Analysis And Performances of DC-DC Converters for Variable Speed Drive Applications.

K.C.Venkataiah[1], Dr.A.Mallikarjuna Prasad[2]
[1]P.G. Scholar, [2]Guide, Head of the Department,
[1,2] Branch:EEE(P&ID)
[1,2] Geethanjali College of Engg.& Technology, Nannur, Kurnool, Andra pradesh.
Email ID:[1]knlvenkat@gmail.com, [2]mallikarjunaprasad0307@gmail.com

Abstract:
This project improves the quality and performance of the power system by using four quadrant chopper circuit in the dc link of the variable speed drive systems. It also affects on reducing the ripple factor for the current and voltage in DC –link is illustrated .In this project we also evaluate the performance of variable speed drive systems is simulated and designed with the proposed chopper circuit. Further we observe the control system of pulses for the transistors is determined. And at last we discussed of the results introduced. The simulated result shows the advantages of proposed chopper circuit with variable speed drive systems. Finally the proposed method over the other newly suggested techniques are analyzed by several simulation scenarios.

We also analyzed the power quality of input current for the proposed systems and improved by reducing total Harmonic distortion factor and increasing the power factor, in addition to reduction both of ripple factor and crest factor in dc-link to acceptable values. Capacitor voltage is reduced to an acceptable values does not lead to the failure of capacitor besides of cancelling the oscillations in dc link voltage. Finally we recommend to continuing by using SVPWM to generate biases voltages with a 12-pulse rectifier variable speed drive system to determine the suitability and adaptability of this chopper with different types of rectifier schemes used in variable speed drive systems.

KEYWORDS: Four- Quadrant Chopper, Variable Speed Drive Systems (VSDS), Power Quality, DC-LINK, Crest Factor, Ripple Factor, Total Harmonic Distortions factor, Active Filters, Passive Filters, PI Controller Tuning.

INTRODUCTION

Recently ,the amount of nonlinear loads in electric grid has increased .these loads cause the harmonics in the eletrical grid and lead to non sinusoidal currents,as well as it is the main causes of electromagnetic compatibilty ,distortion of voltage and current waves and reduce the grid power nad their efficiency.The voltage waves that feed industrial facilities are non sinusoidal and have many undesirable harmonics.One the main source of compaatiblity in the industirail grids is the oltage speed drive systems can be simplified as non linear loads.This kind of loads can be a source of problems with the quality is provided power.the total harmonic distortion factor (THD) of the wave in these systems is about 60% and the voltage wave is about 5.6%.the permissible value of the total harmonic distortionis 5% as per IEEE.

Several methods have been used to improve the quality characteristics of variable speed drive systems ,the most common method is using passive filters,but they were limited spread because of of their size,weight and potential of the capacitor explosion.A buck converter is a step-down DC to DC converter. Its design is similar to the step-up boost converter, and like the boost converter it is a switched-mode power supply that uses two switches (a transistor and a diode), an inductor and a capacitor. The simplest way to reduce a DC voltage is to use a voltage divider circuit, but voltage dividers waste energy, since they operate by bleeding off excess power as heat; also, output voltage isn't regulated (varies with input voltage). Buck converters, on the other hand, can be remarkably efficient (easily up to 95% for integrated circuits) and self-regulating, making them useful for tasks such as converting the 12–24 V typical battery voltage in a laptop down to the few volts needed by the processor Finally, filtering pulses is not just about the pulse frequency but about the duty cycle and how much energy is in the pulse. The same filter will do better on a low or high duty cycle pulse compared to a 50% duty cycle pulse. Because the wider pulse has more time to integrate to a stable filter voltage and the smaller pulse has less time to disturb it the inspiration was a request to control the speed of a large positive displacement fuel pump. The pump was sized to allow full power of a boosted engine in excess of 600 Hp.

At idle or highway cruise, this same engine needs far less fuel yet the pump still normally supplies the same amount of fuel. As a result the fuel gets recycled back to the fuel tank, unnecessarily heating the fuel. This PWM controller circuit is intended to run the pump at a low speed setting during low power and allow full pump speed when needed at high engine power levels. A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc. This is a summary of some of the popular DC-to-DC converter topologies.

In this project a novel technique is proposed to achieve a good performance of the variable speed drive systems (VSDS) in the industrial facilities by reducing the THD % for the both voltage and current waveforms and increasing the power factor.THD% reduction of the voltage and current waves is positively reflected on the work in the voltage drop on the facility inputs, leading to larger currents by loads. This leads to a loss of this work is by operations required for high performance .small size and low weight of the drive and control circuits with the chopper circuit are very suitable for integration with variable major changes in both power and control circuits. Allowing it to be integrated with any existing system by adding some simple modifications .some of the main contributions in this project as follows

1. Proposing a novel four chopper for variable speed drive systems.
2. Introducing a new VSDS method able to highly reducing THD.

PULSE WIDTH MODULATION

Pulse Width Modulation (PWM) is the most effective means to achieve constant voltage battery charging by switching the solar system controller’s power devices. When in PWM regulation, the current from the solar array tapers according to the battery’s condition and recharging needs consider a waveform such as this: it is a voltage switching between 0v and 12v. It is fairly obvious that, since the voltage is at 12v for exactly as long as it is at 0v, then a 'suitable device' connected to its output will see the average voltage and think it is being fed 6v - exactly half of 12v. So by varying the width of the positive pulse - we can vary the 'average' voltage is shown in Fig: 7.1

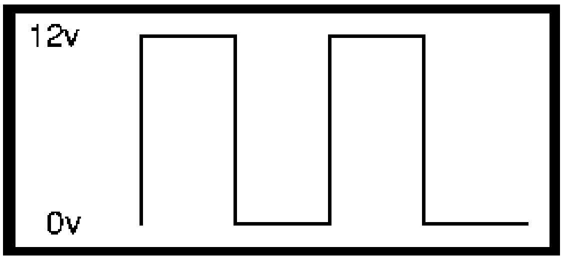


Fig.7.1. Positive Average Voltage

Similarly, if the switches keep the voltage at 12 for 3 times as long as at 0v, the average will be 3/4 of 12v - or 9v, as shown in Fig.7.2Voltage and if the output pulse of 12v lasts only 25% of the overall time, then the average is

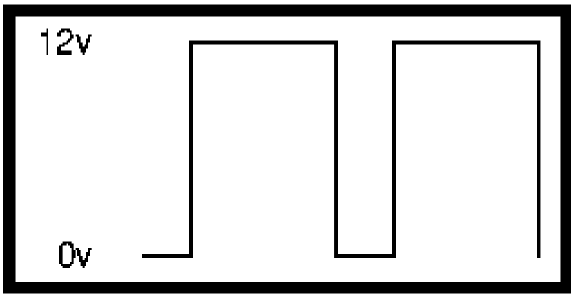


Fig.7.2. Negative Average voltage

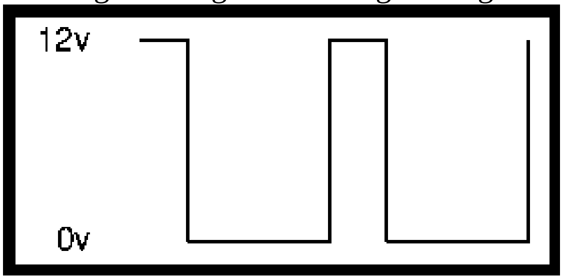


Fig.7.3. Average voltage

By varying - or 'modulating' - the time that the output is at 12V (i.e. the width of the positive pulse) we can alter the average voltage. So we are doing 'pulse width modulation'. I said earlier that the output had to feed 'a suitable device'. A radio would not work from this: the radio would see 12V then 0V, and would probably not work properly. However a device such as a motor will respond to the average, so PWM is a natural for motor control as shown in Fig.7.3

7.1 PULSE WIDTH MODULATOR

So, how do we generate a PWM waveform It's actually very easy; there are circuits available in the TEC site. First you generate a triangle waveform as shown in the diagram below. You compare this with a dc voltage, which you adjust to control the ratio of on to off time that you require. When the triangle is above the 'demand' voltage, the output goes high. When the triangle is below the demand voltage, the

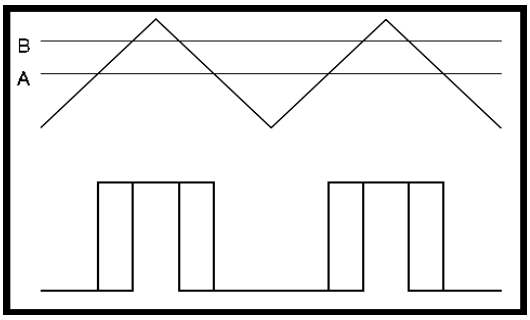


Fig.7.4. Average TEC voltage

When the demand speed it in the middle (A) you get a 50:50 output, as in black. Half the time the output is high and half the time it is low. Fortunately, there is an IC (Integrated circuit) called a comparator: these come usually 4 sections in a single package. One can be used as the oscillator to produce the triangular waveform and another to do the comparing, so a complete oscillator and modulator can be done with half an IC and maybe 7 other bits.

The triangle waveform, which has approximately equal rise and fall slopes, is one of the commonest used, but you can use a saw tooth (where the voltage falls quickly and rinses slowly). You could use other waveforms and the exact linearity (how good the rise and fall are) is not too important. Traditional solenoid driver electronics rely on linear control, which is the application of a constant voltage across a resistance to produce an output current that is directly proportional to the voltage. Feedback can be used to achieve an output that matches exactly the control signal. However, this scheme dissipates a lot of power as heat, and it is therefore very inefficient.

A more efficient technique employs pulse width modulation (PWM) to produce the constant current through the coil. A

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 07 Issue 07
July 2020

PWM signal is not constant. Rather, the signal is on for part of its period, and off for the rest. The duty cycle, D, refers to the percentage of the period for which the signal is on. The duty cycle can be anywhere from 0; the signal is always off, to 1, where the signal is constantly on. A 50% D results in a perfect square wave. (Fig.7.3)

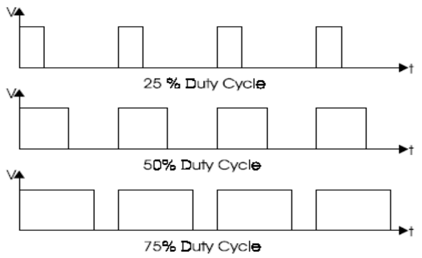


Fig.7.3. Duty cycle waveforms.

A solenoid is a length of wire wound in a coil. Because of this configuration, the solenoid has, in addition to its resistance, R, a certain inductance, L. When a voltage, V, is applied across an inductive element, the current, I, produced in that element do not jump up to its constant value, but gradually rises to its maximum over a period of time called the rise time (Fig7.4). Conversely, I do not disappear instantaneously, even if V is removed abruptly, but decreases back to zero in the same amount of time ashen rise time.

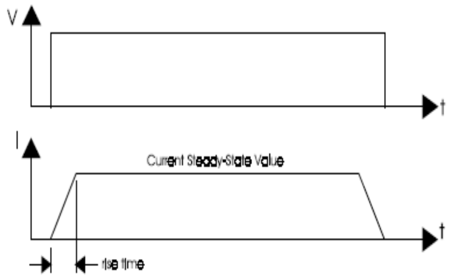


Fig7.4 Instantaneously Wave Forms.

Therefore, when a low frequency PWM voltage is applied across a solenoid, the current through it will be increasing and decreasing as V turns on and off. If D is shorter than the rise time, I will never achieve its maximum value, and will be discontinuous since it will go back to zero during V's off period (Fig.7.3).* In contrast, if D is larger than the rise time, I will never fall back to zero, so it will be continuous, and have a DC average value. The current will not be constant, however, but will have a ripple (Fig7.4).

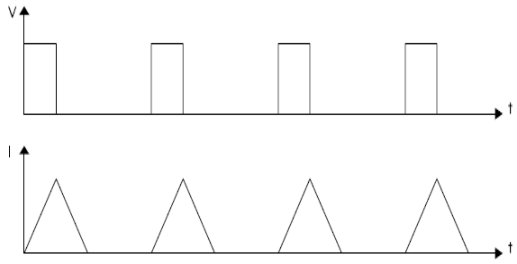


Fig.7.5.Continouus wave forms ripple

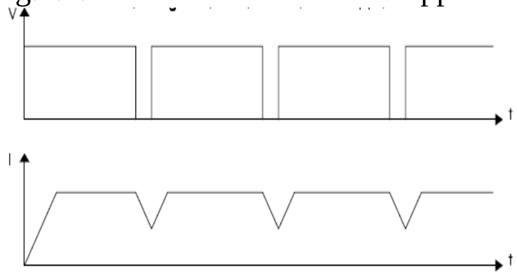


Fig.7.6.Discontinouus wave forms ripple

At high frequencies, V turns on and off very quickly, regardless of D, such that the current does not have time to decrease very far before the voltage is turned back on. The resulting current through the solenoid is therefore considered to be constant. By adjusting the D, the amount of output current can be controlled. With a small D, the current will not have much time to rise before the high frequency PWM voltage takes effect and the current stays constant. With a large D, the current will be able to rise higher before it becomes constant. (Fig7.7)

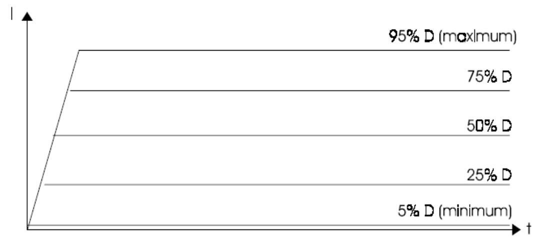


Fig.7.7 Minimum and Maximum waveforms.

7.2. PWM FREQUENCY

The PWM is a large amplitude digital signal that swings from one voltage extreme to the other. And, this wide voltage swing takes a lot of filtering to smooth out. When the PWM frequency is close to the frequency of the waveform that you are generating, then any PWM filter will also smooth out your generated waveform and drastically reduce its amplitude. So, a good rule of thumb is to keep the PWM frequency much higher than the frequency of any waveform you generate.

Finally, filtering pulses is not just about the pulse frequency but about the duty cycle and how much energy is in the pulse. The same filter will do better on a low or high duty cycle pulse compared to a 50% duty cycle pulse. Because the wider pulse has more time to integrate to a stable filter voltage and the smaller pulse has less time to disturb it the inspiration was a request to control the speed of a large positive displacement fuel pump. The pump was sized to allow full power of a boosted engine in excess of 600 Hp.

At idle or highway cruise, this same engine needs far less fuel yet the pump still normally supplies the same amount of fuel. As a result the fuel gets recycled back to the fuel tank, unnecessarily heating the fuel. This PWM controller circuit is intended to run the pump at a low speed setting during low power and allow full pump speed when needed at high engine power levels.

7.3. Motor Speed Control (Power Control)

Typically when most of us think about controlling the speed of a DC motor we think of varying the voltage to the motor. This is normally done with a variable resistor and provides a limited useful range of operation. The operational range is limited for most applications primarily because torque drops off faster than the voltage drops. Most DC motors cannot effectively operate with a very low voltage. This method also causes overheating of the coils and eventual failure of the motor if operated too slowly. Of course, DC motors have had speed controllers based on varying voltage for years, but the range of low speed operation had to stay above the failure zone described above.

Additionally, the controlling resistors are large and dissipate a large percentage of energy in the form of heat. With the advent of solid state electronics in the 1950’s and 1960’s and this technology becoming very affordable in the 1970’s & 80’s the use of pulse width modulation (PWM) became much more practical. The basic concept is to keep the voltage at the full value and simply vary the amount of time the voltage is applied to the motor windings. Most PWM circuits use large transistors to simply allow power On & Off, like a very fast switch.

This sends a steady frequency of pulses into the motor windings. When full power is needed one pulse ends just as the next pulse begins, 100% modulation. At lower power settings the pulses are of shorter duration. When the pulse is On as long as it is Off, the motor is operating at 50% modulation. Several advantages of PWM are efficiency, wider operational range and longer lived motors. All of these advantages result from keeping the voltage at full scale resulting in current being limited to a safe limit for the windings.

PWM allows a very linear response in motor torque even down to low PWM% without causing damage to the motor. Most motor manufacturers recommend PWM control rather than the older voltage control method. PWM controllers can be operated at a wide range of frequencies. In theory very high frequencies (greater than 20 kHz) will be less efficient than lower frequencies (as low as 100 Hz) because of switching losses.

The large transistors used for this On/Off activity have resistance when flowing current, a loss that exists at any frequency. These transistors also have a loss every time they “turn on” and every time they “turn off”. So at very high frequencies, the “turn on/off” losses become much more significant. For our purposes the circuit as designed is running at 526 Hz. Somewhat of an arbitrary frequency, it works fine.

Depending on the motor used, there can be a hum from the motor at lower PWM%. If objectionable the frequency can be changed to a much higher frequency above our normal hearing level (>20,000Hz).

7.4. PWM CONTROLLER FEATURES

This controller offers a basic “Hi Speed” and “Low Speed” setting and has the option to use a “Progressive” increase between Low and Hi speed. Low Speed is set with a trim pot inside the controller box. Normally when installing the controller, this speed will be set depending on the minimum speed/load needed for the motor. Normally the controller keeps the motor at this Lo Speed except when Progressive is used and when Hi Speed is commanded (see below). Low Speed can vary anywhere from 0% PWM to 100%.

Progressive control is commanded by a 0-5 volt input signal. This starts to increase PWM% from the low speed setting as the 0-5 volt signal climbs. This signal can be generated from a throttle position sensor, a Mass Air Flow sensor, a Manifold Absolute Pressure sensor or any other way the user wants to create a 0-5 volt signal. This function could be set to increase fuel pump power as turbo boost starts to climb (MAP sensor). Or, if controlling a water injection pump, Low Speed could be set at zero PWM% and as the TPS signal climbs it could increase PWM%, effectively increasing water flow to the engine as engine load increases. This controller could even be used as a secondary injector driver (several injectors could be driven in a batch mode, hi impedance only), with Progressive control (0-100%) you could control their output for fuel or water with the 0-5 volt signal.

Progressive control adds enormous flexibility to the use of this controller. Hi Speed is that same as hard wiring the motor to a steady 12 volt DC source. The controller is providing 100% PWM, steady 12 volt DC power. Hi Speed is selected three different ways on this controller:

1) Hi Speed is automatically selected for about one second when power goes on. This gives the motor full torque at the start. If needed this time can be increased (the value of C1 would need to be increased).

2) High Speed can also be selected by applying 12 volts to the High Speed signal wire. This gives Hi Speed regardless of the Progressive signal.

When the Progressive signal gets to approximately 4.5 volts, the circuit achieves 100% PWM – Hi Speed.

7.5. SPACE VECTOR PWM

The Space Vector PWM generation module accepts modulation index commands and generates the appropriate gate drive waveforms for each PWM cycle. This section describes the operation and configuration of the SVPWM module.

A three-phase 2-level inverter with dc link configuration can have eight possible switching states, which generates output voltage of the inverter. Each inverter switching state generates a voltage Space Vector (V1 to V6 active vectors, V7 and V8 zero voltage vectors) in the Space Vector plane (Figure: space vector diagram). The magnitude of each active vector (V1to V6) is 2/3 Vdc (dc bus voltage).The Space Vector PWM (SVPWM) module inputs modulation index commands (U_Alpha and U_Beta) which are orthogonal signals (Alpha and Beta) as shown in Figure. The gain characteristic of the SVPWM module is given in Figure . The vertical axis of Figure represents the normalized peak motor phase voltage (V/Vdc) and the horizontal axis represents the normalized modulation index (M).

The inverter fundamental line-to-line Rms output voltage (Vline) can be approximated (linear range) by the following equation:

$$Vline = Umag * Mod\_Scl * Vdc / \sqrt{6} / 2^{25}$$

…………….. (7.1)

where dc bus voltage (Vdc) is in volts

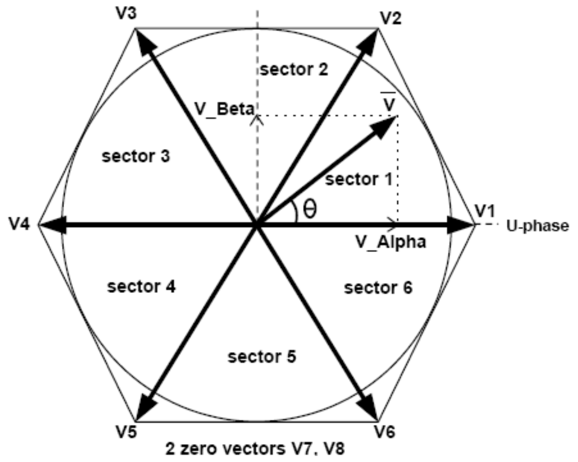


Fig.7.8.Space Vector Diagram

This document is the property of International Rectifier and may not be copied or distributed without expressed consent

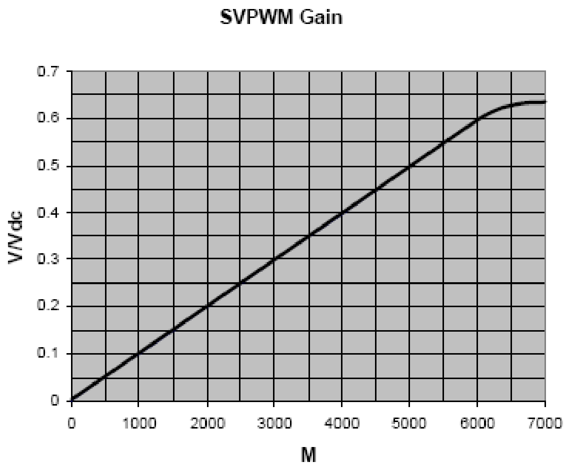


Fig.7.9 Transfer Characteristics

The maximum achievable modulation (Umag_L) in the linear operating range is given by:

$$Umag\_L = 2^{25} * \sqrt{3} / Mod\_Scl$$

… ……….. (7.2)

Over modulation occurs when modulation Umag>Umag_L. This corresponds to the condition where the voltage vector in (Fig.7.8 voltage vector rescaling) increases beyond the hexagon boundary. Under such circumstance, the Space Vector PWM algorithm will rescale the magnitude of the voltage vector to fit within the Hexagon limit. The magnitude of the voltage vector is restricted within the Hexagon; however, the phase angle (θ) is always preserved. The transfer gain (Fig.7.9 transfer characteristics) of the PWM modulator reduces and becomes non-linear in the over modulation region.

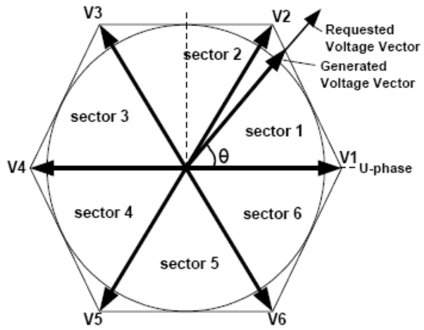


Fig.7.10.Voltage Vector Rescaling

This document is the property of International Rectifier and may not be copied or distributed without expressed consent.

7.6. PWM Operation

Upon receiving the modulation index commands (U_{Alpha} and U_{Beta}) the sub-module SVPWM T_m starts its calculations at the rising edge of the PWM Load signal. The SVPWM T_m module implements an algorithm that selects (based on sector determination) the active space vectors (V1 to V6) being used and calculates the appropriate time duration (w.r.t. one PWM cycle) for each active vector. The appropriated zero vectors are also being selected. The SVPWM _Tm module consumes 11 clock cycles typically and 35 clock cycles (worst case T_r) in over modulation cases. At the falling edge of n_{SYNC}, a new set of Space Vector times and vectors are readily available for actual PWM generation (Phase-U, Phase-V, Phase-W) by sub module Pwm Generation. It is crucial to trigger PwmLoad at least 35 clock cycles prior to the falling edge of n_{SYNC} signal; otherwise new modulation commands will not be implemented at the earliest PWM cycle.

The above Figures voltage vector rescaling illustrates the PWM waveforms

International Journal of Research
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 07 Issue 07
July 2020

for a voltage vector locates in sector I of the Space Vector plane (shown in Fig7.11). The gating pattern outputs (PWMUH … PWMWL) include dead time insertion

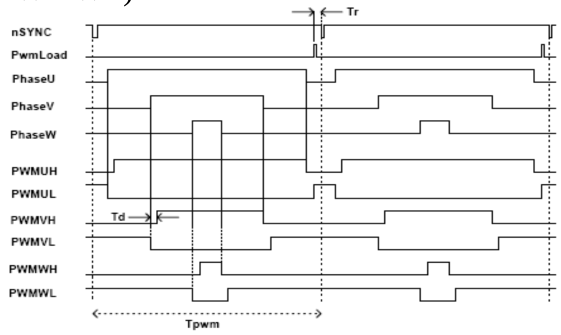


Fig7.11PWM waveforms

3-PHASE SPACE VECTOR PWM

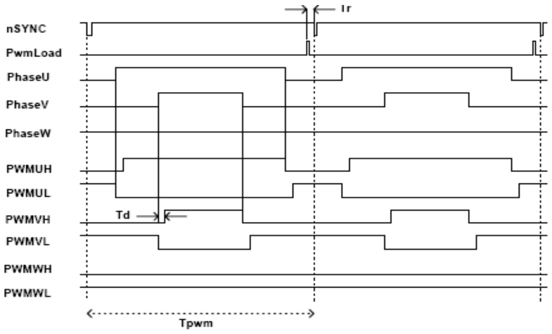


Fig.7.12.2-phase (6-step PWM) Space Vector PWM

7.8. PWM CARRIER PERIOD

Input variable $P_{wm}C_{val}$ controls the duration of a PWM cycle. It should be populated by the system clock frequency (C_{lk}) and P_{wm} frequency ($P_{wm}F_{req}$) selection. The variable should be calculated as:

$$PwmCval = Clk/(2*PwmFreq)-1 \quad \text{……….. (7.3)}$$

The input resolution of the Space Vector PWM modulator signals U_Alpha and U_Beta is 16-bit signed integer. However, the actual PWM resolution (PwmCval) is limited by the system clock frequency.

Dead time Insertion Logic

Dead time is inserted at the output of the PWM Generation Module. The resolution is 1 clock cycle or 30nsec at a 33.3 MHz clock and is the same as those of the voltage command registers and the PWM carrier frequency register.

The dead time insertion logic chops off the high side commanded volt*seconds by the amount of dead time and adds the same amount of volt*seconds to the low side signal. Thus, it eliminates the complete high side turn on pulse if the commanded volt*seconds is less than the programmed dead time.

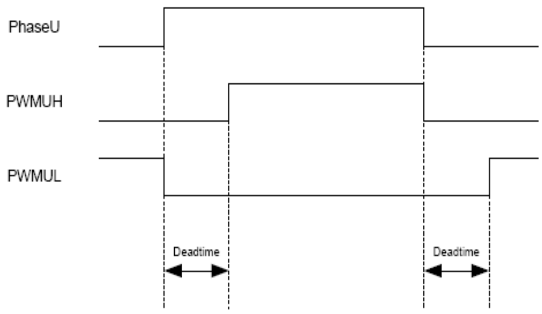


Fig.7.13.2-phase (6-step PWM) Space Vector PWM

Dead time Insertion

The dead time insertion logic inserts the programmed dead time between two high and low side of the gate signals within a phase. The dead time register is also double buffered to allow "on the fly" dead time change and control while PWM logic is inactive.

7.8. SYMMETRICAL AND ASYMMETRICAL MODE OPERATION

There are two modes of operation available for PWM waveform generation, namely the Center Aligned Symmetrical PWM (Fig7.13) and the Center Aligned Asymmetrical PWM (Fig7.13)The volt-sec can be changed every half a PWM cycle (Tpwm) since P_{wm} Load occurs every half a PWM cycle (compare Fig7.14 :symmetrical p_{wm} and Figure :asymmetrical PWM). With Symmetrical PWM mode, the inverter voltage Configuration = 0), the inverter voltage can be changed at two times the rate of the switching frequency. This will provide an increase in voltage control bandwidth, however, at the expense of increased current harmonic

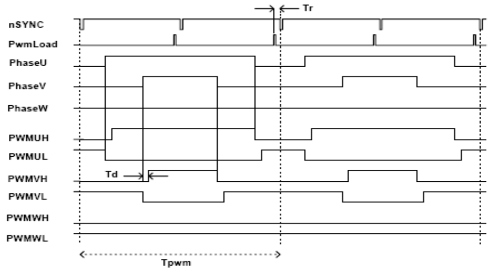


Fig7.15.Asymmetrical PWM Mode

7.9. THREE-PHASE AND TWO-PHASE MODULATION

Three-phase and two-phase Space Vector PWM modulation options are provided for the IRMCx203. The Volt-sec generated by the two PWM strategies are identical; however with 2-phase modulation the switching losses can be reduced significantly, especially when high switching frequency (>10Khz) is employed. Fig7.15: three-phase and two phase modulation shows the switching pattern for one PWM cycle when the voltage vector is inside sector 1

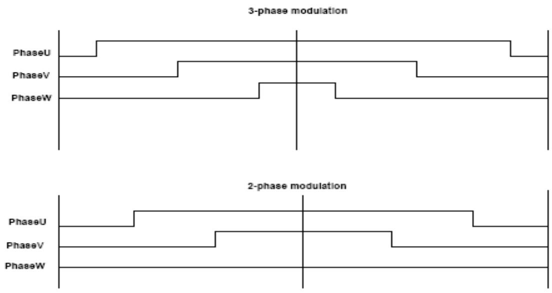


Fig7.15.Asymmetrical PWM Mode

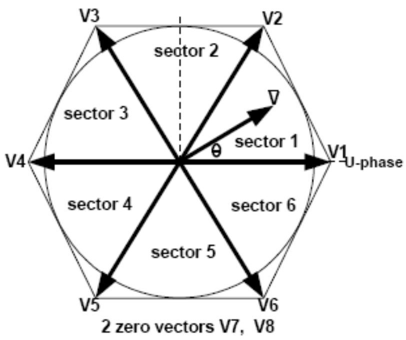


Fig7.16 Space Vector diagram Mode

7.10. Three Phase and Two Phase Modulation

The field Two Phase PWM of the PWM Config write register group provides selection of three-phase or two-phase modulation. The default setting is three-phase modulation. Successful operation of two-phase modulation in the entire speed operating range will depend on hardware configuration. If the gate driver employs a bootstrap power supply strategy, disoperation will occur at low motor fundamental frequencies (< 2Hz) under two-phase modulation control.

7.11. Sinusoidal Pulse Width Modulation

In many industrial applications, Sinusoidal Pulse Width Modulation (SPWM), also called Sine coded Pulse Width Modulation, is used to control the inverter output voltage. SPWM maintains good performance of the drive in the entire range of operation between zero and 78 percent of the value that would be reached by square-wave operation. If the modulation index exceeds this value, linear relationship between modulation index and output voltage is not maintained and the over-modulation methods are required

7.12. Space Vector Pulse Width Modulation

A different approach to SPWM is based on the space vector representation of voltages in the d, q plane. The d, q components are found by Park transform, where the total power, as well as the impedance, remains unchanged.

Fig: space vector shows Fig.7.17 space vectors in according tofig.7.16 switching positions of inverter, V* is the phase-to-center voltage which is obtained by proper selection of adjacent vectors V_1 and V_2.

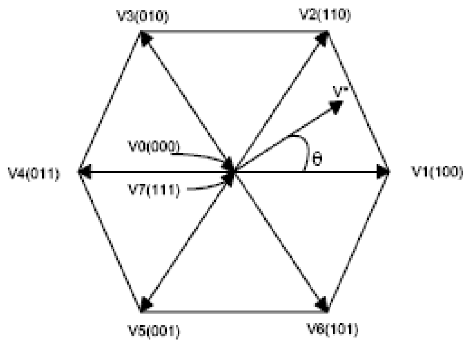


Fig.7.17.Inverter output voltage space vector

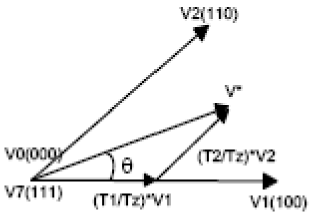


Fig.7.18.Determination of Switching times

The reference space vector V* is given by Equation (7.1), where T_1, T_2 are the intervals of application of vector V_1 and V_2 respectively, and zero vectors V_0 and V_7 are selected for T_0.

$V^* Tz = V_1 *T_1 + V_2 *T_2 + V_0 *(T_0/2) + V_7 *(T_0/2)$………. (7.4)

7.13. Space Vector Pulse Width Modulation (continued)

Fig.7.19. below shows that the inverter switching state for the period T_1 for vector V_1 and for vector V_2, resulting switching patterns of each phase of inverter are shown in Fig. pulse pattern of space vector PWM.

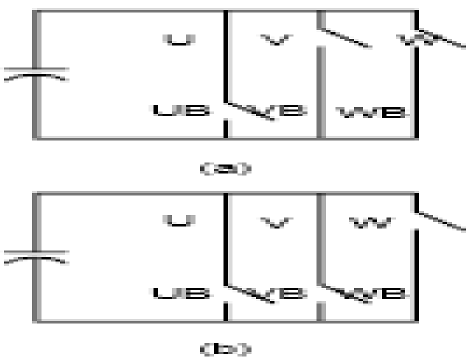


Fig.7.19 Inverter switching state for (a)V1, (b) V2

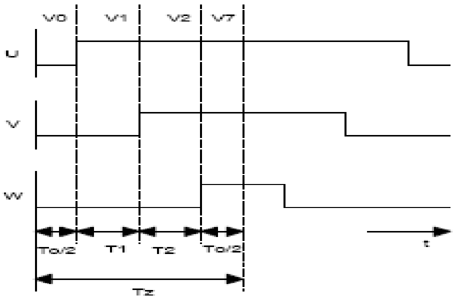


Fig.7.20. Pulse pattern of Space vector PWM

Comparison

In Fig: 7.20 comparisons, U is the phase to- center voltage containing the triple order harmonics that are generated by space vector PWM and U_1 is the sinusoidal reference voltage. But the triple order harmonics are not appeared in the phase-to-phase voltage as well. This leads to the higher modulation index compared to the SPWM.

7.14.Comparison of SPWM and Space Vector PWM

As mentioned above, SPWM only reaches to 78 percent of square wave operation, but the amplitude of maximum possible voltage is 90 percent of square-wave in the case of space vector PWM. The maximum phase-to-center voltage by sinusoidal and space vector
PWM are respectively

$V_{max} = V_{dc}/2$, Sinusoidal PWM

$V_{max} = V_{dc}/\sqrt{3}$: Space Vector PWM

Where, V_{dc} is DC-Link voltage.

This means that Space Vector PWM can produce about 15 percent higher than Sinusoidal PWM in output voltage.

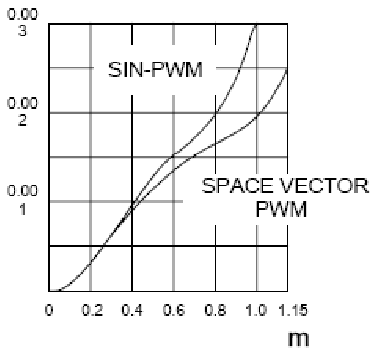


Fig.7.21 (a) space vector harmonics

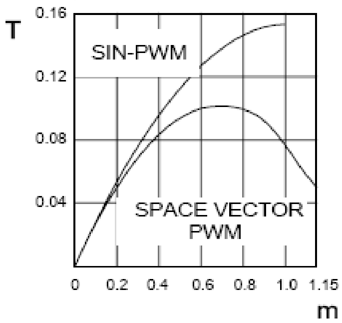


Fig.7.22. (b) Torque Harmonics

7.15.SVM PWM Technique

The Pulse Width modulation technique permits to obtain three phase system voltages, which can be applied to the controlled output. Space Vector Modulation (SVM) principle differs from other PWM processes in the fact that all three drive signals for the inverter will be created simultaneously. The implementation of SVM process in digital systems necessitates less operation time and also less program memory.

The SVM algorithm is based on the principle of the space vector u*, which describes all three output voltages u_a, u_b and u_c :

$u^* = 2/3 . (u_a + a . u_b + a_2 . u_c)$ ………(7.5)

Where a = -1/2 + j . V3/2 We can distinguish six sectors limited by eight discrete vectors u0…u7 (fig:-7.21 inverter output voltage space vector), which correspond to the 23 = 8 possible switching states of the power switches of the inverter.

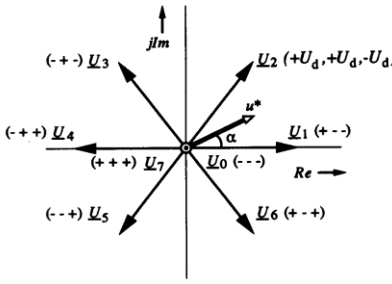


Fig:-7.21 inverter output voltage space vector

7.16. Space vector Modulation

The amplitude of u_0 and u_7 equals 0. The other vectors $u_1 \ldots u_6$ have the same amplitude and are 60 degrees shifted.By varying the relative on-switching time Tc of the different vectors, the space vector u* and also the output voltages u_a, u_b and u_c can be varied and is defined as:

$u_a = Re (u^*)$

$u_b = Re (u^* . a-1)$

$u_c = Re (u^* . a-2)$ …………(7.6)

During a switching period Tc and considering for example the first sector, the vectors u0, u1 and u2 will be switched on alternatively.

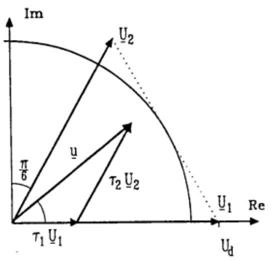


Fig:-7.22 inverter output voltage space vector diagram.

Definition of the Space vector

Depending on the switching times t_0, t_1 and t_2 the space vector u* is defined as:

$u^* = 1/Tc . (t_0 . u_0 + t_1 . u_1 + t_2 . u_2)$

$u^* = t0 . u0 + t_1 . u_1 + t_2 . u_2$

$u^* = t_1 . u_1 + t_2 . u_2$ ………….. (7.7)

Where

$t_0 + t_1 + t_2 = T_c$ and

$t_0 + t_1 + t_2 = 1$

t_0, t_1 and t_2 are the relative values of the on switching times.

They are defined as: $t_1 = m . \cos (a + p/6)$

$t_2 = m . \sin a$

$t_0 = 1 - t_1 - t_2$

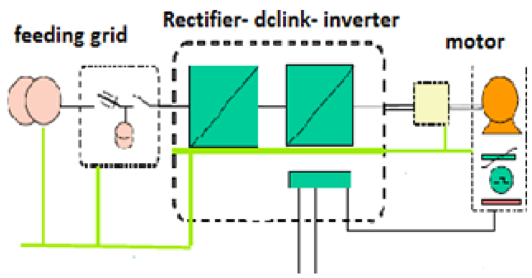
Their values are implemented in a table for a modulation factor m = 1. Then it will be easy to calculate the space vector u* and the output voltages ua, ub and uc. The voltage vector u* can be provided directly by the optimal vector control laws w_1, v_{sa} and v_{sb}. In order to generate the phase voltages u_a, u_b and u_c corresponding to the desired voltage vector u* the following SVM strategy is proposed.

PROPOSED SPEED SYSTEM COMPONENTS

Variable speed drive systems consist of three basic components: electrical motor, direct and indirect power converter, and control system. Fig. 2, shows the basic structure of the variable speed system with an indirect power converter. Converter schemes for medium-power industrial driving are located in two basic plans direct and indirect. Speed control methods used in the industry are classified into three main sections: electric, electrolytic,

International Journal of Research
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 07 Issue 07
July 2020

mechanical



The following advantages of VSDS have given it significant importance in industrial facilities:

Smooth regulation of motor speed.

To use VSDS in industrial facilities, a choice must be made between designing nonlinear devices that provide low levels of THD% ,or installing substation compensation equipment at the substations. Recently, buck-boost chopper has been used in DC-LINK for variable-speed drive systems.

PARAMETERS OF THE EQUIVALENT CIRCUIT

To perform the simulated process, we must choose the parameters of this system:

1. Input line impedance:

Input line impedance depends on various factors such as distribution connected transformer in line or other equipment connected at point of common coupling (PCC). Grid inductance varies from few hundreds of μH to some mH, depending on the numbers of transformers connected in transmission and distribution system and their leakage inductances.

2. The capacitor output:

Outputcapacitorof10μFisobtainedbyputtingtwo film capacitor of 5μF in parallel; these capacitors are purposed to operate at 800V 70 ° C and 700 ° Fat 80 °C.

3. The inductor of four-quadrants chopper circuit: Required value for the inductance value of four-quadrant chopper is found by the following equation:

$$L_{DC} = \frac{\left(\frac{3}{2}\right)V_i - (V_o - V_c)}{0.4 I_L * 2 f_s}$$

where, Vi, Vo, Vc, IL and fs are three phase diode bridge output voltage, inverter voltage, chopper capacitor voltage, load current, and cutting off frequency respectively. The average value of duty cycle is 0.5. Therefore, the current ripples on active switches and diodes equal to half of the rated current. For output power 4 KW, dc inductor is chosen to be 40 μH, depended on20% ripple current is allowed.

4. Capacitor of four-quadrant chopper circuit: Chopper capacitor C stores energy corresponding to changes of output voltage of diode bridge output voltage which has a sixteen ripple of mains frequency. In three levels operation, rms value of capacitor current depends on the ratio of peak value rectified voltage to chopper capacitor voltage.

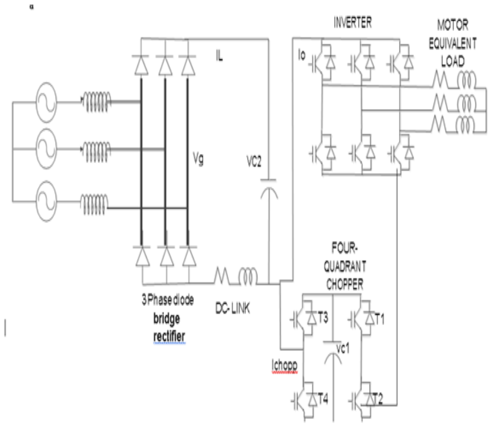


Fig. 4. VSDs with four – quadrant chopper in DC- LINK

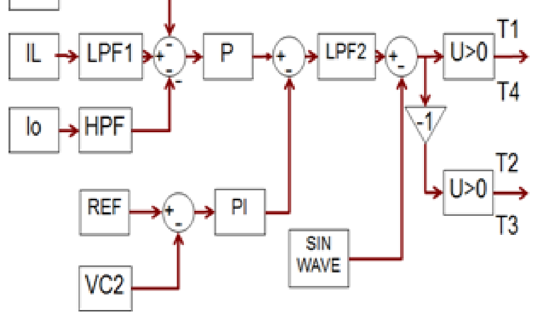


Fig. 5. The proposed control Scheme for variable speed drive system

In order to improve the performance grid, we used the four-quadrant chopper in the DC-LINK instead of buck–boost chopper, as shown in Fig. 4.In this scheme, current i_L doesn't pass through the active elements of the chopper, four-quadrant chopper works as a hybrid filter passes only high-frequency currents. Charging and discharging of capacitor C1 is determined by chopper current signal iCHOPP, so it is necessary to control the bi-directional chopper current $i_{CHOPP} = i_L - i_O$, where i_O is the inverter current. Three level voltage modulations $v_{C2} - v_{C1}$, v_{C2} ,$v_{c2} + v_{c1}$ available on the inverter input. The current L increases at$v_O = v_{C2} - v_{C1}$, decreases at $v_O = v_{C2} + v_{C1}$.

Besides, thecurrenthasanindividualpassregarding the capacitor C. The current I_O which passing to the positive side of inverter shows in Fig. 15 , thus the current passing to the chopper, iCHOPP, different from inverter current i_O and inductor current i_L as shown in Fig.15.

When Inverter operates without chopper circuit, the inverter input voltage V_O is equal to V_{C2}. In the case of chopper is bypassed, V_O is always equal to V_{C2}, When only one of T1 and T4 is on, then chopper capacitor is bypassed. As well as, one of T2 and T3 will be on during this time.ThecontrolschemeillustratinginFig.5similartobuck- boost chopper control adding some modifications, SPWM block has to generate four signals.

Four- quadrant chopper has to deliver the required high frequency current to the inverter, the current Io flowing from positive rail of DC-LINK to inverter wont flow through the chopper circuit, also current flowing in chopper is bidirectional. Therefore, the duty-cycle of the switch is determined by an inner current control loop and the constant dc output voltagevc2. The inductor current I_L is controlled to have a constant value by four transistors operation T1, T2, T3 and T4.

Both (T1,T2) and (T3,T4) operate by complementary signals for gates, also Operate by complementary gate signals.

1. In the turn-on period of both T1 and T4, inverter voltage V_O is $V_{C2} - V_{C1}$.
2. WhenbothT2andT3areturnedoninvertervoltage V_O is $V_{C2}+V_{C1}$.

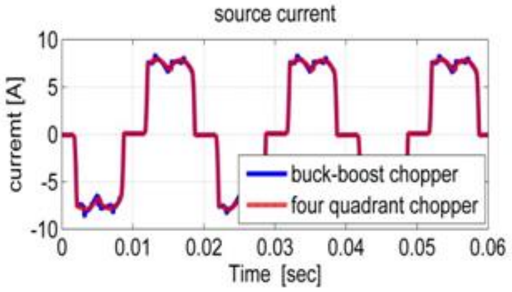
Low-pass filter LPF1 is used to reduce the high- frequency components in pulse load currents. The proportional control P is used to control reshape of the current I_L, where high P-value produces a current with ripples lower by six times from the main frequency in the DC- LINK.

The high pass filter, HPF, is used to detect the resonant currents and block the low frequency components of e rectified current. To reduce the equivalent switching ripple, a low pass filter LPF2 should be employed in the main control loop. The cut-off frequency is selected around500Hz, whichshouldbehigherthanthesixtimes than the main frequency and enough to reduce the equivalent switching frequency ripple to a sufficient level.

For controlling DC-LINK voltage V_C, a PI-type controller is used and connected in parallel to the main control loop. This allows offset adjusting of control signal. This scheme has many advantages over buck- boost chopper, but the controlling of four-quadrant chopper is much more complex and has many problems.

RESULTS

The input currents of the VSDS suffer from a THD% factor 45% and for voltage wave up to 5.6%, ripple factor (RF) of the output rectified current 3.2, crest factor (CF) 1.74 and power factor (PF) 0.951. In VSDS improving the power quality characteristics. The main goal of this paper is reducing both ripple factor and crest factor of DC-LINK current. This will affect positively on the input current total harmonic distortion factor of input currents in the VSDS.



Grid currents of VSDS with buck-boost chopper and with four quadrant chopper circuit show in Fig. 6, we note that grid currents distortions are clearly reduced. The total harmonic distortion factor of grid currents VSDS has decreased from 28.81% to 25.53% as shown in Fig.6.Fig. 8, shows the maximum and effective value of this current and the amount of distortion in each harmonic in this wave. Fig. 9, shows the phase – phase input voltage of studied variable speed drive system with buck-boost chopper and with four quadrant chopper circuit. Fig. 10, shows that total harmonic distortion of output voltage decreased from 2.72% to 2.53% that reflex advantages of using four - quadrant chopper in DC-LINK.

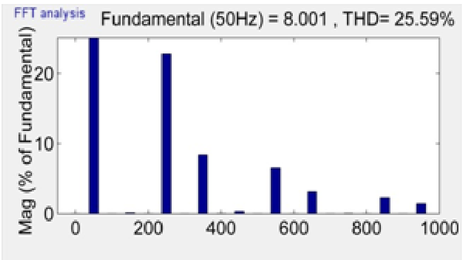


Fig. 7. Total harmonic distortion factor of VSDS

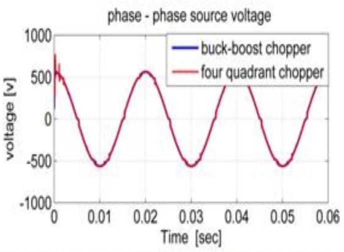


Fig. 9. Phase to phase for input voltage ofproposed VSDS

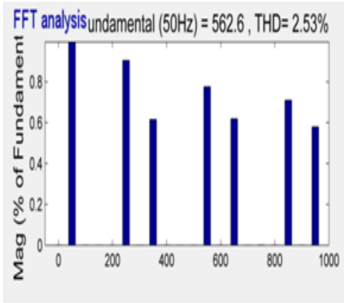


Fig. 10. FFT analysis of phase – phase grid voltage for proposed VSDS

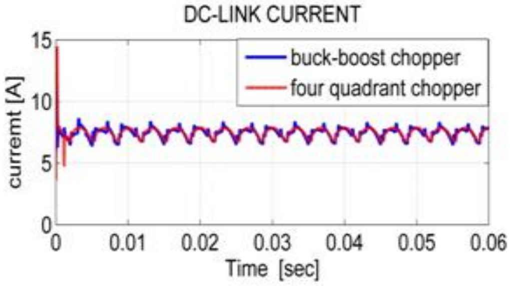


Fig. 11. DC-LINK Current

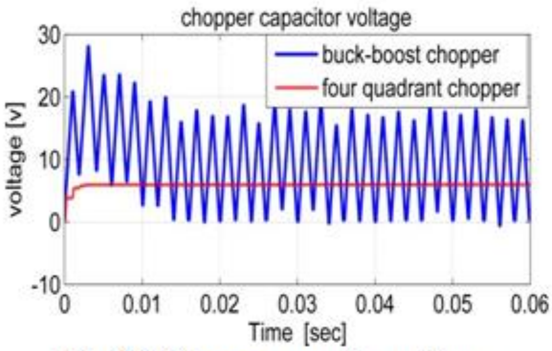


Fig. 12. Chopper capacitor voltage

Fig. 11, shows DC-LINK current in both cases mentioned previously, ripple factor has been reduced from the value 1.95 to 1.105 when using the four-quadrant section. The conventional VSDS has a ripple factor of the continuous vehicle current about 4.9.Crest Factor calculation is intended to give an idea about the effect of the wave form. Crest factor is defined as the ratio of peak value to effective one. Crest factor of grid current is reduced from 1.4when use buck – boost chopper to 1.30 with four quadrant chopper.

In addition crest factor for dc-link current is reduced from 1.12 to 1.05 with four quadrant chopper. Grid currents of conventional VSDS have crest factor1.74 and DC-LINK current 1.40.Power factor is increased from 0.951 in conventional drive system to 0.953 when using buck-boost chopper in DC-LINK, and to 0.956 when using four-quadrant chopper in this paper. Fig. 12 shows that chopper capacitor voltage is reduced to 6 V when using the four-quadrant chopper. Also this figures shows that the voltage of the capacitor is a varying pulse. The peak of these pulses is reached to24V, while its effective value is 12V.The output voltage has lower oscillations as shown in Fig. 13. Therefore, the use of the four-quadrant chopper in dc-link gives lower oscillations in output voltage. Constant dc-link voltage is achieved after using four- quadrant chopper in DC-LINK, but the effective value ofthevoltageinbothcasesremained540Vasshownin Fig.14.The aforementioned results validate the proposed method for implementing it in the reality. It is clear that the proposed method has the ability of diminishing the voltage oscillations and ensure of constant voltage in the DC-LINK. Likewise, the THD is highly reduced using the proposed method. Furthermore, the ripple factor is highly reduced by implementing the proposed variable speed drive system.

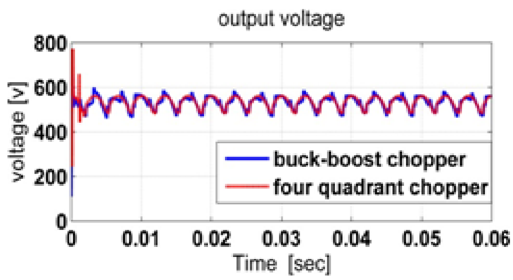


Fig. 13. Output voltage

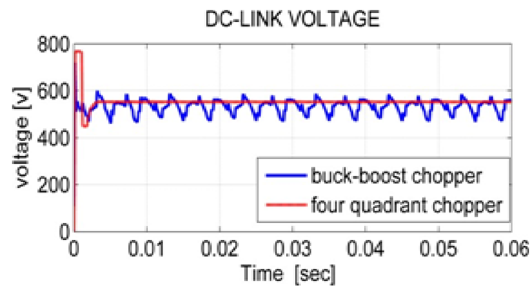
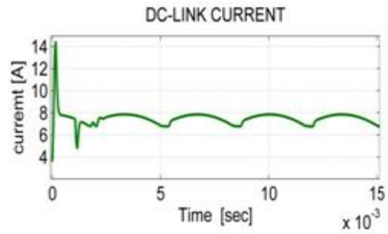
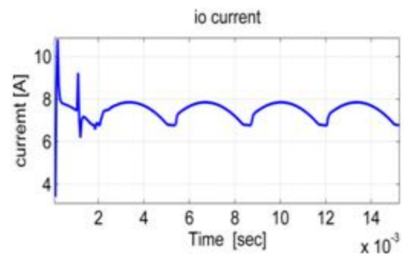


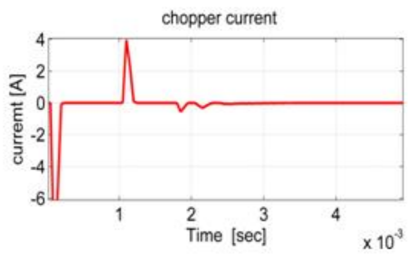
Fig. 14. DC-LINK voltage



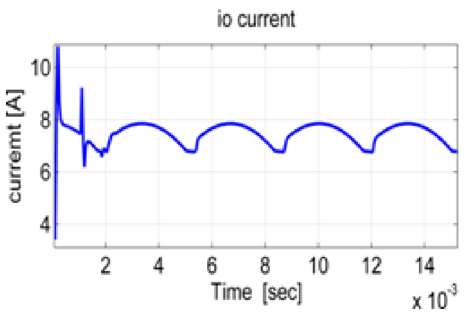
(a)



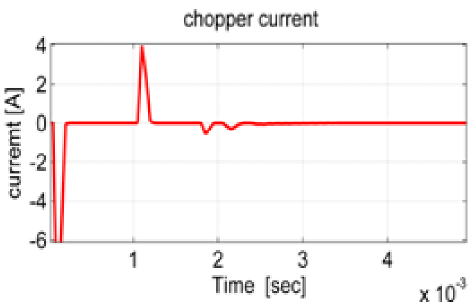
(b)



(c)



(b)



(c)

Fig. 15. Currents of the different components: b) DC-LINK current, and c)chopper current

CONCLUSION

In this project a novel technique is proposed to achieve a good performance of the variable speed drive systems (VSDS) in the industrial facilities by reducing the THD % for the both voltage and current waveforms and increasing the power factor.THD% reduction of the voltage and current waves is positively reflected on the work in the voltage drop on the facility inputs, leading to larger currents by loads. This leads to a loss of this work is by operations required for high performance .small size and low weight of the drive and control circuits with the chopper circuit are very suitable for integration with variable major changes in both power and control circuits. Allowing it to be integrated with any existing system by adding some simple modifications .some of the main contributions in this project as follows

1. Proposing a novel four chopper for variable speed drive systems.
2. Introducing a new VSDS method able to highly reducing THD
3. The ripple effects on the current and voltage of DC-link are diminished.
4. 4-A new method for determine the control signals is proposed.

Modeling variable speed drive system with four – quadrant chopper added to DC-LINK using MATLAB / SIMULINK. Evaluating the performance of the variable speed drive system by comparing the results of the total harmonic distortion factor THD% for both voltage and current waves with and without using the controlled chopper circuit. Comparing the results with the standard values IEC standard by comparing the results before and after using proposed chopper and comparing results with international standard limits found in IEEE 519-1992.

From the practical study, we can concludes that the power quality of input current for these systems was improved by reducing total harmonic distortion factor (THDs) and increasing the power factor(PF), in addition to reduction both of ripple factor and crest factor in dc-link to acceptable values. Capacitor voltage is reduced to an acceptable value doesn't lead to the failure of capacitor besides of canceling the oscillations in dc-link voltage. Finally, we recommend to continuing this work by using SVPWM to generate biases voltages for chopper transistors, and using this chopper with a 12-pulse rectifier variable speed drive system to determine the suitability and adaptability of this chopper with different types of rectifier schemes used in variable speed drive systems.

FUTURE SCOPE

As a future work, the proposed method can be investigated for different types of industrial systems. Likewise, the intelligent methods might be combined with the proposed method and presenting a comprehensive assessment results.

REFERENCES

1. Robak, J. Wasilewski, P. Dawidowski, M. Szewczyk, "Variable Speed Drive (VSD) – towards modern industry and electric power systems," rzegląd Elektrotechniczny, 92(6), pp.207-210., 2016.
2. N. Shah, "Harmonics in power systems Causes, effects and control," Siemens Industry, Inc 2013, Printed in USA© 2013
3. H. S. Haes Alhelou, M. E. H. Golshan, and M. H. Fini. "Multi agent electric vehicle control based primary frequency support for future smart micro-grid." In Smart Grid Conference (SGC), pp. 22-27. IEEE 2015.
4. IEEE, "Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems". IEEE Std. 519 – 1992.
5. IEC, "Limits for harmonic current emissions (equipment input current 16A per phase)" IEC 61000-3-2, 2005.
6. H. H. Alhelou, and M. E. H. Golshan. "Hierarchical plug-in EV control based on primary frequency response in interconnected smart grid." In Electrical
7. Engineering (ICEE), 2016 24th Iranian Conference on, pp. 561-566. IEEE, 2016.
8. R. Zamani, M. E. Hamedani-Golshan, H. H. Alhelou, P. Siano, and H. R. Pota. "Islanding Detection of Synchronous Distributed Generator Based on the Active and Reactive Power Control Loops." Energies 11, no. 10 (2018): 2819.
9. D.Kumarand,F.Zare,"Analysis of Harmonic Mitigations using Hybrid Passive Filters ", 16th International Power Electronics and Motion Control Conference and Exposition Antalya, Turkey 21-24 Sept 2014, pp. 945-951
10. A. Hussein, D. Kazem, and T. Alizadaeani Harmonic Mitigation Techniques Applied to Power Distribution Networks", Hindawi Publishing Corporation Advances in Power Electronics Vol. 2013, Article ID591680.
11. H. H. Alhelou, M. E. H. Golshan, and J. Askari- Marnani. "Robust sensor fault detection and isolation scheme for interconnected smart power systems in presence of RER and EVs using unknown input observer." International Journal of Electrical Power & Energy Systems 99 (2018): 682-694.
12. H. Ahmed, K. Addoweesh, Y. Khan, "Effect of short circuited DC link capacitor of an AC–DC–AC inverter on the performance of induction motor," 2016, Journal of King Saud University – Engineering Sciences, 2016.
13. H. Alhelou, "Fault Detection and Isolation in Power Systems Using Unknown Input Observer" Advanced Condition Monitoring and Fault Diagnosis of Electric Machines; IGI Global: Hershey, PA, USA (2018): 38.
14. C. Makdisie, B. Haidar, and H. H. Alhelou. "An Optimal Photovoltaic Conversion System for Future Smart Grids." In Handbook of Research on Power and Energy System Optimization, pp. 601-657. IGI Global, 2018.
15. Y. Singh, P. Rasmussen, T. Andersen, H. Shaker, "Modeling and control of three phase rectifier with electronic smoothing inductor,".IECON 2011 - 37th Annual Conference on IEEE Industrial Electronics Society, vol., no., pp.1450,1455, 7-10 Nov.
16. R. Nageswara, "Harmonic Analysis of Small Scale Industrial Loads and Harmonic Mitigation Techniques in Industrial Distribution System," in IJERA, Vol. 3, Issue 4, Jul-Aug 2013, pp. 1511-1540.

17. H. H. Alhelou, M. E. Hamedani-Golshan, R. Zamani, E. Heydarian-Forushani, and P. Siano. “Challenges and Opportunities of Load Frequency Control in Conventional, Modern and Future Smart Power Systems: A Comprehensive Review.” Energies 11, no. 10 (2018): 2497.
18. K. Mino, M. L. Heldwein and J. W. Kolar, “Ultra compact three-phase rectifier with electronic smoothing inductor,” in Applied Power Electronics Conference and Exposition, Twentieth Annual IEEE, 2005, pp. 522-528
19. H. Ertl, and J.W. Kolar), “A constant output current three-phase diode bridge rectifier employing a novel Electronic Smoothing Inductor," Industrial Electronics, IEEE Transactions on, 2005. 52(2): p. 454- 461.
20. W. Lockley, T. Consultant, L. Engineering, “What's New In Medium Voltage Drives,” in IEEE Northern Canada & Southern Alberta Sections PES/IAS Joint Chapter Technical Seminar, 2018.
21. H. Kazem, “Harmonic Mitigation Techniques Applied to Power Distribution Networks,” Advances in Power Electronics. Article ID 591680, 2013.
22. IEEE, “The Need For a large Adjustable Speed Drive Standard,” IEEE Std. 1566-2007.
23. Patrick A. Brady, “Application of AC motors with variable speed drive,” IEEE, Vol.89, 978-1-4245, 2009.
24. S. Dash, B. Nayak, “Buck-Boost Control of Four Quadrant Chopper using Symmetrical Impedance Network for Adjustable Speed Drive,” International Journal of Power Electronics and Drive System (IJPEDS), 5(3), pp.424-432, Feb, 2015.
25. M. Khodaparastan, A. Mohamed, W. Brandauer, “Recuperation of Regenerative Braking Energy in Electric Rail Transit Systems,” 2018 Electrical Engineering and Systems Science. arXiv preprint arXiv:1808.05938, 2018.
26. M. Swamy, J.. Kang, and K. Shirab, “Power Loss, System Efficiency, and Leakage Current Comparison Between Si IGBT VFD and SiC FET VFD With Various Filtering Options,” IEEE Transactions on Industry Applications, vol. 51, no. 5, pp. 3858-3866, 2015.
27. H. Chung, F. Blaabjerg, H. Wang, and M. Pecht, “Reliability of Power Electronic Converter Systems,” (no. Book, Whole). Stevenage: Institution of Engineering & Technology, 2018.