Design and Simulation of a MOSFET-Based Inverter using Battery

Prachi Dhunde, Vinayak Zirmile, and Parth Shirsat
Dept of Electrical Engineering
AISSMS Institute of Information Technology
Project Guide: Prof.S.S Shingare

Abstract— **The inverter functions as a vital power electronics component which transforms direct current (DC) electricity into alternating current (AC) electricity to power standard AC devices that operate on battery-powered systems. The paper presents the entire procedure which requires the development and evaluation and construction of a MOSFET inverter system that functions from a 12V battery. The system uses an H-bridge design which enables MOSFETs to operate as rapid switches that create an AC output waveform.**

The engineers designed the inverter circuit and validated its performance through simulation testing which assessed crucial operational parameters that included output voltage and load current and switching characteristics and total efficiency. The report explains how the inverter operates while describing how MOSFETs achieve efficient switching operations. The simulation results show that the system successfully changed DC power into AC power while maintaining reliable switching operations and producing acceptable output results.

The proposed system connects with the ThingSpeak IoT platform which enables users to monitor inverter performance parameters in real time while displaying those metrics through visual tools. The cloud-based monitoring system allows technicians to perform remote voltage and current monitoring which enhances system monitoring capabilities and voltage and current performance assessment.

The study shows that MOSFET-based inverters deliver energy-efficient low-power performance with minimal switching losses for use in portable power supplies and backup systems and renewable energy systems. The next phase of the project will focus on developing PWM-based sine wave generation methods and advanced filtering techniques which will decrease harmonic distortion and enhance output waveform quality.

I. INTRODUCTION

These days there’s a lot of talk about renewable energy and portable power sources, so converting between different types of energy is super important in electrical stuff. Batteries are key for storing energy, and they output direct current, DC, which feels pretty steady and reliable for a lot of uses.

But most home appliances and machines in factories or wherever need alternating current, AC, to run properly. That creates a real issue, right, because you cannot just plug in a battery directly most of the time.

Inverters help’s fix that by converting DC supply into AC. They are in things like uninterruptible power supplies for computers, solar panel systems, electric cars, and even backup generators for emergencies. Without them, a bunch of modern tech wouldn’t work so smoothly.

The performance of an inverter depends a lot on its internal components, such as the switches and transistors inside. When this technology started, designers used bipolar junction transistors, or BJT’s, which were okay but not the best one.Then MOSFETs took over, and that changed everything because they handle switching way better with less hassle. MOSFET is short for Metal Oxide Semiconductor Field Effect Transistor, I believe that is the full name. What stands out about MOSFETs is how they only require a small amount of current to turn on and off, which is great for battery powered inverters. Energy efficiency counts a lot in those setups, it seems like, especially when you are trying to make things last longer. This is basically about designing an inverter, looking at how it behaves under different conditions, and running some simulations to test it out. Some parts of the explanation might feel a bit off or not fully clear, but that is how it goes sometimes.

II. OBJECTIVE OF THE STUDY

Converting DC power from a battery to AC power is a crucial process, and this study aims to achieve it in a simple and efficient manner. The focus is on designing and testing a MOSFET-based inverter, which is a type of converter that utilizes MOSFETs to switch on and off quickly, thereby minimizing power losses. MOSFETs are ideal for this application due to their fast switching capabilities, making them a key component in creating an efficient converter. The primary objective is to take the DC power from the battery and convert it into AC power, which is the standard power format used in most homes and devices. This project has significant implications, particularly in situations where AC devices need to be powered using battery power. By developing an efficient MOSFET-based inverter, we can optimize the use of battery power and make it more practical for various applications. The converter’s efficiency and simplicity are critical factors, as they will directly impact its performance and usability. Overall, this study aims to provide a innovative solution for converting DC power to AC power, which can have a substantial impact on the way we utilize battery power in our daily lives.

Another key objective is to understand the working principle of the inverter, particularly the role of the H-bridge configuration in producing an alternating output waveform. The research also focuses on evaluating important performance parameters such as output voltage, load current, efficiency, and waveform characteristics.

The goal of this project is to examine the limitations of a basic square wave inverter, specifically when it comes to harmonic distortion, and to identify potential solutions, such as utilizing Pulse Width Modulation (PWM) and filtering techniques. By leveraging simulation, we aim to test theoretical concepts and ensure the inverter design functions as intended under various conditions. This approach will enable us to evaluate the inverter's performance, pinpoint areas for improvement, and gain insight into its behavior. Furthermore, we will investigate how PWM and filtering can mitigate harmonic distortion and enhance the overall performance of the inverter. This knowledge will ultimately allow us to better design and optimize inverters for a range of applications. The simulation will be instrumental in helping us understand how the inverter operates and whether it meets our expectations, thereby providing a foundation for future improvements. As we explore the capabilities of PWM and filtering, we can develop more efficient and effective inverter designs.

III. METHODOLOGY

The methodology adopted in this research involves a systematic approach that includes circuit design, component selection, simulation, and performance analysis.

To start, we need to design the inverter circuit, and we're going to use a full-bridge, also known as an H-bridge, topology. We've chosen a 12V DC battery as our input source. Now, we arrange four MOSFETs in a bridge configuration, which allows us to reverse the current flowing through the load. When it comes to selecting the right MOSFETs, there are a few key things we need to consider. First, we need to think about the voltage rating - it's got to be high enough to handle the job. Then there's the current handling capability - we don't want our MOSFETs to get overwhelmed. And finally, we want low ON-state resistance, so our circuit can operate efficiently. By choosing the right MOSFETs, we can make sure our inverter circuit works smoothly and does what it's supposed to do.

To regulate the MOSFETs, a switching system is created. This system utilizes a square wave oscillator, such as a 555 timer or signal generator, to produce gate pulses at a frequency of 50 Hz. These pulses are then applied to the MOSFET pairs in a complementary manner, resulting in the generation of alternating current at the output. It is also crucial to introduce a brief dead time between the switching signals, which prevents short-circuit conditions from occurring. This dead time is essential because it prevents the MOSFETs from being activated simultaneously, which could lead to a short circuit. By incorporating this dead time, the switching system can function correctly and safely, thus preventing potential damage to the circuit. The dead time serves as a safety mechanism, ensuring that the MOSFETs are not turned on at the same time, and it allows the switching system to operate efficiently and reliably.

So you've got your circuit designed, now it's time to see how it works. You use special programs like MATLAB/Simulink, Proteus, or LTspice to run a simulation. First, you build a model of your circuit in the program, and set all the important details, like the voltage going in, the resistance of the load, and how often the switch turns on and off. Then you do a thing called transient analysis, which shows you how the voltage and current change over time. This is really helpful for figuring out how your circuit will act in the real world. It's like a test run, before you actually build the circuit. You can see how it behaves, and make any changes you need to, before you start building. This way, you can be sure your circuit will work the way you want it to, and you won't have any surprises when you turn it on.

Finally, the performance of the inverter is analyzed based on the simulation results. Parameters such as output waveform, RMS voltage, load current, efficiency, and harmonic distortion are evaluated. The results are compared with theoretical expectations to validate the design. Based on the analysis, conclusions are drawn and possible improvements are suggested to enhance the performance of the inverter.

IV. THEROTICAL BACKGROUND

A. WORKING PRINCIPLE OF INVERTER AND MOSFET OPERATION

An inverter flips DC into AC by constantly reversing the current's direction. So basically, it turns the straight, one way flow of DC into an alternating pattern like a heartbeat, always switching back and forth.

If you look at a basic square wave inverter, it just swaps between the positive and negative side of your DC input. The math behind it. Maybe a bit tricky but you can picture it as the sign flipping every so often, kind of like a seesaw. It's definitely AC just not smooth there are lots of rough edges because extra frequencies sneak in.

Now, about MOSFETs they're the real stars of the show here. Since they're voltage-controlled, you just apply a voltage to the gate, and if it's high enough compared to the source, the gate opens up and lets current zip through. Take the voltage away and the gate slams shut no more flow.

In inverters, MOSFETs act like lightning-fast switches, flipping on and off to craft that AC pattern. They're super efficient, too, thanks to their speed and the tiny resistance they have when on. That's a huge deal for devices running on batteries because every bit of saved energy counts. Honestly, the way they keep things humming along without wasting power? That's pretty impressive.

B. MATHEMATICAL REPRESENTATION OF INVERTER OPERATION

A square wave inverter is pretty straightforward. The output voltage just snaps between the positive and negative sides of the DC input. The basic formula is:

$$V_{out}(t) = V_{dc} \cdot \mathrm{sgn}(\sin(\omega t))$$

That breaks down like this: $V\ dc$ is your DC input voltage. ω means 2π times the frequency, so if you're running at 50 Hz or 60 Hz, just plug those numbers in.

As time ticks by, the output switches sharply—no gradual slope, just flipping from positive to negative. It's like following the shape of a sine wave, but instead of smoothly rising and falling, it's all or nothing. So the inverter's output is always at full voltage, either positive or negative, never anything in between.

RMS Value of Output Voltage

With a square wave inverter, the RMS output voltage is the same as the DC input so VRMS is just Vdc. That's pretty useful when you are trying to work on how much power goes to the load.

Load Current Calculation

Figuring out the load current is straightforward. Grab Ohm's Law: I = V / R. Here, I stands for load current, V is your output voltage, and R is the resistance of the load.

Fourier Series Representation (Harmonics)

A square wave isn't just a simple tone—it's loaded with harmonics. If you break it down with a Fourier series, here's what you get:

$$V(t) = \frac{4V_{dc}}{\pi}\left[\sin(\omega t) + \frac{1}{3}\sin(3\omega t) + \frac{1}{5}\sin(5\omega t) + \cdots\right]$$

So when you see a square wave, you're actually looking at a blend of all these odd harmonics: sin(ωt), sin($3\omega t$), sin($5\omega t$), and more. That's what gives the wave its sharp edges and punchy sound, instead of the smooth look or tone of a pure sine wave.

MOSFET Drain Current Equation

When a MOSFET's in the active region, you can figure out its drain current with one simple equation:

$$I_D = k(V_{GS} - V_{TH})^2$$

Basically, the current shoots up as the gate-source voltage beats the threshold—all squared, and then scaled by the constant k. Engineers rely on this relation to tweak and control MOSFETs in their circuits. It's a handy way to predict how much juice is flowing.

V. INVERTER TOPOLOGY AND OPERATION

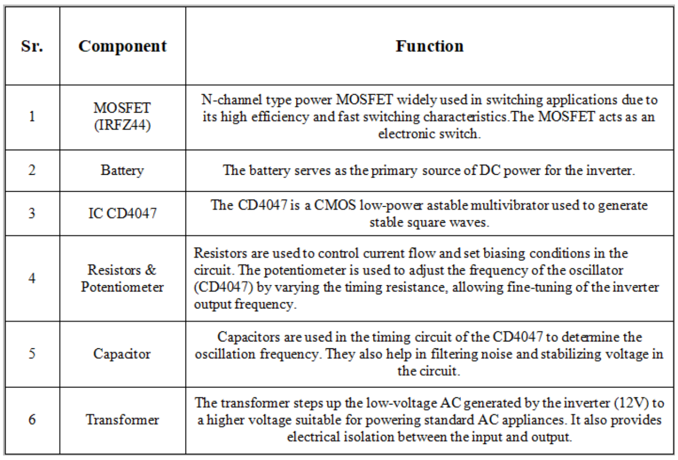
This design uses an H-bridge configuration. Picture four MOSFETs laid out like a bridge, with your load connected right in the middle where the pairs meet.

Here's the idea: To get a positive output, you switch on one pair of diagonally opposite MOSFETs. That sends current through the load one way. For the negative output, you turn on the other diagonal pair, so the current flows the other way. Switching between those pairs creates an AC waveform across your load. You've gotta be careful though. If you accidentally turn on both MOSFETs on the same side, you're basically shorting out the battery—that's called shoot-through. The fix? Add a bit of dead time between switching so there's no overlap. That keeps your circuit safe.

VI. CIRCUIT DESIGN AND COMPONENT SELECTION

This inverter runs off a 12V battery, so you start with a simple DC input—pretty standard for portable gadgets and DIY projects. It keeps everything straightforward and easy to work with.

When it comes to MOSFETs, pick ones rated for higher voltages than your battery. You also want low ON resistance, so you don't end up losing energy as heat. The IRFZ44N works well here—it's efficient, tough, and easy to find just about anywhere.



Sr.	Component	Function
1	MOSFET (IRFZ44)	N-channel type power MOSFET widely used in switching applications due to its high efficiency and fast switching characteristics.The MOSFET acts as an electronic switch.
2	Battery	The battery serves as the primary source of DC power for the inverter.
3	IC CD4047	The CD4047 is a CMOS low-power astable multivibrator used to generate stable square waves.
4	Resistors & Potentiometer	Resistors are used to control current flow and set biasing conditions in the circuit. The potentiometer is used to adjust the frequency of the oscillator (CD4047) by varying the timing resistance, allowing fine-tuning of the inverter output frequency.
5	Capacitor	Capacitors are used in the timing circuit of the CD4047 to determine the oscillation frequency. They also help in filtering noise and stabilizing voltage in the circuit.
6	Transformer	The transformer steps up the low-voltage AC generated by the inverter (12V) to a higher voltage suitable for powering standard AC appliances. It also provides electrical isolation between the input and output.

Fig. 1. Components Selection

To actually switch the MOSFETs, you'll need an oscillator circuit. A 555 timer fits the bill and is sort of a go-to component for beginners and pros alike. It produces a square wave, which decides your AC output frequency—so, 50 Hz or 60 Hz, depending on where you live.

That oscillator signal isn't strong enough on its own, so you need a driver circuit next. Its job is to boost the signal high enough to drive the MOSFET gates properly. Give them plenty of gate voltage, because if the signal's too weak, the MOSFETs don't fully turn on. You lose power and risk them heating up for no good reason.

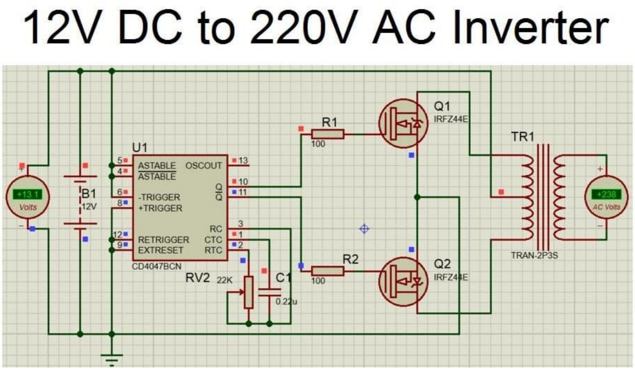


Fig. 2. Circuit Diagram

VII. SIMULATION METHODOLOGY

Before you start building the inverter, it's smart to run a simulation first. That way, you'll know if the design actually works. Programs like MATLAB/Simulink, Proteus, or LTspice make the whole process pretty straightforward. You just build your circuit, press play, and see what happens.

Start by putting together the H-bridge. Grab the MOSFET models that come with the software, connect your DC voltage source, and add a resistor for the load. The gate signals can get a bit tricky, so make sure the MOSFETs switch together in pairs but opposite from the other pair. That's what makes the inverter function.

When the circuit's all ready, run a transient analysis. You're looking for the output voltage to swing from positive to negative—if it does, your design works. Keep an eye on the current, power, and any losses from switching. This whole process gives you a clear idea of how well your inverter performs, long before you have to mess with real hardware.

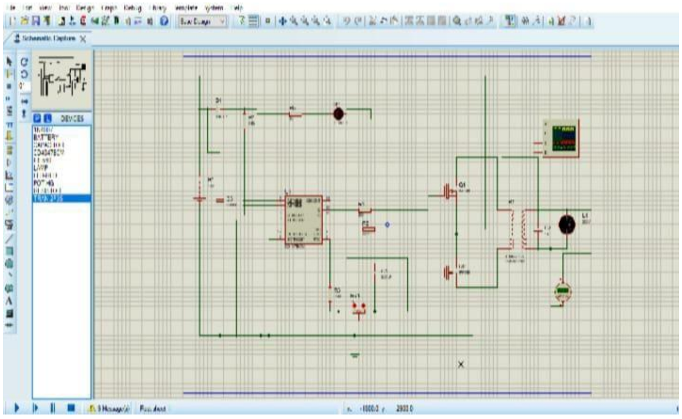


Fig. 3. MOSFET Based Inverter Circuit

VIII. RESULT AND DISCUSSION

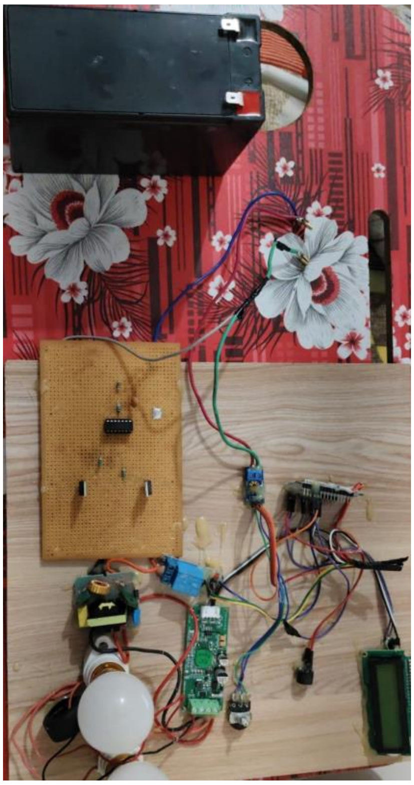


Fig. 4. MOSFET Based Inverter Circuit

The simulation makes it clear—the inverter takes a 12V DC input and flips it into AC, bouncing between +12V and -12V. You get a square wave, meaning the H-bridge is running just like it's supposed to.

The current going through the resistor depends on how big the resistance is. With a 100-ohm resistor, the current stays pretty low, so this setup is really only good for low-power jobs.

Efficiency matters a lot with inverters, and here it mostly depends on the MOSFETs. Losses happen both while they're conducting and while they're switching. Most MOSFETs have low ON resistance and switch fast, so you can expect solid efficiency—usually somewhere between 85% and 95%.

Still, square wave inverters have their ugly side. Harmonic distortion is the main problem. The output isn't just one frequency—it's loaded with other, unwanted frequencies. Those harmonics can mess up sensitive electronics and drag down the overall power quality.

A. *ThingSpeak-Based IoT Monitoring*

The proposed MOSFET-based inverter system is integrated with the ThingSpeak IoT platform for real-time monitoring and visualization of inverter parameters. The system continuously uploads important electrical parameters such as battery voltage, inverter output voltage, and inverter current to the cloud platform for analysis.

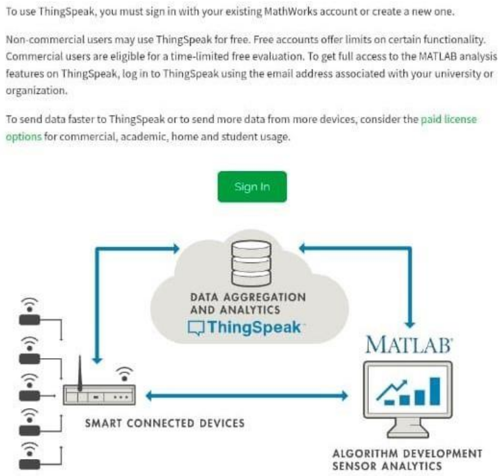
The graphical data obtained from ThingSpeak helps in evaluating inverter performance under different operating conditions. Real-time monitoring improves system reliability and enables easier fault analysis and performance optimization.

Channel Stats
Created: 2 days ago
Last entry: less than a minute ago
Entries: 264

Fig. 5. Thingspeak Dashboard

IX. CONCLUSIONS

This paper presented the design, simulation, and implementation of a MOSFET-based inverter powered by a 12V battery source. The inverter successfully converted DC power into AC output using an H-bridge configuration. The simulation results confirmed the proper operation of the inverter and showed satisfactory voltage and current characteristics. MOSFETs were chosen as switching devices because of their high switching speed, low power losses, and efficient performance in battery-powered applications. The simulation



To use ThingSpeak, you must sign in with your existing MathWorks account or create a new one.

Non-commercial users may use ThingSpeak for free. Free accounts offer limits on certain functionality. Commercial users are eligible for a time-limited free evaluation. To get full access to the MATLAB analysis features on ThingSpeak, log in to ThingSpeak using the email address associated with your university or organization.

To send data faster to ThingSpeak or to send more data from more devices, consider the paid license options for commercial, academic, home and student usage.

Fig. 6. Thingspeak

and analysis showed that the proposed inverter offers reliable operation and good efficiency for low-power AC applications.

Integrating the ThingSpeak IoT platform allowed for real-time monitoring and visualization of key inverter parameters such as output voltage and current. The cloud-based monitoring system improved performance analysis and highlighted how IoT technology can be used in modern power electronic systems.

Even though the generated square-wave output has harmonic distortion, the inverter's performance can be improved by using Pulse Width Modulation (PWM) techniques and output filtering methods. Future work may include developing a pure sine-wave inverter, better protection circuits, and improved IoT-based monitoring and control systems.

REFERENCES

[1] "Power Electronics: Circuits, Devices, and Applications", M. H. Rashid, Pearson Education, 3rd Edition, 2004
[2] "Power Electronics: Converters, Applications, and Design", N. Mohan, T. M. Undeland, and W. P. Robbins, John Wiley & Sons, 3rd Edition, 2003
[3] "Fundamentals of Power Electronics", R. W. Erickson and D. Maksimovic, Springer, 2nd Edition, 2001
[4] "Microelectronic Circuits", A. S. Sedra and K. C. Smith, Oxford University Press, 7th Edition, 2014
[5] "IRFZ44N Power MOSFET Datasheet", International Rectifier, Available: https://www.infineon.com
[6] "Design and Simulation of Single Phase Inverter Using MOSFET", S. Kumar and R. Singh, International Journal of Engineering Research and Applications (IJERA), vol. 4, no. 6, pp. 45–50, 2014
[7] "PWM Techniques for Inverter Applications", J. Holtz, IEEE Transactions on Industrial Electronics, vol. 39, no. 5, Oct. 1992
[8] "Simulation of Power Electronics Circuits Using MATLAB/Simulink", MathWorks Documentation, Available: https://www.mathworks.com