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RESEARCH ARTICLE
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MULTI-LEVEL INVERTER-BASED BLDC MOTOR DRIVE FOR COLD STORAGE APPLICATION

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Abstract
This research introduces a BLDC motor drive system that relies on a multi-input Z-source inverter for use in cold storage applications. The designed multi-input inverter is capable of transmitting power from all input sources, either individually or simultaneously, to the load. This enables the integration of the three-phase utility power supply with a solar array as input sources for the load. The system incorporates a Z-source inverter based on multi-input technology, featuring a unique impedance circuit connecting the main circuit to the power source. This configuration offers distinctive advantages not achievable with conventional voltage-source or current-source inverters.
The BLDC motor is chosen over the induction motor due to its numerous advantages, leading to its widespread replacement of induction motors in modern applications. Simulation results are provided to validate the theoretical concepts.

Keywords: Multi-input inverter, brushless DC(BLDC) motor, Z source inverter, closed loop speed control, cold storage plant.

1- INTRODUCTION

In a developing country like India more than 65% of population of India is engaged in agriculture. India is the 2nd largest producer of fruits and vegetables in the world, hence cold storage is important. For the cold storage application we can use solar array that are not dependent on the grid electricity supply. In addition we can use the roof space of the cold storage plant for installation of solar array. In order to combine more than one energy source, to get the regulated output voltage, and current different circuit topologies of multi-input inverters have been proposed in recent years. The multi input inverter can continue to operate even if one of the supply sources has failed [1]. The general form of the multi input inverter consists of several input sources and a single load. Each of the input source-to-output.
Load pair can be considered as an individual PWM inverter separately. All of the input sources can deliver power to the load either separately or simultaneously through the multi input inverter. When only one of the input sources feeds the multi input inverter, it will transfer power to the load separately and the multi input inverter will operate same as a PWM inverter, otherwise more than one input sources are supplied to the multi input inverter then all these input sources will deliver power to the load simultaneously without disturbing other's operation[2].The Z-source inverter is a novel

topology that overcomes the theoretical barriers and limitations of the voltage-source inverter and current-source inverter and supplies regulated voltage and current to the motor load[3].Due to advantages of a BLDC motors such as, Better speed versus torque characteristics, High efficiency, Long operating life, Noiseless operation, Higher speed ranges, over the DC motor and induction motor it is becoming more popular in industries. Therefore in recent year's induction motor for cold storage application is being replaced by BLDC motor.

II. CIRCUIT CONFIGURATION AND OPERATION PRINCIPLE OF THE PROPOSED SYSTEM

Figure 1 shows the block diagram of Multi input z-source inverter based BLDC motor drive for cold storage application It consists of three major parts, viz. multi input system, Z source inverter and the load. These three section are explained in detail in following sections.

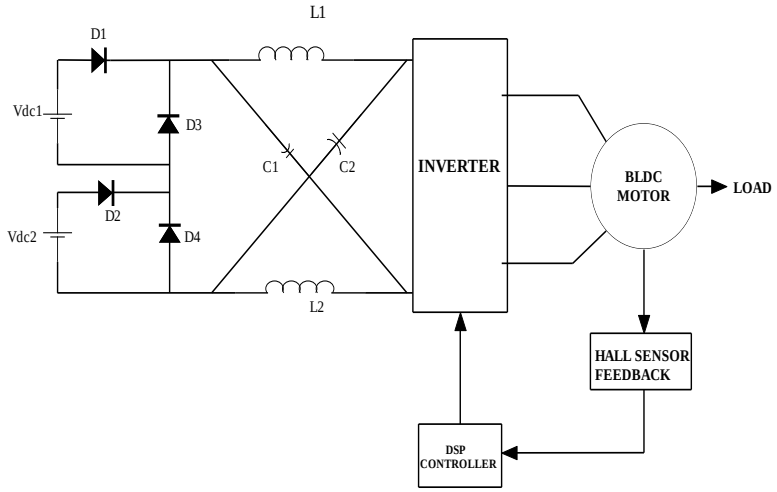

Fig 1.Block diagram of multi input z-source inverter based BLDC motor drive for cold storage application.

A. Z-source inverter

Fig. 2 shows the general Z-source inverter structure. It employs a unique impedance network to couple the inverter supply to the BLDC motor load. The Z-source inverter overcomes limitations of the traditional voltage source inverter and current source inverter and provides a novel power conversion concept. It is two-port network that consists of a two inductors and two capacitors and connected as shown in figure is used to provide an impedance source coupling the inverter to the BLDC load. The supply DC source can be either a voltage or a current source [3].

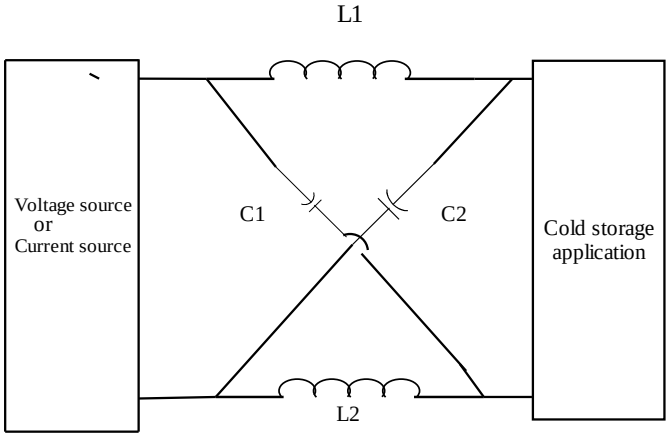

Fig 2Basic structure of z- source inverter.

B. Principle operation of a multi input system

There are four different operation states with respect to ON or OFF states of dc sources. As previously mentioned, both of the input sources can deliver power to the load either separately or simultaneously through the multi input inverter. When only one of the input sources feeds the Multi input inverter, it transfers power to the load separately and the multi input inverter will operate as does a PWM inverter.

The detailed explanation of these four states is given below [2].

1) State one, both source one and source two are ON

Fig. 3shows equivalent circuit of state one. When both source one and source two are ON, the inverter input dc voltage is addition of supplied sources, as Fig. 3 and equation (1) illustrate.

$$Vin = Vdc1 + Vdc2 \qquad (1)$$

In this state, because both two sources are ON, D1 and D2 are forward biased and D3 and D4 are reverse biased. Thus, the sources current enters in Z-source inverter through D1 and D2 and after passing load impedance, comes back into sources through negative polarity.

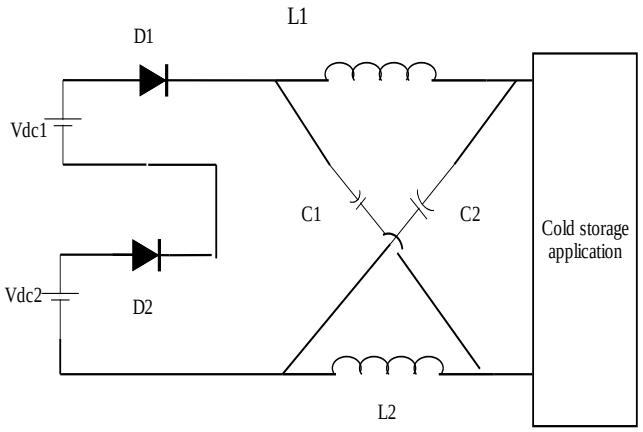

Fig 3Equivalent circuit of state one.

2) State two, source one is ON and source two is OFF

The equivalent circuitof statetwo is shown in Fig 4. In this state, source one is ON, so only this source provides power to the inverter. Because of source one is ON then D1 is forward biased and D3 is reverse biased, so current follows from D1 to Z-source inverter to load.In reverse path from load to the source, current can't pass through source two and D2, so D4 is forcedly turned on and conduct current to source one. In state two, inverter input dc voltage is only provided by source one, as equation (2) shows.

$$Vin = Vdc1 \qquad (2)$$

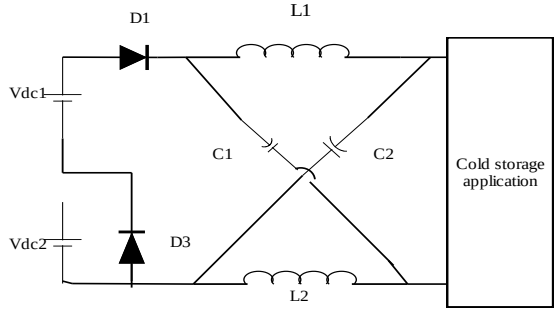

Fig 4 equivalent circuit of state two

3) State three, source one is OFF and source two is ON

If source one is eliminated for each reason and source two is ON, the inverter can operate normally without effect of source one elimination. Fig.5 shows the equivalent circuit for state three. In state three, it's only source two that supplies inverterand load. Source two activation causes forward bias of D2 and reverse bias of D4. Because of source one disconnection, current passes through D3 and indeed, current turns it on forcedly to complete current path. In state three, inverter input dc voltage is only provided by source two, as equation (3) shows.

$$V\text{in} = \text{Vdc2} \qquad (3)$$

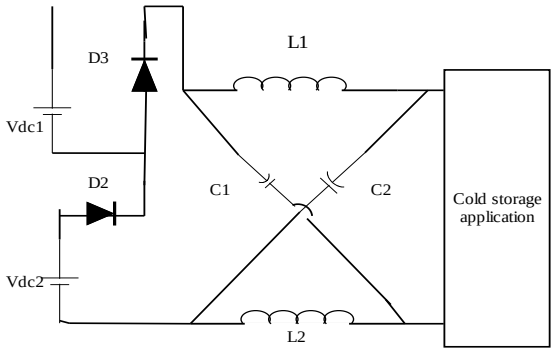

Fig 5 Equivalent circuit of state 3

4) State four, both source one and source two are OFF

Basically, this state is only following of one of the previously mentioned three states. Because in this state both dc sources are OFF and disconnected from inverter, D1and D2 are forcedly turned off and consequently, the only existing path for remain current, from previous state, is provided by D3 and D4. Thereupon, in state4 D3 and D4 are turned on. Fig. 6shows equivalent circuit of state four. Input voltage is zero in this state as shown in equation (4).

$$V\text{in} = 0 \qquad (4)$$

Obviously, because both dc sources disconnect from inverter, duration of this state is very short and when current descends to zero, whole of inverter will be OFF.

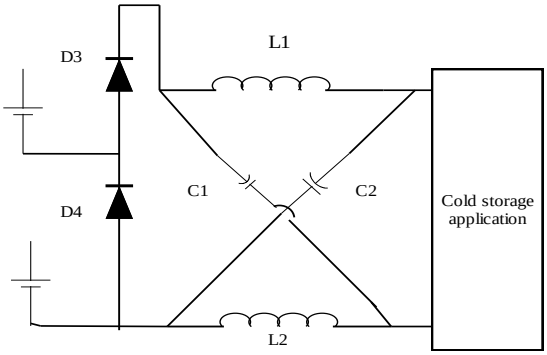

Fig 6 Equivalent circuit of state 4

C. Cold storage load.

In cold storage applications compressor decides the, required output rating of motor. Brushless Direct Current motors are one of the types of synchronous motor rapidly gaining popularity in industries. The applications of BLDC motors are Industrial Automation Equipment, Instrumentation, Aerospace, Consumer and Medical. BLDC motors do not use brushes for commutation, instead they are electronically commutated .Closed loop Speed Control Systems allow one to easily set and adjust the speed of a BLDC motor. A properly designed feedback controller makes the system insensible to

disturbance and changes of the parameters [4].
For the automatic control of cooling temperature closed loop speed control of BLDC motor is used. In this application, we have achieved the closed loop speed control by using two PI controllers, one for speed control and another for torque control. It consists of a proportional and integral gain that produces an control effort proportional to the input error and makes the steady state error zero for a step change in the input. For these speed and torque controllers the reference speed(200rpm) and the reference torque(10 Nm) is provided as per requirement. The purpose of a motor speed controller is to take a signal representing the desired reference speed, and to drive a BLDC motor at that.Speed controller calculates the difference between the reference speed and the actual speed producing an error signal, which is fed to the PI controller[5].

iii SIMULATION RESULTS AND ANALYSIS

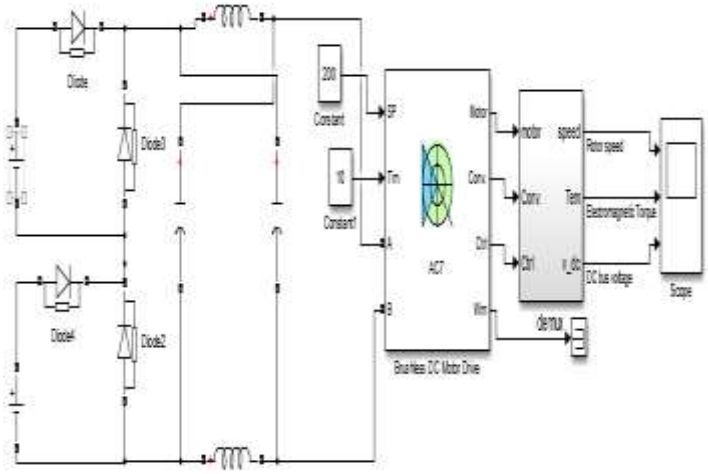

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Fig 7.Block diagram of multi input z-source inverter based BLDC motor drive for cold storage application.

To assess the performance of different states, simulations designed and implemented in MATLAB. In MATLAB simulation sources one or two voltage is 100V when it is in ON state otherwise zero. Results are obtained for various states. Speed reference and torque reference for all states are 200 rpm and 10Nm. Figure shows rotor speed, electromagnetic torque and DC bus voltage waveforms for the above four states.

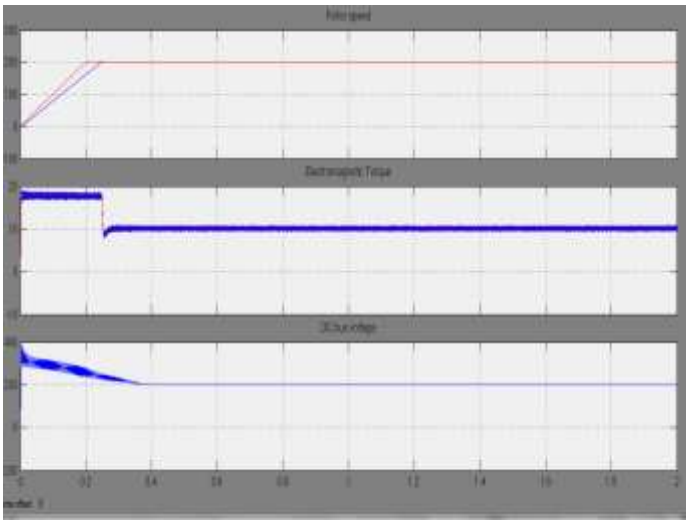

Fig.8Rotor speed electromagnetic torque and DC bus voltage for state one

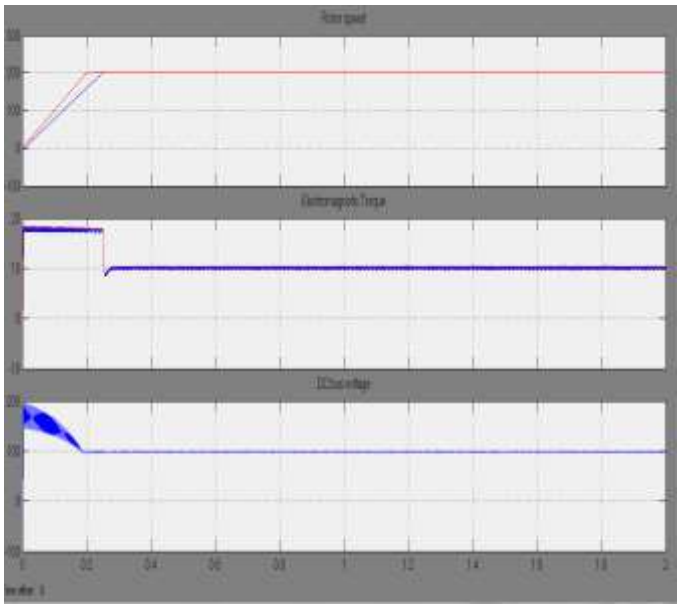

Fig.9 Rotor speed electromagnetic torque and DC bus voltage for state two

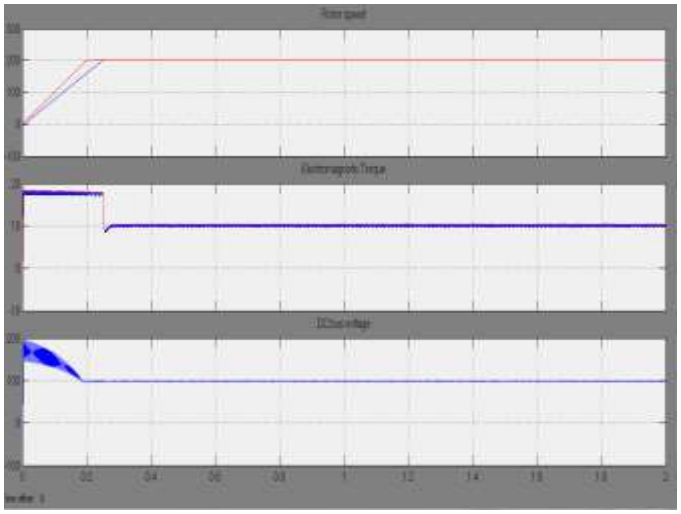

Fig.10 Rotor speed electromagnetic torque and DC bus voltage for state three

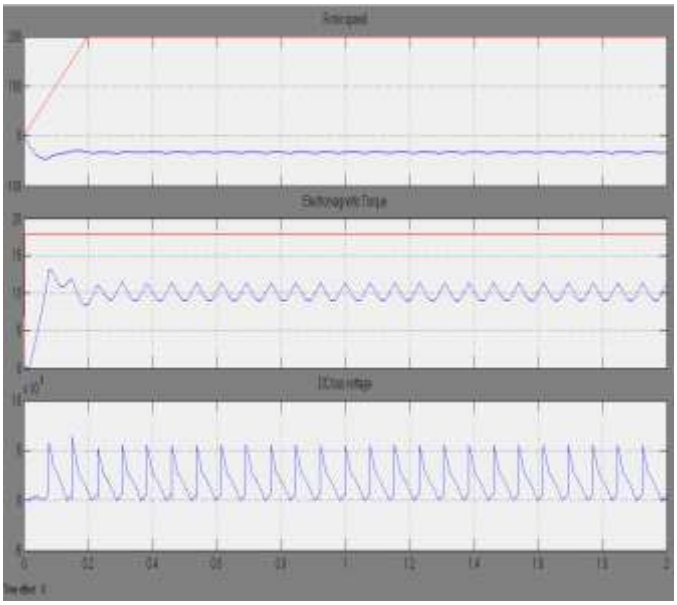

Fig.11 Rotor speed electromagnetic torque and DC bus voltage forstate four

IV.CONCLUSION

This paper concludes that Multi input z-source inverter based BLDC motor drive is suitable for cold storage application. The operation principle of various states and analysis is explained in detail for closed loop speed control of BLDC motor. Analysis and simulation results show the input dc sources can deliver power to load separately or simultaneously, as failure of each input sources doesn't disturb the operation of load. Due to closed loop algorithm the motor tracks the reference speed. Two input sources can have different current and voltage magnitude. Also, z- source inverter improves the reliability of a closed loop system.

V. REFERENCES

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