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Design of Three-Phase Inverter for Motor

Engineering

KEYWORDS : MOSFETs, IGBTs PWM Control Circuit, GATE Drive Circuit

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ABSTRACT

This paper deals with a method of design of three phase inverter for d.c. submersible motor. According to design prototype model is made and it is tested in laboratory & it's work successfully The selection of MOSFETs as compare to IGBTs play key role. Inverter section is made up of 6 MOSFETs. MOSFETs of 20 volts, 10 Amp, 57 Watts (IRFP 460).

I. Introduction

Inverters can be broadly *classified* into two types:

1) Single-phase inverters
2) Three-phase inverters.

Each type can use controlled turn-on and turn-off devices (e.g. BJTs, MOSFETs, IGBTs, MCTs, SITs, GTOs) or forced-commutated thyristors depending on applications. These inverters generally use ***PWM control signals*** for producing an ac output voltage.

A) Selection of Devices :-

IGBTs are generally preferred under following conditions :-

- High voltage applications (>1000 volts)
- High output power (>5 kw)
- Small load variations

MOSFETs are generally preferred under following conditions :-

- Low voltage applications (< 250 volts)
- Low Output power (< 500 Watts)
- Wide load variations.

From above comparison , ***MOSFETs are used*** as power switching devices for Three-Phase Inverter as supply voltage is 12 volts (D.C.), power rating is ***45** Watts of PMBLDC Motor.*

B) Comparison Between MOSFET and BJT :-

On-state losses of the device are decided by the resistance. The on-state resistance of a MOSFET has a positive temperature coefficient (typically 1.1/˚C above 25˚C). The value of resistance increases with temperature causing the diversion of current from hotspots. Thus there is no damage to the device due to hot spots. ***The MOSFETs*** are thus ***free from secondary breakdown*** which is present in BJTs due to negative temperature coefficient.

The ***saturation*** of BJTs and the saturation in MOSFETs are of ***opposite nature.***

The MOSFET have ***high over load capacity*** as compare to BJT. Also in BJT ***snubber often required*** as compare to MOSFET.

II. design of three phase inveter

A) *GATE DRIVE REQUIREMENTS FOR MOSFETS:-*

The MOSFETs are voltage control devices, so the gate currents are not dependent on the drain currents. There fore the gate power required to maintain the MOSFETs in ON condition is neglible.

The gate circuit energy is used only to turn ON and turn OFF the MOSFETs. During turn ON, a peak current of 'ig +' is applied which is used to turn ON the MOSFETs. During turn OFF of a negative peak current of ' ig –' is provided for fast turn OFF of the MOSFETs.

Igon = equivalent constant gate current during ON period.

= [ig +] % 2

The ***main function*** of drive circuit are

1. To provide isolation between the control circuit and power circuit.
2. To provide amplification for the proper magnotude of trigger pulse which can turn on the power device in power circuit.

B) *INVERTER SECTION:-*

Inverter section is made up of 6 MOSFETs. MOSFETs of 20 volts, 10 Amp, 57 Watts (IRFP 460).

For giving the protection to gate of MOSFETs, back to back zener diodes of 12 volts rating are used between gate and source of each MOSFETs.

Here back to back series connected zener diodes are located between the gate and source terminals for giving ***protection*** against ***static electricity***. When the gate source voltages is high enough to reverse bias one of the diodes in to breakdown, the other diode is forward biased. Thus the gate source voltage can not exceed ±(Vz+Vf).

A capacitor (0.0022 μF) is provided to boost up the gate pulse for each MOSFETs.

A diode 1 N 5408 is provided to prevent nagative spikes in gate pulse.

A resistor of 56 Ω is provided for allowing the positive gate pulse in each MOSFETs.

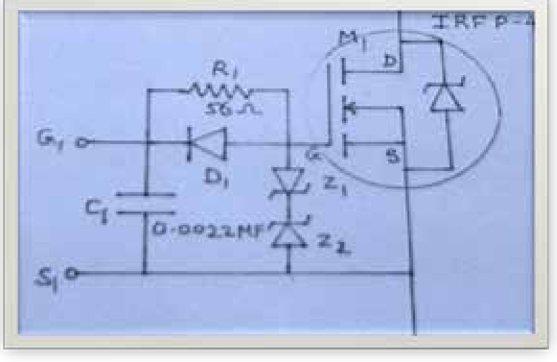


Fig.1 Inverter Section

III. FIRING CIRCUIT OF INVERTER

The complete firing circuit is devided into following sections :-

1. PWM control circuit (pulse generator circuit)
2. Gate drive circuit

The details of each section and their working is as follows.

A) *PWM control circuit (pulse generator circuit)*

For PWM control circuit a single **TL 4941 N IC** is used. The important feature of this IC as follows.

Features of TL 4941 N IC.

1) Complete PWM power control circuit.
2) Over voltage and under voltage locking.
3) Operation from -40 °C to 85 °C.
4) Vcc lies between 7 volts to 40 volts.

The description of this IC is as follows.

The TL4941 N incorporates all the functions required in the construction of a ***PWM control circuit*** on a single chip.

Designed primarily for power supply control, this device offers the flexbility to tailor the power supply control circuitry to a specific application.

The TL 4941 N contains two error amplifiers, an on chip adjustable oscillator circuit, a DTC comparator, a pulse steering control flip-flop, a 5 v, 5% precision regulator and output control circuit.

Here, push-pull operation and common emitter configuration of output transistor is used.

B) *GATE Drive Circuit:-*

If the load is connected between source and ground, and the drive voltage is applied between gate and ground, the effective voltage between gate and source decreases as the device turn on.

For this ***reason,*** it is often advantageous to have the gate drive circuit referenced to the source rather than to the ground. Here, opto-isolators are used for this purpose.

C) *High speed logic Opto isolator H11N1 :-*

The H11N1 opto isolator consists of an LED and NAND gate. It is 6 pin IC and requires 12 v D.C. supply.

A resistor 1 KΩ is used to limit the current through LED of opto isolator.

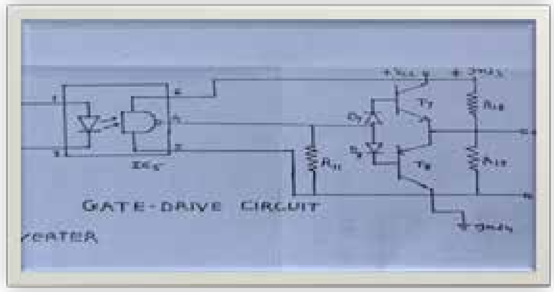
D) *Push pull output stages:-*

This consists of a complementary pair (BD 911[NPN] & BD 912[PNP]) of silicon power transistors. Here 12 volts D.C. is supplied to collector of BD 911 transistor and collector of BD 912 is working as source (ground) terminal for MOSFET (M1). The complementary pair of transistors is used for each MOSFET.

Here, output of opto-isolator is given to the base terminal of complementary transistor pair.

When the output at pin No: 4 is low then PNP transistor is OFF and gate pulse is absent and at the same time the NPN transistor remains ON and 12 volts is available at NPN (BD 911) transistor. Similarly when output at pin No: 4 is High, then gate pulse of 12 volts is available at G1.

Hence six gate pulses of amplitude 12 volts are available at G1, G2, G3, G4, G5 & G6 of M1, M2, M3, M4, M5 & M6 respectively. Here diodes in base of each transistor are connected for unidirectional conduction of transistors.



IV Basic Design Considerations:-

A) Air-Gap flux Density Distribution :-

The shape and the magnetization pattern of the PMs dictate the air-gap flux density distribution. Furthermore, they have substantial influence on cogging torque, harmonic contents, and magnetic saturation so trapezoidal flux distribution is considered here.

B) Magnet Material :-

Normally, a magnet is a integral part of the motor so mechanical and electrical properties have to be considered. Nd-Fe-B and samarium cobalt permanent magnets are preferred because of their high-energy product (BHmax) and retentivity (Br). The selection depends on the cost and the thermal stability. SmCo offers the resistance to temperature effects and several grades are suitable upto 350°C. So samarium cobalt magnet is chosen here.

C) Specific Loadings **:-**

Specific magnetic loadings depends on the type of configuration and permanent magnet properties. Higher values of specific slot electric loading leads to increase in copper loss; but because of the reduction in the permanent magnet requirement, reduces the overall cost.

D) Winding Configuration :-

Both amplitude and shape of back EMF and the stator MMFs in these machines are determined by the winding arrangements and general machine geometry.

These configurations in turn are dictated by optimum use of space and materials in the machine. Here double layer winding configuration is proposed which also minimizes the end turns length.

E) Length of Airgap :-

Larger length of airgap results in reduced phase-inductance, armature reaction effects and also the cogging torque, but requires bigger magnets, therby increased cost so 1mm gap is selected.

V LIST OF COMPONENTS:-

A) *For Inverter Section :-*

Name of Component	Type / Rating	Quantity
MOSFET	20 Volts, 10 Amp, 57 Watts	06

B) For Control Circuit :-

Name of Component	Type / Rating	Quantity
IC1	PWM control IC, TL4941 N	01

X) *For Gate Drive Circuit :-*

Name of Component	Type / Rating	Quantity
IC2 TO IC7	Opto isolators, H11 N1	06
D1 to D12	1 N 4148	12
T1,T3,T5,T7,T9,T11	Transistors, BD 911 (NPN)	06
T2,T4,T6,T8,T10,T12	Transistors, bd 912 (PNP)	06

∆) **Rating of PMBLDC Motor :-**

1) D.C. Voltage :- 12 V
2) Power :- 45 W
3) Speed :- 2900 R.P.M

VI CONCLUSIONS

IGBTs are generally preferred under following conditions :-

- High voltage applications (>1000 volts)
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