University of the Witwatersrand

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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-tie mode or the stand-alone, 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 injected into the grid is controlled 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 $\pm 10\%$ 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. SYSTEM OVERVIEW OF THE INVERTER SYSTEM

Figure 1 shows the block diagram of the dual-inverter system that can operate in stand-alone or grid-tie mode.

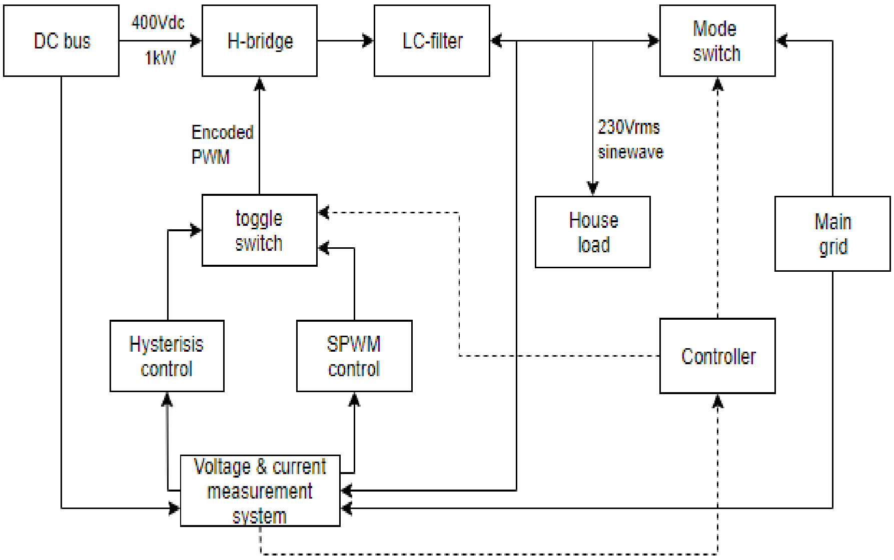

Figure 1: Block diagram of the of the dual-inverter system.

In the stand-alone mode, voltage control is important. A small sinusoidal voltage of 2Vp-p (50Hz) is compared with a triangular wave carrier signal of similar magnitude at a frequency between 6-20kHz. The output of the comparator becomes the modulated sine-wave encoded in form of square wave with varying duty cycle at higher frequency. This output signal of the comparator is then used to drive the MOSFET of the H-bridge. The output measured at the terminals of the H-bridge resemble the small encoded signal but at higher voltage of 400V. To achieve a pure sine output voltage from the H-bridge, a filter is used to attenuate high frequency of the carrier signal and allow the reference 50Hz to pass which result in output similar to the reference sinusoidal excluding the magnitude. This technique of converting DC to AC voltage is known as Sinusoidal pulse width modulation (SPWM). The stand-alone forms a close-loop voltage control to ensure a stable 220Vrms is achieved since the output of the H-bridge is at 400V. The mode switch is present in the system to ensure that in the presence of main grid power, the system switches to the grid-tie mode.

Under grid-tie mode, the hysteresis technique is used to control the drivers of the H-bridge MOSFET's, to ensure the inverter is in phase with the grid. The mode switch also ensures that the system switches to the stand-alone mode in the presence of the main-grid power.

4. DESIGN OF THE STAND-ALONE MODE

The inverter in stand-alone mode, is designed to convert the DC voltage into 220Vrms AC voltage that should achieve a pure sine wave form at the frequency of 50Hz. Multiple designs of the DC/AC inverter exist. In this design, the H-bridge inverter topology is used due to its simplicity. The inverter uses the SPWM technique under the stand-alone mode to control the drivers of H-bridge MOSFET's, the trilevel model is used in this design due to its efficiency compared to the bilevel [].

4.1 Inverter Bridge Switching Details

To understand the operation of the inverter under stand-alone mode, it is required to have the knowledge of the operation of the four MOSFTET's in Figure 2 since their operation is different in the grid-tie mode.

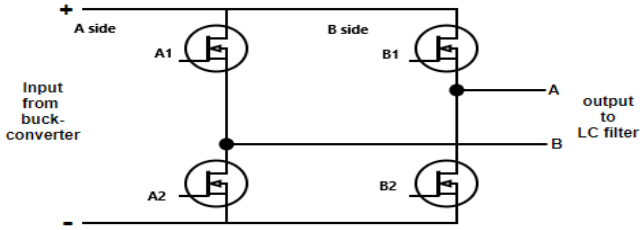

Figure 2: H-bridge inverter power circuit.

Considering Figure 2, on the A side of the H-bridge MOSFET's, the PWM to control its drivers is produced using a sinusoidal reference of 50Hz and high frequency carrier signal of triangular wave chosen to be 20kHz to improve sine sampling quality and to avoid aliasing. The resultant square wave is encoded such that negative peak of the reference signal are symbolized by smallest duty cycle and the positive peak is symbolized by biggest duty cycle as showcased in Figure 3.

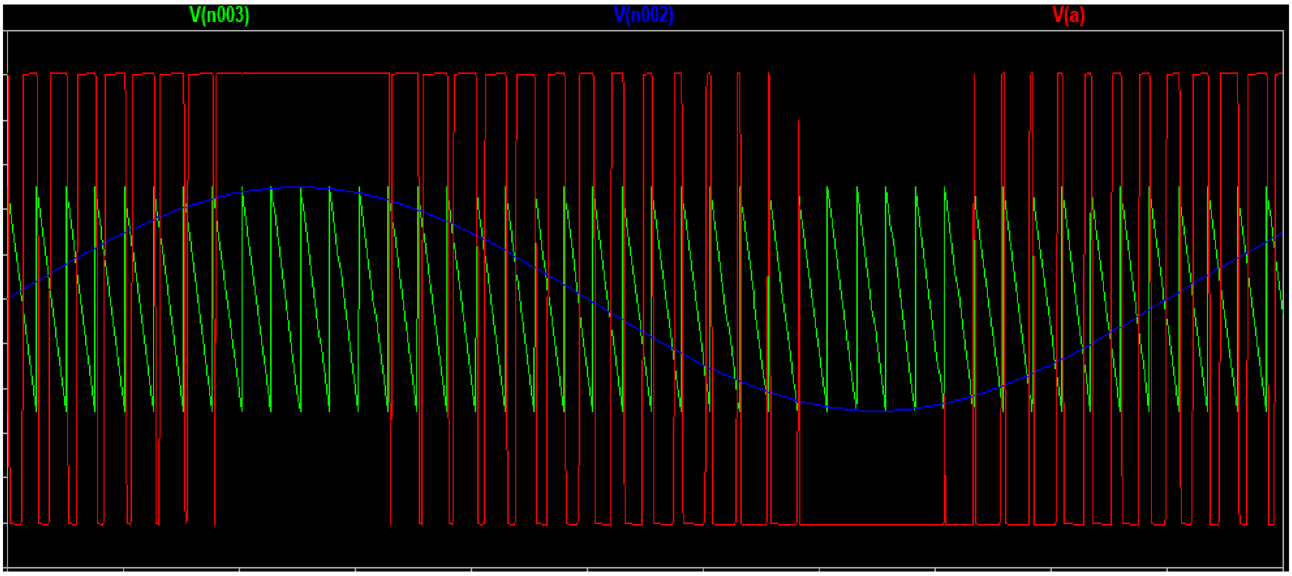

Figure 3: Encoding of sine wave with high frequency carrier signal.

To achieve the trilevel PWM, on the B side of the H-bridge in Figure 2 the reference sine-wave is phase shifted by 180^o and then the PWM to drive the MOSFET's is created in the similar manner as aforementioned. Figure 4 summarizes the generation of the trivel PWM to control the H-bridge gates. The last sub-plot in that figure is the resultant trilevel PWM.

The output from the terminals A-B of the H-bridge driven with trivel PWM is expected to be also trilevel, PWM square wave which changes cycles by appearing on the positive half for 10ms the change to negative cycle for the next 10ms which result into 400V peak-to-peak voltage.

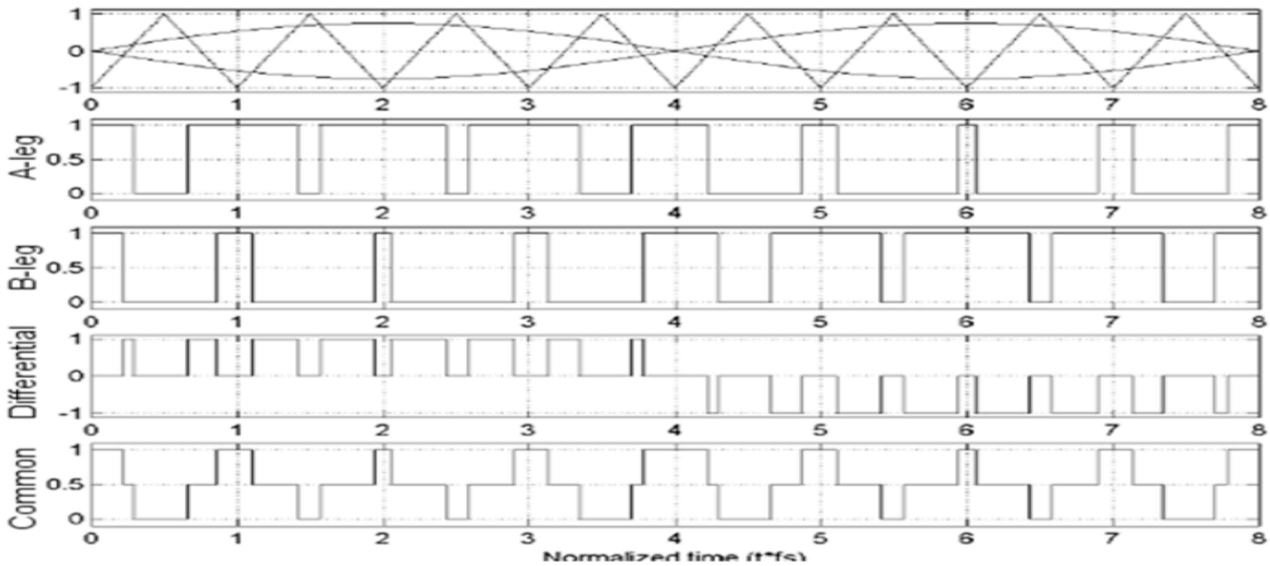

Figure 4: H-bridge control signal generation.

4.2 Filter

Considering the expected output from the H-bridge, which is not a sine wave, a filter is therefore required to eliminate the high frequency of the carrier signal so that the output will be a sine wave of total harmonic distortion not greater than 5%. 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) compared to the LC filter (40dB/decade) [1].

4.3 Mode Switch

5. DESIGN OF THE GRID-TIE MODE

6. TESTING AND RESULTS

6.1 Stand-Alone Mode

6.1.1 ***Unfiltered H-bridge Output*** Figure 5 shows the simulated output from the H-bridge. The output resembles the encoded trilevel PWM signal as expected. The frequency at which both the positive and negative half of the output appear is also the expected 50Hz. The output is 350V peak-to-peak instead of the expect 400V.

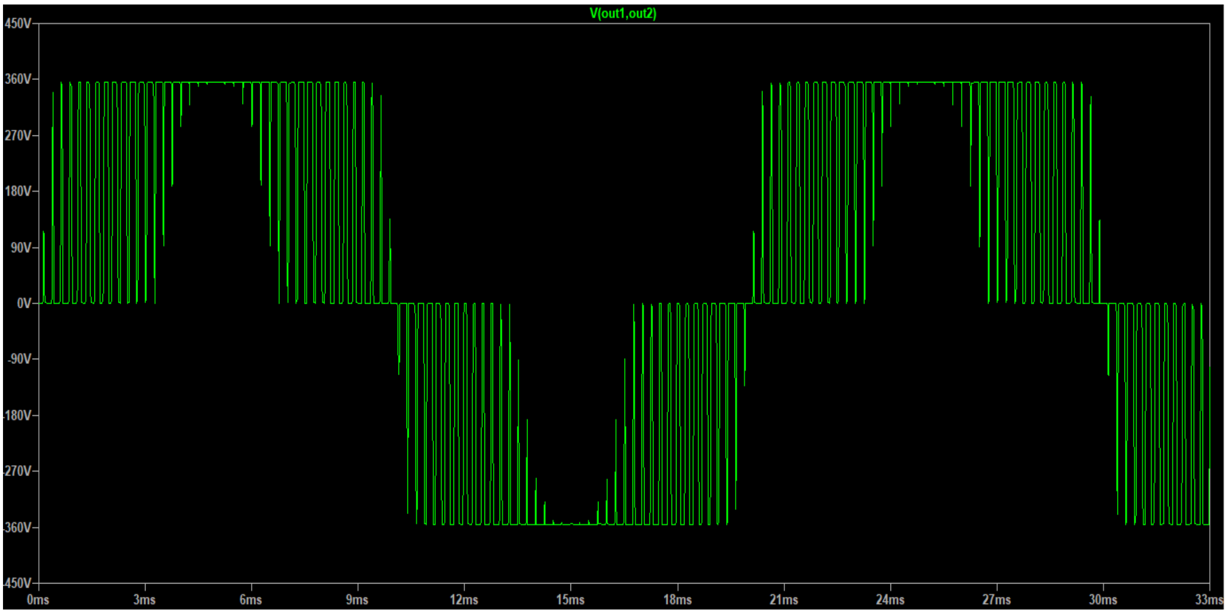

Figure 5: H-bridge control signal generation.

7. DISCUSSION AND ANALYSIS

8. FUTURE RECOMMENDATIONS

9. CONCLUSION

REFERENCES

[1] G. L. Calzo, A. Lidozzi, L. Solero, and F. Crescimbini. "LC filter design for on-grid and off-grid distributed generating units." *IEEE transactions on industry applications*, vol. 51, no. 2, pp. 1639–1650, 2014.

APPENDIX A

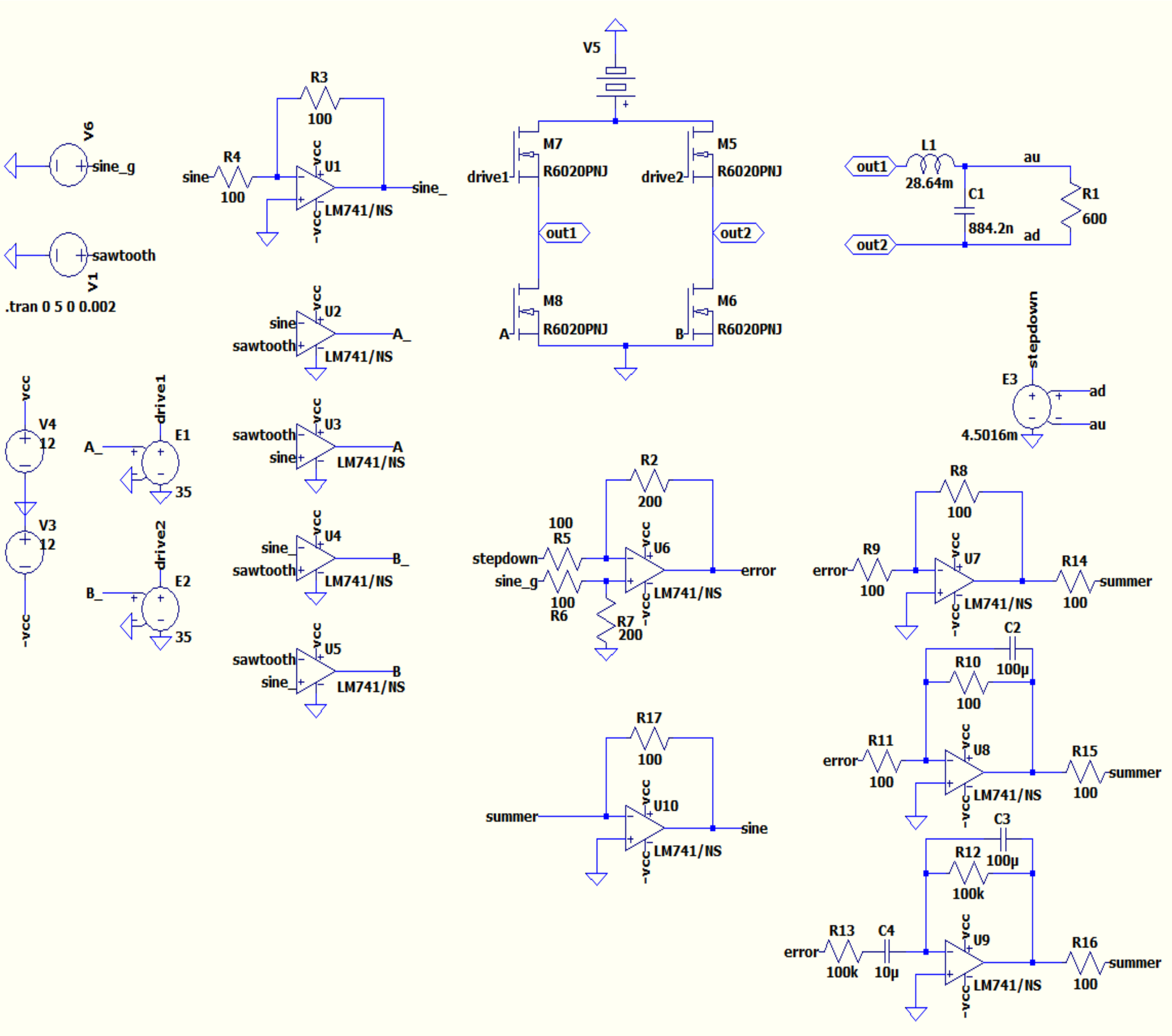

Figure 6: Stand-alone circuit.