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Review of Voltage and Speed control of Grid Connected Induction Motor

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Abstract **- As the application of induction motors is more and more extensive in industry, it is very important to provide solution of voltage and speed control of grid connected grid connected induction motor using a different methods. Earlier, the nature of commercial application of induction motor where off constant speed mechanical drives to different speed control systems but the recent development in power electronics component have given the way for the event for the facility electronics based variable speed induction motor drives. For a power electronics controlling based grid connected Induction Motor is used to enhance steady state operating performance , actively reducing the motor power losses over its entire load range; lower the motor's operating temperature to enhance lifetime expectancy. By controlling a voltage in series with the grid , above or below the grid voltage, under transient or continuous steady-state conditions, and over the whole range of the motor load , these features reduces the losses in the motor and controlled the speed. Among the no of methods of induction motor drive techniques this paper explain the detail about solution of controlling voltage and speed of Induction motor which is connected to a Grid.**

Keywords— High efficiency induction motors, thyristor, motor loss reduction, converter, cycloconverter

I. INTRODUCTION

For more than a century, electric drives have served to enhance the productivity of industry with wide ranging applications using traditional loads such as pumps, fans, and compressors [7].The 3-phase ac induction motor is the workhorse of modern industry. Worldwide about 50 million motors are installed every year [1] and approximately 50% of electrical energy produced is used in electric drives. Typically 60-80% of the electricity in the industrial sector and about 20-35% of the electricity in the commercial sector is consumed by motors [2]. Around 67% of this energy, and representing 85% of all motor energy losses, is associated with induction motors with a rating below 75 kW [3-4].Since the induction motor naturally operated with lagging power factor.

There are different technique for voltage control as well speed control of Induction motor, However these soft start system cannot used for power factor correction and they having poor harmonics and lagging characteristics [6] and more of reactive power correction within the grid device takes the form of reactive current injection such as capacitor bank or STATCOM[19-20].Many attempts have been made to operate a grid connected induction machine with leading power factor, such as using a parallel auxiliary windings in the machine [14-15] with rotating convertors [12] .The grid-connected induction motor remains an industry workhorse, due to the low system cost and direct online starting capability. However, it is well known that during a directly on-line start, where the full grid voltage is applied across motor, the motor has a low lagging power factor with a large starting torque and a high starting current. The large starting torque and torque pulsation results not only in a short acceleration time but can also cause significant stress on mechanical equipment. The large starting currents can also damage the electrical distribution equipment and can cause a voltage sag in the electrical system feeding the motor: the latter may have a negative impact on nearby equipment connected to the same grid. Moreover, if the large starting current lasts too long, and electrical protection is not properly coordinated, protection devices may trip .Therefore, reduced current conditions are desired not only to decrease the strain on both the motor and the connected mechanical system, but also to avoid power company penalties [7]. By controlling the voltage supplied to the motor during starting, the current and torque surges can be suppressed substantially [9-10]. There exist a number of methods to realize soft

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start of an induction motor, such as series-connected silicon-controlled rectifiers (SCRs, Fig. 1(a)), autotransformer, wye-delta, resistor/reactor, variable frequency drive (VFD).

II. SCR BASED CONTROLLING OF INDUCTION MOTOR

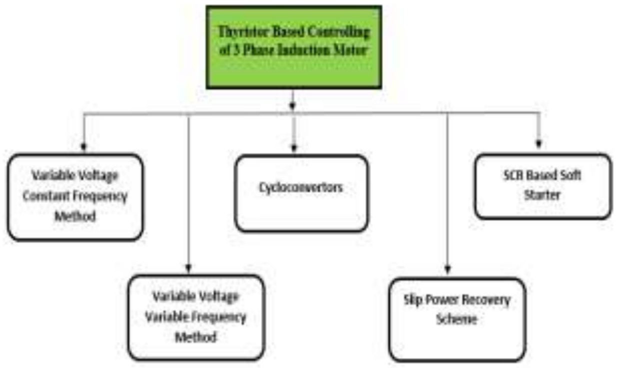

Fig 1 Classification of thyristor based controlling of 3 Phase Induction Motor

In fig3 shows that detail classification of thyristor based controlling of 3 phase IM Induction motors are widely used for many applications like pumps, fans, compressors, lifts and conveyors because of low cost, easy and cheap maintenance, and can be easily found in surrounding. but at time starting of induction motor it would be proudces inrush current which is very high . Inrush current causes voltage dip at the top of distribution line when an outsized induction motor is being started up. The voltage dip is additionally harmful for other electrical appliances, especially for voltage sensitive devices like fluorescent lamps. To prevent the voltage dip thyristor based voltage control technique has been used in various application.

As we have know that to control the starting current of 3 phase IM there should be a starter, thyristor based controlling of 3 phase Induction motor but thyristor based controlling mechanism has a several disadvanges due to thyristor. The disadvantages could be a because of higher ripple content in the converter output, motor heating and commutation problems are serious, Due to switching action of thyristors and non-sinusoidal nature of current, there is more possibility of interference with the communication networks. This threats are not suitable for grid connected IM because it required grid voltage near to IM voltage which is not possible in thyristor based controlling of 3 phase IM.

- **Variable Frequency Constant Voltage Method**

The major difficulty with this method is how to get variable supply frequency. The auxiliary equipment required for this purpose result in high first cost, increased maintenance and lowering the overall efficiency. That is why, this method is not employed for general purpose speed control application. In spite of the fact that this scheme is complicated, there are certain application in which its wide used, continuously variable, speed range and good speed regulation makes its use highly desirable.

If an Induction motor is to be operated at different frequencies with practically constant values of efficiency , power factor, over load capacity and a constant absolute slip, then iron core unsaturated due to this this method is not suitable for speed control of IM.

- **Variable Frequency Variable Voltage Method**

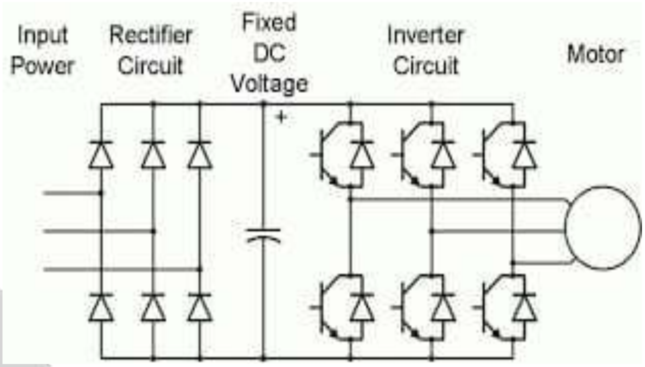

Fig 2 Circuit of Variable Frequency Constant Voltage Method

If only frequency is changed and stator voltage is kept constant, the stator flux will not be at its rated value. The operation with flux below or above its rated value is not desirable. For constant flux operation, it is necessary that the induced emf decreases or increases linearly with applied frequency. At higher voltages and at high frequency operation stator drops are very small and thus constant flux operation is obtained by keeping V/F ratio constant.

The variable voltage and variable frequency can be obtained from the system shown in fig 3 known as square wave inverter and pulse width modulator inverter respectively.

Converter is used to convert 3 phase AC into DC. The output of rectifier is supplied to the filter circuit to remove the harmonics. The DC output from filter is fed to controlled inverter which provides variable voltage variable frequency output. This supply is fed to stator of 3 phase induction motor whose speed is controlled. When the frequency is less than normal frequency, the voltage is reduced by the same proption and V/F ratio maintain constant. The PWM method which has been implemented these days have more drawbacks compared to other methods, they are heating of motor resulting in breakdown of the insulation. This is due to thyristor switching at high frequency, non –regenerative operation, and production of harmonics. Hence the PWM has not been implemented as the drawbacks do not justify for the economical method of controlling the speed of the Induction motor [21]

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- **Slip Power Recovery Scheme**

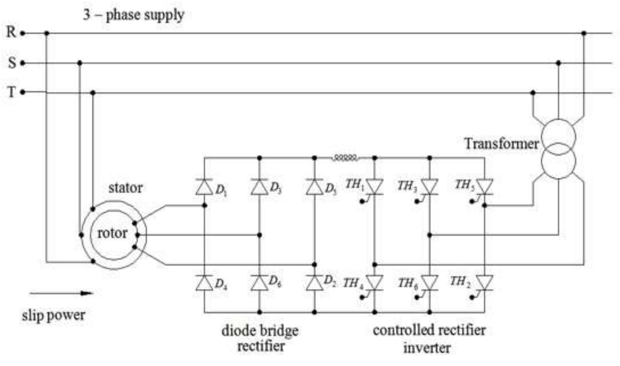

Fig 3 Slip Power Recovery Scheme

Fig shows a slip power recovery system the rotor terminal are connected to 3 phase AC supply mains through two fully controlled thyristor bridges. Bridge one act as rectifier and bridge 2 act as inverter. Power output from rotor can be supplied back to supply source. Since the frequency of rotor current is slip frequency, this method is known as slip power recovery scheme. By controlling the firing angles of two bridges, the rotor power can be varied, thus the motor slip and speed (for the same torque) will also change. However the drawback of this scheme is that both the bridges draw reactive power from the supply mains. Therefore, the overall power factor of motor is poor. If speeds only below synchronous are desired rectifier bridge may be uncontrolled and, thus may consist of diodes. If both bridges are controlled, the operation of two bridges can be reversed also to get speed above synchronous one.

The drawback of this scheme is that reactive power consumption is large when firing angle is more than 90 degree of thyristor which reduce power factor and enlarge the total harmonic distortion (THD) of the source[4] to sortout this problem proposed system has used IGBT based H Convertor.

- **Cycloconverter**

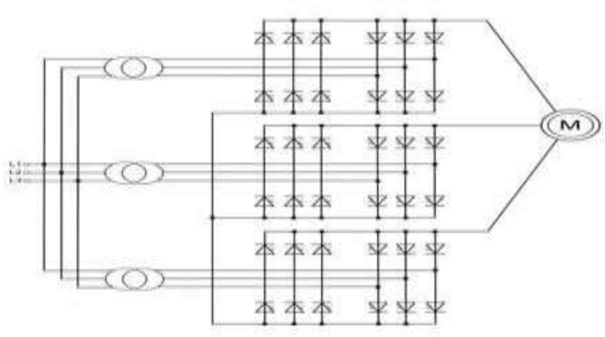

Fig 4 Cycloconvertor Circut

In very high-power drives usually above one megawatt, the Cycloconverter has been traditionally used[23]In very high-power drives usually above one megawatt, the Cycloconverter has been traditionally used. A cycloconverter can converts AC at one frequency to an AC of another frequency. THE BASIC power circuit scheme of 3 phase cycloconverter is shown in fig 5.

Cycloconverters as recurrence transformers basically discover entrenched applications in high-power low-speed reversible air conditioning engine drives with steady recurrence information and consistent recurrence power supplies with a variable-recurrence contribution as in VSCF (variable-speed steady recurrence) framework, though they discover likely applications in controllable VAR (volt amperes responsive) generators for power factor revision and air conditioning framework interties connecting two free force frameworks[24]. Independent control of output frequency and voltage is obtained with only one parameter variation, by variation of firing angle of controlled rectifier. The frequency of output voltage is controlled by the rate at which the firing point is varied about the quiescent point and the output voltage is controlled by maximum excursion of the firing point from the quiescent point.

The operation of cycloconverter has been characterized by several features. They are generally employed as step down frequency converter. There can not fixed minimum ratio of input to output frequency; however the output frequency is restricted typically to

One-third or one-half of the input or line frequency. Below these ratios, the efficiencies of both the cycloconverters and motor supplied by them starts falling significantly.

Reversibility is another feature of cycloconverter drive system. A cycloconverter fed AC motor drive will answer change in polarity of input by changing the direction of rotation of motor without the utilization of contactors to reverse phase sequence.

The ability of cycloconverter to handle power flow in either direction would be another important feature. This, together with the above mentioned reversibility feature, provides an induction motor drive capable of operating in any of the four quadrants of the motor speed-torque curve.

While cycloconvertors has many attractive features from theoretical point of view, there are several limitations because of which they have not gained popularity. It needs more power semiconductors than inverter. For example the three phase cycloconvertors need 18 thyristors. Where rectifier and inverter combination need only 12 thyristors. Cycloconvertors can be produce only sub frequency output. Line pollution with harmonics and low power factor can also be problems with cycloconvertors of high power rating.

 DOI : 10.35291/2454-9150.2020.0552

- **Soft Starter (Reduced voltage starting)–**

Fig 6 shows schematic diagram of SCR based soft starter. The starting line current at full voltage of Induction motor may be about 6 times the rated full load current. Such a high current may cause serve voltage dip in the network supplying the IM[18].

The circuit illustrated in fig can be used for feeding a reduced voltage at the start. By proper control of firing angle the regulator provides a coffee output voltage which is supplied to the induction motor. When motor attains the full or rated speed, the regulator can be short circuited by mechanical contactor so the motor operates **normally at rated** voltage when the mechanical load is small. Operation at reduced voltage causes decreases in power losses in the motor thus results is energy saving.

While operating of soft starter using SCR there should have changing of firing angle for the variation of output voltage , however the SCR has several disadvantages like low switching frequency and it cannot be used for high power application. However, the soft starter cannot be used for power factor correction and it can be expensive [6].

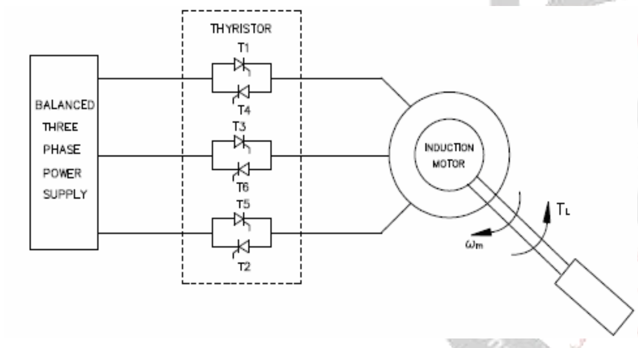

Fig 5 SCR Based Soft Starter

III. CSI FED INDUCTION MOTOR DRIVE WITH OPEN END WINDING

Modern-day current source inverter (CSI) fed motor drives have always been an attractive answer for excessive power applications because of their benefits like inherent quick circuit safety and easy four quadrant operation [12]. SCR is a semi-controlled device it requires forced commutation circuit in many applications [12].Silicon controlled Rectifier (SCR), one of the most rugged electricity semiconductor devices to be had in excessive voltage and present day ratings, is a favored switching tool in excessive strength CSI fed drives[13]. Natural commutation of SCR is possible if the current through it is leading ahead of the voltage. Here in this block diagram (Fig 2) 3 phase SCR based controlled rectifier is used to provide a DC voltage to Current source inverter through a filter circuit. The 3 Phase SCR based current source inverter is used to convert pure DC voltage into AC voltage for operation IM.SCR based CSI fed synchronous motor drives became an attractive choice for high power applications. Induction motor, known as the work horse of the industry is the most widely used motors as they are rugged, cheap, almost maintenance free and efficient. In this scheme number of SCR required have been more in rectifier as well converter so there is commutation problem at SCR. This system so difficult for the operation of whole inverter as well rectifier.

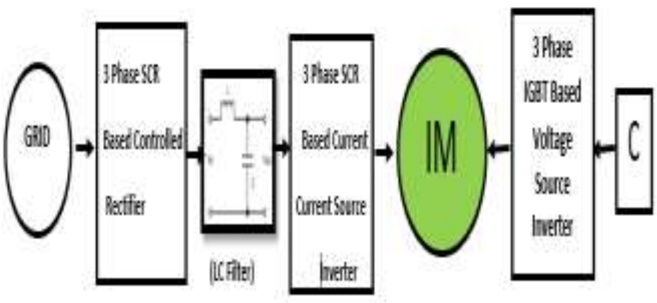

Fig 6 block diagram of CSI fed induction motor drive with open end winding

IV SPEED CONTROL METHODS OF 3 PHASE INDUCTION MOTOR

Speed control of IM has a huge importance in Industry as per the application so its necessary to control speed of IM. During the controlling of Speed, in some methods there would controlling of voltage is also done.The wide use of induction motors makes their electronic operating systems one of the main means to achieve significant electrical energy saving [17].Speed control methods of IM divided into two parts like a Electrical based speed control methods and Power Electronics Based Speed control method.

- **Electrical Based Speed Control Methods**

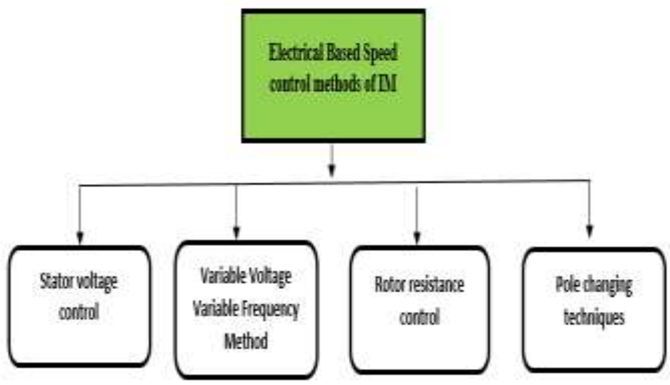

Fig 7 classification of Electrical based speed control methods of IM.

Fig 7 Shows classification of Electrical based speed control methods of IM, Explanation of controlling methods are given below.

 DOI : 10.35291/2454-9150.2020.0552

- **Stator voltage control-**
  In this method the applied voltage across the stator is modified which changes the speed of the motor. This however changes the torque of the motor. This may be achieved by means of resistance, inductance or the semiconductor devices.
- **Rotor resistance control-**
  This method of speed control are often utilized in the connection induction motor only. Here the resistance are often added to the rotor so as to scale back the speed of the motor. This also increases the starting torque of the motor.
- **Pole changing techniques-**

The synchronous speed of the motor is given by the formula:

Ns = 120*f/p…….. 1

Where Ns is the synchronous speed in rpm, f is frequency in Hz & p is no of poles. Hence changing the no of poles will change the synchronous speed which in turn changes the speed of the motor as

N = (1-s)*Ns………. 2

Where N is speed of motor in rpm, s is the per unit slip & Ns is synchronous speed in rpm. This may be achieved by:

a) Pole amplitude modulation

b) Multiple stator winding

- **V / f control or frequency control-**

From equation 1 it is clear that the synchronous speed can be changed by changing the frequency and hence the speed of the motor will also change according to the equation 2. The emf induced is given by E = 4.44*flux*f*T. Where E is emf induced in Volts, ij is flux in Weber, T is number of turns & f is frequency in Hz. Therefore a reduction in f will lead to an increase in flux which will lead to saturation of rotor as well as stator which will lead to higher magnetizing current. Hence ij should be kept constant which is done by maintaining the V/f ratio constant.

- **Power Electronics Based Speed Control Method.**

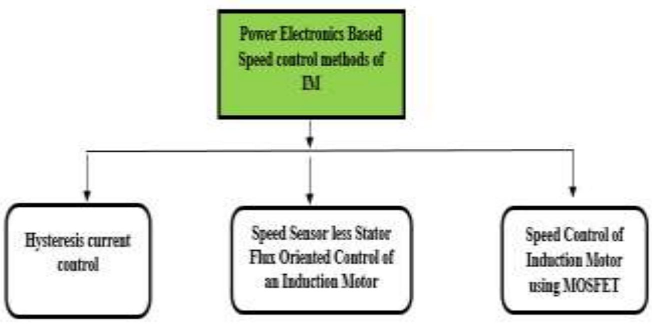

Fig 8 classification of Power Electronics based speed control methods of IM.

- **Hysteresis Current Control**

These days, the hysteresis current control has quickly picked up because of its simple control mode, easy

hardware implementation, reliable operation and quickdynamic response practical need is to make sure that the input current should be a sine wave because only when the current in stator windings is three-phase symmetrical, the torque would be a constant value. If we can ensure the current's sine waveform by using the hysteresiscurrent control method, the system will clearly get good performance by setting hysteresis layer, we can control the outputcurrents fluctuate around the given values of currents as shown in Fig. 8.

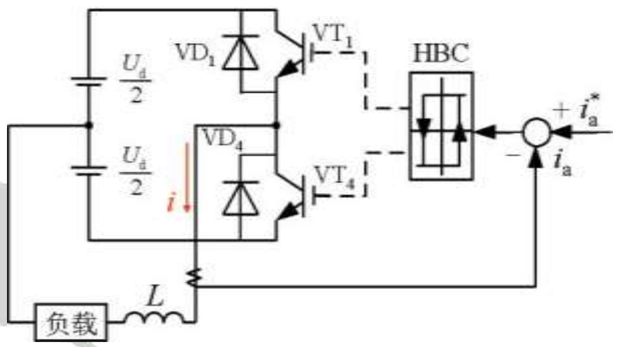

Fig 9 The current control principle of phase A

As the figure shows hysteresis current control technique for 3 phase induction motor. It include speed control technique for 3 phase induction motor but it has one disadvantages that it has a separate hase control i.e it has separately three phases for speed control of Induction motor so it required more no of devices for controlling the speed of IM.

- **Speed Sensor less Stator Flux Oriented Control of an Induction Motor**

In this paper, a replacement rotor speed estimation algorithm is proposed. The speed is computed from stator terminal quantities and the computation is done in a reference frame whose direct axis is linked to the stator space vector. This results in an easy equation for speed calculation which may be a function of the stator flux. In direct stator flux oriented control (DSFOC), the stator flux is out there for measurement or estimated. In the case presented in this paper, the stator flux is estimated using a reduced order Kalman Filter (KF) algorithm to alleviate the computational burden. The proposed speed sensor less stator flux oriented controller is implemented and tested numerically for different conditions of motor operation on an FPGA real-time simulation platform Real-time simulation results show that accurate and fast speed

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estimation is achieved even at standstill.

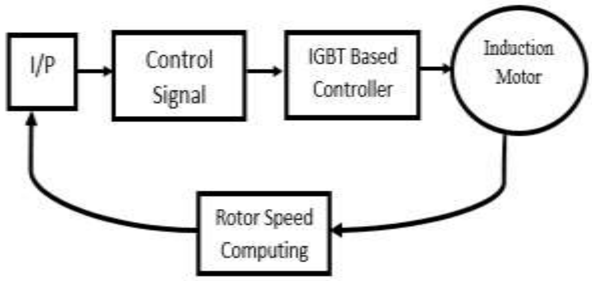

Fig 10 Block Diagram of Speed Sensor less Stator Flux Oriented Control of an Induction Motor

- **Speed Control of Induction Motor using controller**

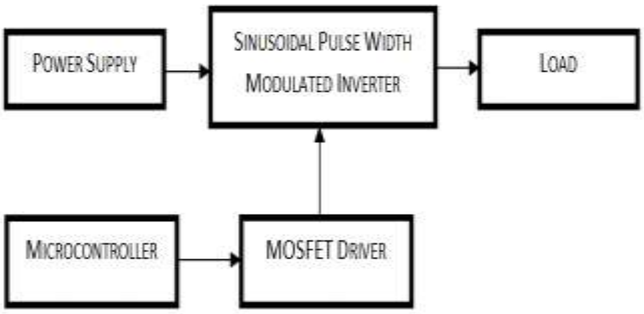

Fig 11 Block Diagram Speed Control of Induction Motor

Fig. 11 shows the block diagram of Speed Control of Induction Motor& Fig 12 shows. Full-bridge single-phase inverter. The power supply circuit consists of a transformer 230/15V which is skilled a single-phase bridge rectifier. The rectifier converts the alternating current (AC), to direct current (DC) and capacitor filters are used for smoothing out the DC. The control system consists of microcontroller AT89C52- 24PI. It is a coffee power, high-performance CMOS 8-bit microcomputer with 8K bytes of Flash programmable and erasable read only memory (PEROM). The AT89C52 microcontroller is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications [25]. The Microcontroller circuit requires +5V DC power supply. The switching schemes to the Metal Oxide Semiconductor Field Effect Transistors (MOSFET) are created by microcontroller. This microchip is the controller circuit that is used to generate the modulating and the carrier signal for the inverter [26]. MOSFETs has used triggering pulses as driver circuit output. These output pulses observed using an oscilloscope. The power circuit consist of the Full-bridge Single-phase PWM Inverter. DC to AC converted using Invertor, transferring power from DC source to an AC load. A sinusoidal pulse width modulation inverter can control the speed of one phase motor. Pulse width modulation offers a means to reduce the Total Harmonic Distortion (THD) of load current. The gating signals are produced by comparing triangular wave as carrier signal and wave because the modulating signal. The sine waves establish the frequency of the output waveform while the triangular waves establish the switching frequency of the MOSFET [26]. The microcontroller is programmed to generate the modulating and the carrier signals. The inverter consists of the DC voltage source with four switching devices M1, M2, M3, M4 and therefore the load. The inverter has two legs; each of which has two power MOSFETs that are connect serial . Short circuit of DC bus is avoided by ensuring that both MOSFETs are not turned ON at the same time.

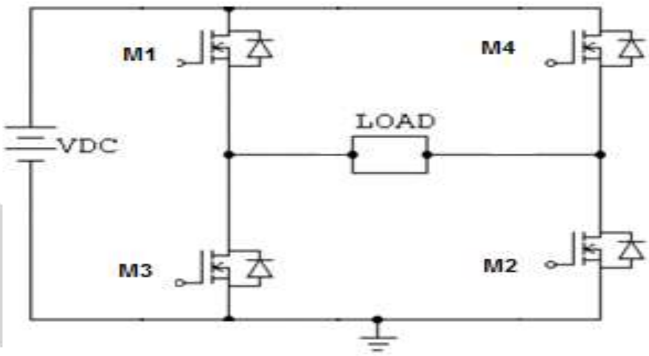

Fig. 12 Full-bridge single-phase inverter

V. CONCLUSIONS

The steady state performance of a grid connected IM is presented when operating with constant supply frequency. A power electronic system is used to improve the operation of the motor considering different operations: (a) Multilevel Invertor (b) Varible Voltage Constant frequency (c) Varible voltage variable frequency (d) Slip Power recovery (e) cycloconvertor (d . The latter was used to obtain experimental performance comparison as it operates with a lower dc-link voltage (hence lower electrical stresses) and can be used with an induction motor using a standard winding. The performance of the power electronics, motor and total system is presented with respect to power losses, system efficiency and the motor output power. The proposed system is demonstrated to have a higher performance: (a) reducing the losses hence temperature rise of the motor; (b) improved motor performance over the direct grid connection when the grid voltage is not the same as the motor rated voltage; (c) variable motor voltage control can lower or increase the motor voltage relative to the grid and hence can be used to lower the machine losses over its entire load range. These performance benefits should be considered in addition to the soft-start and voltage sag compensation capabilities reported in [6, 7]. Here we introduce speed control methods of IM like electrical and power electronics based speed control methods so its beneficial for controlling the voltage and speed of IM simultaneously.

 DOI : 10.35291/2454-9150.2020.0552

VI. REFERENCES

[1] Berringer, K.; Marvin, J.; Perruchoud, P., "Semiconductor power losses in AC inverters," Industry Applications Conference, 1995. Thirtieth IAS Annual Meeting, IAS '95., Conference Record of the 1995 IEEE , vol.1, no., pp.882,888 vol.1, 8-12 Oct 1995

[2] Aníbal, T. de Almeida Fernando J. T. E. Ferreira; João Fong & Paula Fonseca, "Efficiency Testing of Electric Induction Motors" (December2007). EUP Lot 11 Motors, Final Report, ISR-University of Coimbra, Lot 11-8-280408

[3] Kostic, M. ; Kostic, B. " Motor Voltage High Harmonics Influence to the Efficient Energy Usage" Invited paper for 15th WSEAS International Conference on Systems, Proc. pp. 276-281, Corfu Island, Greece, July 2011

[4] Hamer, P.S.; Lowe, D.M.; Wallace, S., "Energy-efficient induction motors-performance characteristics and life-cycle cost comparison for centrifugal loads," Petroleum and Chemical Industry Conference, 1996, Record of Conference Papers. The Institute of Electrical and Electronics Engineers Incorporated Industry Applications Society 43rd Annual , vol., no., pp.209,217, 23-25 Sep 1996

[5] Blaabjerg, F.; Pedersen, J.K.; Rise, S.; Hansen, H.-H.; Trzynadlowski, A.M., "Can soft-starters help save energy?,"IEEE Industry Applications Magazine, vol. 3 issue 5,pp . 56-66, 1997

[6] S. Leng; R. Ul Haque; N. Perera; A. Knight; J. Salmon, "Soft Start and Voltage Control of Induction Motors using Floating Capacitor H-bridge Converters," in IEEE Transactions on Industry Applications, early access article, no.99.

[7] S. Leng; R. Haque; N. Perera; A. Knight; J. Salmon. "Smart grid connection of an Induction motor using a 3-phase floating H bridge system as a series compensator," IEEE Transactions on Power Electronics, vol .PP, no.99, Dec. 2015.

[8] B. Wu, High-Power Converters and AC Drives, chapter 7, March, 2006 Wiley-IEEE Press.

[9] Bruce, F. M.; Graefe, R. J. ; Lutz, A. ; Panlener, M. D., "Reduced-voltage starting of squirrel-cage induction motors," Industry Application,IEEE Transactions on, vol. IA-20, no.1, pp. 46-55 , Jan./Feb. 1984.

[10] Zenginobuz, G.; Cadirci, I.; Ermis, M.,"Performance optimization of induction motors during voltage-controlled soft starting," Energy Conversion, IEEE Transactions on, vol. 19, no.2, pp. 278-288, 2004.

[11] Di Wu, Hongbin Wu and Hao Dong"Influence of Induction Motor Starting on Microgrid"2018 IEEE PES Asia-Pacific Power and Energy Engineering Conference.

[12]J. R. Espinoza and G. Joos, "A current-source-inverter-fed induction motor drive system with reduced losses," IEEE Trans. Ind. Appl, vol. 34,no. 4, pp. 796-805, July/August. 1998.

[13] B. Wu, 1. Pontt, J. Rodriguez, S. Bernet, and S. Kouro, "Current-source converter and cycloconverter topologies for industrial medium-voltage drives," IEEE Trans. Ind. Electron, vol. 55, no. 7, pp. 2786-2797, July. 2008.

[14]Muljadi, E.; Lipo, T. A.; Novotny, D.W., "Power factor enhancement of induction machines by means of solid-state excitation," Power Electronics, IEEE Trans. on vol. 4, no.4, pp. 409-418, 1989.

[15]Nicolae, D.V., "Electric Motor Performance Improvement Using Auxiliary Windings and Capacitance Injection", in Electric Machines and Drives, Dr. Miroslav Chomat (Ed., 2011.

[16]Malik, N.;.Sadarangani, C.; Cosic, A.; Lindmark, M., "Induction Machine at Unity Power Factor with Rotating Power Electronic Converter," Power Electronics, Electrical Drives, Automation and Motion (SPEEDAM), June, pp. 401408, 2012.

[17]A R N M Reaz Ul Haque , Dr. Siyu Leng, Ian Smith, Dr. John Salmon,"Performance Analysis of Grid Connected Induction Motor Using Floating H-Bridge Converter"978-1-5090-5366-7/17/ ©2017 IEEE.

[18}J B Gupta "Theory of Machines" October 1999.

[19]Spee, R.; Wallace, A.K., "Comparative evaluation of power factor improvement techniques for squirrel cage induction motors", Industrial Applications, IEEE Transactions on , vol.28, no.2, pp.381-386, Mar/April, 1992.

[20] Wessels, C.; Hoffmann, N. ; Molinas, M. ; Fuchs, F., "StatCom Control at Wind Farms with Fixed Speed Induction Generators under Asymmetrical Grid Faults," Industrial Electronics, IEEE Transactions on, vol.60 , issue: 7, pp. 2864 – 2873, July 2013.

[21]Sachin Wadhankar, Ashish Dongre "VVVF Techniques for Speed Control of Induction Motor"International Conference on Science and Engineering for Sustainable Development (ICSESD-2017),Special Issue-1ISSN: 2454-1311.

[22]Sita Ram, O. P. Rahi, Veena Sharma, and K. S. R. Murthy "Investigations in to Induction Motor Drive using Slip Power Recovery Scheme with GTO Inverter and Chopper"978-1-5386-4318-1/17 ©2017 IEEE.

[23]B.Brindha, Dr.T.Porselvi, R.Ilayaraja "Speed Control of Single And Three Phase Induction Motor Using Full Bridge Cycloconverter"978-1-5386-3817-0/18@2018IEEE.

[24]Mohammed Abdul Khader Aziz Biabani, Md Akheel Pasha "Control of Induction Motor using Step up and Step down Cyclo converter."978-1-4673-9939-5/16©2016 IEEE.

[25]Datasheet: Atmel 8-bit Microcontroller with 8K Bytes Flash

[26] Muhamad Zahim Bin Sujod, "Single-phase motor speed control using SPWM inverter," Honors dissertation, Dept. Electrical & Electronics Eng., Univ. of Malaysia, Pahang, 2008.

 DOI : 10.35291/2454-9150.2020.0552