International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 3, March - 2014

Low Cost, Dual Voltage Converter for High- Speed Application

Gayathri. S
M. Tech in Power Electronics and Control
Govt. Engineering College,
Idukki

Sreedevi. G
M. Tech in Power Electronics and Control
Govt. Engineering College,
Idukki

***Abstract*—Different types of motors are used for high speed applications have to be inexpensive and efficient. One of which reluctance motors are known to be cheap and robust, but their use in such mass market applications has been limited by the cost and limitations of their associated power converters. A new converter concept is proposed in this paper has the ability to apply higher voltages across the machine windings than could be obtained with standard circuits to achieve high-speed operation. A 1-kW prototype converter is designed and constructed to experimentally validate the operation of the new circuit.**

***IndexTerms*—Dual voltage converters, Charge transfer circuit, Reluctance motor, Motor drives**

I. INTRODUCTION

For high- speed application various motors are used especially switched reluctance machines and stepper motors, in which high cost of the associated power electronic drive outweighs the cost of the machine itself. These motors the need for rotor windings, brushes, commutators and any type of rotor bars or permanent magnets. This reduces the total cost, losses, and inertia of these machines and increases their robustness, making them the most suitable for high-speed applications. However, they produce a discontinuous torque and are therefore only suitable for applications insensitive to torque pulsations.

There are many applications in which the merits of these machines used. Examples of such applications are the textile processing industry and the aerospace industry. Torque production (Speed of the motor is dependent on torque) in these types of machines depends mainly on the variation of the magnetic reluctance (or inductance) with rotor position. The instantaneous torque at rotor position (θ) is given by

$$T(\theta) = \frac{1}{2}\, i(\theta)^2 \frac{dL(\theta)}{d\theta}. \quad (1)$$

The inductance varies from a minimum to a maximum as the rotor moves from an unaligned position (where the stator poles of one phase are exactly aligned with the interpolar axis of the rotor) to an aligned position (where the poles of that phase are aligned with a pair of rotor poles) and vice versa. A positive torque can be produced only when the inductance is increasing. Applying a high positive voltage across the machine winding during magnetization and a high negative voltage during demagnetization will guarantee fast current rates of rise and fall. Consequently, high-speed operation can be achieved without the need for a lower inductance value.

With higher inductance values, the stator current rise (magnetization) and fall (demagnetization) takes longer. This may not be a problem at low speeds where the duration of the inductance increase/decrease period is long. However, for high-speed operation, a fast rate of rise of current must be achieved to allow the current to reach its reference value. A fast rate of fall of current must also be ensured to avoid (or at least reduce) any negative torque pulses resulting from the existence of current after the inductance had started to decrease. Fast rates of change of current can be achieved if the motor is designed with lower inductance. However, this reduces the torque production capability of the machine as illustrated by (1).

Conventional converters (capacitor boost converter) provide a limited range of output voltage magnitude. The additional auxiliary capacitor can be placed in parallel or in series with the dc-link capacitor provides a boost to the voltage across the motor windings. For most of these configurations, the maximum voltage is applied across the machine winding during the magnetization period only. The demagnetization process is load dependent, limiting the motor speed at higher loads.

This paper proposes a new converter concept for reluctance motor drives operating at high-machine voltages. The high voltage across the machine windings is achieved by introducing a simple dual voltage supply to generate high voltages across the machine windings. The need for a high dc-link capacitance value is thus eliminated. In the following sections, the behavior of the converter is analyzed and simulated. A dual voltage supply has been integrated into the new converter topology so that the machine windings are supplied from two (positive and negative) voltage rails. A 1-kW prototype is constructed and tested with a stationary inductive load to experimentally verify the operation of the circuit.

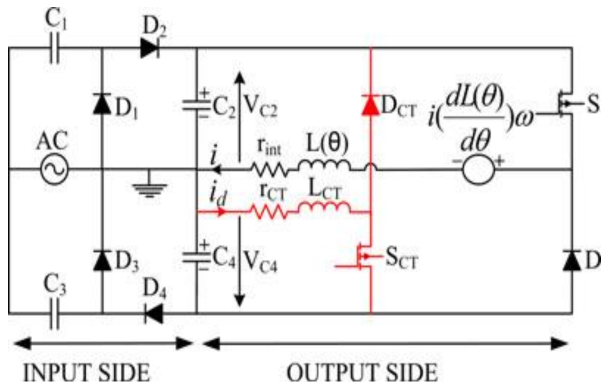

Fig no: 1 Circuit diagram of dual voltage converter

OPERATING PRINCIPLES OF THE PROPOSED CONVERTER

Fig. 1 shows a circuit diagram of the proposed dual voltage converter. The input stage of the converter comprises the ac mains feeding four capacitors as temporary storage elements. The output stage is comprised of one switch *S* and one diode *D*. Connected in parallel with the output stage is a charge transfer circuit which is used to transfer the excess charge from *C*4 to *C*2 keeping the voltage level on *C*4 nearly constant.

Single-phase diode bridge rectifier, a DC-link capacitor and an Asymmetric bridge inverter. Switches S1 and S2 at the turn-on angle θ_0 , connecting the dc-link voltage across the machine winding magnetization of motor is achieved. For low-speed operation, a turn-on angle of 90^0 at unaligned position. When the current reaches the upper limit I_{upper} , S1 and S2 are switched OFF and the current freewheels through D1 and D2. In this case, a 'negative dc-link voltage' appears across the machine winding forcing the current to decrease.

When the current falls to the lowerI_{lower} , S1 and S2 are switched ON. Rotor reaches the commutation angle θ_{C} at the aligned position (θ =180^0). S1 and S2 are then switched OFF applying a negative voltage across the winding until the current decays to zero. The rotor continues to move through its inertia until it reaches the unaligned position.

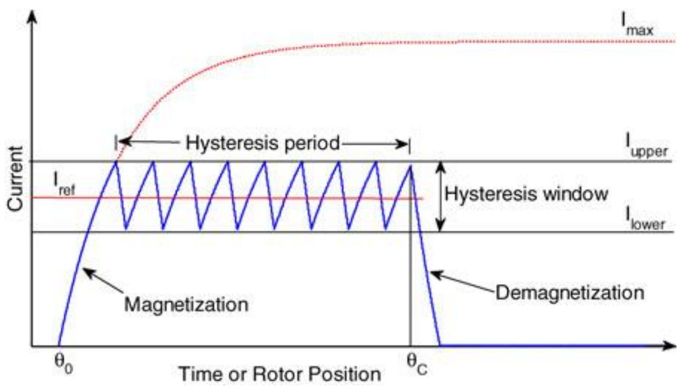

Fig No: 2 Hysteresis current waveform

The rotor continues to move through its inertia until it reaches the unaligned position again and the sequence is repeated. During demagnetization, the energy is supplied back to the dc-link capacitor.

There are mainly three stages for the converter as Input stage (ac main feeding four capacitor**),** Output stage (switch S1 diode D), Charge transfer circuit (resistor r_{int} inductor L(θ) switch S_{CT} diode D_{CT}).

II. INPUT STAGE

In high voltages at relatively low currents, circuit consist of diodes and capacitors.

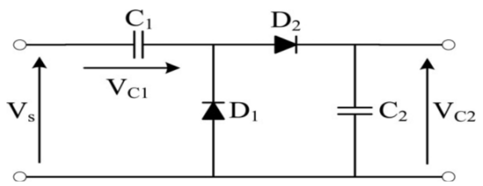

Fig no: 3 Dual voltage converter

Assuming no losses, the operation is at *t* = 0, all capacitors are uncharged. During the negative half cycle of the supply voltageV_s, capacitor C_1 is charge a voltage VC_1given by

$$VC_1 = V_s\text{,peak} \quad (2)$$

where VS ,peak is the peak supply voltage. During the positive half cycle, capacitor C_2 is charged to a voltage VC_2given by

$$VC_2 = VC_1 + VS\text{,peak} \quad (3)$$

Substituting for VC_1 , it is clear that the output voltage VC_2 is now double the peak supply voltage

$$VC_2 = 2V_s\text{,peak} \quad (4)$$

Thus input stage of the proposed converter employs two half-wave voltage doubler circuits connected back to back.

OUTPUT STAGE

It consist of mainly three modes

i) Magnetization

ii)Hysteresis period

iii)Demagnetization

In magenetization S turned ON causing C_2discharge and magnetizing the windings.

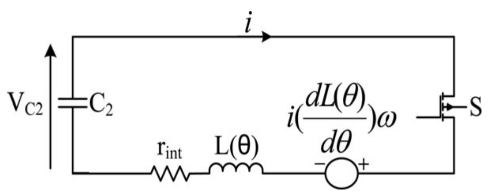

Fig no: 4 Effective circuit during magnetization

Current through the load increases from zero toward a maximum value Imax,

$$i(t) = I_{max\,1}\,(1 - e{-}t/\tau) \quad (5)$$

$$I_{max\,1} = VC_2\,(r_{int} + dL(\theta)/d\theta\omega) \quad (6)$$

$$\tau = L(\theta)/(r_{int} + dL(\theta)/d\theta\omega) \quad (7)$$

In hysteresis once the current reaches I_{upper} , switch S OFF and diode D starts to conduct. The current decays exponentially until it reaches the lower hysteresis limit I_{lower}

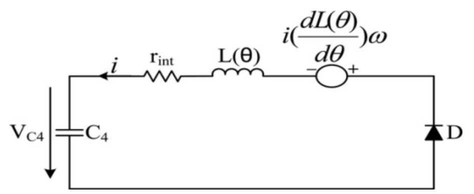

Fig no: 5 Effective circuit during demagnetization

$$i(t) = I_{max\,2} + (Iupper - I_{max\,2})e{-}t/\tau \quad (8)$$

$$Imax\,2 = VC_4/(r_{int} + dL(\theta)/d\theta\omega) \quad (9)$$

In demagenetization the windings are demagnetized when S is switched off and D starts to conduct. During this period, the current decreases from iupper to zero and the energy stored in the machine winding is injected into C_4 . The demagnetization starts at the maximum value of machine inductance i.e., At the maximum value of τ. consequently demagnetization takes longer than magnetization.

III. CHARGE TRANSFER CIRCUIT

In magnetization, capacitor C_2 discharges and VC_2 decreases in which voltage across the capacitor C_4 is constant. In demagnetization, freewheeling diode conducts and machine inductance current charges the capacitor C_4 , increasing its voltage VC_4 . No discharge possibility for C4 (iC_4 is always positive). Its terminal voltage continues to increase as leading to the eventual failure of the circuit

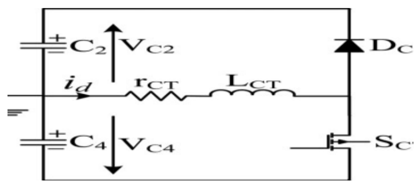

Fig no: 6 Charge Transfer Circuit

To solve this problem**,** inductor L_{CT} with internal resistance r_{CT} , a switch S_{CT} and a diode D_{CT} is added in parallel to the output stage Voltage across VC_4 exceeds an upper limit VC_{4max} , a 50% duty cycle control signal is enabled to switch S_{CT}ON and OFF at 10 kHz. S_{CT} is ON, the current id rises toward a maximum value equal to VC_4/r_{CT}. The switching continues until the voltage across C_4 falls below a lower limit.

To investigate the operating characteristics of the new circuit topology and verify circuit design parameters, simulations were carried out using PSIM software. Components used are Converter(1-kW), ac voltage (340V) , rectifier diodes(D1-D4), soft recovery diodes(D, D_{CT}),insulated gate bipolar transistor switch(S_{CT}), power MOSFET(S), four capacitors (160 μF), inductive load (17-mH), inductor (4-mH).

IV. CIRCUIT DIAGRAM IN PSIM SOFTWARE

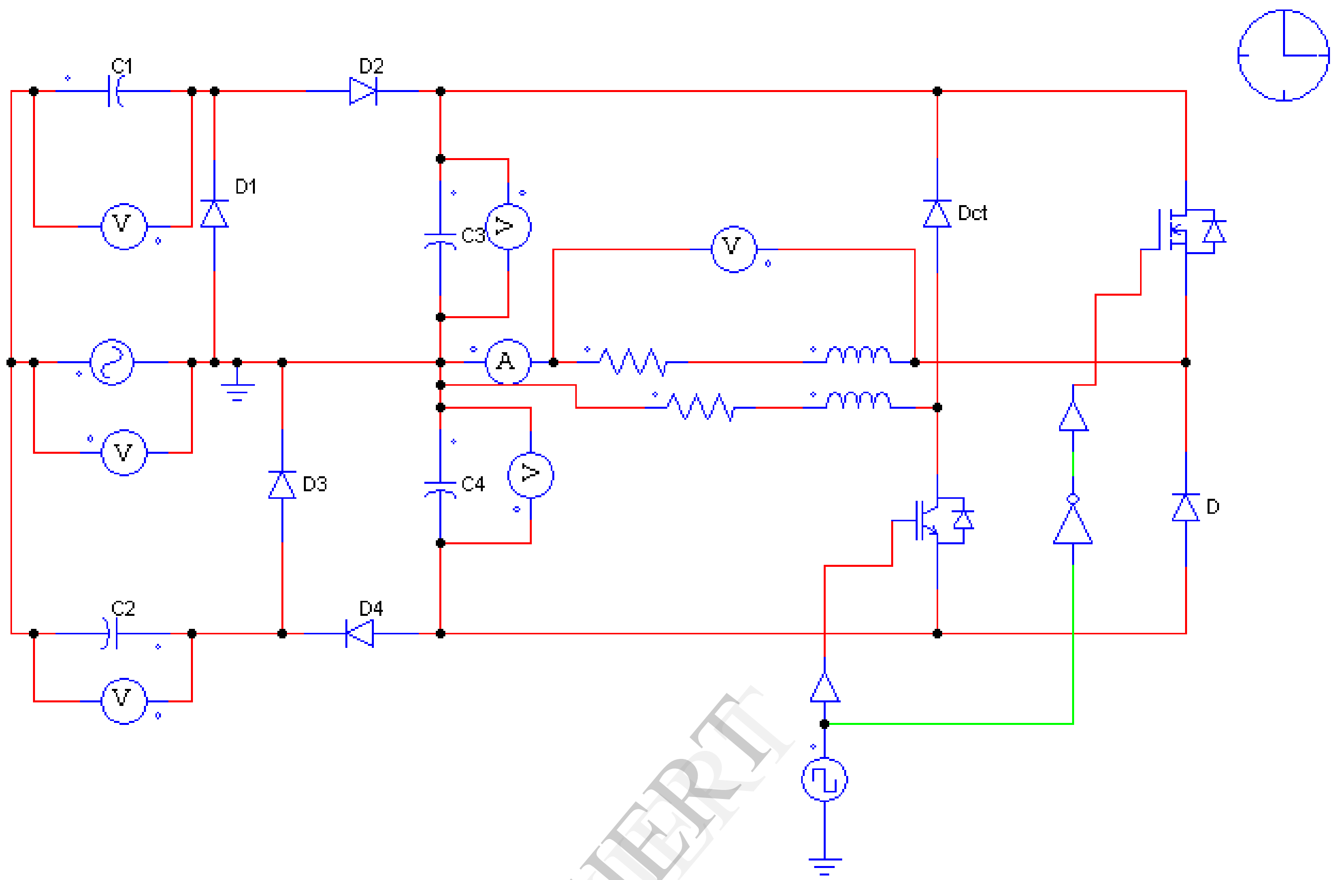

Fig No: 7 Circuit setup of Dual Voltage Converter in PSIM software

V. SIMULATION RESULTS

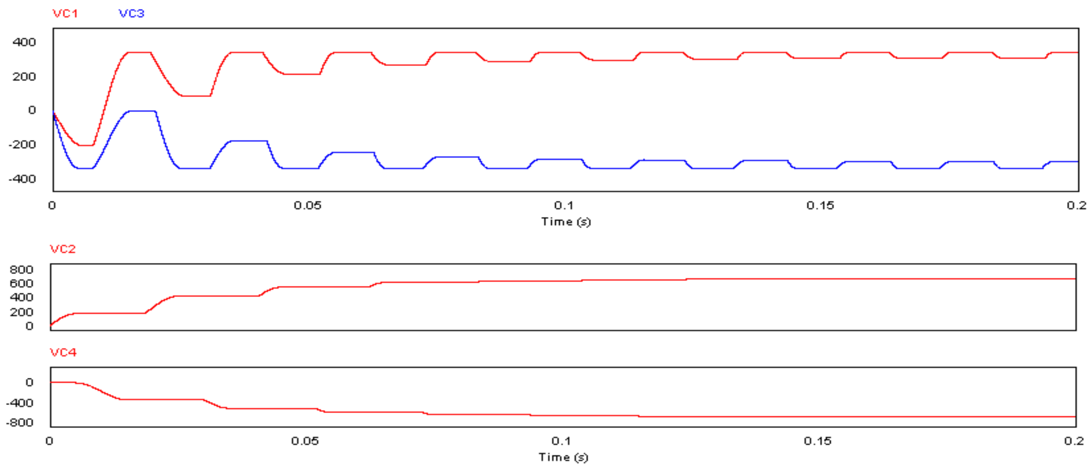

Fig No: 8 Output Voltage waveform

VI. CONLUSION

A new converter has been proposed for reluctance motor drives with the ability to supply double the peak supply voltage to the machine winding. Higher voltages across the machine windings will increase the rate of change of current during the winding magnetizing and demagnetizing periods to enable the machine to work at higher speeds. The simulation results shows dual voltage supply has been integrated into the new converter topology so that the machine windings are supplied from two (positive and negative) voltage rails. This is the only converter that is suitable for high-speed operation at all load conditions.

REFERENCES

[1] A. Mohammed Elgendy , Bashar Zahawi and Afida Ayob "Dual Voltage Supply Converter for High-Speed Doubly Salient Reluctance Motors"*IEEE Trans.Power., Electron*, vol. 28, no. 2, Feb. 2013.

[2] J. Kim, K. Ha, and R. Krishnan, "Single-controllable-switch-based switched reluctance motor drive for lowcost, variable-speed applications,"*IEEE Trans. Power Electron.*, vol. 27, no. 1, pp. 379–387, Jan. 2012.

[3] H. J.Brauer, M. D. Hennen, andR.W.DeDoncker, "Control for polyphase switched reluctance machines to minimize torque ripple and decrease ohmic machine losses," *IEEE Trans. Power Electron.*, vol. 27, no. 1, pp. 370–378, Jan. 2012.