PSPICE modelling of a photovoltaic system with a single phase voltage cancellation inverter

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Abstract. In this research, a pv panel built from previous work will be used as a DC source for voltage cancellation inverter with help of PSPICE program. PV panel model defined as a hierarchical block in PSPICE library so, it called directly from PSPICE library as a special source and used it for most PV systems applications. A designed voltage cancellation inverter will be connected with this hierarchical block to simulate it in PSPICE. All results obtained from this simulation will be compared with experimental results. The voltage cancellation inverter will convert the dc input voltage to an approximate 130V 50Hz modified square signal.

Key word: Photovoltaic, PSPICE, voltage cancellation inverter

1. Introduction

In the upcoming feature, renewable energy sources are expect to add more than 35% energy within the power industries. Solar energy is one of the solutions of the energy squeeze as it is renewable, has no environmental hazards and could supply all the present and feature needs of the world. [1] These systems can generate direct current electricity without any environmental impact. Being semiconductor device, the PV system is static and free of moving parts which make it easy for operation and also requires less maintenance.[2] In my country and due to long time of war and hardship financial the researchers went to simulate their circuit and ideas for PV systems to be in scientific field. Since inverter circuits has an important role in PV system, this research was verified.

There is three types of inverter square wave, pulse width modulation and single - phase inverter with voltage cancellation [3][4], which would be the subject of this paper. In this search a pv panel built from previous work will be used as an individual source for voltage cancellation inverter with help of PSPICE program.[5-6] PV panel model defined as a hierarchical block in PSPICE library so, it could be called directly from this library as a special source and used it for most PV systems applications. A designed voltage cancellation inverter will be connect with this hierarchical block to simulate it in PSPICE. All results obtained from this simulation will be compared with experimental results. The inverter will change the PV panels DC power to AC power for the load. It will convert the PV voltage to an approximate 130V, 50Hz modified square signal.
2. Experimental details

2.1 PV panel PSPICE model
PV panel constructed in a simulated program PSPICE with 75W, 4.8A and 21V from previous work was tested with voltage cancellation inverter. This model contains most parameters affecting PV output like solar radiation, temperature and short circuit current. Figure 1 gives some curves obtained from this model and researcher could be back to this work.[5-6]

![Figure 1: The PSPICE PV panel and there curves](image)

2.2 H-Bridge inverter Configuration
The inverter converts a DC input voltage from PV panels to AC output voltage. H bridge inverter circuit consists of four switches corresponding to high (left – right) or low (left – right) side.[7] To overcome the difficulties of driving high side MOSFETs, the driver devices use an external source to charge a bootstrapping capacitor connected between Vcc and MOSFET source terminals. As the switch begins to conduct, the capacitor maintains a potential difference, rapidly causing the MOSFET to further conduct, until it is fully on. The name bootstrap component refers to this process and how the MOSFET acts as if it is “pulling itself up by its own boot strap. [7]

2.3 Voltage Cancellation Pulse Generator and drive circuit
This type of control is not used with three-phase inverter but only with single-phase.[3] The combination of square wave switching and "PWM" with a unipolar voltage switching is the based of its. The waveform overlaps angle $\alpha$ could be control, with $\alpha = 0$, the output waveform is similar to a square wave inverter with the maximum possible fundamental output magnitude.[8] From figure 2 the fundamental and the harmonic frequency components of the output voltage is driven.

\[
(V_o)_h = \frac{2}{\pi} \int_{-\pi}^{\pi} V_o \cos(h \theta) d\theta
\]  
(1)

\[
(V_o)_h = \frac{2}{\pi} \int_{-\beta}^{\beta} V_d \cos(h \theta) d\theta
\]  
(2)

\[
(V_o)_h = \frac{4}{\pi h} V_d \sin(h \beta)
\]  
(3)
Where $\beta = 90^\circ - \alpha/2$, and $h$ = an odd integer.

![Waveforms of full bridge inverter controlled by voltage cancellation](image)

**Figure 2**: Waveforms of full bridge inverter controlled by voltage cancellation

The I.C timer 556 is used to generate a pulse, which is suitable to the drive circuit of MOSFET as shown in fig. (3). A range of I.C timers is suitable for monostable mode or astable operation. In the monostable mode these timers are capable of producing accurate delays over a very wide range. In the astable mode, a wide frequency coverage is coupled with variable duty cycle capability. The pulse generator is coupled to two (CD4013 I.C), one of them is connected directly to the signal and the other was connected via a 2N2222 transistor. The output signal from Qs of CD4013 is applied to the driving transistor of the upper power MOSFET and Q′s is applied to the driving transistor of the lower power MOSFET as shown in figure (3).

![The pulse generator and drive circuit](image)

**Figure 3**: The pulse generator and drive circuit

### 2.4 LC filter

Low pass filter is used to obtain the clean output sinusoidal alternating current output of 130 V at 50Hz. Low pass filter is selected as the cut off frequency. The filter inductor value was set such that the voltage drop across it is less than 5% of the output voltage which is given in the eq. below [9]
\[ I_{\text{max}} \cdot 2\pi f L < 0.05V_{\text{rms}} \]  \hspace{1cm} (4)

Where \( I_{\text{max}} \): maximum load current

\( f \): output frequency

\( V_{\text{rms}} \): rms value of inverter output voltage

For calculating the filter capacitor value the resonant frequency of the LC circuit is giving in the eq.

\[ 2\pi f = \frac{1}{\sqrt{LC}} \]  \hspace{1cm} (5)

Figure 4 represent the complete circuit of the inverter with voltage cancellation pulse generator and drive circuit as simulated in PSPICE. The inverter was rated at 1kW with a DC bus voltage of 130V generated from six PV panels built in PSPICE is connected in series to supply 130V to the inverter as shown in figure 4 and 5.

Figure 4: The complete inverter circuit as simulated in PSPICE

Figure 5: The PV panels voltage
2.5 Results and discussion
The proposed voltage cancellation inverter in figure (4) was built in the laboratory as shown in figure 6. The simulated and the designed inverter was compared under identical conditions so as to precisely determine their relative merits.

![Figure 6: the realized voltage cancellation inverter built in the lab.](image)

The switching characteristic of the MOSFET during the turn-on and off intervals are given in figure (7). It can be observed that the gate pulses are switched at the frequency of 50 Hz with amplitude 12V where the over-lab angle equal to about 36 degrees from simulated and experimental results.

![Figure 7: MOSFET gate pulses for M1 and M2 from a) simulated result b) experiment results](image)

The simulated and experimented inverter load voltage and current waveforms are presents in Figure 8 and Figure 9 respectively. It is apparent from the figures that the performance of both techniques is virtually indistinguishable. For all cases the load current equal 2A with 50Hz and the voltage 130V.
The experimental work and PSPICE simulation results on the circuit were recorded when the capacitance and inductance are 300μf and 66μH.
3. **Conclusion**

In this paper, the model of the solar panel, which includes all the variables that affect its work as temperature and intensity of radiation was presented. Model reliability has been confirmed by previous research. This PSPICE model used to design a voltage cancellation inverter for photovoltaic cell systems. PSPICE program can be used for steady-state analysis of inverters including the switching characteristics of MOSFET effectively. It has given results that are consistent with practical results. This leads us to say that the model could be used by researchers and students to learn about all PV cell systems and their results without bothering to work under the sun.

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