Inverter using powerbank as power source with pure sine wave output

Muhammad Arif Wicaksono¹, and Estananto Estananto¹

¹Telkom University, School of Electrical Engineering, Jalan Telekomunikasi No. 01, Terusan Buah Batu, Bandung, Jawa Barat 40257, Indonesia

Abstract. The current factory-generated inverters, typically use high power sources or energy sources, with a minimum input voltage of 12VDC, 24VDC, 48VDC with an effective voltage output of 220 VAC with a frequency of 50Hz/60Hz. These power sources are usually obtained from starting battery or deep-cycle battery. The problem of inverter currently that portable inverter using a low power source with a sine wave output is not available. So in this research conducted inverter design using power source/ energy source from powerbank 5 VDC 16000 mAh with 50 Hz 40 Vpp sine wave output. Inverter design method in this final project research based on simulation which used LTspice application. And in this inverter system, have been decided to using MOSFET as switching and using h-bridge as inverter topology, because MOSFET has high efficiency compared with BJT or J-FET. This final project research is expected to be an inverter using powerbank resources and become a portable inverter so in the future can be used for loads that require sinusoidal signals such as electric stoves, and can be used also for climbing purposes.

1 Introduction

An inverter is a device or circuit of power electronics that converting direct current into alternating current [4][6]. The output voltage source of the inverter are single phase, and three phase. Based on the output waveform, the inverter is divided into three, namely: pure sine wave, square wave, and modified sine wave [4]. In general, inverters have been widely applied to renewable energy systems, home and industrial lighting, AC motor settings, and standby power supply such as uninterruptible power supply (UPS) which requires a backup battery for everyday purposes or entertainment purposes (Television, cars, etc.) [4]. Inverter voltage source can be battery, fuel cell ($H_2 + O_2 \rightarrow 2H_2O$) or solar cell (sun).

Inverters manufactured by manufacturers today typically use a high power source or energy source with a minimum input voltage of 12 VDC, 24 VDC or 48 VDC with an effective voltage output of 120 VAC, 220 VAC with a frequency of 50 Hz / 60 Hz. Input voltage is often obtained from the battery, either the starting battery or the deep-cycle battery [1]. The starting battery is a lead-acid type battery designed to provide a large current jolt during initial use. Typically used on loads that require large currents such as on vehicles (motorcycles on cars, motorcycles) and pumps. Meanwhile, the deep cycle battery is a lead-acid type battery designed for loads that do not require large and stable currents for long periods of time. This type of battery was use in electronic equipment (radio, cooling, lighting, house power, solar cell, and so on). Each type

of battery uses depend on the need. Both types of batteries both have high power capacity and current capacity. As for the difference of the deep cycle battery with the starting battery lies in the structure, characteristics and application of its use. Pure sine wave inverter with high quality usually has an efficiency of 90-95% while for modified sine wave inverter has an efficiency of 70-75% [1].

About the problem of the currently inverter is the absence of a portable inverter using a low power source with a sinusoidal wave output. In this research, we designing an inverter which using powerbank as power source 5 V 16000 mAh with sinusoidal wave output 50 Hz 40 Vpp. We use MOSFET as switching. In this research, we use h-bridge topology for designing an inverter, for powerbank we simulate using DC source 5 V 2 A, and not using transformer but using a LC filter to stepping up AC voltage and resistor as load [3]. We using LTspice for simulation. Results from currently research, that the use of MOSFET as switching with powerbank as power sources has some potential to developed, especially shown good efficiency in low load. The test has shown that the use of MOSFET as switching in inverter without transformer, with 15 k Ω load has an output voltage is 88.89 Vpp, with an efficiency is 5.21%. The efficiency of inverter will increase with a low resistor value as load or we added a transformer. For the future this research is expected to be an inverter using powerbank as power source and become a portable inverter so that can be used for loads that require sinusoidal signals such as electric stoves, and can be used also for climbing purposes.

* Corresponding author: arif.115134158@gmail.com

2 Method

Our system in this research is explained in fig. 1 :

Fig. 1. System of inverter.

That the source or input VDC flow to the inverter then the inverter start processing the signal, so DC was converting to AC. Because the output voltage wave form still square wave and a low voltage, filter is needed to shaping the square wave to sinusoidal wave [1]. Beside that LC filter is also using as amplifier. Based in our sytem, the method of this research is used LTspice application for simulation. In this simulation is divided into several parts, inter alia : powerbank, oscillator, inverter and, filter.

2.1 Powerbank

In this simulation, we are not designing a real powerbank circuit, but use ideal voltage source that adjusting from powerbank specification, see in fig. 2. Our powerbank specification is 5 V, 2 A, and 16000 mAh. So we used 5 V as an ideal DC voltage. We got the value of internal resistance voltage source amount 2.5Ω with equation (1) [4]. And we get 80 Wh the maximum power capacity of powerbank from equation (2) :

$$R(\Omega) = \frac{V}{I} \quad (1)$$

$$P(W) = V \cdot I = I^2 \cdot R \quad (2)$$

Fig. 2. Voltage source as powerbank.

2.2 Oscillator

There are two oscillator. Both oscillator or input voltage for switching gate, used sinusoidal voltage but with different phase. For leg B (-pwm), the phase is negative,

the amplitude voltage that we used is -5 V, DC offset is 2.5 V, and the frequency is 50 Hz. For leg A (pwm), the phase is positive, the amplitude voltage that we used is 5 V, DC offset is 2.5 V, and the frequency is 50 Hz. You can see in fig. 3. This sinusoidal voltage flow to gate of switch. The DC offset voltage or a DC bias MOSFET is to activate the MOSFET.

Fig. 3. Sinusoidal voltage as oscillator.

2.3 Inverter

Fig. 4. H-bridge inverter use MOSFET as switching.

In figure 4, is h-bridge inverter using MOSFET as switching. In this inverter circuit, the complementary MOSFET (C-MOS) was use as a configuration [3]. P-channel MOSFET using IRF 4905, and N-channel MOSFET using IRF 3205. The reason we used IRF 4905, and IRF 3205, because $R_{ds(on)}$ or the resistance is very low, so its keep the efficiency. The output this inverter still square wave, so we need a filter to make this inverter output sinusoidal [4][5].

2.4 Filter

Fig. 5. LC filter and 15 kΩ as load.

In figure 5, the filter circuit consist of inductor and a capacitor. The inductor is series between the output of inverter (leg B) and the capacitor. While the capacitor is parallel. In this research we were using LC filter to make the wave form output of inverter is sinusoidal [7][8]. You can see in figure 5.

$$\omega_0 = 2\pi f_0 \quad (3)$$

$$\omega_0 = \frac{1}{\sqrt{L_c}} \quad (4)$$

$$f_0 = \frac{1}{2\pi\sqrt{L_c}} \quad (5)$$

The inductor value is 0.1H and the capacitor value is 100u. This value from equation (5) that we get from equation (3) and (4). This filter cut at 104.318 Hz.

3 Results and discussion

Mostly the previous research about inverter was using a high power source like 12 VDC from starting battery which usually uses for electricity system in vehicle, or from a Photovoltaic (PV) array [2][3][5]. Using 12 VDC high power source is more easy to design and build an inverter than using 5 VDC low power source from powerbank. It's because low power source such as powerbank, has a low voltage and low current so is more complex to converting DC to AC with sinusoidal wave form, specially for efficiency [11]. The method usually uses, is multilevel inverter with unipolar PWM or two level inverter with bipolar PWM [2][4][5][6]. So in this research, we using two sinusoidal voltage as a simple oscillator to triggering the MOSFET.

The test in this simulation used a various values of resistor, range from 99 Ω-15 kΩ. This simulation shows the significant results and reaches the desired target. The output of inverter is pure sine wave, the frequency is 50Hz and the voltage is 88.89 V (Vpp) or 23.436 V (Vrms) with the value of resistor as load is 15 kΩ..

Fig. 6. Output voltage wave form of inverter with 99Ω-15kΩ load.

In figure 6, shows that the voltage waveform output of inverter is consistent with a different value of load. And the peak voltage value (V_p) are variated, 9 VAC - 45 VAC depend on load. To calculated the efficiency of inverter, using equation (6) below.

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \quad (6)$$

In figure 7, shows that the frequency output of inverter at 15 kΩ load is 50 Hz. The output frequency is 50 Hz its because the both of sinusoidal voltage as an oscillator have 50 Hz frequency.

Fig. 7. The frequency output of inverter at 15kΩ load is 50Hz.

The test and the result in this research, shown at table 1. In table 1, there are input power value of inverter, output power value of inverter, the value of resistor as load, the efficiency, and the output voltage of inverter.

Table 1. The test and the result.

No.	Load	Input Power(Source)	Output Power(Load)	Efficiency	Vout(Vrms)
1	15k	702.31mW	36.616mW	5.21%	23.436
2	14k	702.37mW	39.154mW	5.57%	23.413
3	13k	702.59mW	42.069mW	5.98%	23.386
4	12k	702.82mW	45.45mW	6.46%	23.354
5	11k	702.8mW	49.422mW	7.03%	23.316
6	10k	702.98mW	54.151mW	7.70%	23.27
7	9k	703.15mW	59.877mW	9%	23.21
8	8k	703.56mW	66.964mW	9.51%	23.14
9	7k	703.91mW	75.932mW	10.78%	23.05
10	6k	704.26mW	87.658mW	12.44%	22.93
11	5k	704.71mW	103.66mW	14.70%	22.76
12	4k	705.38mW	126.71mW	17.96%	22.51
13	3k	706.16mW	162.72mW	23.04%	22
14	2k	706.37mW	226.17mW	32%	21
15	1k	697.73mW	359.56mW	51.53%	19
16	900	694.29mW	379.96mW	54.72%	18
17	800	689.17mW	401.78mW	58.29%	18
18	700	681.72mW	424.7mW	62.29%	17
19	600	670.81mW	447.87mW	66.76%	16
20	500	653.95mW	469.35mW	71.77%	15
21	400	627.22mW	485mW	77%	14
22	300	582.84mW	485.98mW	83.38%	12
23	200	506.54mW	454.36mW	89.69%	10
24	100	376.69mW	359.59mW	95.46%	6
25	99	375.1mW	358.25mW	95.50%	6

In table 1, the highest output voltage of inverter is 23.436 VAC with 15 kΩ load, and the efficiency is 5,21%. This shown that the inverter is not efficient with 15 kΩ. Because at 15 kΩ, the inverter consume 702.31 mW from powerbank, and resistor as load only consume 36.616 mW from inverter. The best efficiency of inverter is 95,50% with 99 Ω load, and the output voltage of inverter is 6 VAC. This shown that the inverter is not optimum work at 99 Ω load, because the output voltage very low. The inverter work optimum and best at 500 Ω because the output voltage of inverter is 15 VAC and the efficiency is 71.77%. The power dissipate is relative small and the output voltage is good enough. The graph about the output voltage and the efficiency of inverter shown at figure 8 and figure 9 below :

Fig. 8. The output voltage of inverter.

In figure 8, the maximum output voltage of inverter is 23.436V at 15kΩ load. At 1kΩ load, the output voltage of inverter is decreased to 19V. And at 200Ω load, the output voltage of decreased again to 10V. And we get the minimum output voltage of inverter is 6V at 99Ω.

Fig. 9. The efficiency of inverter.

For the efficiency of inverter, shown in figure 9. The best efficiency of inverter is 95.50% at 99 Ω load. And the worst efficiency of inverter is 5.21% at 15kΩ load.

4 Conclusions

The conclusion that this inverter design, have the best efficiency is at 95.50% at 99 Ω load but with lowest voltage output is 6 VAC. And have the maximum output voltage is 23.436 VAC (Vrms) at 15k Ω load but with

bad efficiency is 5.21%. The inverter work optimum and best at 500 Ω because the output voltage of inverter is 15 VAC and the efficiency is 71.77%. This research is succeed because we reaches our target. And based on the simulation results, this research is very potentially to develop and to implemented for the future

for ultra-low power applications, in *IEEE Fourth Latin American Symposium on Circuits and Systems (LASCAS)*, Feb pp. 1–4. (2013)

5 Future work

It could be interesting if an inverter can operate optimally with low power sources especially in climbing samples for cooking water using an electric stove operated by this inverter.

References

1. B. Ismail, S.Taib MIEEE, A. R Mohd Saad, M. Isa, C. M. Hadzer, Development of a Single Phase SPWM Microcontroller-Based Inverter, *IEEE International Power and Energy Conference*, pp. 437-440. (2006)
2. Beigi L.M.A., Azli N.A., Khosravi F., Najafi E., Kaybhosravi A, A New Multilevel Inverter Topology with less Power Switches, *International Conference on Power and Energy 2012*, IEEE , 2-5 December (2012)
3. E. Koutroulis, J. Chatzakis, K. Kalaitzakis and N.C.Voulgaris, A bidirectional, sinusoidal, high-frequency inverter design, *IEEE Proc.Electr. Power Appl.*, Vol. **148**, No. 4, July, pp. 315-318, (2001)
4. Hart, D. W. Intoduction to Power Electronics. (Prentics-Hall, New Jersey, 1997)
5. M Hasan, J Maqsood, M Q Baig, S M A S Bukhari, S Ahmed, Design & Implementation of Single Phase Pure Sine Wave Inverter Using Multivibrator IC, *International Conference on Modelling and Simulation (UKSim-AMSS)*, 17th, (2015).
6. Mohan, N., Undeland, T.M., Robbins, W.P. Power Electronics. Converters, Applications and Design. John wiley & sons, Inc. Luigi T. De Luca, *Propulsion physics* (EDP Sciences, Les Ulis, 2009)
7. Sedra, S. A., Smith, C. K. Microelectronics Circuits, 1450, (2009)
8. Sandeep Roy, Alok Sahu, M. K Pradhan, Total harmonic distortion reduction using Photovoltaic cell and LC filter in Three Phase 11 Level Inverter, *Int. J. of Research in Advent Technology {IJRAT}*, Vol. **4**, No.4, April (2016)
9. Sandeep Phogat, Analysis of Single Phase SPWM Inverter, *Int. J. of Science and Research (IJSR)*, Vol. **3**, Issue 8, August (2014)
10. Shahana P saith, K Radhakrishnan, Krishnakumar P, Switch Mode Power Amplifier with Feedback Control for Electro Acoustic Projectors, *Int. J. of Engineering and Innovative Technology (IJEIT)*, Vol. **3**, Issue 3, September (2013)
11. W. Wilson, T. Chen, and R. Selby, A current starved inverter based differential amplifier design