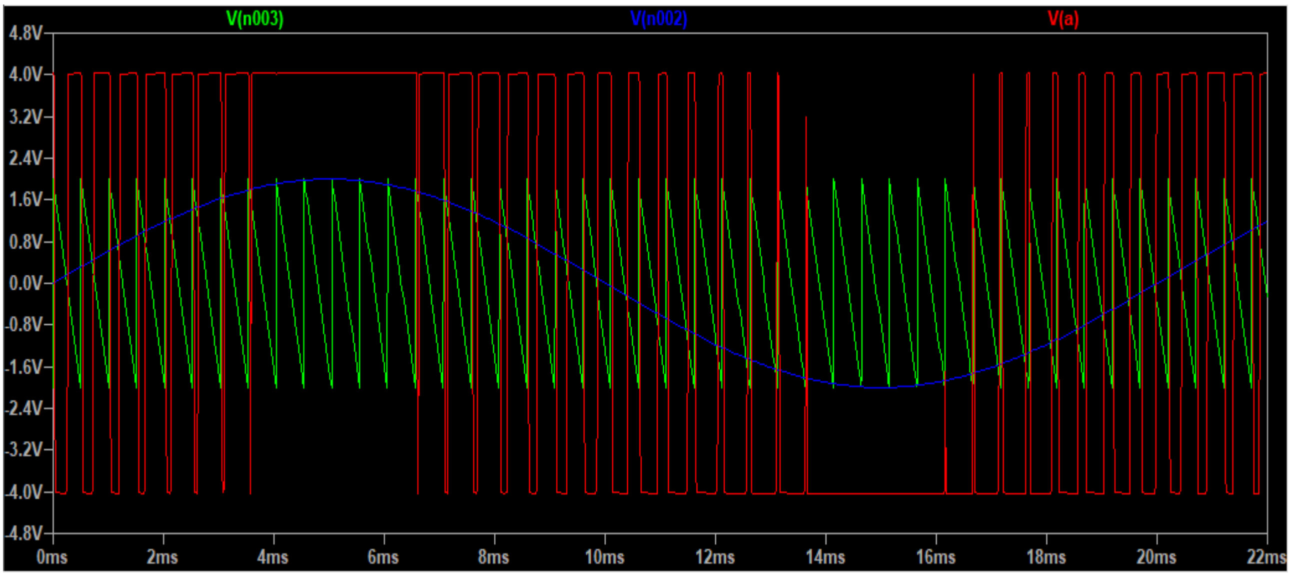

Figure 2: H-bridge inverter power circuit.

3.2 Inverter

Multiple designs of the DC/AC inverter exist. In this design, the H-bridge inverter topology is used due to its simplicity. The MOSFET's switch on in pairs at the time, with bottom left pair with top right MOSFET from Figure 3. The output to the inverter is a square wave.

MOSFET's are susceptible to the electrostatic discharge and their extra insulator increases the capacitance which makes them vulnerable to arcing of the voltage and further damages the internal circuit. The new IGBT can tolerate voltage arcing and overloads. The response of the IGBT is also greater than the MOSFET's [1]. The H-bridge will therefore use the IGBT's.

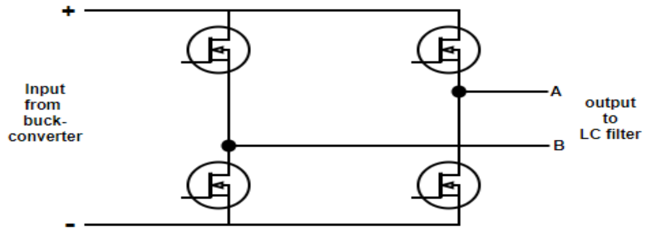

Figure 3: H-bridge inverter power circuit.

3.3 Filter

A filter is required to minimize or eliminate the harmonic distortion produced by the inverter to reach standard recommended value.The LC filter will be used instead of the RC filter. The RC filter limits the maximum output voltage that can be achieved at the output of the inverter due to voltage drop across the resistor. The RC filter also provides less attenuation (20dB/decade) which result in high ripple on the output compared to the attenuation provided by the LC filter (40dB/decade) [2, 3].

3.4 Mode Switch

For the inverter to be utility-interactive, a switch is required to ensure that the inverter system connection and disconnection with the main-grid is rapid and smooth. The system mode switch will utilize the IGBT-based switch. Reference [4] analyzed three different type of switches used in micro-grids systems. The IGBT-based switch is found to be the most acceptable for dual-mode inverter considering response time and efficiency.

4. TESTING AND RESULTS

4.1 Inverter Bridge Control

4.1.1 ***SPWM Control*** Figure 4 showcases the simulated results of the trilevel PWM for controlling the H-bridge gates. From the Figure it is observed that the voltage signals $V(a)$ and $V(b)$ are 180^o out of phase, their compliments are also OFF when this voltage signals are ON as expected.

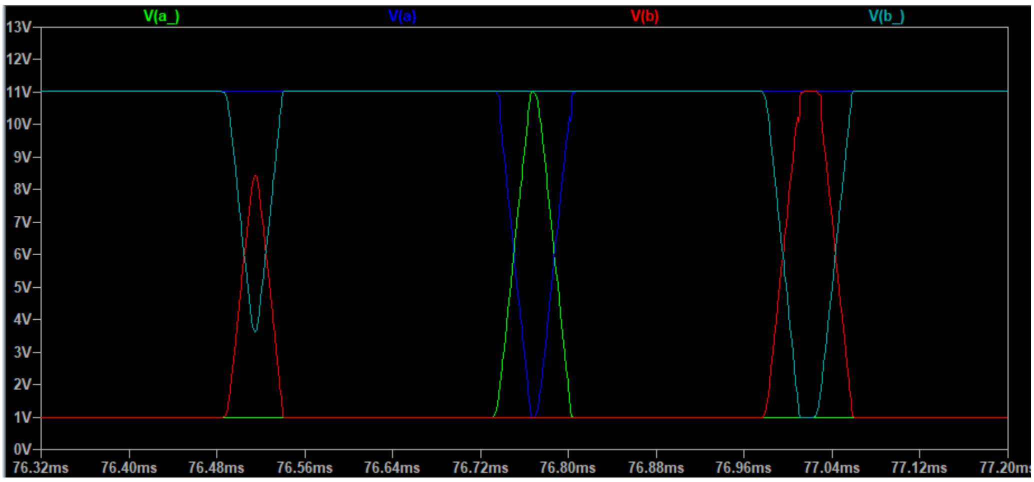

Figure 4: Trilevel PWM signal.

4.1.2 ***MOSFET drivers*** Figure 5 showcases the output of H-filter in the absence of boostrap MOSFTET drivers. From the results it is observed that the output is always 0V, and reaches 350V every after 10s for less than 0.2ms. This result shows that the MOSFET switches on immediately when the output of the comparator is greater than the threshold of the MOSFET. The drain and source of the MOSFET will be on the same potential (400V) when the MOSFET turn ON. In this case drain and the gate-source voltage becomes less than zero for which the MOSFET will shutdown due V_{GS} being less V_{DS} plus the threshold voltage.

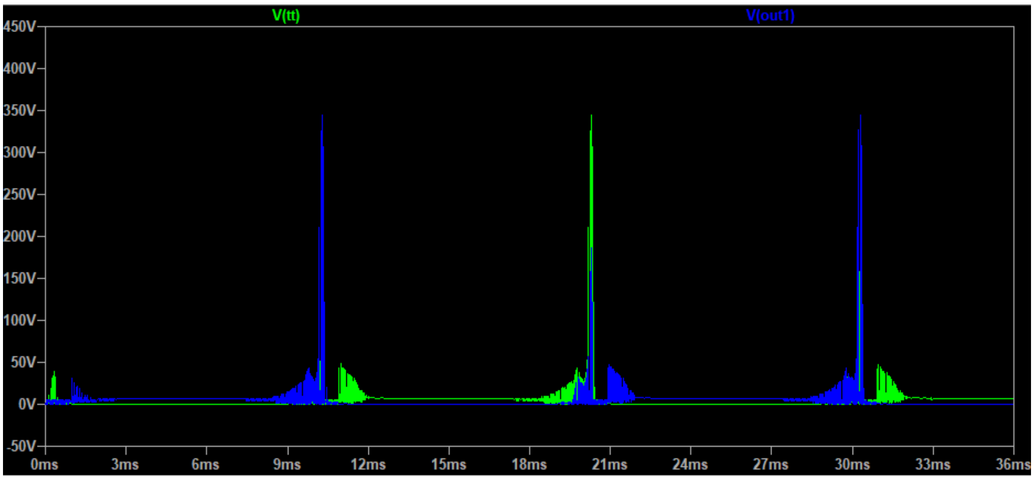

Figure 5: H-bridge output without MOSFET drivers.

4.1.3 ***H-bridge output*** Figure 6 below shows the square wave outputs from the H-bridge varying from 25V-382V. The output is a square wave of varying duty cycle which resembles the low voltage modulated sine wave using SPWM technique. The output V(out1) and V(out2) are complements of each other their difference will results in a three-level output. Three-level output requires the oscilloscope to observe the positive and negative cycle, therefore it was not observed since there is no oscilloscope on Ltspice. The frequency of the output is also higher than the required 50Hz due to the carrier signals.

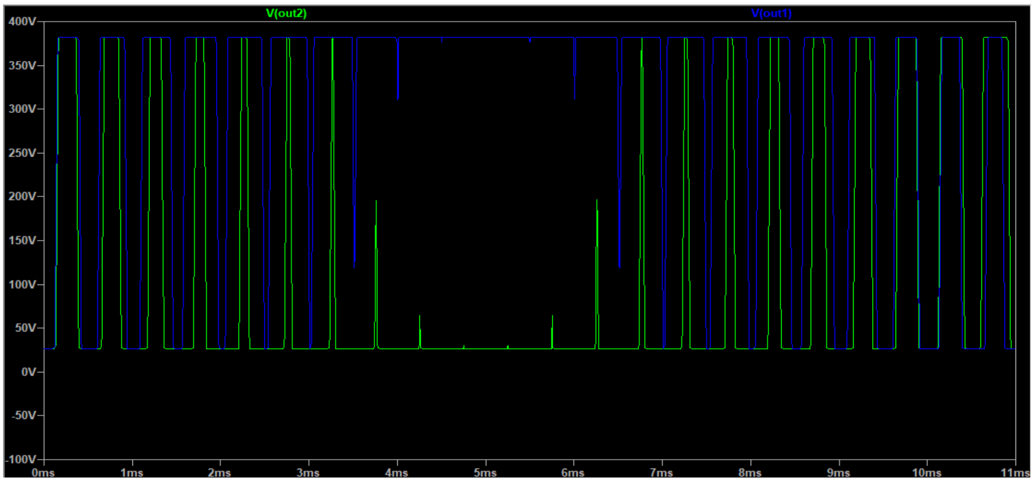

Figure 6: Unfiltered H-bridge output

4.2 *Filter*

5. DISCUSSION AND ANALYSIS

6. FUTURE RECOMMENDATIONS

7. CONCLUSION

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APPENDIX