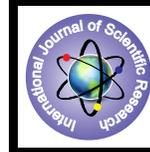


Electronic Commutation & Inverters



Engineering

KEYWORDS : commutatorless D.C. motor, pulse-width-modulation (PWM) control, MOS-FET inverters

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ABSTRACT

This paper deals with a electronic commutation in brushless dc motor. If the dc input voltage is fixed and it is controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse-width-modulation (PWM) control within the inverter. The inverter gain may be defined as the ratio of the ac output voltage to dc input voltage.

I. INTRODUCTION:-

A) Electronic Commutation:-

It is known that in a d.c. motor there are stationary electromagnets which supply the magnetic field and an armature having a number of coils distributed over its surface rotates in this magnetic field. The armature coils, of course, are interconnected to form a close winding.

The armature receives current through a mechanical commutator and brushes and torque is produced due to interaction of fields produced by armature and the magnets.

When a commutator segment comes in contact with the brush, current flows through that section of the winding which is connected to the d.c. supply through the brush and commutator segments. Thus the commutator serves the purpose of switching current from one section of the armature winding to the other at the correct instant.

Thus a d.c. motor can be thought of as an ac synchronous machine in which the field is stationary and the armature with its multiphase ac winding is rotating. The armature receives ac power from a dc source through brushes and commutators. ***The brushes and the commutator constitute an inverter sensitive to the shaft position.***

In a similar way, a synchronous motor may be considered to operate as a dc motor. In a synchronous machine the field is rotating whereas the armature is stationary but it should be supplied by an inverter controlled by shaft position-sensitive controller sensing signals.

The static inverter with the shaft positions-sensitive controller can very well be regarded as an electronic commutator serving the same function as does the mechanical commutator. (Here dc motor compare with ac synchronous motor.)

This facilitates the operation of the synchronous motor as a versatile-speed drive like a d.c. motor but having no mechanical commutations and brushes. This is no doubt ***a great advantage.***

The stator winding of the commutatorless d.c. motor may be the conventional three-phase winding of a synchronous motor or the conventional armature winding of a d.c. motor. However, in both cases, the stator winding has to be supplied from a static inverter triggered by shaft position sensitive signals so that the supply frequency is proportional to shaft speed. The d.c. field winding is placed on the rotor and supplied from a static d.c. source through slip rings mounted on the motor shaft. The equivalent block diagram of a commutatorless d.c. motor is shown in fig. 2.

It has already been explained that, the static inverter together with the shaft-position sensitive trigger circuit is equivalent to the mechanical commutator of a d.c. machine.

If the stator winding is ***similar*** to the armature of d.c. machine, six symmetricalappings from the winding can be taken out and the stator winding may be fed from a six-phase SCR bridge inverter. This is equivalent to six segment commutation. There may be many other variations of the electronic commutation arrangement.

It is, therefore, ***clear*** that a three-phase synchronous motor when fed by a three phase inverter behaves like a simple d.c. motor but the SCRs of the inverter should be triggered in proper sequence and instant proportional to the position of the rotor shaft. The SCRs may be turned off naturally owing to the nature of the load which is a synchronous motor.

Since the system ***behaves*** like a conventional separately excited d.c. motor, the speed can be controlled by the variation of the d.c. supply to the inverter or to the field. The speed is inversely proportional to the field current. The torque-speed characteristics are similar to those of a separately excited d.c. motor but is slightly more drooping in this case.

There are several possible methods of detecting the rotor position, using sensors like Hall elements or optical sensors.

II. Three phase Inverters:-

DC-to-ac converters are known as inverters. The function of an inverter is to change a dc input voltage to a symmetrical ac output voltage of desired magnitude and frequency. The output voltage could be fixed or variable at a fixed or variable frequency.

If the dc input voltage is fixed and it is controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse-width-modulation (PWM) control within the inverter. The inverter gain may be defined as the ratio of the ac output voltage to dc input voltage.

Inverters can be broadly classified into two types:

- Single-phase inverters
- 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. An inverter is called a voltage fed inverter (VFI) if the input voltage remains constant, a current-fed inverter (CFI) if the input current is maintained constant, and a variable dc linked inverter if the input voltage is controllable.

A three-phase output can be obtained from a configuration of six transistors and six diodes. **Two types** of control signals can be applied to the transistors: 180° conduction or 120° conduction.

A) 180-Degree conduction :-

Each transistor conduct for 180°. Three transistors remain on at any instant of time. When transistor Q1 is switched on, terminal a is connected to the positive terminal of the dc input voltage. When transistor Q4 is switched on, terminal a is brought to the negative terminal of the dc source.

There are six modes of operation in a cycle and the duration of each mode is 60°. The transistors are numbered in the sequence of gating the transistors (e.g. 123, 234, 345, 456, 561, 612). The gating signals are shifted from each other by 60° to obtain three-phase balanced (fundamental) voltages.

The load may be connected in wye or delta.

B) 120-Degree Conduction :-

In this type of control, each transistor conducts for 120°. Only two transistors remain on at any instant of time. The conduction sequence of transistors is 61, 12, 23, 34, 45, 61.

There is a delay of $\pi/6$ between the turning off of Q1 & turning on of Q4. Thus there should be **no short circuit of the dc supply** through one upper and one lower transistors. At any time, two load terminals are connected to the dc supply and third one remain open.

The potential of this open terminal will depend on the load characteristics and would be unpredictable. Since one transistor conducts for 120°, the transistors are less utilized as compared to that of 180° conduction for the same load condition.

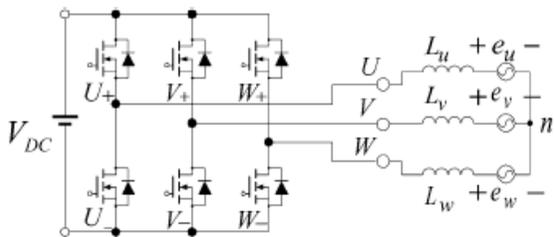


Fig. 1. Block diagram for a three-phase BLDCM drive fed by MOSFET inverter.

For three-phase brushless dc motor (BLDCM) control, two of the windings are excited and the other one is floating and therefore the back-EMF information can be used for commutation control. The commutation instants are directly derived from the zero-crossings of the back-EMF (electromotive force) in the floating motor windings. This excitation feature provides a chance to reconsider the PWM techniques and the associated performance index.

For small power applications of BLDCM drives, which are driven by MOSFET inverters in general, e.g., fan and spindle applications [1]-[3], due to the use of battery or/and limited space for heat dissipation, reduction of power consumption becomes one of the main concerns for the development of PWM technique.

The well-known pulsewidth modulation (PWM) techniques have been developed for inverter and converter control. For two-level inverter applications, PWM techniques are used to control power devices to give variable voltage and frequency.

Fig. 1 shows the block diagram for a three-phase BLDCM drive, which consists of a three-phase inverter and a BLDCM.

The inverter is controlled by the PWM technique to give proper commutations such that two of the three phases are with on-states and the remaining one is with a floating-state. Moreover, the sequence of commutations is retained in proper order such that the inverter performs the functions of brush and

commutator in a conventional dc motor, to generate a rotational stator flux.

Fig. 2 shows the PWM waveforms for conventional approach, which is referred as the 120° PWM method. This approach is with low switching losses in the inverter side at the cost of significantly high harmonic contents, which result in increase of loss in the motor side.

Fig. 3 shows a well-known PWM technique, which has been widely applied to BLDCM motor drive applications [20]. As shown in Fig. 3, the high-side power device is chopped in fundamental period and the duty ratio is derived from the speed reference or error of speed. Moreover, the high-side power device is clamped to the positive dc link rail in the consecutive fundamental period. When the high-side device is either with chop control or clamp control, the associated low-side power device is not triggered and retains "off." Similar control signal is applied to the low-side power device with 180 shift. However, as the low-side device is "on," the output terminal is connected to the negative dc link rail rather than the positive one as that for the high-side power device control.

These control signals are applied to the other two phases with 120 shift as shown in Fig. 3. Fig. 4 illustrates the current path using $\omega t [60^\circ, 120^\circ]$ and "U + " = "off," as an example. As shown in Fig. 4, power devices "U - " and "V - " are with "off-" and "on-states," respectively. Under the illustrated condition, the current flows through the antiparallel diode of power device "U -," and thereby resulting in significantly conduction losses, which equal to the product of forward drop voltage of diode and load current.

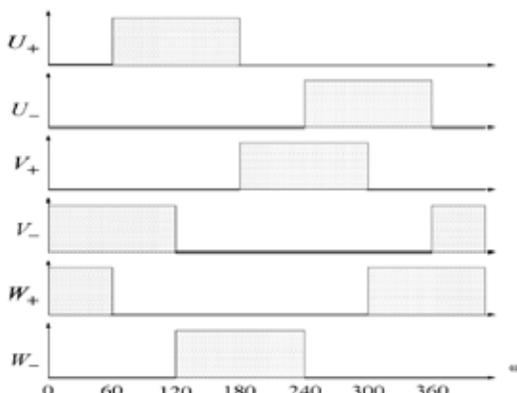


Fig. 2. PWM waveforms for a conventional approach [18], [19].

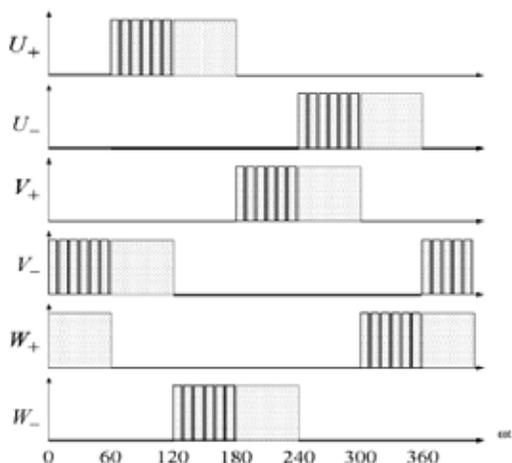


Fig. 3. PWM waveform for conventional technique [21].

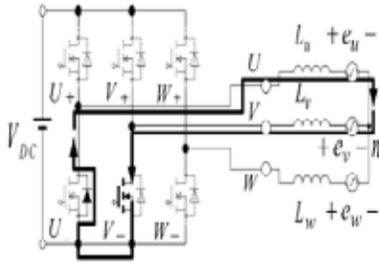


Fig. 4. Illustration of current path, conventional PWM technique, and $\omega t \in [60^\circ, 120^\circ]$ “ U_+ ” = “off.”

III. Commutation of PM brushless motors :-

A) Full-wave operation :-

The d.c. voltage V_{dc} is switched between phase terminals and for the Y connection two windings belonging to different phases are series connected during each conduction period. The current sequence is ia AB, ia AC, ia BC, ia CA, ia CB, Two solid state switches per phase are required. For this current sequence, the MMFs FAB, FAC, FBC, FBA, FCA, FCB,rotate counterclockwise. This operation is called **full-wave operation because** conduction occurs for both the positive and negative half of the EMF waveform.

For sinusoidal EMF waveform the current can be regulated in such a way as to obtain approximately **square waves**. The electromagnetic power and torque are always positive because negative EMf times negative current gives a positive product. The conduction period for line currents is 60° and both positive and negative halves of the EMF waveform are utilized. As a result, **the torque ripple is substantially reduced.**

Theoretically, the flat top EMF waveforms at d.c. voltage V_{dc} = const produce square current waveforms and a constant torque independent of rotor position. Owing to the armature reaction and other parasitic effects, the EMF waveform is never ideally flat. However, the torque ripple below 10% can be achieved.

IV CONCLUSIONS

The static inverter with the shaft positions-sensitive controller can very well be regarded as an electronic commutator serving the same function as does the mechanical commutator.(Here dc motor compare with ac synchronous motor.)

The inverter is controlled by the PWM technique to give proper commutations such that two of the three phases are with on-states and the remaining one is with a floating-state. Moreover, the sequence of commutations is retained in proper order such that the inverter performs the functions of brush and commutator in a conventional dc motor, to generate a rotational stator flux.

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