H-Bridge Converter Based Performance Analysis of Induction Motor

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Abstract:
In this paper, the performance investigation of induction motor using floating H-bridge converter which connected to the grid is implemented using MATLAB Simulink. The H-bridge converter can be connected in series in-between utility grid and induction motor to infuse the voltage in series with grid voltage. This infused voltage is used to maintain the motor terminal voltage under steady state operation over whole load range to trim down the motor power losses. By inserting three phase H-bridge, the motor terminal voltage can be boost and diminish the voltage relative to grid voltage as essential. Due to H-bridge converter, the overall performance of induction motor is enhanced, especially; the efficiency, output power and power factor are enhanced. When induction motor is operated under rated voltage then maximum output power and efficiency can be attained by scheming the voltage according to the square root of the measured motor input power. The controller and performance of three phase H-bridge converter are described in this paper. The controller of proposed work results is enhanced performance of three phase H-bridge and induction motor using MATLAB Simulink.

Keywords: Induction motor, Series voltage, floating capacitor, H-bridge converter.

I. INTRODUCTION

Every year, about 50 millions of induction motors are installed. In industrial region, the electrical energy are addicted typically 65-85% and 15-35% of electrical energy is addicted in commercial region [4]. In electrical power sector, the most frequent problem is that of turbulences of grid voltage. Sag and swell of voltage are the most frequent voltage turbulences that turbulences are caused by faults at remote bus. The induction motor is mainly allied with energy loss of typically 12% to 15% [5, 6]. Hence, grid connected induction motor has foremost interest from economic and environment viewpoint. The electronics operating systems are used in the induction motor applications.

These systems have the connotation to accomplish the saving of energy, cost reduction and provide grid voltage sustainability. Variable frequency drive (VFD) is the most fashionable system. Accomplishment of power electronics to induction motor can be used to bound the starting current; to control the motor voltage under multiplicity of situations; VAR compensation and voltage support; reduces the losses for lower input power. The transformer less three phase H-bridge system connected between grid and induction motor is shown in fig.1. The another option with open winding induction motor is also shown in fig.1. The three phase H-bridge can be execute with 12 switches similar to back to back converter of regenerative drive. Normally three phase H-bridge is operating on much lower dc link voltage. To asses and judge against the steady state performance of induction motor, this paper is employing the simulation records over a wide range of motor load condition.

Different situations to investigate the data are:
1. Inferior grid voltage, motor operating at rated voltage
2. Under uneven load condition.

In addition, projected system is providing the operation allied with maximum efficiency and power factor improvement by VAR generation.

II. PROBLEM IDENTIFICATION

To drive induction motor, the three phase H-bridge system has noteworthy of soft starting which helps to boost and diminish the motor voltage under transient as well as steady state operation. This introduces the facial appearance of improvement in efficiency and independent of voltage fluctuations. Different circumstances of motor voltage control by using H-bridge scheme are as below:

A. Motor voltage inequality
Induction motors can be located where the supply voltage may be frequently fluctuating near to allowable voltage confliction specified by NEMA (National Electric Manufacturing Association) [1]. The broadmindedness of higher copper loss and current is -10% and higher iron losses is associated with the tolerance of +10%. An example, in commercial and domestic application the mains are powered by 230V but the induction motors are nearly powered by 207V and it persists...
to compromise the induction motor performance. In live out at industrial region, in the late afternoon, the induction motors are lightly loaded as judge against to day time loading of induction motor. Under these circumstances, the voltage supplied to the induction motor is higher than its rated voltage that is conciliate the motor efficiency [7].

B. Motor with deviation of load

However, the induction motors can operate with small load factor for long duration. The projected work can resolve these above problems. By projected system, the induction motor can be operating at rated voltage over a large load deviation. Three phase H-bridge converter can boost and diminish the motor voltage at higher efficiency over extensive range of load [2].

II OPERATING PRINCIPLE

The supplied voltage to the induction motor can be boost or diminish as match up to grid voltage by introducing the phase voltage \( V_b \) which is leading by 90° to motor current and the voltage across the bridge capacitor can be vary as per the obligation.

![Figure 2. Equivalent circuit per phase](image)

**Figure.2. Equivalent circuit per phase**

The phase voltage vector illustration for voltage diminution and rated motor voltage control are shown in fig. 3 and fig. 4 respectively. The bridge voltage \( V_b \) is leading to the grid voltage \( V_g \) by an angle \( 180°-\phi \) and the bridge voltage \( V_b \) injected to the grid voltage \( V_g \) which consequential in the motor voltage \( V_m \) as shown in fig. 3 and fig. 4. The motor voltage \( V_m \) can be control the rated motor voltage by using the angle \( \alpha \) [3]. The bridge fundamental voltage \( V_b \) is at 90° to the motor current to maintain zero net power flow to the bridge capacitor. The angle \( \alpha \) can be change with the angular range from 0° to 90°. As an angle \( \alpha \) is increased then the motor voltage \( V_m \) is also increase and as \( \alpha \) is decreased then the motor voltage \( V_m \) is also decrease. Hence the bridge capacitor is allowable to fluctuate with predefined range of an angle \( \alpha \) that fluctuation affects on the power factor to improve the power factor of induction motor [8, 9]. The motor voltage can be set as per the obligation with the reference of grid voltage \( V_g \) and measured capacitor voltage. If the grid voltage \( V_g \) and bridge dc voltage \( V_{dc} \) are identified then \( \alpha \) is set by the control system shown in fig. 3 and fig. 4, to set the desired motor voltage \( V_m^* \) in such a way that:

\[
cos \alpha = \frac{V_g^2 + V_b^2 - V_m^2}{2V_gV_b}
\]

Where, \( V_m^* \) corresponds to the desired voltage for induction motor terminal voltage. \( V_m^* \) can be progressively increase in such a way that the induction motor current can be limit [3]. \( V_b \) is the fundamental component of voltage infused by H-bridge which is given by

\[
V_b = \frac{m_i V_{cap}}{\sqrt{2}}
\]

Where, \( m_i \) is the modulation index for H-bridge.

In this manuscript, the Pulse Width Modulation (PWM) is used. Modulation index is determined with the help of the equation (2). Modulation index \( m_i \) is fixed and set to 1.12 to reduce the bridge capacitor voltage. Normally, H-bridge is generating the ripple of low frequency. Measuring three capacitors voltages of low frequency ripple and taking the average of that measured voltage is nothing but \( V_{dc}^{avg} \) which is used as feedback signal. The three phase H-bridge control scheme is shown in fig. 5.

![Figure 5. Control system of projected scheme](image)

**Figure. 5. Control system of projected scheme**

Three quantities \( V_m, V_a, V_{dc}^{avg} \) are used as input to the control scheme and prearranged to law of cosine. Output of law of cosine is an angle \( \alpha \) and it is derived from equation (1). A phase correction \( \phi_{corr} \) is set as 5° in a projected scheme. The inverse Park’s transformation has applied to converting the d-q-0 frame signal that are \( d_a, d_b, d_c \) into the abc frame \( d_a^*, d_b^*, d_c^* \). These three signals are transformed into modified signals \( d_a^*, d_b^*, d_c^* \) through Space Vector Pulse Width Modulation (SVPWM) [10-12]. The comparison of modified signals \( d_a^*, d_b^*, d_c^* \) and the carrier waves generates the gate signals as \( D_a, D_b, D_c \) for H-bridge.

IV. MATLAB SIMULATION

A three phase H-bridge is prefer for the Simulink with typical motor winding. A 5 hp, 230V is set for the MATLAB simulation and H-bridge is located between the grid and induction motor to each phase. The induction motor is used
with the rating of 5 hp, 60Hz, 4 poles, 230/460V, 12.5/6.4A and 1760 revolution per minute. IGBT is used as power electronic switch which is mostly preferable for high switching frequency. H-bridge is having two legs which are separated by 8mF, 500V. Implementation of Grid Connected Induction Motor through H-bridge with the help of MATLAB Simulink is as shown in fig. 6.

![Simulink diagram of Grid Connected Induction Motor through H-bridge](image)

**V. INDUCTION MOTOR PERFORMANCE**

Motor is drive at the grid frequency and it is connected to the grid through three H-bridges. For performance evaluation, Capacitor voltage, efficiency, losses and power factor are selected as the main parameters for steady state examination over the large range of load on induction motor.

![Induction Motor Voltage](image)

![Induction Motor Efficiency](image)

![Power Factor](image)

![Power Loss](image)

![Rotor Speed](image)
C. Voltage Mismatch
To examine the voltage mismatch that is grid voltage less than motor rated voltage, the grid voltage of 180V is applied to the H-bridge and the results of the same are shown in fig. 8 and fig. 8 illustrates that the motor performance is enhanced by using three phase H-bridge. Since the H-bridge can transport the rated voltage to the induction motor which are not eminent to the rise in temperature and augmented power loss of induction motor.

D. Load Variation
In this case, the motor terminal voltage is same as grid voltage with the supplied voltage of 230V however the load variation has been carried out in terms of load torque. The load torque 0.1 has been given for the run time of 1sec and at the run time of 1sec, the load torque has increased to 5. After rising the load, the capacitor voltage is hang about same to uphold the performance of induction motor as shown in fig. 9. The power factor has enhanced with the help of H-bridge.
When working with constant supply frequency, the steady state performance of induction motor is accessible. The investigation of induction motor performance has been carried out by using MATLAB Simulink with the two different cases as: (a) Voltage mismatch (b) Load variation, by commencing three phase H-bridge. The projected system is confirmed to enhance the performance of induction motor that are (a) for voltage mismatch or with inequality between the voltage of grid and motor, the induction motor has enhance the performance (b) plummeting the power losses which mean to lower rise in temperature. The projected system has valuable solution where the problem of voltage fluctuation and sag with reasonable cost.

VI. CONCLUSION

When working with constant supply frequency, the steady state performance of induction motor is accessible. The investigation of induction motor performance has been carried out by using MATLAB Simulink with the two different cases as: (a) Voltage mismatch (b) Load variation, by commencing three phase H-bridge. The projected system is confirmed to enhance the performance of induction motor that are (a) for voltage mismatch or with inequality between the voltage of grid and motor, the induction motor has enhance the performance (b) plummeting the power losses which mean to lower rise in temperature. The projected system has valuable solution where the problem of voltage fluctuation and sag with reasonable cost.

VII. REFERENCES


