PERFORMANCE COMPARISON OF SEMICONDUCTOR DEVICES AND IMPLEMENTATION OF SINGLE PHASE H-BRIDGE INVERTER

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Abstract

Most of the available inverters using either PSW or MSW may cause damages to delicate microprocessor controlled electronics due largely to their switching frequency and speed, efficiency, conduction losses, thermal conductivity etc. This necessitates the need for implementation of efficient and more reliable inverter systems. In the first part of this work, Semiconductor devices such as silicon (Si), silicon carbide (SiC) and Gallium Nitride (GaN), are compared. They are considered by previous researches to have high switching frequency, high switching speed, higher efficiency, lower conduction losses, lower switching losses, and thermal conductivity. The devices with such properties can improve the performance of an inverter, and make the implementation of single-phase H-bridge inverter system a reality. The basic principle of inverter system is to convert the DC input power into AC output power at desired output voltage and frequency. The second part is based on the implementation of Single Phase H-Bridge Inverter using Semiconductor [redacted]

Devices and its operation is simulated using PLECS (a software tool for system-level simulations of electrical circuits developed by Plexim). Hence, a single-phase full-bridge inverter with perfect AC output voltage has been realized.

KEYWORDS:
Silicon (Si); Silicon Carbide (Sic); Gallium Nitride (Gan); H- Bridge Inverter; Single Phase Inverter.

Introduction

In power Electronics, most of power semiconductor devices served by device produced using silicon, and the fundamental requirement of any power semiconductor devices must be efficient, reliable and low cost. However, the fundamental physical properties of silicon have restrictions which obstruct the devices based on Silicon (Si) materials being the contender for the future of power electronics. To provide a solution to limitations of silicon devices leads to considerations of wide band gap (WBG) semiconductors materials, for instance, Silicon Carbide (SiC) and Gallium Nitride (GaN) power semiconductor device[1]. The main advantages of these semiconductor materials are significant operations over a wide temperature range, high saturation drift velocity, and high dielectric quality. Power MOSFET in some applications has become the device that replaced silicon because of its high switching speed, lower switching losses and under the steady condition it has high input impedance, to improve the efficiency of semiconductor devices it is crucial limit the switching losses[2]. The properties of these materials are potent to designers in light of the fact that wide band gap semiconductor devices promise significant execution enhancements over their silicon counterparts [3]. It is, in this manner, it is essential to think about other semiconductor materials if further enhancement in the performance of the device is to understand later.

The performance of these power semiconductor devices, give semiconductor devices a requirement for the promises high switching frequency, high switching speed, higher efficiency, lower conduction losses, lower switching losses, and high thermal conductivity. Semiconductor devices with such properties can improve the performance of an inverter. For this report, we investigate the conduction and switching losses of semiconductor devices as well as single design phase H-Bridge inverter using PLECs.

Literature Review

Silicon (Si) MOSFET

Silicon (Si) was one of the main powers MOSFETs ever constructed and by a wide margin the most generally utilized semiconductor material for power devices [1]. Silicon MOSFET confirm to be extremely efficient at the time and was a leap forward in technologies in the field of power MOSFETs. Si has a massive example of overcoming difficulty throughout the most recent decades and made it for example possible to assemble switched mode control supplies or solar powered

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inverters with efficiencies around 95% or even near 100% [4]. However, after some time, silicon shows to be less effective at high-frequencies and new semiconductor materials needed to come into the picture [2].
Silicon is not Wide Band-gap (WBG) material [16][17][18] and low switching frequencies which result in bulky [4]. A few semiconductors are listed "Wide-Band-gap" semiconductors on account of their Wider Band-gap. Silicon has a Band-gap of 1.1 eV and therefore, is not considered a wide Band-gap semiconductor material[1]. In general, high power silicon semiconductor device operate at lower frequencies (<10 Hz)[5].
The few suitable technologies utilized in high frequencies and high temperature are silicon carbide (SiC) and gallium nitride (GaN) [2].

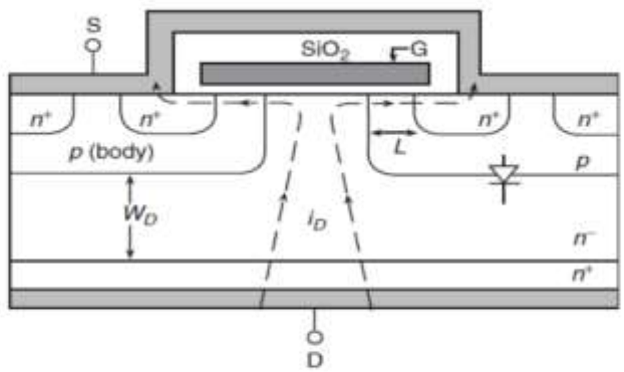

Figure 1: Cross-sectional view of Si MOSFET

The figure 1 above show a cross-sectional view of on a Si MOSFET labeled (S, G, D) which are the source, gate and drain terminals respectively. Here, the source and drain are on the opposite sides. the diffusion used are, the one p-type form the body, and the other n+-type to form the source area, therefore, for such reason is called vertical double-diffusion MOSFET.

Silicon Carbide (SiC) MOSFET

Silicon carbide (SiC) semiconductor is a wide band gap semiconductor material which proven to use in many applications, and it's few properties also made it is more beneficial than silicon counterpart, in new applications, which require high frequency furthermore, operational ability at a higher temperature[2]. These wide Band-gaps (WBG) semiconductor devices can operate with limited switching loses and conduction losses over higher frequencies and higher temperatures limits needs for some passive components and also conducts heats efficiently [2][6].

Wide band-gap (WBG) semiconductor can work at high frequency and higher power within the space silicon semiconductor device cannot [7][8][9][9]
Innately silicon carbide (SiC) has a substantial atomic bond quality which gives large breakdown field strength and higher saturated electrons speed [10]. Achieving more benefit from those qualities during switching transition and conduction, silicon carbide (SiC) power semiconductor device have become to be progressively prominent for high power density, higher switching frequencies and high efficiency[10]. Other significant advantages of silicon carbide (SiC) semiconductor materials have a significant operation over a wide range of temperature, higher saturation drift velocity, and high dielectric strength.[1]
At the point when high power is required, SiC has benefited over Si and GaN because of its better heat conductivity and higher field [2]. Silicon carbide (SiC) semiconductor has higher thermal conductivity than Si or GaN implying that SiC devices can hypothetically work at higher power densities than either Si or GaN. Higher thermal conductivity mixed with wide Band-gap and high primary field gives SiC semiconductors favourable position when high power is a critical attractive device quality.[11].
As wide Band-gap (WBG) semiconductors materials Silicon Carbide (SiC) offer much lower on-state resistance (RDS(on)), good thermal conductivity and better breakdown field than practical counterpart silicon power semiconductor device.[12]. These properties permit high voltage blocking ability, operation at high temperatures, and lower switching losses when compare with that of Silicon (Si), which make it more attractive for high power applications.[1]. However, silicon carbide (SiC) power semiconductor device is severely limited in light of a high density of crystal weakness which is available in the drift region of the semiconductor device [12]. The figure 2 below shows the cross-sectional view of Silicon carbide (SiC) 4H-SiC MOSFET.

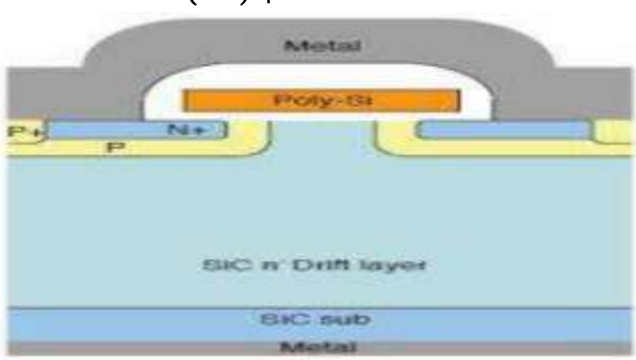

Figure 2. Cross-sectional view of SiC MOSFET

Gallium Nitride (GaN) MOSFET

Gallium Nitride (GaN) is one the latest semiconductor device which entered power electronics arena which has been set up and still is being dominated by silicon [4]. It is a wide band-gap semiconductor material like Silicon carbide (SiC), GaN semiconductors are likewise ordinarily referred to as compound semiconductors since they include numerous components from the occasional table[13]. Gallium nitride is one of the devices, which has effectively implemented in the assembling of MOSFETs [1][9][14]

Gallium Nitride (GaN) semiconductor is a wide band gap semiconductor material which proven to use in many applications, and it's few properties also made it is more beneficial than silicon, in new applications, which require high-frequency application[2]. Gallium Nitride (GaN) proved which is less expensive and very efficient than traditional low-cost silicon [1]. The combination of low losses and high switching performance confirm to be suited especially appropriate for a rising class of switching power supplies with ultra-high bandwidth (in the MHz range)[9]. These devices are considered to be most suitable for different switching and RF power applications [11].

The advantages of those qualities during switching transition and conduction losses GaN furthermore, power semiconductor device have confirmed to be progressively well known for high power density, high switching frequency, and high efficiency[10]. and faster switching speed[15]. GaN semiconductor MOSFETs discovered incredible use within the power supply network because low switching losses and their simplicity of drive makes them ideal for high switching frequency applications[16]. GaN semiconductor device is more efficient, smaller (lighter) and lower cost as compared to silicon (Si) semiconductor device[17]. However, the moderately poor thermal conductivity of GaN semiconductor materials makes heat the heat management for GaN semiconductor device a challenge for the system designers to battle with[11].

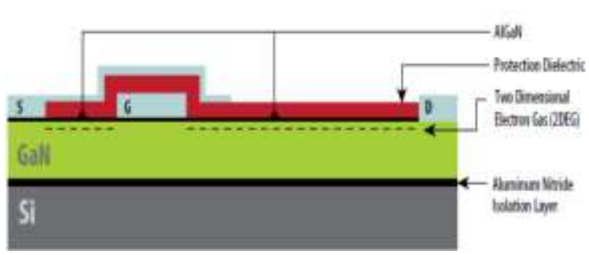

Figure 3: Cross-sectional view of E-mode GaN.

Physical properties of semiconductor devices

a. Silicon (Si) MOSFET

The Silicon (Si), generally low Band-gap (1.1 eV) and low primary electric field (30 V/µm) require high voltage devices to have significant basic thickness. The considerable thickness means devices with high resistance and related conduction losses. Therefore, Silicon (Si) has high conduction losses[7]. As Silicon (Si) has moderately low Band-gap additionally contributes to the higher characteristic carrier concentrations in the device, which leads to high leakage current at higher temperatures and considered as poor higher temperature performance[7].

Silicon (Si) with Lower ban-gap means a smaller electric breakdown field (Ec), which results in Silicon (Si) semiconductor device with lower breakdown voltages ($0.3x10^6$V/Cm). Furthermore, with a lower electric breakdown field, much lower doping level could be achieved, and the device can be made thicker.

Silicon (Si) semiconductor has lower drift velocity ($1x10^7$), leads to low frequency switching capability because the high frequency switching capability of a semiconductor device is directly proportional to its drift velocity, even though Silicon (Si) has a high Electron Mobility (1300cm^2/V.s), in addition, the high electron mobility and the electron saturation velocity which lead to higher switching operation of a device[11]. Therefore, the high switching frequency is ascribed to the high electron mobility and Saturation Drift Velocity.[1] Silicon (Si) semiconductor device has a thermal conductivity of (1.5 W/Cm.K) which is relatively low, this is because as the temperature increases the thermal energy of the electrons in the valance band increases, At a specific temperature, they have inadequate energy to move to the conduction band as such, silicon has a bad thermal conductivity at higher temperature.

b. Silicon Carbide (SiC) MOSFET

The analysis of physical properties of Silicon carbide (SiC) (4H-SiC) semiconductor materials, the device is considered as wide ban-gap semiconductor devices which has a Band-gap energy of (3.26 eV) which gives it more significant advantages for power electronic user for high power applications. Silicon carbide (SiC) has higher electric breakdown field (3x106V/CM)[1], this property allows the device to reduce its drift layer thickness also decreasing the minority carrier charge storage and increase the switching frequency of the device, hence suitable for high switching frequency applications.

Silicon carbide (SiC) has higher thermal conductivity (3.7W/CM. K) enhance heat dissipation and combined with wide Band-gap energy offer the device to be more efficient at high temperature up to 350◦C [13] Operation in high power application. Besides, Silicon carbide has lager saturated electrons drift velocity (2x107), coupled with Electrons Mobility to offer the device high-frequency switching capability because the high frequency switching capability of a semiconductor device is directly proportional to its drift velocity[1]. Also, the high electron mobility and the electron saturation velocity make it be the higher switching frequency device. Therefore, the high switching frequency is lead to high electron mobility and Saturation drift velocity.

Silicon carbide (SiC) lower Electron Mobility (900 cm2/V. S) as compared to silicon counterpart. With this Silicon carbide (SiC) have advantages and silicon (Si), which result in high switching frequency, high switching speed, lower conduction losses, and lower switching losses. In addition, silicon carbide (SiC) has excellent thermal conductivity than Si and GaN which allows for high-temperature operation and efficient thermal management[16].

c. Gallium Nitride (GaN) MOSFET

Gallium Nitride (GaN) semiconductor device is a wide band-gap semiconductor material like Silicon carbide (SiC), GaN semiconductors, Band-gap energy (3.4 eV) which offer several benefits for power electronic designers.

Gallium Nitride (GaN) has a higher electric breakdown field (3.5x106V/CM)[1], which permit the device to reduce its drift layer thickness also decreasing the minority carrier charge storage and increase the switching frequency of the device, hence good for high switching frequency applications.

Gallium Nitride (GaN) has lager saturated electrons drift velocity ($2.5x10^7$), coupled with Electrons Mobility and wide band-gap to allows the device high frequency switching capability because the high frequency switching capability of a semiconductor device is directly proportional to its drift velocity [1], with higher Electron Mobility (900-200 cm2/V.S) which result in high switching frequency, high switching speed, lower conduction losses and lower switching losses. However, Gallium Nitride (GaN) has lower thermal conductivity (1.3W/CM.K) which is much lower than that of silicon carbide (SiC) that make the device not suitable for high-temperature applications [1].

d. Physical Properties

The table 1 below shows the physical properties of Silicon (Si), Silicon carbide (SiC) and Gallium Nitride (GaN), the properties include Band-gap energy, Electron mobility, Breakdown field, saturation drift velocity, and thermal conductivity. This property reveals the performance of a semiconductor device such as high switching frequency applications, lower switching losses as well as excellent thermal conductivity which is necessary for high-temperature applications.

Table 1 Physical Properties of Silicon (Si), Silicon Carbide (4H-SiC) and Gallium Nitride (GaN). [1][5][11][16]

Electrical	*unit*	*Si*	*4H-SiC*	*GaN*
Band-gap Energy	***eV***	***1.1***	***3.26***	***3.4***
Electron Mobility	***CM2/V.s***	***1300***	***900***	***900-2000***
Breakdown field	***V/CM***	***$0.3x10^6$***	***$3x10^6$***	***$3.5x10^6$***
Saturation Drift velocity	***CM/s***	***$1x10^7$***	***$2x10^7$***	***$2.5x10^7$***
Thermal conductivity	***W/Cm.K***	***1.5***	***3.7***	***1.3***

IV. METHODOLOGY

Single phase full bridge inverter converts DC to AC, otherwise called inverter. The inverter Converts dc voltage to AC voltage at desired output power and frequency[18]. The inverter performance depends primarily on its modulation strategy, many carrier-based pulse-width modulations (PWM) and to acquire a quality output voltage waveform with a minimum ripple and distortion they need higher switching frequency with several pulse width modulation (PWM)[19]. The h-bridge transformerless inverter could be achieved with lower cost, smaller volume, less complicated and higher efficiency compared to transformer counterpart.

However, the transformerless inverter has the challenges of leakage current which flow through the parasitic capacitance of PV due to the common high-frequency mode (CM). This challenge of leakage results to PV module degradation, high power losses, and other issues which require attention[20]. In order to provide a solution to these problems of leakage current, several technique and topologies use during the main dissertation and investigations will be carried out.

Design of single-phase Inverter

The design consideration of H-Bridge single-phase inverter, voltage source inverter (VSI) design control of such inverter can see in the circuit diagram below and calculation of the inverter parameters.

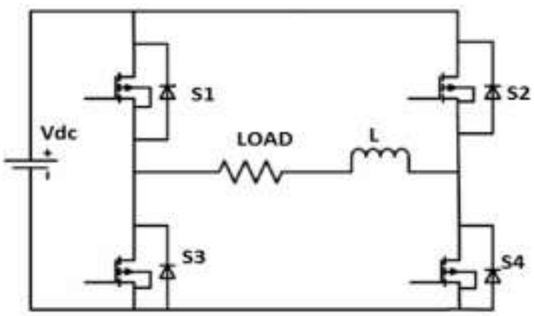

Figure 4 H- Bridge inverter Circuit

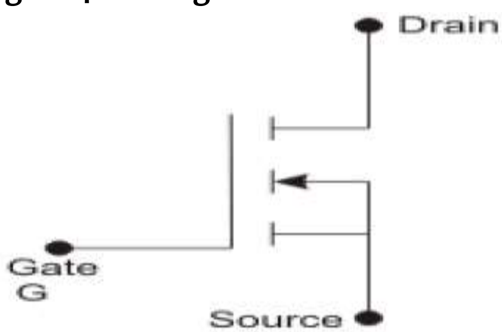

Figure 5. MOSFET[22]

From the given data, we can find some of the invert parameters.

The MOSFET Drain current:

From System power P = 1000Watt (P =1 KW)

Input voltage (Vdc) = 400V.

Therefore, the Drain current of the MOSFET

$$I_D = \frac{P}{V} = \frac{1000}{400} = 2.5\ A$$

The output voltage of inverter V_{output} (V_{rsm}) V_{rms} = 240V.

To find the full load output current I_{output} (I_{rms}) $= \frac{P}{Vrms} = \frac{1000}{240} = 4.166A$

We can also find the switching Time (T) from the switching frequency fs = 50Hz.

The switching Time (T) = $\frac{1}{Fs} = \frac{1}{50000}$ = 0.02ms

Table 2. shows the inverter parameter which include the input/ output voltage as well as system power.

Parameter	*Value*
Input voltage (V_{in})	***400V***
Input Current (I_{in})	***2.5A***
Output Voltage (V_{rsm})	***240V***
Output Current (I_{rsm})	***4.166A***
System Power	***1000Watt***
Switching Frequency	***50Hz***
Output Inductor	***2.2mH***
Output Capacitor	***20µF***
Inverter frequency	***50Hz***

Operation of H-Bridge inverter

An H Bridge inverter is a switching arrangement made out of four switches arrange like H shape. The single phase full wave H- bridge inverter circuit shown in figure 4 which consist of DC voltage supply, switches S1, S2, S3, S4, Load and a filter, the filter on the other hand consist of capacitor and inductor while the switching element used is metal oxide semiconductor field effect transistors (MOSFETs), with a diode connected in anti-parallel to it which provide alternative path for the load when the power switches turn off.[18]. The square wave from the PWM is powering the gate of the MOSFETs.

Fundamentally, to turn the MOSFETs (in figure 3.2) on, a voltage between drain and source (VGS) must be connected. This reality, together with a positive voltage between drain and source (VDS), result in an electron channel that permits current flow in the drain (ID). The operation of the MOSFETs, firstly switch S1 and S4 turned on by triggering the gate of the MOSFET for a period of time, at that time the input supply voltage is 400V DC and the output voltage 400V applied across the resistive load. The current flows from the supply S1, S2, load and the negative of the supply S1, S2. This is a conduction path of the first half cycle (180) of operation, the output voltage = +Vdc.

Secondly, switch S2 and S3 are turned on by giving a trigger pulse to the gate of the MOSFETs for a period of time. During this time the DC input voltage supplied at the output, however, is in a negative direction, the output voltage = – Vdc. Therefore, the current begins to flow from the supply S2, S3, load and to the negative of the supply. As the two half cycles proceed with the positive and the negative voltage is connected at the load and the current direction changes in the two half cycles.
Finally, as the current direction changes the alternating voltage is obtained at the load and consequently converting Dc voltage to AC voltage at desired power output and frequency.[23]

Table 3. Switching state and output voltage

State	*Switches Closed*	*Output Voltage*
1	***S1 & S4***	***+Vdc***
2	***S2 & S3***	***-Vdc***
3	***S1 & S2***	***0***
4	***S2 & S4***	***0***

Switches- MOSFETs

MOSFET is a semiconductor device used in converting DC voltage into AC voltage, as shown the figure 4. The four switches used to generate AC wave from the output of the DC supply voltage and a diode connected in parallel with the switches, on the other hand, it is called feedback diode, they are used to return power to the DC voltage source when inductive load connected to the system. While using MOSFETs to switch a DC voltage over a load, the drain terminals of the high side MOSFETs regularly connected with the highest voltage in the system. This makes the situation complicated, as the gate terminal must be 10V higher than the drain terminal voltage for the MOSFET to start conducting[24].

Pulse Width Modulation

In an inverter system, PWM is utilized broadly as a method for powering alternating current (AC) devices with the help direct current (DC) supply by DC source for an advance conversion (inverter). The duty cycle variations in the PWM signal results in a DC voltage over the load in a specific instance which appear to the load as an AC signal.

The PWM control requires the generation of both carrier and reference signals that feed into a comparator, the comparator compares and makes output signals based on the variation between the signals, the frequency of the desired output signal is sinusoidal, which is the reference signal. While the carrier signal is frequently either sawtooth or triangular wave, a frequency fundamentally more noteworthy than the reference and whenever the carrier signal overshoots the reference, the comparator output signal is at one state, and when the reference is at a higher voltage, the output is at its second state. This is continuously feeding and powering the power MOSFETs [25].

Therefore, for a single-phase sine wave generation, two PWM pulses are required. The reference sinusoids of these two pulses have a mutual shift of 180° each and both of them with the same switching frequency [26]. One of the benefits of PWM switching control is that one can able to generate perfect sinusoidal AC output voltage.

However, the disadvantage the PWM switching control is that it not simple than the square wave control and it required complex control to feed the inverter. Another disadvantage of PWM inverter is that due to frequent switching action of power semiconductor devices, it increases the switching losses.[27]. Unipolar PWM switching inverter produces less EMI and offers fewer switching losses. Besides, it offers an advantage of generating high efficiency in inverter [28].

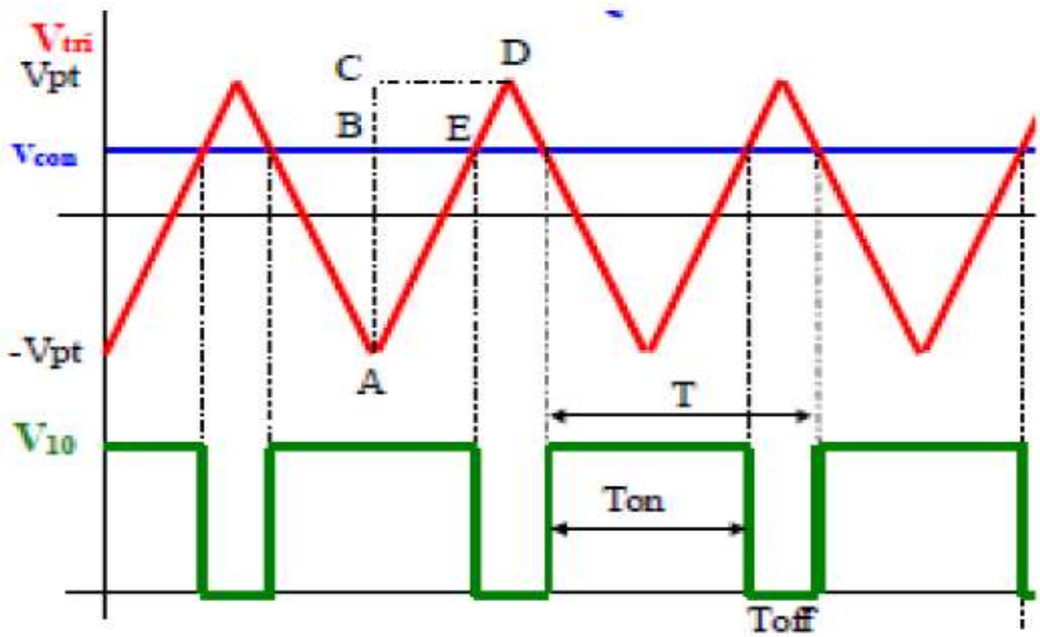

Figure 6. PWM

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Filter

In order to improve the efficiency of inverter and the quality of the output voltage, specific switching frequency must be selected which is low enough to keep the switches in line, yet sufficiently high to ensure the filter inductor is not superfluously huge. Higher switching frequency introduces little losses, however, improve the quality of output voltage and reduces the ripples[25].

The filter utilized here is an L-C passive filter, comprising of an inductor and a capacitor. Ferrite core component may use in light of the fact that the higher switching frequency (50 Hz) prompts first heat. The capacitance of the capacitor is 20μF. Furthermore, the inductor's inductance is 2.2 mH. Moreover, a resistive load connected in parallel with the filter, which attenuates the PWM and produces a pure sine wave with fewer ripples and less Harmonic distortions [26].

Simulations

Simulation is referring to the way toward experimenting with a model to foresee how to predict the system would carry the same condition. Therefore, simulations have been carried out for H-bridge single-phase inverter and the comparison of conduction and switching losses of the semiconductor devices such Silicon (Si), Silicon carbide (SiC) and GaN using PLECS software.

PLECS

The PLECS means Piece-wise Linear Electrical Circuit Simulation. PLECS is a software package that facilitates the simulations and modelling of the complete active circuit which include inverters as well as load that covers the thermal, electrical, magnetic and mechanical aspect of the inverters including their control. The software has many advantages[30]. The experiments were performed using PLECS as the model shown in figure 7 below, the model consists of input voltage, DC 400V, four MOSFETs, PWM with switching frequency of 50Hz, inductor of 2.2mH, capacitor of 20μF and Resistive load of 57Ωas well as voltmeter and a scope connected across the load which measured the output voltage. The output voltage obtained AC, 240V, 50Hz which can directly see on the scope connected to the voltage.

The MOSFETs has two types of losses:

- Conduction loss which occur as a result of current flow and the resistivity from the rain to source which is called RDS (ON).

- Switching loss which occurred as a result of rise and fall time as well as transistor's little signal capacitance with the gate and source terminal shorted[31].

These MOSFETs losses can also be seen on the scope directly and the total losses obtained by the display. The experiment for conduction and the switching the losses were carried out and the model shown in figure 7 below. Besides, the waveform for all experiments can also be presented.

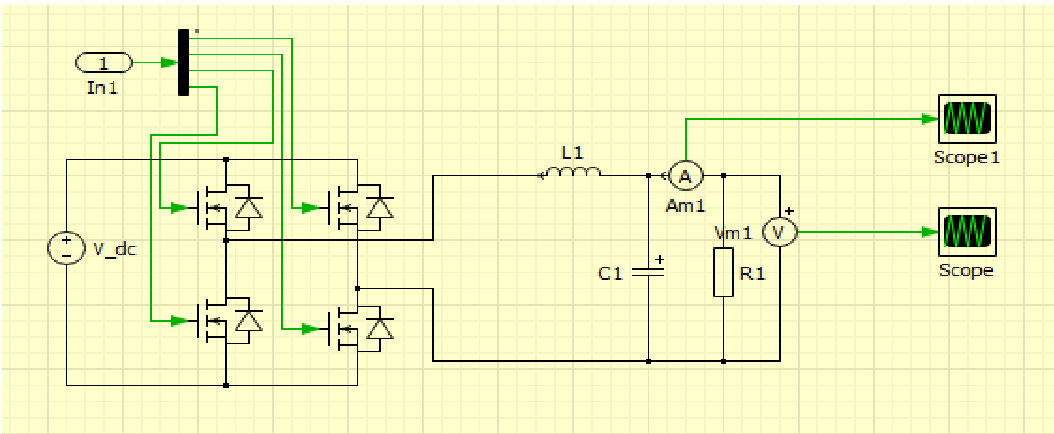
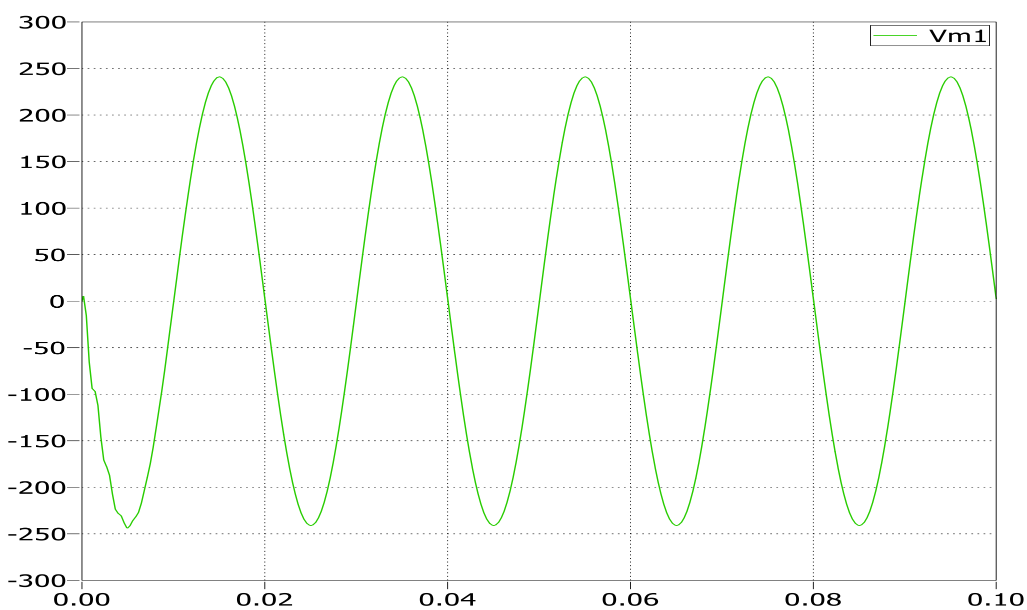


Figure 7. H-bridge single phase inverter model.



The comparison between High speed switching series third generation Silicon IGBT and the Silicon Carbide Power MOSFETs have carried out using PLECS and the results of the simulations of voltage and current waveforms shown in figure 8 and 9 below. Total conduction losses at 50Hz switching frequency is also given in figure 10

Figure 8. Output Voltage Waveform of H-bridge inverter (240V AC)

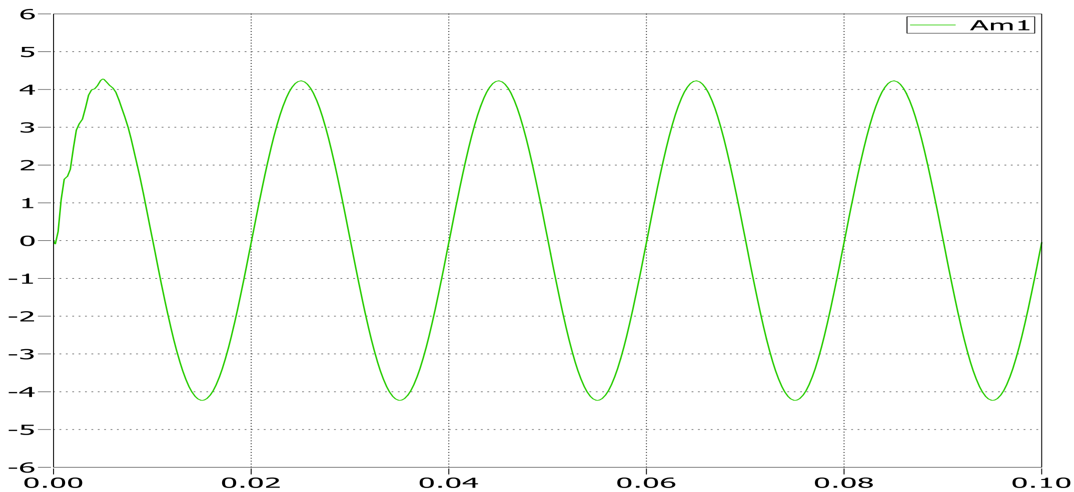


Figure 9. Output Current Waveform of H-Bridge Inverter

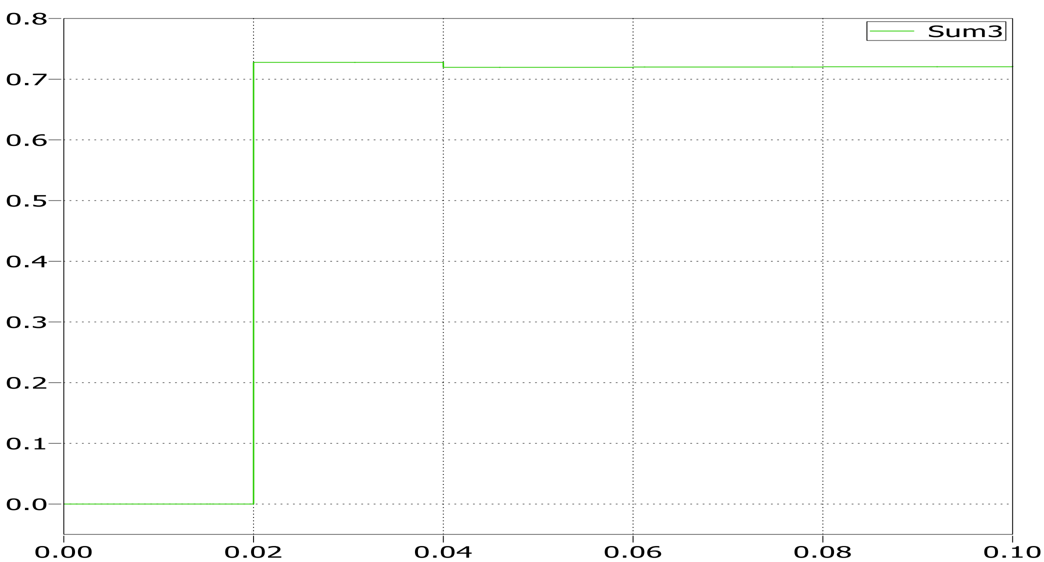


Figure 10. Total conduction losses SiC MOSFETs at 50Hz switching frequency

The comparison between High speed switching series third generation Silicon IGBT and the Silicon Carbide Power MOSFETs have carried out using PLECS as shown in figure 11a and figure 11b, the results of the simulations also shown in table 4 and 5 which detailed the conduction and switching losses as well as efficiency under various switching frequencies have considered.

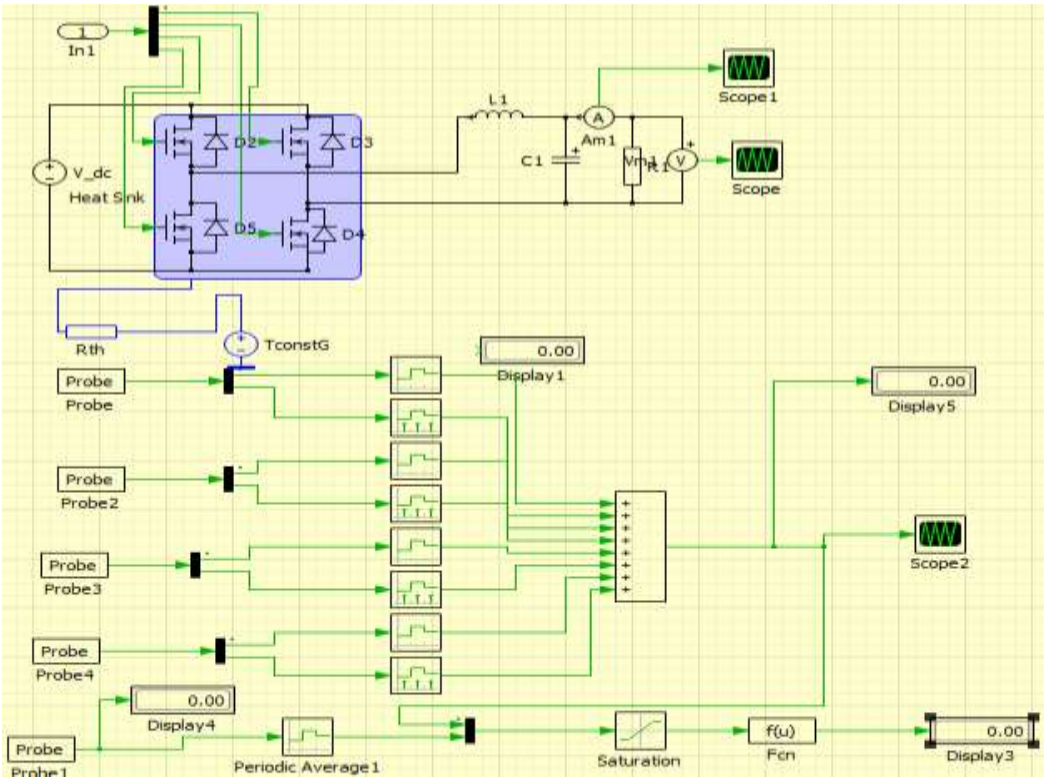


Figure 11a. Total conduction and switching losses model.

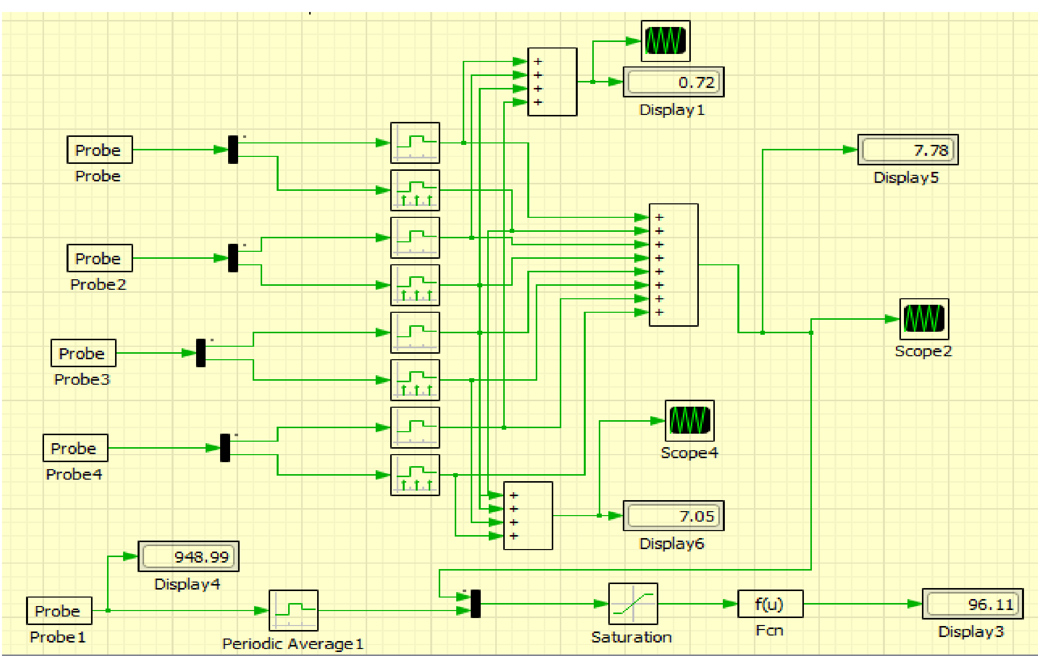


Figure 11b. conduction and switching losses model.

SIMULATION RESULTS AND DISCUSSION

The simulation of single-phase H-bridge inverter has been implemented using PLECS, as shown in figure 7. Cc side connected to the dc voltage source of Vdc= 400V and the ac side consist of four MOSFETs and connected to a purely resistive load of R=57Ω, the inductance of L=2.2mH and capacitor of C=20µF. The ac voltage has designed with a fundamental frequency of 50Hz.

The PWM also connected with a modulation index of 0.6 and a switching frequency of 50Hz. Figure 8 shows the resulting voltage across the resistive load is a sine wave of 240V, AC voltage. Even though the LC filter applied to remove some of the high-frequency noise, for better output, a better filter may be required at the final design during the dissertation.

Figure 9 also shows the output current of the inverter system which is Ac waveform. The fundamental working principle of the inverter is to convert dc power into ac power at the desired frequency and output voltage, therefore, from the two waves form it can confirm that AC output voltage at desired output power and frequency achieved.

The simulations also carried out on model shown in figure 11a and 11b to investigate the switching losses, and conduction losses model have been implemented using PLECS. Figure 10,12,13,14 and 15 show the results of conduction and switching losses of silicon IGBT and Silicon carbide MOSFETs.

The results indicated that silicon IGBT has higher switching and conduction losses when compared with silicon carbide MOSFETs. Also, silicon IGBT becomes less efficient at high switching frequency because it generates high switching and conduction losses. However, it can be useful at lower power and lower switching frequency.

Silicon Carbide MOSFETs has lower switching and conduction losses when compared with silicon, and silicon carbide confirmed high efficiency at the high switching frequency.

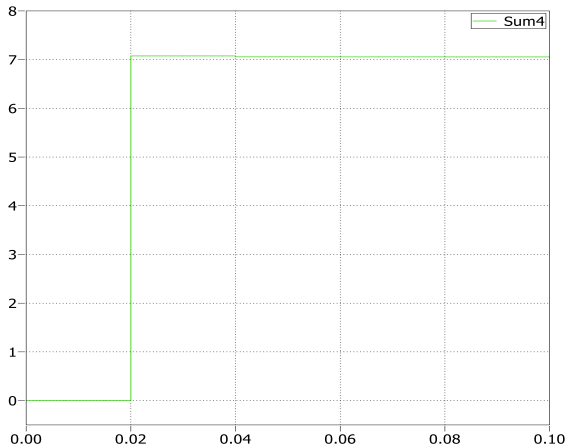


Figure 12. Switching losses of SiC MOSFETs at 50Hz switching frequency

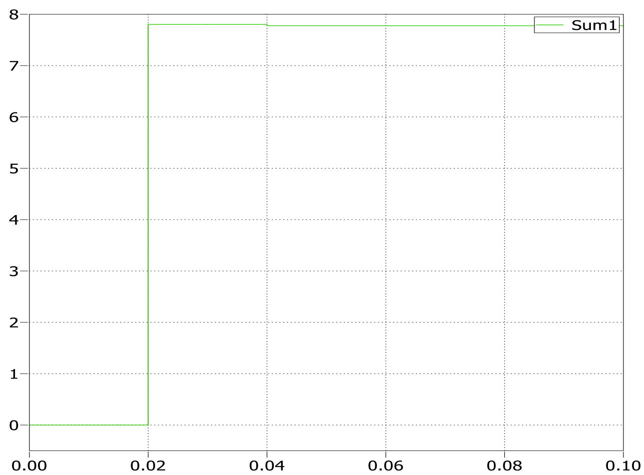


Figure 13. Total losses SiC MOSFETs (sum of switching & conduction losses at 50Hz frequency.)

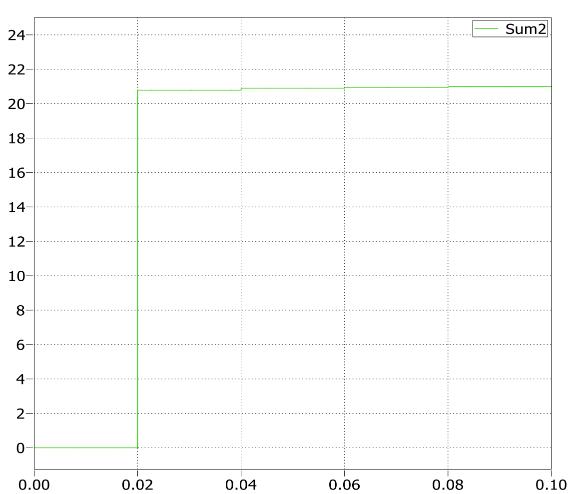


Figure 14 switching losses of Silicon IGBT at 100Hz switching frequency.

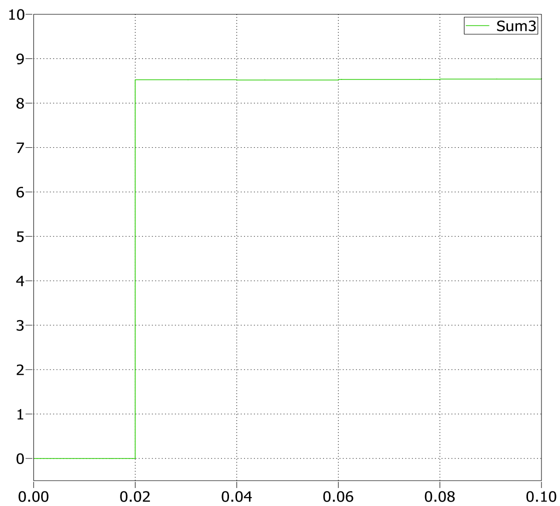


Figure 15 conduction losses of Silicon IGBT at 100Hz switching frequency.

Table 4 Conduction and switching losses for Silicon Carbide (SiC) under various switching frequency.

Switching Frequency	Cond. Losses	Switching losses	Total Losses	Efficiency
10Hz	0.99w	1.80 w	2.79 w	98.61%
20Hz	0.79 w	2.93 w	3.72 w	98.14%
30Hz	0.74 w	4.26 w	5.00 w	97.50%
40Hz	0.72 w	5.65 w	6.37 w	96.81%
50Hz	0.72 w	7.05 w	7.78 w	96.11%
60Hz	0.72 w	8.47 w	9.19 w	95.14%
70Hz	0.72 w	9.90 w	10.6 w	94.69%
80Hz	0.71 w	11.33 w	12.04w	93.98%
90Hz	0.71 w	12.76 w	13.76w	93.26%
100Hz	0.71 w	14.19 w	14.90w	92.55%

Table 5. Conduction and switching losses for Silicon (Si) IGBT under various switching frequency.

Switching Frequency	Cond. Losses	Switching losses	Total Losses	Efficiency
10Hz	4.35w	2.20 w	7.27w	96.37%
20Hz	4.43 w	4.00 w	8.57w	95.71%
30Hz	4.85 w	6.01 w	10.48w	94.76%
40Hz	5.34 w	8.08 w	12.53w	93.74%
50Hz	5.86 w	10.21 w	14.63w	92.69%

60Hz	6.39 w	12.34w	16.75w	91.63%
70Hz	6.93 w	14.50w	18.90w	90.55%
80Hz	7.46 w	16.66 w	21.05w	89.47%
90Hz	8.00 w	18.83 w	23.23w	88.39%
100Hz	8.55 w	21.02 w	25.41w	87.31%

From table 4 and 5, it can see that conduction and switching losses of Silicon IGBT and silicon Carbide MOSFETs as well as their efficiency at various switching frequency (10Hz – 100Hz). It shows for Silicon the higher the switching frequency, the higher the switching and conduction losses and less efficient. The silicon carbide MOSFETs has fewer conduction losses even higher switching frequency; even though it has some switching losses, it has higher efficiency even at the high switching frequency. Therefore, silicon carbide has advantages at high switching frequency applications.

CONCLUSION

The objective of this report is comparing the performance of semiconductor device, and find out the behaviour of their physical properties, based on the literature review and simulations confirmed that wide Band-gap semiconductor such as silicon carbide (SiC) and Gallium Nitride (GaN) has more significant advantages over silicon (Si). The performance of these power semiconductor devices, give semiconductor devices a requirement for the promises high switching frequency applications. Also, the model of single-phase H-bridge inverter is analyzed. Based on the simulated model of H-bridge inverter and the simulation results indicated that current and voltage waveform obtained, which shows that DC voltage has converted into AC voltage at desired output power and frequency.

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