Improving the Performance of Mosfet Field Effect Transistors Using SPWM Technology

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Abstract: Electronic applications based on MOSFET technology have witnessed widespread adoption, particularly in the field of voltage regulators that convert direct current to alternating current. These systems rely on feedback loops that monitor transistor performance and adjust the width of the control pulse applied to the transistor gate to improve thermal stability and ensure operational efficiency. In this research, we present an innovative control mechanism based on pulse width modulation by measuring the load current and transistor temperature. This allows the system to adapt to different operating conditions, thereby improving performance efficiency. To achieve this, the sinusoidal pulse width modulation (SPWM) technique will be adopted, which offers additional advantages over the traditional PWM modulation method. The research will also examine the signal distortion coefficient resulting from applying both techniques to transistors, analyzing the effect of pulses on signal quality and the extent of performance improvement when using SPWM instead of PWM. In addition, a variable frequency half-bridge converter will be designed and implemented to test the two technologies in practice and compare the results obtained from each, providing a comprehensive evaluation of the effectiveness of the new system in improving transistor performance under different loading conditions.

Keywords: *Mosfet , SPWM, PWM* **.**

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I. INTRODUCTION

Microcontrollers are a qualitative leap in the world of electronics, as they have given electronic circuits and systems enormous capabilities that no one could have imagined before [1]. We now find microcontrollers in all devices and things around us in our daily lives, starting with televisions, washing machines, modern refrigerators, cars, children's toys, computers, air conditioners, modern ovens, and electric elevators. Even further, we find them in automated factories, satellites, and missile systems. In short, microcontrollers have become part of all automatic and semi-automatic systems and are an essential part of many systems.

II. RESEARCH IMPORTANCE AND OBJECTIVES

The importance of the research lies in developing new control systems that improve the efficiency and performance of MOSFETs through feedback loop systems that monitor transistor performance and adjust the pulse width to achieve optimal thermal stability.

The importance of the research is highlighted by the following points:

- Improving transistor efficiency: By monitoring the load current and transistor temperature, improvements in transistor efficiency can be achieved under various load conditions.
- SPWM technology: The research presents the use of SPWM technology in pulse width control, which helps reduce signal distortion and increase system efficiency.
- Reducing signal distortion coefficient: Studying the signal distortion coefficient when applying conventional pulses and SPWM will contribute to improving signal quality and thus improving overall performance.

III. POWER TRANSISTORS

Improvements in the MOSFET transistor are linked to the significant development of MOS (metal-oxide-semiconductor) technology, which relies on incorporating metal oxides into the structure of semiconductor electronic components to take advantage of their high insulating properties..[2] This transistor belongs to the family of unipolar transistors, which rely solely on the majority of charge carriers to generate current. The

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power MOSFET is characterized by its high switching speed (on/off), as it can operate at a switching frequency exceeding MHz, making it the fastest switch used in electronics.[3]

IV. ELECTRICAL AND ELECTRONIC RESEARCH MODEL:

Electronic switches must be capable of achieving fast on-off states. Tremendous achievements have been made in the technology of manufacturing electronic switches with high powers (with high nominal conduction currents and hold-down voltages) and high switching speeds (responding to operation at high frequencies)[4]. Various electronic switches are used in the formation of dies, including:

- Gate turn-off thyristor (GTO).
- MOS controlled thyristor (MCT).
- Bipolar junction transistor (BJT).
- MOS field-effect transistor (MOSFET).
- Insulated gate bipolar transistor (IGBT).

Insulated gate transistors (IGBTs) are formed by combining a MOSFET with a bipolar junction transistor (BJT). The gate of these transistors is insulated, similar to that of MOSFETs, and they can be controlled by gate pulses at low power, while the conduction voltage is low and comparable to that of bipolar junction transistors (BJTs). Currently, IGBTs are commonly used in medium-power motor drive systems. The nominal currents of IGBT models reach 1 kA at a holding voltage of approximately 3 kV, replacing thyristors used in high-power industrial applications [5]. Reverse recovery diodes are connected in parallel with IGBT transistors to ensure current flow in the opposite direction to the voltage polarity when operating on inductive loads such as induction motors (see Figure 1.1). This prevents transient disconnections of the induction motor, which generate high transient voltages at the IGBT transistor terminals and cause damage. Figure (1) shows a single-arm switching circuit, known as a single-phase half-bridge switching circuit [6].

The output voltage depends on the switching state (electronic switching modes) and the direction of load current flow. Each arm of the switching circuit contains an upper and lower transistor (T1 and T4) and an upper and lower diodes (D1 and D4). When the transistor T1 is in the conduction state, the output voltage applied to the load is equal to ½ Udc, and the instantaneous inductive load current is increasing in the positive direction and the direction of the instantaneous power from the DC loop to the load. Conversely, the diode D1 is connected when the load current flows to phase a (ia) in the opposite direction and the direction of the instantaneous power from the load to the DC loop[7].

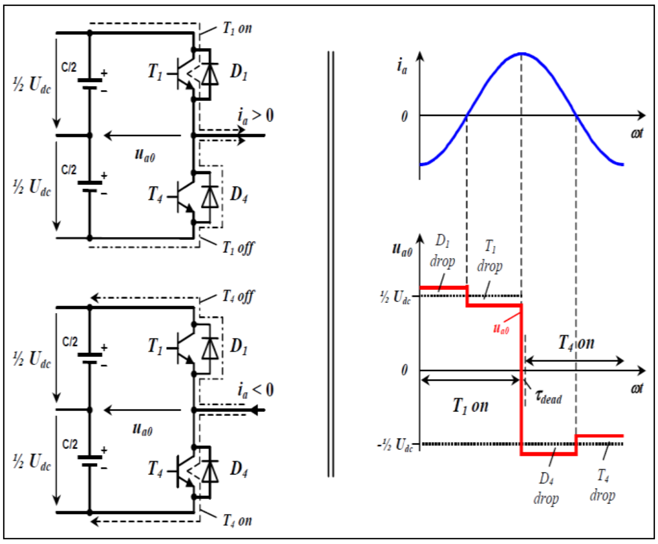

Fig (1) Half-Bridge Circuit.

Similarly, when T4 is connected, which corresponds to T1 being disconnected, the output voltage applied to the load is equal to ½ Udc-, and the instantaneous load induced current (ia) increases in the negative direction, in the direction of the instantaneous power from the DC loop to the load. Conversely, when the load current (ia) flows in the opposite (positive) direction, the direction of the instantaneous power from the load to the DC loop, diode D4 is connected. [8]

During the T1 connection period, the load current (ia) is positive, and the output voltage (ua0) will be less than ½ Udc, by an amount equal to the voltage drop across T1. When the load voltage reverses direction by connecting diode D4 while maintaining the current direction, the output voltage (ua0) will be higher than ½ Udc-, by an amount equal to the voltage drop across D4. Similarly, the output voltage can be derived for the T4 and D1 connection periods.

Assuming that the voltage drops across the diodes are neglected, which are equal to (≈1V), the output voltage during half a cycle can be considered equal to ½ Udc and -½ Udc, respectively [9]. We can also neglect the τdead (dead-time interval) to simplify the study, which achieves the ideal case of turning off one of the feedback diode and turning on one of the transistors simultaneously (by neglecting the τdead) or vice versa [10].

V. PRACTICAL CIRCUIT

Figure (2) shows the practical circuit, which contains the controller, display screen, control panel, and half-bridge module.

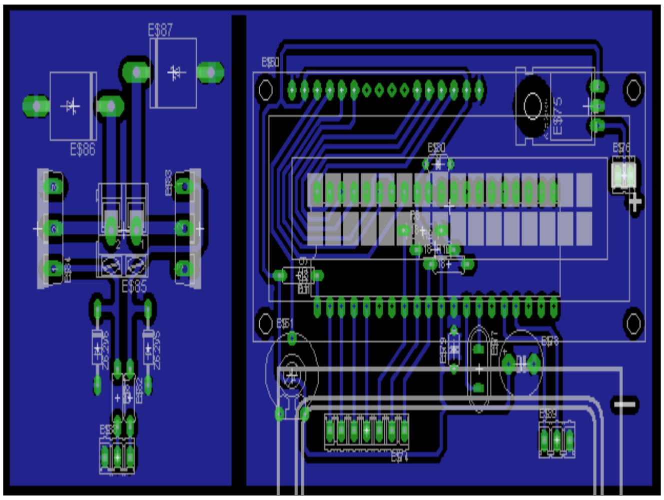

Fig (2) Practical Circuit

VI. RESULTS

Through the above, a converter was achieved that operates at different frequencies input by the user. The results were analyzed according to the PSNR standard. Table (1) shows the results of the converter whose sine signal was compared with a reference sine signal from MATLAB:

Table (1) Results of the Mold Whose Sine Signal was Compared with a Sine Signal

PSNR (dB) PWM	**PSNR (dB)** SPWM	**Signal Frequency**
54.2	47.3	10
45	41.2	20
38.8	35.7	30
36.6	34.12	40
33.1	30.5	50
32.5	29.7	60
31.6	30.5	80
28.7	26.3	100

From the previous table (1), we note that the PSNR values were not large even for frequencies (100), so the signal is close to ideal, which allows the possibility of using the converter with many loads.

VII. CONCLUSION

This paper addresses the growing applications of metal-oxide semiconductor field-effect transistors (MOSFETs) in DC-to-AC voltage conversion systems. Recognizing the critical need for efficient feedback mechanisms to monitor MOSFET performance and dynamically adjust the control pulse width to achieve optimal thermal stability, this research proposes a control strategy based on continuous monitoring of the load current and MOSFET temperature. This approach ensures adaptive circuit behavior and enhances efficiency under changing load conditions. The control pulse width is determined using a sinusoidal pulse-width modulation (SPWM) technique. Experimental validation on a half-bridge inverter topology demonstrated a 12% improvement in the peak signal-to-noise ratio (PSNR) of the output sine waveform, indicating enhanced load stability.

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