Regenerative braking method used in converter for traction application.

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Abstract - ***In this paper an attempt is made to investigate the performance of PWM VSI-fed induction motor drive. The open loop Simulink model of the voltage source inverter-fed induction motor drive is presented. Mainly focused on the braking of an induction motor . The PWM VSI squirrel-cage motor traction drive is shown in fig (2) .DC link is supplied from ac source through a transformer and a diode rectifier .because use of diode rectifier regenerative braking is not possible .so some changes are made in simulation in order to have an regenerative braking operation of an ac drive.***

Key Words: *converter ,induction motor, pwm technic ,ac to dc converter, dc link , synchronous link converter* **,** *drive***.**

1. Introduction

Induction motors have been used in the past mainly in applications requiring a constant speed because conventional methods of their speed control have either been expensive or highly inefficient .Variable speed applications have been dominated by dc drives .Availability of thyristors , power transistor , IGBT and GTO have allowed the development of variable speed induction motor drives . The main drawback of DC motor is the presence of commutator and brushes ,which require frequent maintenance and make them unsuitable for explosive dirty environments . on the other hand , Induction motors , particularly squirrel –cage are rugged , cheaper ,lighter, smaller ,more efficient ,require lower maintenance and can operate in dirty and explosive environments. Although variable speed induction motor drives are generally expensive than DC drives, they are used in a number of applications such as fans ,blowers, mill run-out conveyers, traction etc . Because of the advantages of induction motors. Other dominant applications are underground and underwater installations ,and explosive and dirty environments.

1. Regenerative braking

The power input to an induction motor is given by

$$P_{in} = 3\, V\, I_s \cos\, \phi_s$$

Where ϕ_s is the phase angle between stator phase voltage V and the stator phase current I_s. For motoring operation $\phi_s < 90^0$. If the rotor rotor speed becomes greater than synchronous speed , relative speed between the rotor conductors and air gap rotating field reverses. This reverses the rotor emf , rotor current and component of stator current which balances the rotor ampere turns. Consequently ϕ_s, angle becomes greater than 90^0 and power flow reverse, giving regenerative braking. When fed from a source of fixed frequency ,regenerative braking is possible only for speeds greater than synchronous speed . With a variable frequency source it can also be obtained for speeds below synchronous speed .Main advantage of regenerative braking is that generated power is usefully employed and main drawback being that when fed from a constant frequency source , it cannot be employed below synchronous speed. The nature of speed –torque characteristic is shown below.

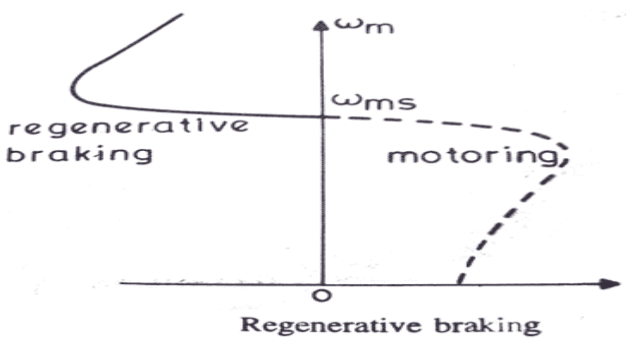

Fig 1: regenerative braking

3 PWM VSI fed induction motor drive with regenerative braking

The PWM VSI squirrel-cage motor tractions drive is shown below .dc link is supplied from ac source through a transformer and a diode rectifier . Because of the use of diode rectifier, regenerative braking is not possible. But the drive can be provided with regenerative braking capability by replacing circuit on the left of AB in fig. by synchronous link converter (SLC) circuit . SLC employs GTO switches for a locomotive and IGBT switches for a motor coach . It operates at unity fundamental power factor and low harmonic content in source current , which can be adequately filtered by a low cost high pass filter .

Operation of 1- phase SLC fed PWM VSI induction motor drive are described in circuit and therefore , employs 1-phase PWM inverter . The inverter and the inductor L_s together form SLC . For producing a given value of I_s in phase with V_s ,the PWM inverter produces an ac input voltage V_1 of given phase and magnitude ,as shown in phasor diagrams of fig (4) and (5) for motoring and regenerative braking operation respectively. During motoring operation ,power flows from source through SLC, dc link and inverter into motor .Here I_s is in phase with V_s and V_d and I_d have polarities as shown in figure . When machine shifted to braking , I_d reverses and I_s has a phase of 180 with respect to V_s , therefore ,power generated by motor flows through inverter , dc link and SLC to ac supply giving regenerative braking . As the power supplied to dc link is independent of power taken from it , a closed loop control of dc link voltage is used to balance the two. A constant voltage across the dc link capacitor is obtained when the power supplied to the dc link equals the power taken from it. Since the SLC works as a boost converter ,the closed loop control of dc link voltage ensures that the torque and power capability of the drive remains unaffected by a drop in source voltage .This SLC fed PWM VSI induction motor drive is the most widely used drive . ABB locomotive in Indian Railway has this drive . It has all the advantages of PWM inverter induction motor drive .As compared to other ac motor drives employed in ac traction ,it has the unique advantages of high power factor ,low harmonics in source current achieved voltages.

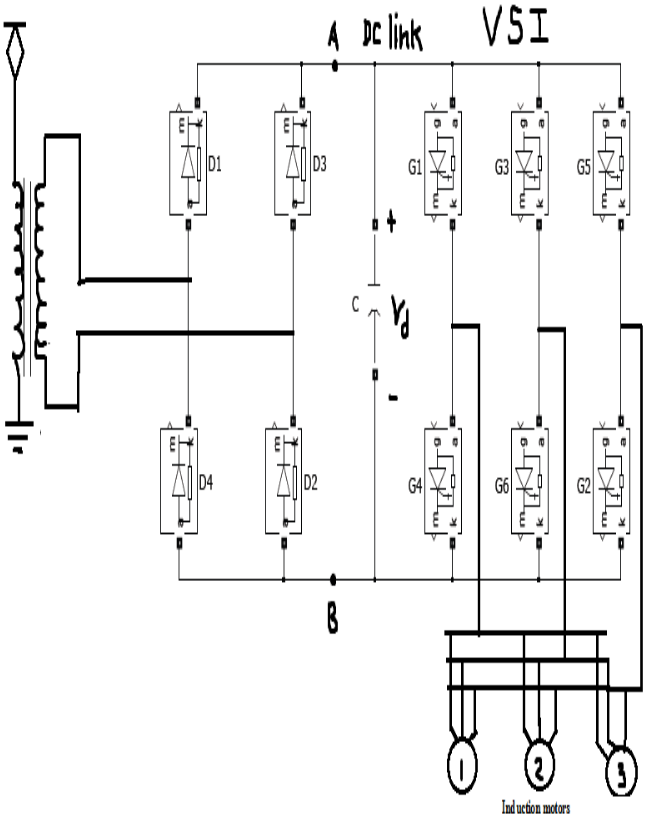

Figure 2: PWM VSI fed induction motor drive.

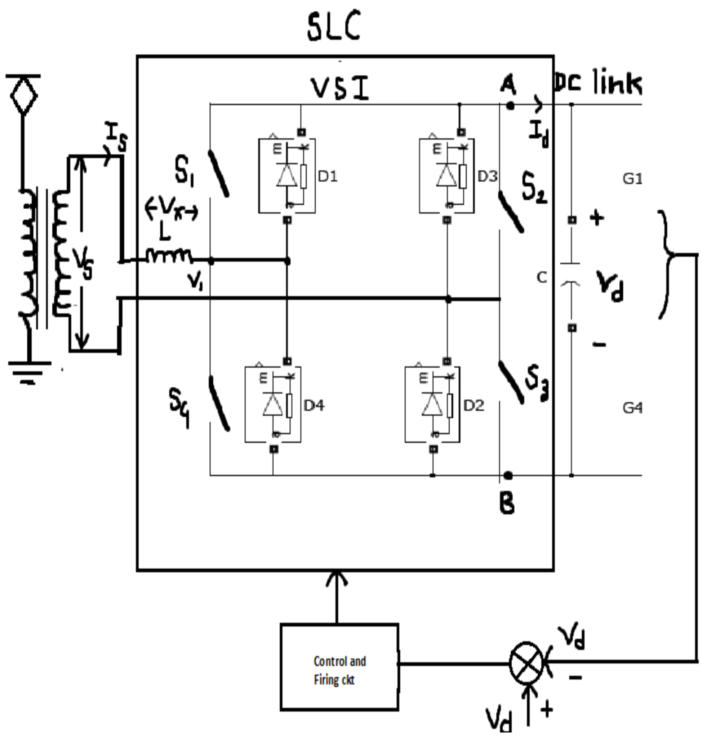

Figure 3: synchronous link converter.

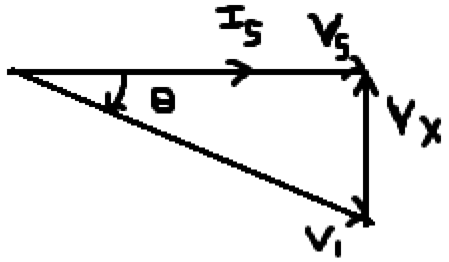

Figure 4: motoring.

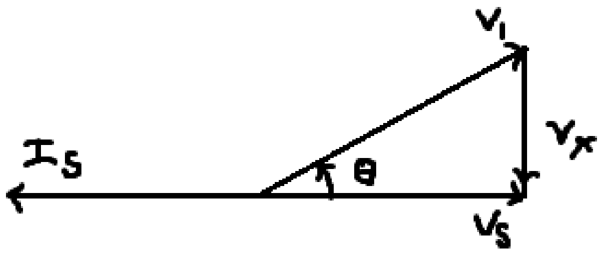

Figure 5: braking.

Figure 3, 4, 5: SLC operation at unity power factor for motoring and regenerative braking operation.

4 Three phase PWM inverter

In AC grid connected motor drives, a rectifier, usually a common diode bridge providing a pulsed DC voltage from the mains is required. Although the basic circuit for an inverter may seem simple, accurately switching these devices provides a number of challenges. The most common switching technique is called Pulse Width Modulation (PWM). In AC motor drives, PWM inverters make it possible to control both frequency and magnitude of the voltage and current applied to a motor. As a result, PWM inverter-powered motor drives are more variable and offer in a wide range better efficiency and higher performance when compared to fixed frequency motor drives. The energy, which is delivered by the PWM inverter to the AC motor, is controlled by PWM signals applied to the gates of the power switches at different times for varying durations to produce the desired output waveform. For step less speed control below and above the rated speed with high torque and to avoid the harmonics, the PWM inverter fed induction motor control is the best suitable one.

The PWM inverter has to generate nearly sinusoidal current, which can control the voltage and current with 120 degrees difference in each phase. The controlling signals of three-phase PWM inverters have many pattern controls. The operation of three-phase inverter can be defined in eight modes, which shows the status of each switch in each operations mode. In inverter operation, the necessary phase-leg-short is naturally realized through anti-parallel diodes in the three-phase bridge. Accordingly, the same gate pulses as in the conventional VSI can be applied. On the other hand, the switch on the DC link must actively operate. The recent advancement in power electronics has initiated to improve the level of the inverter instead of increasing the size of the filter.

Fast switching of IGBTs (typically <1 ms) results in high dV=dt, typically 3–5 kV=ms, and possible voltage overshoot at turn-off that can last for a few microseconds. The fast rate of rise=fall of voltage combined with high peak voltage at the turn-off results in a premature failure of motors as well as EMC. The high-power PWM VSI using new power devices (IGBT=IGCT) appears to be the best solution for the future. Benefits include better power factor, no limit on frequency, and higher voltages. Potentially either the two-level or the multilevel solution will meet the market requirements.

5 Simulation result

The circuit of six switch three phase inverter system is shown in Figure 6.1. In three phase inverter fed drive system, AC is converted into DC using uncontrolled rectifier. DC is converted into variable voltage variable frequency AC using three-phase PWM inverter. The variable voltage variable frequency supply is applied to the motor .simulink result is been shown below figure 6.2, 6.3, 6.4, 6.5, 6.6, 6.7.

5.1 Simulink model:

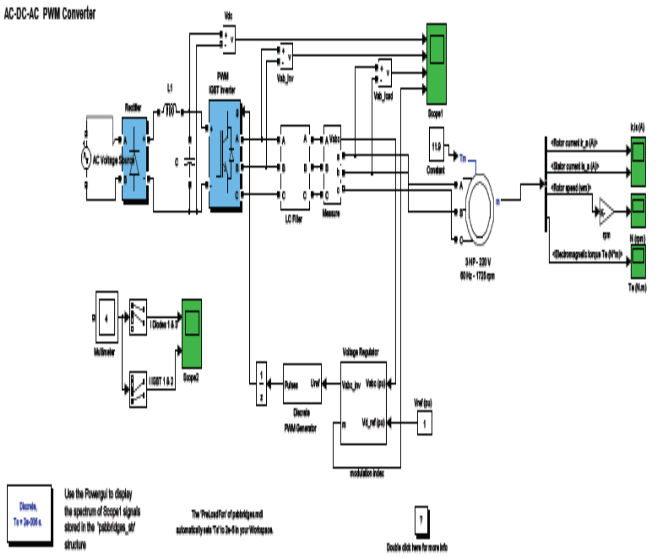

Figure 6.1.

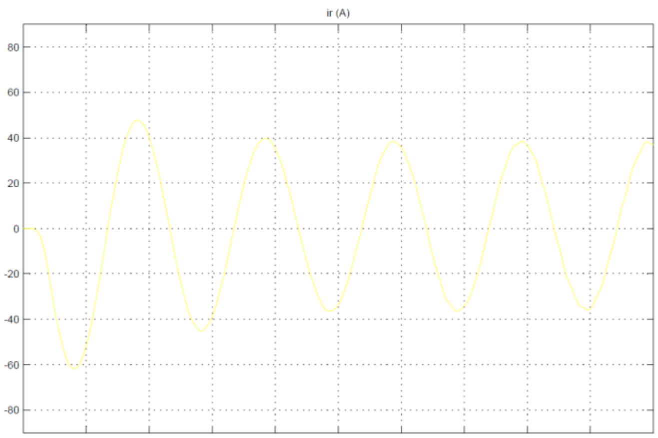

Figure 6.2.

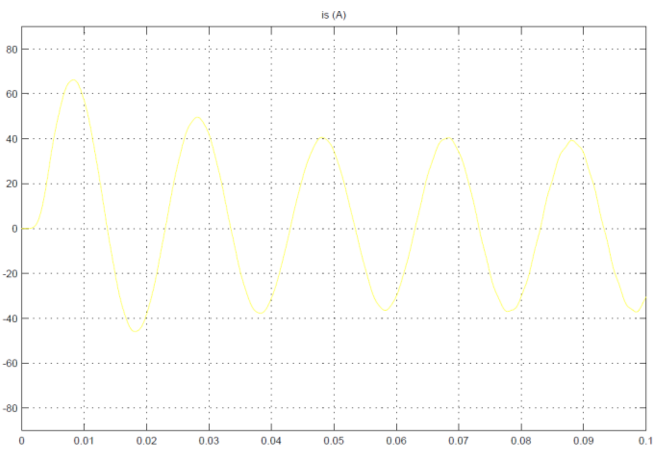

Figure 6.3.

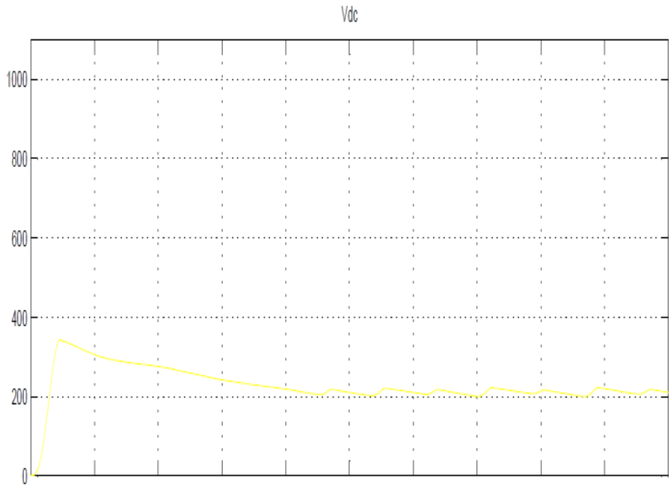

Figure 6.4.

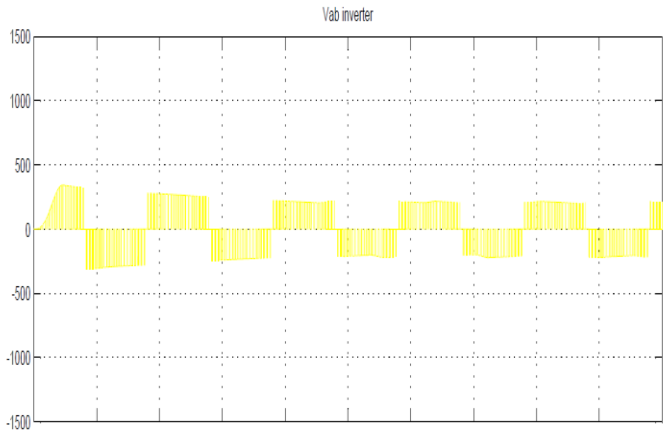

Figure 6.5.

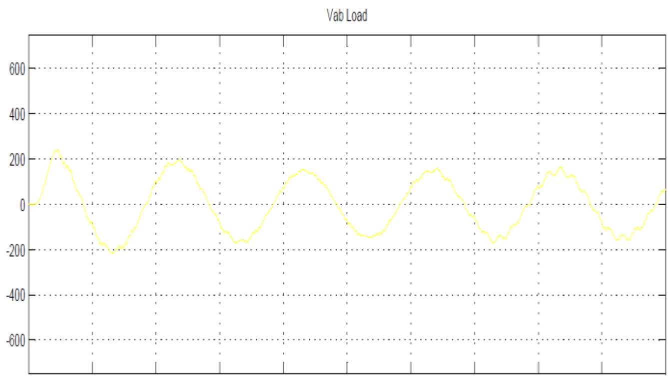

Figure 6.6.

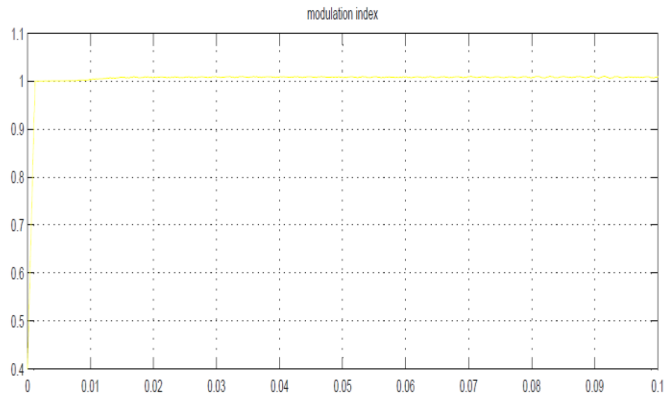

Figure 6.7.

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