



POWER LOSS ANALYSIS AND MODELING OF A SINGLE-PHASE PV INVERTER

Lappeenranta–Lahti University of Technology LUT

Bachelor's Programme in Technology and Engineering Science /Electrical Engineering,

Bachelor's thesis

2023

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Examiner(s): Professor Jianliang Chen

ABSTRACT

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LUT School of Energy Systems

Electrical Engineering

Double degrees, In co-operation with partner university/universities:

Hebei University of Technology

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Power loss analysis and modeling of a single-phase PV inverter

Bachelor's thesis

2023

28 pages, 15 figures and 3 appendices

Examiner(s): Professor Jianliang Chen

Targets: Design of inverter structure and analysis of inverter losses

Due to the non-renewable nature of fossil fuels, the global energy market demand continues to be tight, and there is an urgent need for a new renewable energy source to fill the gap. In this context, photovoltaic power generation has received widespread attention as a new energy generation method characterized by green and sustainable development. In the PV power generation device, the inverter as a kind of alternating current (AC) and direct current (DC) conversion device, plays an important role in the power supply quality and power generation efficiency. Therefore, the research and analysis of inverter is of great significance. This thesis takes the single-phase full-bridge inverter system with RL - type filter circuit as the research object, completes the overall design of the inverter system, and carries out functional debugging and performance testing of the system. The main contents of the thesis are summarized as follows:

According to the technical specifications of the inverter system, the topology of the power unit is selected, and then the overall design scheme of the inverter is completed, the selection of the main components such as power switching tubes is determined, and then the power loss of the inverter is calculated through modeling and simulation.

Keywords: Single-Phase inverter, Power loss analysis, IGBT

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Appendix 1 CM100DY-34A Datasheet

1 Introduction

The importance and background of this study and the development of inverters will be described . A brief statement of the methodology and inverter structure used in this thesis.

1.1 Background and significance of the study

Energy is an indispensable part of the progress of human civilization, and due to centuries of use and the non-renewable nature of fossil energy, oil reserves are no longer sufficient at present. Oilfields around the world are largely past their peak oil production, and the difficulty of finding new oilfields has further contributed to a sense of crisis. Moreover, the excessive combustion of fossil fuels releases a large amount of toxic substances, exacerbating environmental degradation and leading to problems such as the hole in the ozone layer. So people are committed to the development of new energy sources such as solar energy, wind energy and other renewable energy sources. According to statistics, the power generation capacity of clean energy worldwide has exceeded that of fossil fuels since 2015, which indicates the global power development towards renewable energy. As the status of new energy sources increases, countries are also promoting the development of new energy technologies, and photovoltaic industry chains of various scales are gradually improving.(Usova and Velkin, 2018)

At the same time, today's large-scale power systems often cause large-scale failures due to their complex structure and harsh operating conditions, which not only cause damage to the power system, but also reduce the speed and quality of power delivery. Small-scale distributed power generation systems have received a lot of attention in many countries due to their reliability and flexibility in power generation. The inverter is the only channel between the power generation unit and the power grid, and plays an important role in the power transmission device. Therefore, the analysis and design of inverter system is of great significance and development prospect.

1.2 Current status of inverter development and research

Inverter is a conversion device that converts direct current into alternating current and plays an important role in electrical energy devices. With the continuous maturity and innovation of solar and wind power generation technologies, inverters play an irreplaceable role in the energy conversion process. Inverters produced in Germany and the United States have the advantages of high reliability and high efficiency, and are far ahead of other countries, among which Kaco, Conergy and Siemens and other companies have been well-known all over the world.

The core of an inverter is a semiconductor power device, usually a MOSFET or IGBT, which converts DC power to AC power through chip control and PWM technology. In order to achieve the requirements of small size and high power, it is necessary to gradually increase the frequency of the inverter, but at the same time will produce switching losses, the higher the switching frequency, the greater the loss, in order to improve the efficiency of the conversion of energy, the loss of inverters is worth being studied and analyzed, and the prospect of the future deserves to be looked at favorably.(Kishore et al., 2022)

1.3 Research methodology

With the increasing demand for renewable energy, the quality of inverters is required to be higher and higher, and the quality of inverters directly affects the stability and efficiency of the whole power system. In order to ensure the stable operation of the inverter system, this thesis will analyze the single-phase full-bridge inverter using RL-type filter, which is more stable and does not cause oscillation. The circuit of the inverter system will be designed first and then the circuit will be constructed in Matlab and simulated and analyzed.(Wei and Sha, 2022)

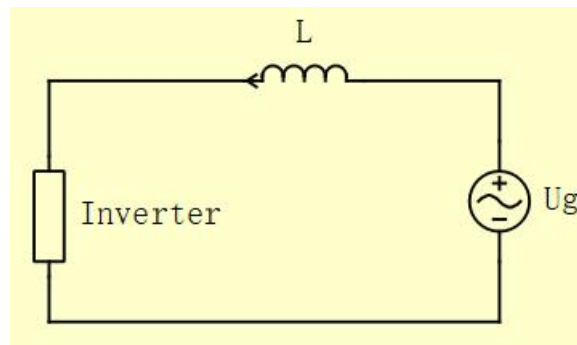


Figure 1. L-shaped filter

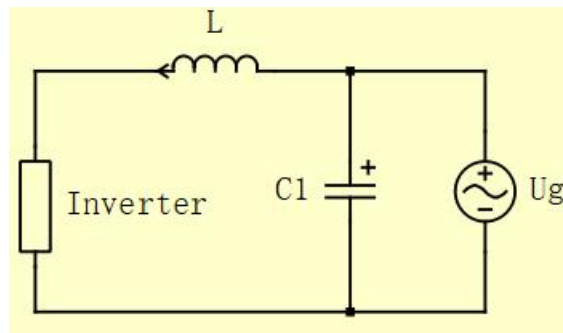


Figure 2. LC-shaped filter

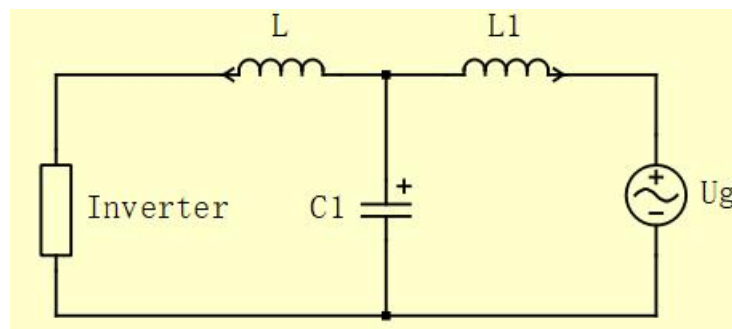


Figure 3. LCL-shaped filter

Several common filter structures are shown above.

2 Structure design of the inverter

Inverter is an important device in the grid energy transmission system, the main role is to realize the conversion of electric energy and energy transfer, so its performance and operating conditions will affect the stability of the whole system. In this section, the design will be based on the RL filter circuit and the main components will be selected.

2.1 PWM waveform modulation

PWM (Pulse Width Modulation) is a very effective technique for controlling analog circuits using the digital output of a microprocessor, which is widely used in measurement, communication, industrial control, etc. The duty cycle in PWM is expressed as the proportion of the high level in a cycle. Assuming a power supply of 10V and a duty cycle of 10%, the corresponding output is an analog signal with an amplitude of 1V. The higher the duty cycle, the longer the high level is maintained.

Electronic components such as MOS tubes or IGBTs are often used in inverters, and the PWM method can be used to control the switching of MOS tubes by controlling the level. But the ordinary PWM signal can't meet the function of inverter to convert DC power supply to sine wave power supply, so we need to use SPWM (Sinusoidal Pulse Width Modulation) signal for control. We usually input the base wave (sine wave) and carrier wave (triangle wave or sawtooth wave) to the positive and negative inputs of the comparator respectively. This produces square waves with different duty cycles to control the switching of the IGBT electronic components in the circuit.(Naik and Venugopal, 2018)

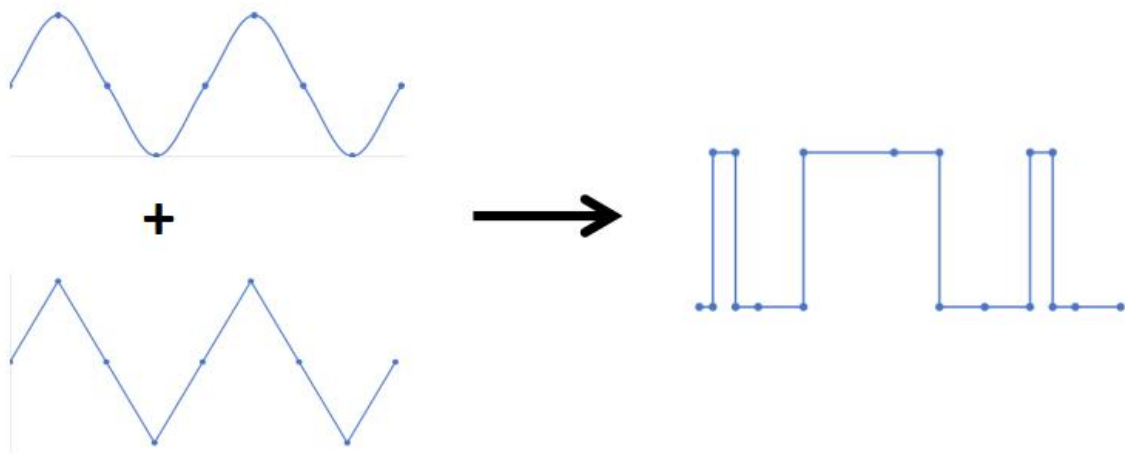


Figure 4. SPWM

For unipolar modulation, the carrier waveform will only vary in positive or negative polarity during half a cycle, and the resulting PWM waveform will only vary in positive or negative polarity. The output PWM waveform in this case has higher harmonic content and lower inverter losses.

For bipolar modulation, the carrier waveform will always vary within the positive and negative polarity, and the generated PWM waveform is the same. This method has higher loss to the inverter.

2.2 Inverter bridge

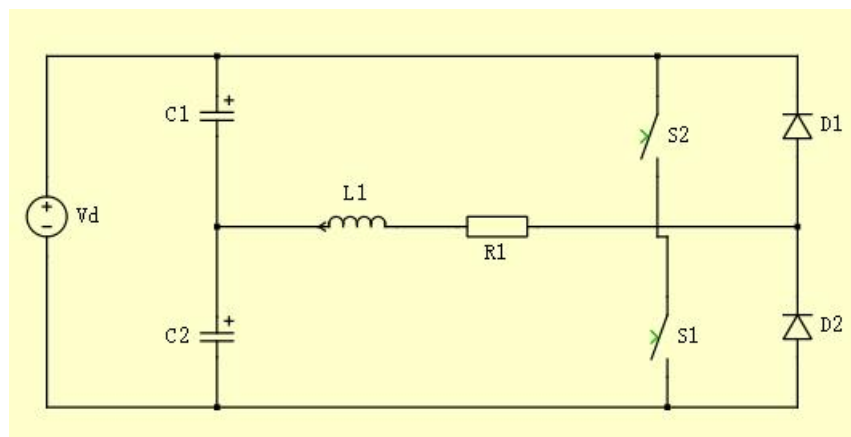


Figure 5. Half-bridge inverter

The half-bridge inverter is shown in the figure above, where the DC bus is connected to two series capacitors and the inverter output is generated by alternating the conduction of two IGBT switches.

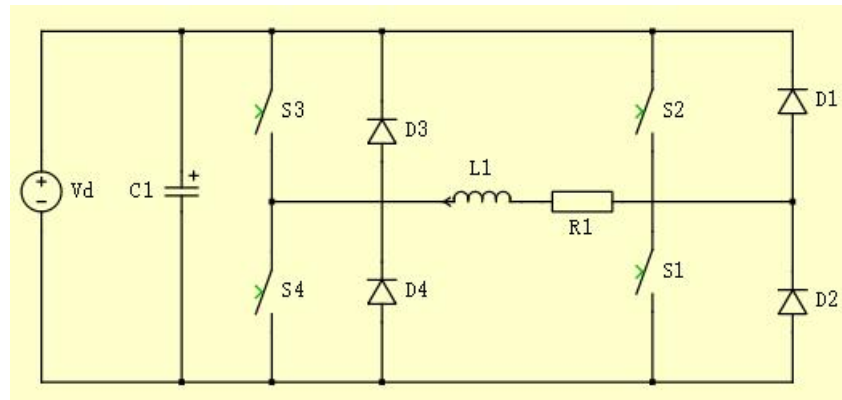


Figure 6. Full-Bridge Inverter

The full-bridge inverter, as shown in the figure above, has four bridge arms, which can be divided into two pairs, 1 and 4 as one pair and 2 and 3 as one pair. The two bridge arms of the same pair conduct and turn off at the same time in the operating state, with the other pair of complementary conduction.

Full-bridge inverters are more costly compared to half-bridge inverters, but full-bridge inverters have half the switching current of half-bridge inverters, making them more suitable for high-power electronics. And the full-bridge inverter can also realize the unipolar SPWM control method. Based on the above comparisons, the full-bridge inverter is chosen as the research object in this thesis.

2.3 Filter Type

The common types of filters are L, LC, and LCL as shown in the figures below:

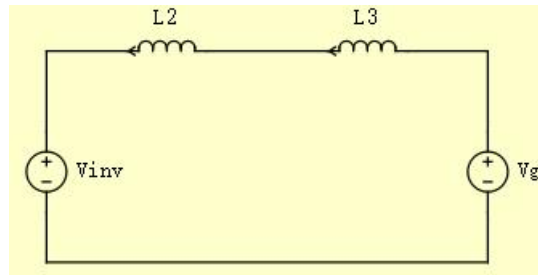


Figure 7. L-shaped filter

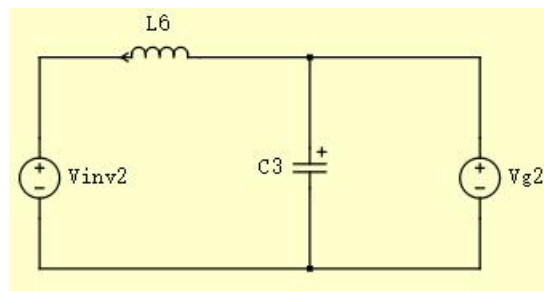


Figure 8. LC-shaped filter

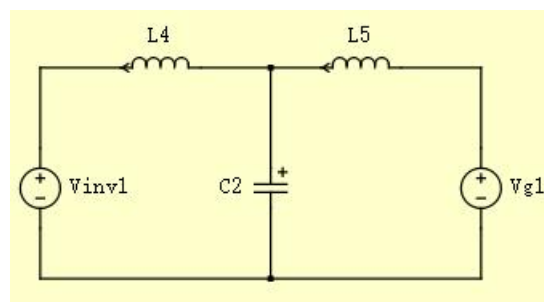


Figure 9. LCL-shaped filter

When a high-frequency harmonic passes through an L-type filter, the filter impedance $Z=\omega L$ is very large due to the large frequency of the harmonic and the corresponding corner frequency, which can effectively suppress the high-frequency harmonic current. This L-type filter, which filters out high-frequency harmonic signals by utilizing the property that the inductor has a large impedance at high frequencies, has a simple structure, belongs to a first-order circuit that does not introduce resonance, and suppresses switching-frequency harmonics with obvious effects. Since conventional LC filters are not damped or under-damped, the output of the filter is prone to large oscillations and electromagnetic interference caused by the strong pulsed output current, and although LCL filters reduce equipment cost and size compared to L-type filters, they are less stable than L-type filters as shown in the figure below and have a more complex structure, so this thesis studies the RL-type filter.

3 Method

3.1 Simulation of RL-type filtered inverter

A sinusoidal modulating waveform with a frequency of f_s and a carrier waveform U_c was used in this thesis which is a triangular waveform with an amplitude of U_{cm} and a frequency of f_c . The expression for a sine wave is as follows:

$$u_s = U_{sm} * \sin(\omega_s t) \quad (1)$$

$$\omega_s = 2 * \pi * f_s \quad (2)$$

The ratio of the carrier signal frequency, f_c , to the modulating signal frequency, f_s , becomes the carrier ratio, denoted by p :

$$P = f_c / f_s \quad (3)$$

The ratio of the amplitude of the sinusoidal modulated signal to the triangular carrier signal can be defined as the modulation depth m :

$$m = U_{sm} / U_{cm} \quad (4)$$

The PWM signal is usually generated by comparing u_s with u_c :

When $u_s > u_c$, power switches S1 and S4 conduct, and the inverter circuit output voltage V_o is equal to V_{in} ;

When $u_s < u_c$, S2, S3 conduct, V_o is equal to $-V_{in}$.

As the switching tubes conduct in turn at carrier frequency f_c , the inverter output voltage V_o is constantly switched between positive and negative voltage. Then an RL full bridge inverter was simulated with the help of Matlab's simulink module.

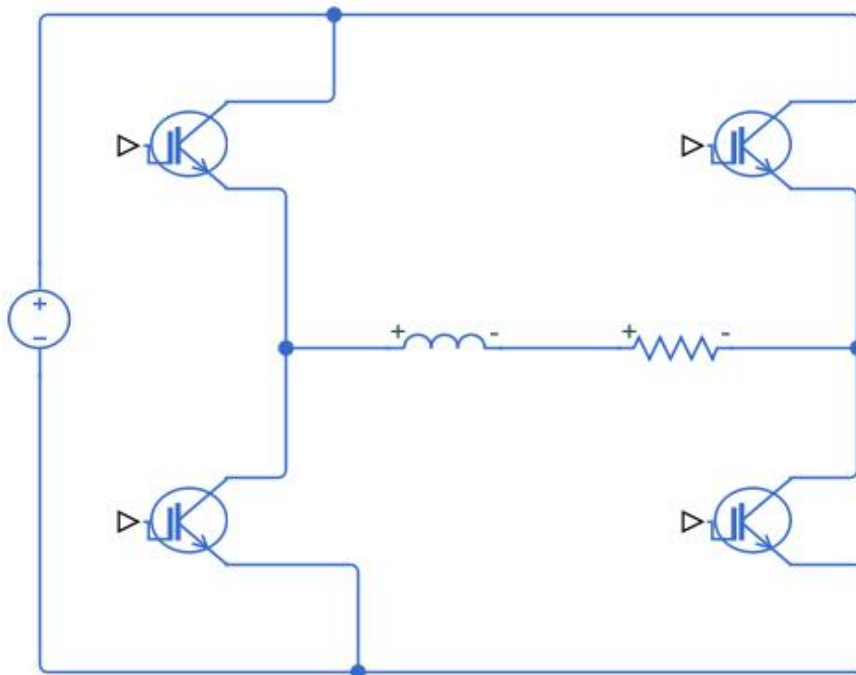


Figure 10. Simplified circuit

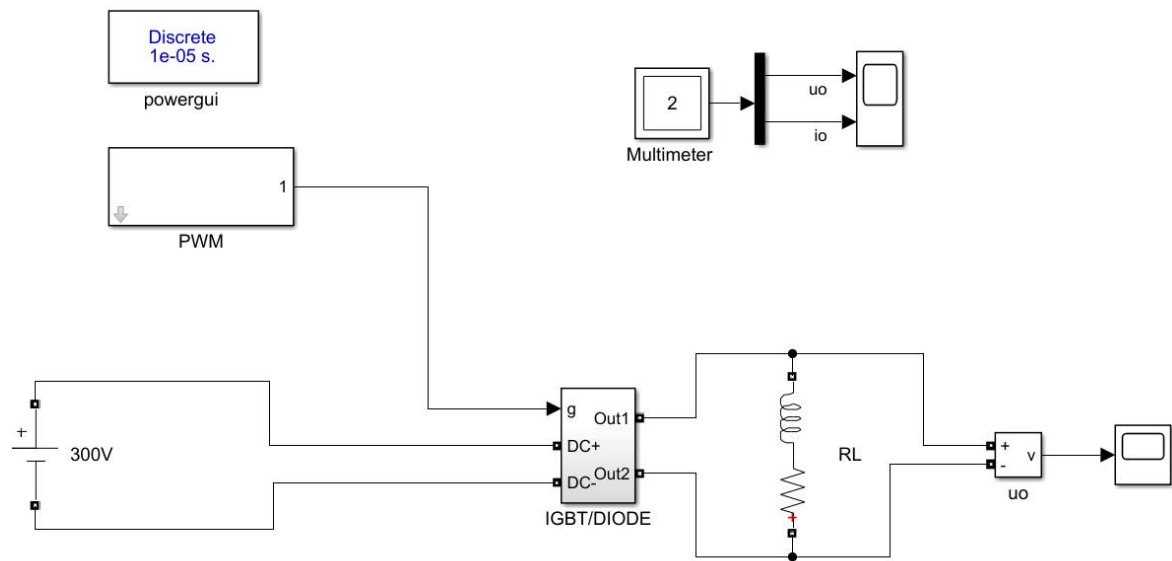


Figure 11. Inverter simulation diagram

The following structures are included in simulink model:

Discrete powergui components, with a sample time of $1e-5$ seconds, allowing the user to graphically build the power system model by dragging and dropping components and connecting them.

Below is a packaged PWM waveform generator that outputs the desired waveform from the carrier and modulating waveforms.

Then there's the 300-volt supply voltage and the encapsulated single-phase full-bridge circuit containing four IGBT switches.

On the right are a multimeter and a scope component for measuring and displaying the changing waveforms of U_0 and I_0 in the circuit, respectively.

To the left of the encapsulated single-phase full-bridge circuit is an RL-type series filter circuit for filtering.

On the right is a Measurement component that measures U_0 and a scope component that displays the value of U_0 .

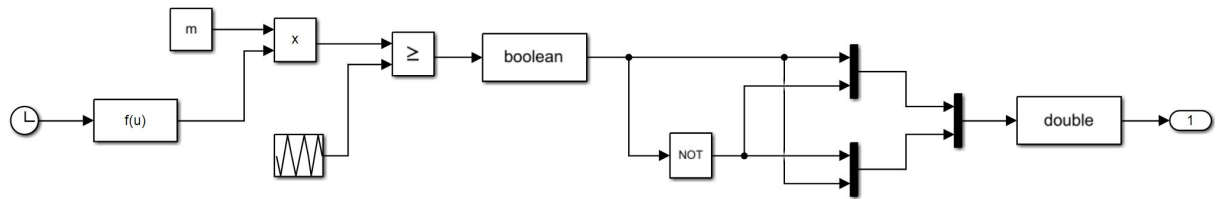


Figure 12.SPWM waveform circuit subsystem

In the PWM element packaged above, a carrier waveform with a frequency of 750 HZ and a modulating waveform of 50 HZ are used. Due to the natural intersection of the sinusoidal modulating waveform and the triangular carrier waveform, this can be equated to a series of square waves of equal amplitude and varying width to further control the opening and closing of the IGBT switch.

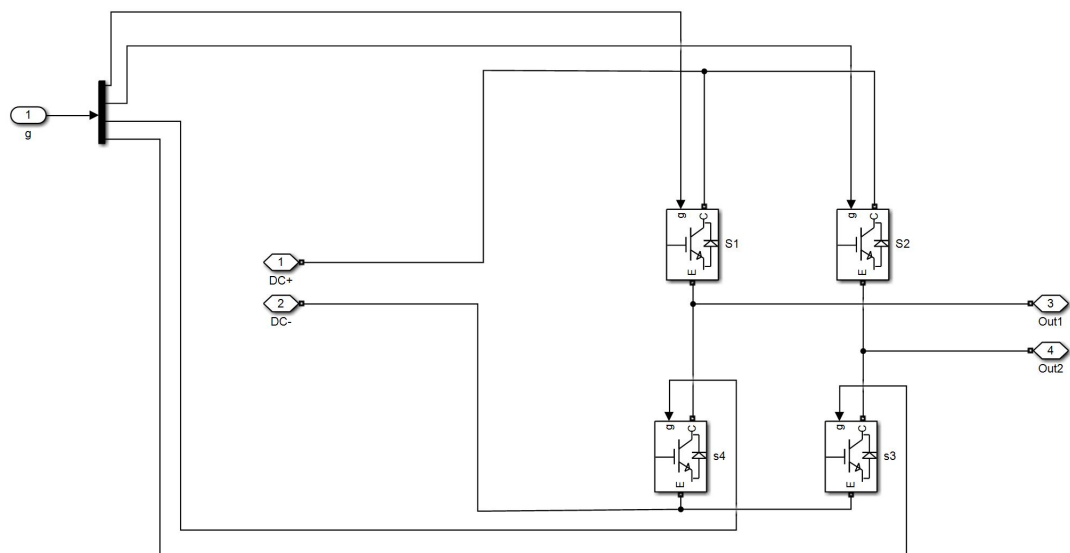


Figure 13. IGBT Switch Diagram

The PWM signal is generated by comparing the size of the carrier waveform and the modulating waveform. when the modulating waveform voltage is greater than the carrier

waveform voltage, the switches S1,S3 conduct, and the output voltage of the inverter circuit U_0 is equal to U_d . similarly when the modulating waveform voltage is less than the carrier waveform voltage, the switches S2,S4 conduct, and the output voltage of the inverter circuit U_0 is equal to $-U_d$. with the continuous conduction of the IGBT switches, the output voltage of the inverter circuit will be As the IGBT switches continue to turn on, the output voltage of the inverter circuit will be switched between U_d and $-U_d$ continuously, so it is called bipolar PWM.(J. W. Kolar; U. Drofenik; J. Biela; M. L. Heldwein; H. Ertl; T. Friedli; S. D. Round, n.d.)

3.2 Inverter Losses

The efficiency of an inverter depends greatly on the power losses of the components in the circuit, of which the most influential are conduction and switching losses.

The conduction losses are mainly in the form of heat generated inside the power devices, due to the resistance that causes the conversion of energy into heat when current passes through them. Since the transistors and diodes used in inverters are highly conductive, there is still a certain amount of resistance within the devices that causes the current to generate heat as it passes through them.(AKORO et al., 2020)

In an inverter, power devices experience sharp changes in current and voltage at the moment they are turned on and off. When the switch switches from the off state to the on state, the current rises rapidly, forming a current spike; while when it switches from the on state to the off state, the current drops rapidly, forming a reverse current spike. At the same time, the switch's state transitions are accompanied by voltage transients, and these transient spikes lead to additional energy loss, i.e., switching losses. During the transition between on-state and off-state of a power device, the capacitive inductance inside the device all leads to energy conversion, which generates heat and dissipation. Higher switching frequencies lead to more switching losses.

In addition to the conduction and switching losses mentioned above, the process of turning the DC input voltage on and off at high frequencies to produce a variable AC output

voltage is constantly harmonic, resulting in motor distortion, heat, noise and vibration, as well as injecting harmonic currents into the grid, which can interfere with other equipment and cause power factor problems. Distortion can be minimized and the quality of the output waveform optimized by choosing the appropriate switching frequency and modulation technique such as sinusoidal pulse width modulation (SPWM).(Yamada et al., 2005)

Losses not only waste energy, but also negatively affect the performance and stability of the inverter. The heat generated during operation may cause the temperature of the device to rise beyond its rated operating temperature range, reducing the efficiency and lifetime of the inverter. Losses can be reduced by improving the device heat dissipation module and optimizing the switching frequency.(Qiang Song; Wei Wang; Shuo Zhang; Yiting Li; Mukhtiar Ahmad, 2019)

3.3 Calculating conduction and switching losses

This thesis mainly calculates the switching loss and conduction loss. The internal IGBT module consists of IGBT chip and FWD chip, and its conduction loss P_{cond} consists of the conduction loss P_T of IGBT chip and the conduction loss P_F of FWD chip. The switching loss P_{sw} is composed of the turn-on loss P_{on} of the IGBT chip and the turn-off loss P_{off} .

$$P_{cond} = P_T + P_F \quad (5)$$

$$P_{sw} = P_{on} + P_{off} \quad (6)$$

Conduction loss:

The conduction loss P_T of the IGBT chip in one output cycle T_0 can be expressed as:

$$P_T = \frac{1}{T_0} \int_0^{T_0} V_T(i_c) \cdot i_{cdt} \quad (7)$$

where V_T is the on-state voltage and i_c is the on-state current. According to the information, the on-state voltage can be fitted linearly as:

$$v_T(i_c) = i_c \cdot R_T + V_{T0} \quad (8)$$

P_T can be obtained by associating the above equations:

$$P_T = \frac{1}{2} D_T \left(\frac{2\sqrt{2}}{\pi} I_m \cdot V_{T0} + I_m^2 \cdot R_T \right) \quad (9)$$

Similarly the conduction loss P_F of the FWD chip can be found as:

$$P_F = \frac{1}{2} D_F \left(\frac{2\sqrt{2}}{\pi} I_m \cdot V_{F0} + I_m^2 \cdot R_T \right) \quad (10)$$

where I_m is the maximum RMS output current; D_T , V_{T0} and R_T are the average on-state duty cycle, equivalent threshold voltage and dynamic average resistance of the IGBT chip, respectively;

D_F , V_{F0} and R_F are the average on-duty cycle, equivalent threshold voltage and dynamic average resistance of the FWD chip, respectively. (alldatasheet.com, n.d.)

Switching loss:

The calculation of switching loss needs to be combined with the IGBT switching energy curve, and this thesis takes the CM100DY-34A model switch as the research object. In the figure, E_{on} and E_{off} are the IGBT turn-on and turn-off energy.

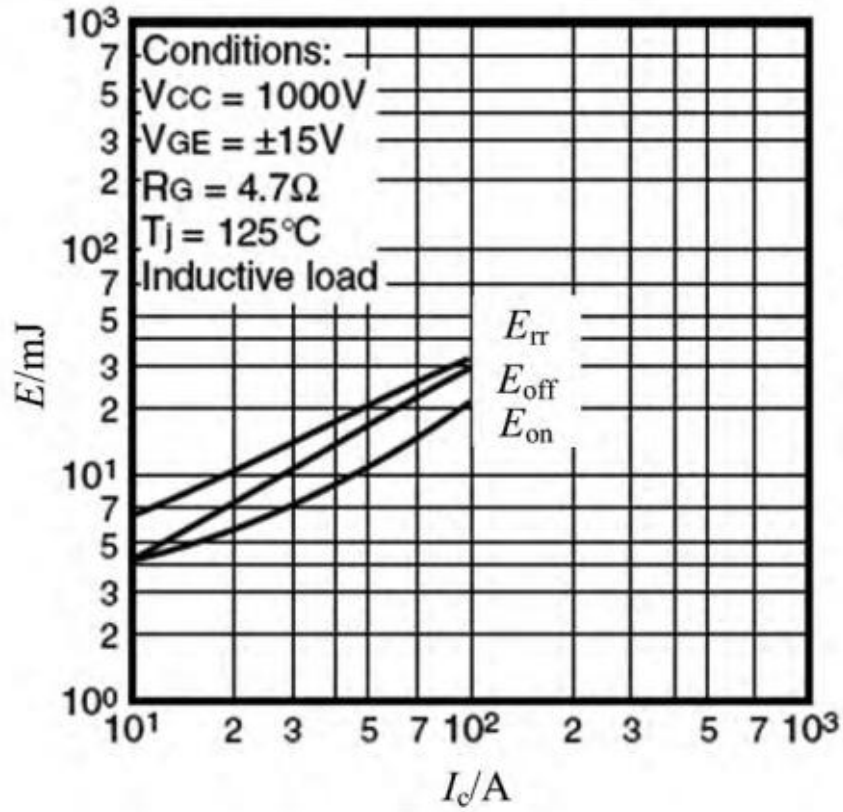


Figure 14. Switching energy curve of CM100DY-34A (REN Qi-mei; JIANG Jian, 2014)

The IGBT turn-on loss P_{on} can be expressed as:

$$P_{on} = f_0 \cdot \sum_{i=1}^n E_{on}(i) \quad (11)$$

In the above equation n is the number of times the IGBT switches in a half cycle. f_0 is the output current frequency; $E_{on}(i)$ is the turn-on energy at the i times turn-on.

Similarly, the IGBT turn-off loss P_{off} can be expressed as:

$$P_{off} = f_0 \cdot \sum_{i=1}^n E_{off}(i) \quad (12)$$

4 Results

The Result section includes the calculation of switching loss and conduction loss of the inverter as well as the analysis of the results. Since the data of IGBT chip and FWD chip of the IGBT switch cannot be defined independently in simulink, as well as the calculation methods of the two chips are similar, the loss of the FWD chip is approximately equal to the IGBT chip loss.

4.1 Switching loss

Switching loss refers to the loss generated by the IGBT in the continuous switching process. When the switching frequency is very low, the loss generated by the device is mainly conduction loss, and when the switching frequency is increased, the proportion of the switching loss in the overall loss of the device rises accordingly. The switching loss of the device includes turn-on loss and turn-off loss. According to Figure 17, when the current increases gradually, the heat generated by the turn-on loss and the turn-off loss also increases gradually, and the turn-off loss is larger than the turn-on loss when the current is less than 100A. By observing the current and voltage plots in simulink it can be calculated that the total IGBT switching loss is about 25.1W.

4.2 Conduction loss

Inverter conduction loss is the power loss that occurs when the inverter switches are in the conduction state, mainly due to the resistance of the IGBT switches and the conduction voltage drop that occurs when current flows through these devices.

The IGBT switch will also have a small resistance when it is in the on state, and the current passing through it will also generate a corresponding heat, which will result in a loss of power. Due to the characteristics of the IGBT switch, a non-zero on-state voltage drop occurs during conduction, which also reduces the output power of the inverter. The inverter model simulated in Matlab and the measured data gives a conduction loss of 187.92W. Since the temperature of the inverter will gradually increase under the operating

condition, the resistance will also increase, so the inverter conduction loss in the actual situation will be larger than the calculated value.

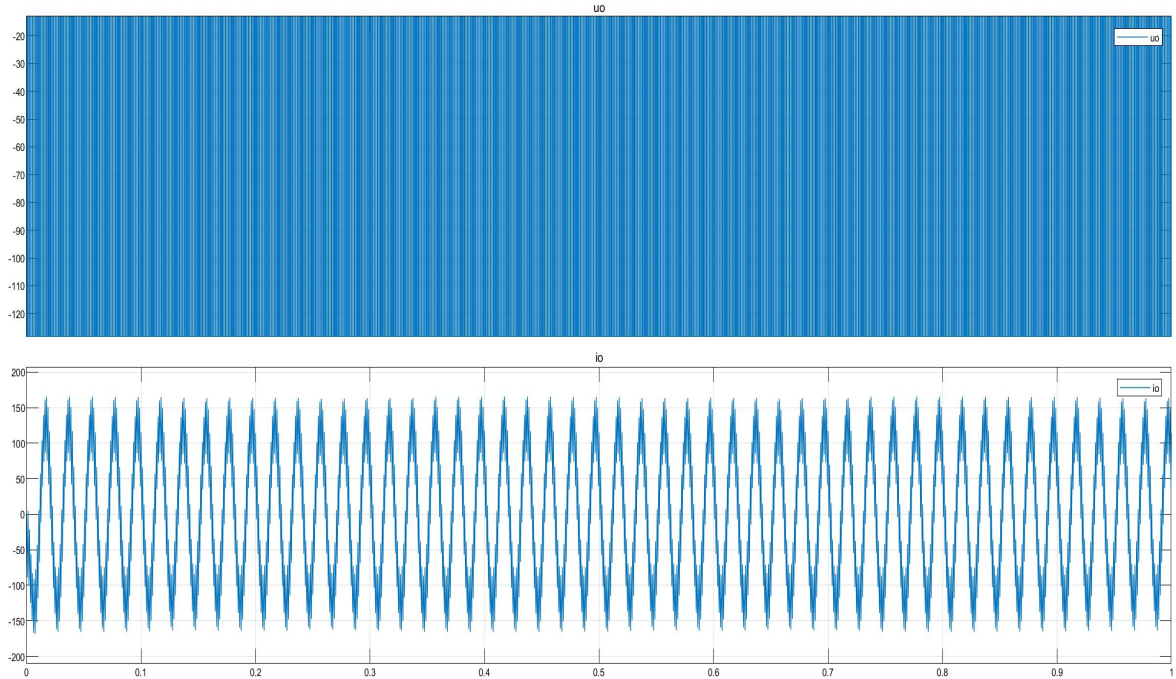


Figure 15. Voltage and Current Output

5 Discussion

In this thesis the power loss of the RL type inverter is calculated, which will be a little different from the loss of the inverter in real operation because of the difficulty of calculating the IGBT loss accurately and simplifying certain calculations and data.

5.1 Reasons for differences from actual losses .

As the temperature of the inverter will increase during the working process, it will increase the resistance and affect the stability of the output of the inverter, which will decrease the efficiency of the conversion between DC and AC power. In this thesis, the temperature variation is not taken into account, so the calculated loss of the inverter will be lower than the actual loss.

The calculation is based on the data provided by the supplier in the query, and there is a discrepancy between the energy curve of the actual inverter operation, the data used in the calculation is based on the data measured under the laboratory conditions in a more ideal situation, and the inverter in actual operation of the capacitance and inductance of the device values will be greater or lesser changes.

In the ideal state, the diode from the conduction state quickly turned to the as-of state when the circuit should be only a small reverse current, due to the diode from forward conduction to the cut-off there is a reverse recovery process, the forward current will suddenly turn into a very large reverse current, this current will be maintained for a period of time and then gradually reduced before entering the reverse as-of state, this process will also have an impact on the output efficiency of the inverter and the switching loss analysis.

5.2 Methods to improve data accuracy

Some inverters with good heat dissipation and little change in temperature during operation can be selected as the object of study, which can greatly reduce the amount of calculations and calculation errors. Alternatively, the temperature of the inverter can be monitored using the use of temperature sensors and the operating parameters can be adjusted as needed to keep the temperature within the safe range.

In order to obtain the inverter loss data with maximum accuracy, a simpler inverter model can be constructed so that real-time monitoring of inverter data can be carried out to obtain the change curve of energy output under actual working conditions.

Products with internal diodes with high speed reverse recovery can be selected to minimize switching losses and minimize calculation errors. More information can also be obtained to calculate the difference between the reverse recovery process and the ideal loss.

5.3 Inverter future development trends

Inverter as a device to convert DC power to AC power is widely used in daily life in the computer TV and other tools, mainly depends on the power semiconductor devices, circuit technology, computer technology, modern control technology and other integrated

technology development. The inverter is the core equipment that realizes the conversion from DC to AC output of the module, and at the same time controls the core equipment that maintains the maximized output of the module power, whose reliability directly affects the revenue of the power station, and whose output characteristics affect the quality of the electric energy. According to the technology route, inverter can be divided into centralized inverter (mainly used for large ground power station, power range 250kW-10MW), distributed inverter (mainly used for complex large-scale ground power station, power range 1MW-10MW), string inverter (mainly used for household, small industrial and commercial distributed and ground power station, etc., power range 1.5kW-250kW) and Micro inverters (mainly used for household use and other small power stations, with a power rating of 200W-1500W). Currently, the market is dominated by string inverters, and micro inverters, which are safer and more efficient, are still in the development stage as a new technology route, with higher technical thresholds and fewer suppliers, and still need a period of time for optimization and improvement. Moreover, due to the high technical threshold of micro inverter, R&D and design require certain investment, and the technology replacement speed is fast, etc. There are certain technical barriers.

The operating frequency of the inverter will gradually increase in the future development, which not only reduces the volume of the overall system, but also improves the dynamic response level of the inverter output voltage. Today's inverter output waveform quality is not high enough and not stable enough, so it is necessary to improve the inverter's ability to quickly adapt to nonlinear loads, even if the load in the system has a sudden change in the output stability can be guaranteed. With the continuous progress of hardware such as chips and the continuous improvement of algorithms, it is believed that the inverter will gradually become more intelligent and digitalized.

6 Conclusion

In this thesis, we have analyzed the losses of the RL type inverter in detail and compared it with other types of inverters presenting its advantages and the reasons for choosing it for analysis. We have simulated the corresponding waveforms by searching for information and MATLAB and analyzed them. For the RL type single-phase full-bridge inverter, its

structure is simple and easy to analyze and build, and the filtering effect is relatively ideal without large fluctuations.

Secondly, we calculated the losses of this type of inverter and showed that an increase in inverter losses leads to a decrease in the overall efficiency of the system and may reduce the power generation of the system. This finding is crucial for the design and operation of power generation systems. Further we discuss potential strategies to reduce inverter losses. The overall performance of the system can be improved by using internal diode products with higher speed reverse recovery and by increasing the heat dissipation performance of the inverter.

However, I also recognize that there are some limitations to this study. For example, our analysis was limited by data acquisition, model design, and loss calculations, which affected the accurate analysis of inverter losses. Future research can further optimize the model and consider more factors in real operating conditions.

In summary, this study provides a comprehensive analysis of inverter losses and explores their impact on power generation system performance. Our study provides an important reference for the design and operation of inverters, and proposes an effective strategy to reduce inverter losses, which provides a new direction for future related research.

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Appendix 1

Appendix 1 CM100DY-34A Datasheet

[CM100DY-34A Datasheet \(PDF\)](#) - [Mitsubishi Electric Semiconductor](#)
[\(alldatasheet.com\)](#)

MITSUBISHI IGBT MODULES

CM100DY-34A

HIGH POWER SWITCHING USE

ABSOLUTE MAXIMUM RATINGS (T_j = 25°C, unless otherwise specified)

Symbol	Parameter	Conditions	Ratings	Unit
V _{CE} S	Collector-emitter voltage	G-E Short	1700	V
V _{GE} S	Gate-emitter voltage	C-E Short	±20	V
I _C	Collector current	DC, T _C = 108°C ^{*1}	100	A
I _{CM}		Pulse	200	
I _E (Note 1)	Emitter current	Operation	100	A
I _{EM} (Note 1)		Pulse	200	
P _C (Note 3)	Maximum collector dissipation	T _C = 25°C ^{*1}	960	W
T _j	Junction temperature		-40 ~ +150	°C
T _{stg}	Storage temperature		-40 ~ +125	°C
V _{iso}	Isolation voltage	Main terminal to base plate, AC 1 min.	3500	V
—	Torque strength	Main terminal M5	2.5 ~ 3.5	N • m
—		Mounting holes M6	3.5 ~ 4.5	
—	Weight	Typical value	310	g

ELECTRICAL CHARACTERISTICS (T_j = 25°C, unless otherwise specified)

Symbol	Parameter	Test conditions	Limits			Unit
			Min.	Typ.	Max.	
I _{CES}	Collector cutoff current	V _{CE} = V _{CE} S, V _{GE} = 0V	—	—	1	mA
V _{GE(th)}	Gate-emitter threshold voltage	I _C = 10mA, V _{CE} = 10V	5.5	7.0	8.5	V
I _{GES}	Gate leakage current	±V _{GE} = V _{GES} , V _{CE} = 0V	—	—	2.0	μA
V _{CE(sat)}	Collector to emitter saturation voltage	T _j = 25°C T _j = 125°C	—	2.2 2.45	2.8	V
C _{ies}	Input capacitance	V _{CE} = 10V	—	—	24.7	nF
C _{oes}	Output capacitance	V _{GE} = 0V	—	—	2.8	nF
C _{res}	Reverse transfer capacitance		—	—	0.53	nF
Q _G	Total gate charge	V _{CC} = 1000V, I _C = 100A, V _{GE} = 15V	—	670	—	nC
t _{d(on)}	Turn-on delay time		—	—	200	ns
t _r	Turn-on rise time	V _{CC} = 1000V, I _C = 100A	—	—	150	
t _{d(off)}	Turn-off delay time	V _{GE1} = V _{GE2} = 15V	—	—	550	
t _f	Turn-off fall time	R _G = 4.8Ω, Inductive load switching operation	—	—	350	
t _{rr} (Note 1)	Reverse recovery time	I _E = 100A	—	—	300	μC
Q _{rr} (Note 1)	Reverse recovery charge		—	10	—	
V _{EC} (Note 1)	Emitter-collector voltage	I _E = 100A, V _{GE} = 0V	—	—	3.0	V
R _{th(j-c)Q}	Thermal resistance	IGBT part (1/2 module) ^{*1}	—	—	0.13	°C/W
R _{th(j-c)R}		FWDi part (1/2 module) ^{*1}	—	—	0.21	
R _{th(c-f)}	Contact thermal resistance	Case to fin, Thermal compound applied (1/2 module) ^{*1,2}	—	0.022	—	
R _G	External gate resistance		4.8	—	48	Ω

*1 : T_C, T_f measured point is just under the chips.

*2 : Typical value is measured by using Shin-Etsu Chemical Co., Ltd "G-746".

Note 1. I_E, I_{EM}, V_{EC}, I_r & Q_{rr} represent characteristics of the anti-parallel, emitter to collector free-wheel diode (FWDi).

2. Pulse width and repetition rate should be such that the device junction temperature (T_j) does not exceed T_{jmax} rating.

3. Junction temperature (T_j) should not increase beyond 150°C.

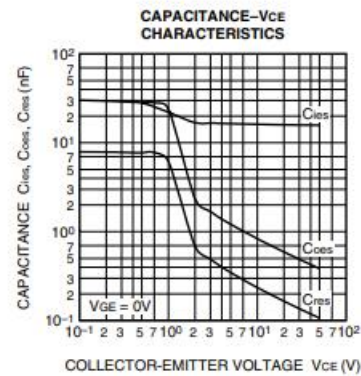
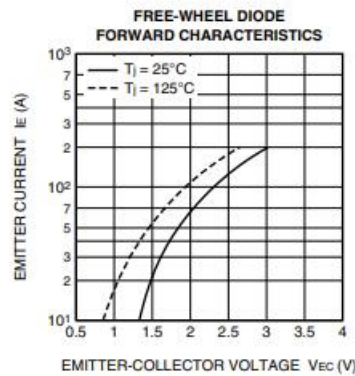
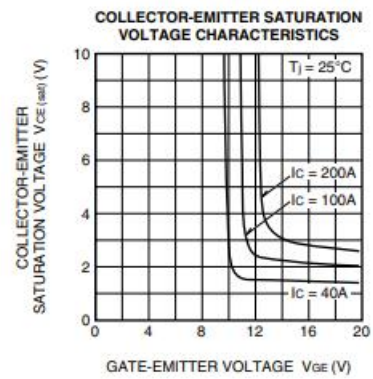
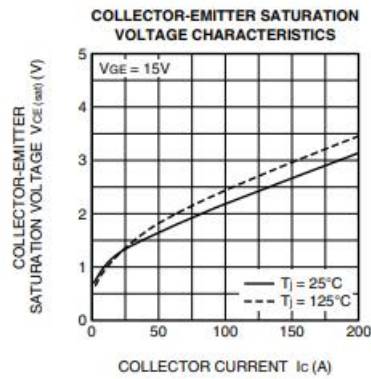
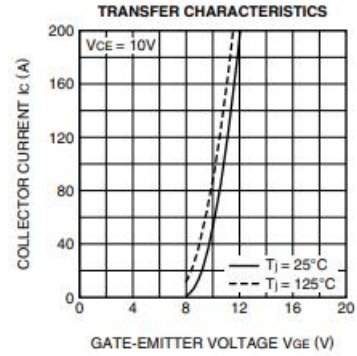
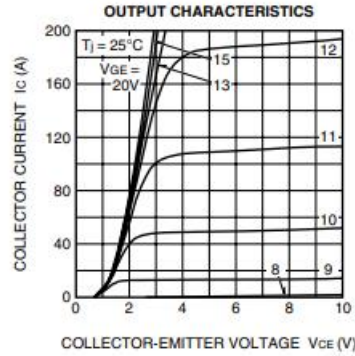
4. Pulse width and repetition rate should be such as to cause negligible temperature rise.

Appendix 2

CM100DY-34A

HIGH POWER SWITCHING USE

PERFORMANCE CURVES



Appendix 3

CM100DY-34A

HIGH POWER SWITCHING USE

