# ALTERNATIVE DESIGN OF A HIGH TORQUE DENSITY TWO-PHASE BRUSHLESS DIRECT CURRENT MOTOR

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**Abstract:** This paper proposes a design of a high torque density dual-stator brushless direct current (BLDC) motor. BLDC motors are known for their high torque capacity and power density characteristics, and therefore, they have many applications. The proposed BLDC motor is a two-phase motor with two stators, and each stator excited by one phase. The duty cycle of inverter switches is complete and coils are continuously excited. So, due to the full and uninterrupted use of all coils and core, the motor has a higher torque density compared to other BLDCs. The mathematical model of the motor provides a better understanding of motor performance. The performance of the designed motor is analyzed using finite element analysis.

## 1. Introduction

The BLDC motor has been used and rapidly developed in various applications such as home appliances, electric vehicles, medical equipment, spacecraft, and submarines. These motors have many advantages compared with conventional DC motors, induction motors, and PMs motors [1]. The BLDC motors have no mechanical brush and commutation is done electronically by switching. The duty cycle of switches is determined based on the structure and number of phases. However, in most structures, the switching duty cycle is not complete, which causes the coils and motor core not to be used optimally. In the structures of three-phase and multi-phase BLDC motors, the optimal duty cycle of the switches is less than 2/3 or 120º [2] .

## 2. Operation

A BLDC motor rotates as a result of the interaction between its permanent magnet (PM) field at the rotor and a magnetic field generated by a DC voltage applied to its stator coils. In the conventional three-phase BLDC motor, the back EMF has an appropriate value about two-third of the period due to the structure of the rotor teeth and poles as shows in Fig 1a. To achieve the maximum energy and optimal use of the core and coils, the back EMF should have value in the entire interval. This is done only when the stator tooth width is equal to the rotor pole pitch. Fig 1b shows a single-phase motor with its back EMF in which all stator coils and cores are utilized simultaneously and the power has its maximum value.

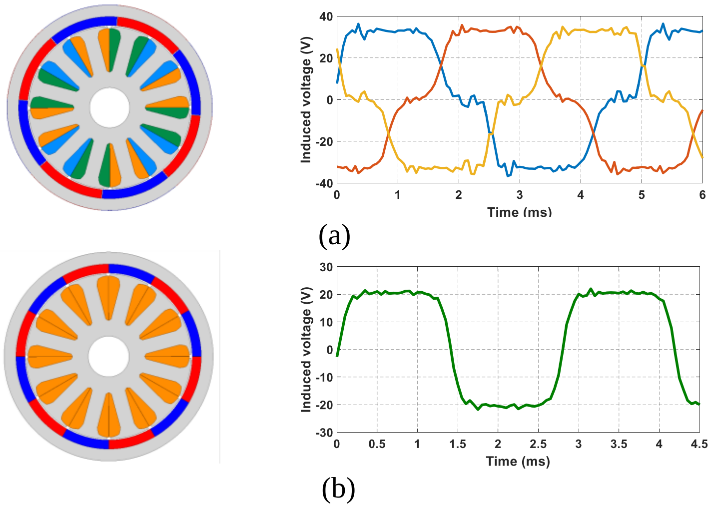



**Fig. 1. Motor structure and back EMF of (a) three-phase BLDC motor and (b) single-phase BLDC motor**

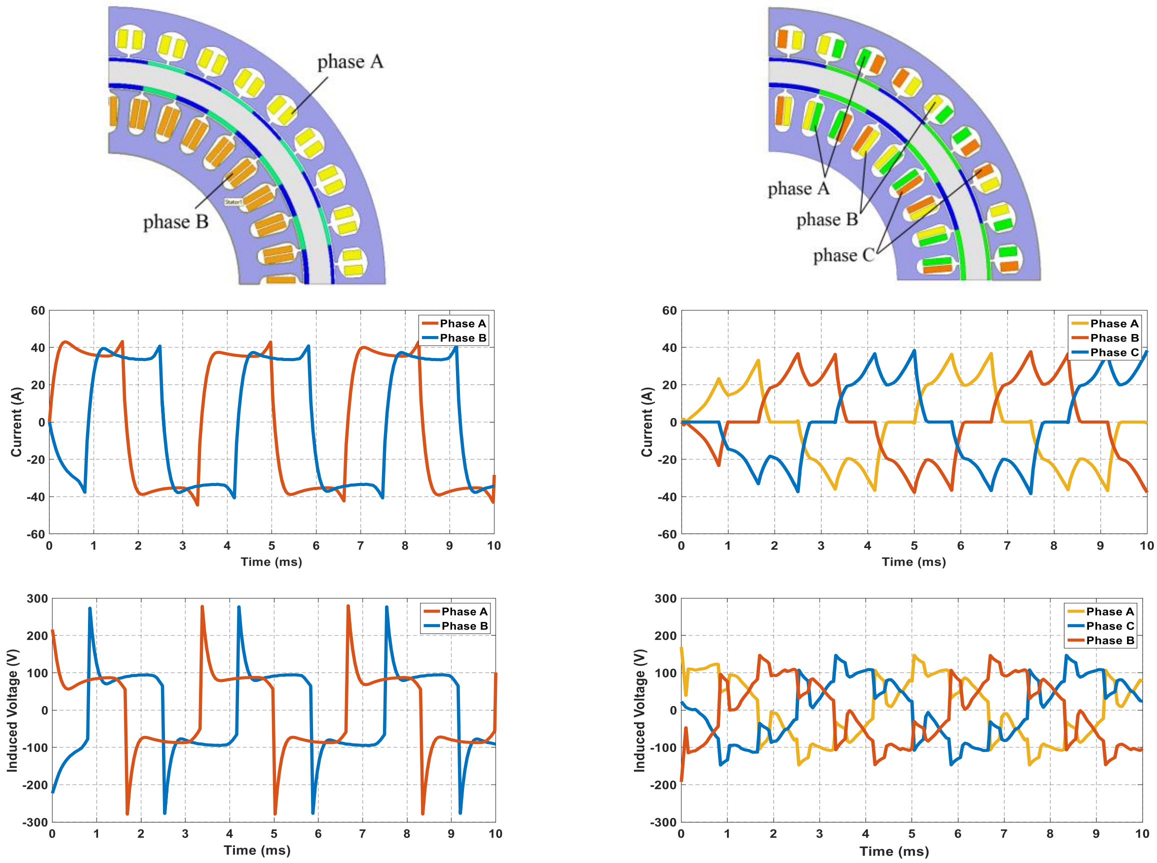
## 3. Design of proposed two-phase bldc

In this section, design procedure for two-phase dual stator BLDC motor is described. Two separate single-phase motors are designed. The first design is an internal rotor and the second design is an external rotor motor. It is noted that both motors have the same characteristics. After designing two motors, they are combined to form a dual stator motor.

## 4. Simulation and results

The proposed two-phase BLDC and a conventional 3-phase dual stator BLDC are simulated using Ansys Maxwell while their control circuit including inverter, supply, etc., are simulated using twin builder Simplorer transient coupling. Fig. 2 shows the structures of the motors. The windings of the two stator phases of the proposed motor must be independent, so, an inverter with 8 switches should be used, which has two more switches compared to that of the conventional three-phase type. With the optimal choice of $25^0$ advance angel, the phase difference between the current and the induced voltage, which caused the increase of torque fluctuations and also the decrease of the average torque, was solved.

As shown in Fig. 2 the RMS current and voltage of the proposed motor is 33 A and 105 V, respectively, and they are 21 A and 81 V for the conventional motor. Fig. 3 shows the average torque and torque ripple of the proposed motor which is 46 Nm and 65% respectively; the corresponding values for the conventional three-phase motor is 32 Nm and 50%. The output powers of the proposed and conventional motors at the speed of 1000 rpm is 4.82 kW, 3.35 kW respectively. Therefore, the simulation also confirms the idea proposed in this paper that in the same volume and dimensions, the torque and output power of the proposed motor is 1.43 times that of the conventional motor. The loss of the proposed machine is slightly higher than that of the conventional machine; however, considering the higher power of the proposed machine, such higher loss is acceptable.




**(a) (b)**

**Fig.2. Motor structure, induced voltage and current: (a) Proposed two-phase BLDC, (b) Conventional three-phase BLDC**

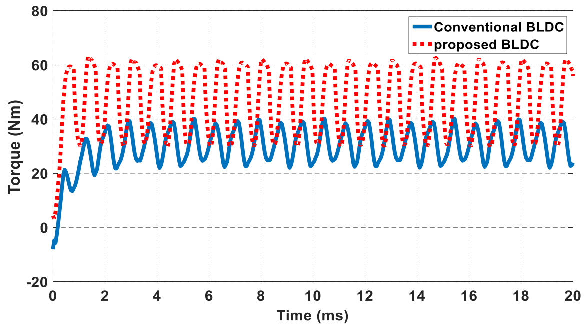



**Fig.3. Developed electromagnetic torque**

## Conclusions:

This paper proposed a new structure for a two-phase BLDC motor. The advantage of this motor is its ability to receive a high energy or power, increasing the torque density compared to other motors with the same size.

Higher developed torque of this motor is due to the duty cycle of the inverter switches, because unlike the conventional motors these switches operate with a full duty cycle. Therefore, the windings and core are always passing the current and magnetic flux, causing optimal and complete utilization of the motor. In this paper, firstly, development of a higher torque was proved by a mathematical model of the motor, then, the desirable motor is designed. The proposed motor is simulated by finite element analysis and its optimal advance angle was selected to have a reasonable torque. To show the higher torque density of this motor, a conventional three-phase dual-stator motor with the same dimensions and specifications were simulated. Finally, the comparisons shown that the torque of the proposed motor is 1.43 times of the three-phase motor.

## References:

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[2] Gholase V., Fernandes B. G. Design of efficient BLDC motor for DC operated mixer-grinder, Proc. IEEE Int. Conf. Ind. Technol., vol. 2015-June, no. June, pp. 696–701, 2015, doi: 10.1109/ICIT.2015.7125179.