

# Regeneration in Variable Frequency Drives and Energy saving Methods

Rasin K R<sup>1</sup>, Arunkumar G<sup>2</sup>

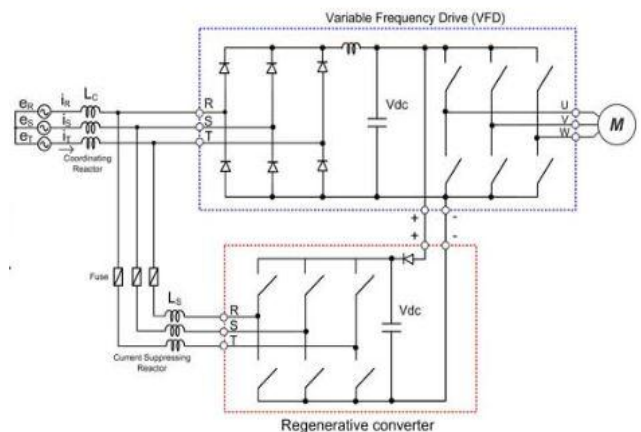
<sup>1</sup>MTEch in Power Electronics and Drives, VIT University, Vellore, Tamilnadu, India

<sup>2</sup>Professor, SELECT school, VIT university, Vellore, Tamilnadu, India

**Abstract** - When an induction motor is driven by a variable frequency drive, electric power delivered from the supply is regenerated back while the motor decelerates by applying negative torque to the motor shaft. Energy storage capacity inside the variable frequency drives is usually high limited so energy regenerated should be return back to the grid instead of dissipating as heat. This paper reviews different supply line regeneration options for effective utilization of regenerated power of variable frequency induction motor Drives and a comparison of this methods.

expensive. So it will be beneficial to understand about the basics of regenerative units and to review estimated energy cost saving. Three types of regenerative power units are available depends on the applications. Basic features and power topologies are explained and compared. Dynamic brake chopper and resistor arrangement is used to convert regenerated power in to heat loss because of low installation cost and simplicity.

## 1.1 Regenerative converter



In most of the Drives applications Braking choppers and resistors are used to simply dissipate the power in the form of heat loss. An efficient low budget alternative solution called line regeneration using Regenerative converters that can replace the use of the dynamic braking chopping circuit and external brake resistor network. During regeneration excess regenerative energy available in the inverter front end of variable frequency Drive bypass it to the ac power source through a converter circuit. Figure 1 illustrates how the excessive regenerative energy will feedback from an induction motor to the supply side by utilizing a regenerative converter circuit parallel to the drive inverter circuit. During motoring mode, the Variable frequency Drives transfer power to the motor terminals without coming the regenerative converter in the picture of main power flow. So during motoring there is no loss in the regenerative converter. When the regeneration taking place, the dc link capacitors starts charging. Regenerative converter will get activated because of regenerative energy

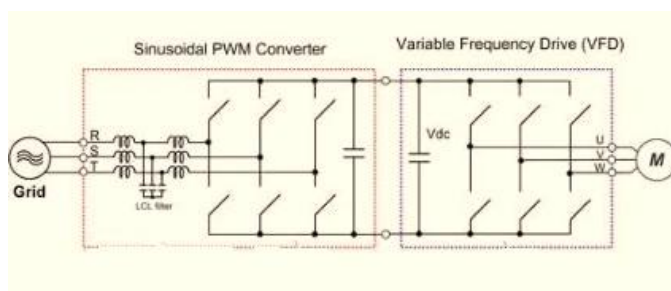
**Key Words:** Variable frequency Drives, Regeneration, Matrix converter, SPWM, Utility cost saving, Regeneration power unit selection.

## 1. INTRODUCTION

Some applications demands operation in a quadrant region where applied torque is in the opposite direction of rotation of Induction motor. The variable frequency Drive must be drive release stored energy from the mechanical load system through the motor terminals to the inverter. This situation faces when the variable frequency drive is trying to break the rotating induction motor, such as the motor inertia starts decelerating or a situation of whenever using loading as in a dynamometer, or when an overhauling holding back. As the Load fed back stored energy to the front end, the main DC bus capacitors of the drive starts charging. The lack of a proper method of utilizing that energy, will leads to continue rise of DC bus voltage to dangerous Level and the drive will get tripped on a fault of Bus over voltage. A method called line Regeneration discharges that energy from the DC bus capacitors and feed it back on the AC utility. The Regenerative power can be dissipated using an arrangement of Brake chopper and Braking Resistor there by the drive will be protected from overvoltage tripping. Also an overvoltage control enabling is available in variable frequency Drives. A significant energy cost saving can be achieved by a regenerative power unit especially in frequent on and off applications, deceleration along with large inertia load, and torque is in overhauling condition. Such applications include decanter centrifuges, hoists, spindle drives, cranes, elevators etc., because of this electricity cost per kilowatt hour is more

charges dc link capacitors of the variable frequency drives. The regenerative converter converts the Dc voltage in to AC and returns stored energy in the dc capacitors to the grid. Size of Variable Frequency Drives will vary according to the power ratings thereby the size of regenerative converters will vary according to drive size, Regenerative Power and Duty Ratio. The 6-step PWM method is used for switching thereby can reduce the switching losses in very low value. Some applications demands very high duty cycle braking, in such situations the regenerative converter can reduce the cost of electricity usage by significantly improving the system efficiency.

### 1.2 Sinusoidal PWM converter



In both motoring and regenerative power conditions a highly efficient solution developed to regulate dc bus voltage called sinusoidal PWM converter. The converter is designed to generate sinusoidal current waveform at supply mains side grid side with very low rate of harmonic distortion, approximately saying total harmonic distortion (THD) will be 5%.The converter is designed to obey the standard of IEEE-519 .To make possible the synchronization with input grid voltage control of input current also taking place, which will help to obtain a unity input power factor. The sinusoidal PWM converter is connected in series between the Variable frequency Drive and incoming power line. To reduce the harmonic from the grid side an AC filter is accompanied in front end of the grid side, usually a LCL filter is used as an external harmonic filter component to reduce input ac current harmonics. For controlling the inverter mostly sinusoidal PWM techniques is used because of it is possible to control the output voltage and frequency accordingly with sine functions Sinusoidal pulse width modulation is widely used in control applications. Because of circuit is less complex and simple control scheme. SPWM techniques are characterized by same amplitude pulses with different duty cycles for each period. The width of these pulses are controlled to obtain inverter output voltage modulation and to minimize its harmonic content there by reducing THD.

### 1.3 Matrix Converter

A matrix converter is a single stage conversion converter with direct ac to ac conversion having motoring and

regeneration capability. With the helps of bidirectional controlled switches direct conversion of power from AC to AC.The converter is characterized by sinusoidal waveforms that decides the output and input switching frequencies. By using bidirectional switches it is possible to control power factor input. In addition, the main advantage is lack of DC voltage link will provide compact design. The matrix converter using to control induction motors has more advantages over traditional rectifier-inverter type Variable Speed converters. The Input and output waveforms of Matrix converter is sinusoidal, with minimized higher order harmonics components, there is no subharmonics will present. Matrix converters has energy flow capability in both directions. Input power factor can be fully controlled.. It has minimal energy storage Requirements, Which will improve the lifespan of energy storing capacitors.

The disadvantages of Matrix converters are transfer ratio of its maximum input output voltage limited to nearly 85 % for sinusoidal output and input waveforms. Comparing to conventional frequency converters matrix converters requires more number of semiconductor devices which will increase the switching stresses. Discrete unidirectional devices are variously arranged to be used for each bi-directional switch because no monolithic bi directional switches exist .It is sensitive to the fluctuations of the input voltage systemIn matrix converters using nine bidirectional switches alternating input is directly transformed into variable frequency ac output. So sinusoidal regeneration converter and Variable frequency Drives functions are combined. This combination enables the induction motors' to operate in regenerating and motoring modes without using an additional Drive.Traditional rectifier-inverter circuit requires more maintenance because there is diode rectifier and dc electrolytic capacitor in the main power flow as a filter circuit. Normally, an electrolytic capacitor is bulky in size also has a shorter lifetime than other parts. But in matrix converters there is electrolytic capacitor present so needs less maintenance. It is possible to control Input current in matrix converters this capability reduce harmonics of input current significantly. Under full load condition input current harmonic THD is in the range of 5% - 10%. Unlike traditional frequency converters external line reactor circuit is not required to minimize current harmonics, which are usually bulky in size.

## 2. ENERGY SAVING USING REGENERATION CONVERTERS

For an application requires to feedback excess regenerative energy to the supply grid, line regeneration is an option. Regeneration happens when the load tries to rotate the motor shaft faster than the output frequency inverter output. This is usually called to as "overhauling", and may occur when trying to reduce speed a load, or applying mechanical power to the motor system by something on the loading. In

these conditions, the inverter is behaves to restrain the motion of the load by inertia and this leads to regeneration. Here a converter is used to sends excess regenerative power back to the grid by line regeneration technique. To accomplish this, the drive system must utilize a regenerative converter. This converter connected into the common dc link just like the existing drives. This converter receives excess feedback energy caused dc voltage from the DC bus and produce a six-step waveform back to the grid. By using matrix converter power factor is always kept nearly at 0.95. Because the power factor is constant or regardless of operation frequency, energy wastage is minimized. Regeneration results in to rise of DC bus voltage, will cause to tripping of variable frequency Drive because of DC bus overvoltage. The traditional method of resolving this issue is by using Brake chopper circuit and external resistors the regenerative power is dissipated as heat loss. A dc bus voltage sensing circuit is accompanied with chopper transistor which will sense the increase in dc voltage and which will enable the transistor and will conduct and dissipate the power in external resistor connected. Instead of simply wasting the energy as heat loss we can convert to efficient form and utilize in grid side. The Regeneration Converters replaces traditional dynamic braking system, and transform this regenerated power back into supply side grid. It converts that regenerated energy back into the grid as three-phase AC supply instead of wasting it as heat loss. By doing so the regenerated power can be feedback to input, and minimizes the energy consumption and therefore the utility bill. In other words regenerative converter unit is like another generator placed on the utility grid, supplying power into it by synchronizing to it.

### 2.1 Estimation of Energy Savings

The Regeneration converter unit converts the excess regenerated power in grid under the same condition of power is dissipated as heat. So that calculating total energy saving using a regeneration converter is same to calculating the heat loss taking place in braking resistor. For the above required braking duty cycle and braking torque must be determined. From the obtained data, we can calculate total amount of regenerated energy for a given period. The Regenerative converter converts almost 95% of regenerated energy in to grid. This gives all the variables needed to calculate the kW-hr reclaimed for give time period. By knowing the utility demand rate, this reading values can be converted into money and hence a payback period.

### 2.2 Comparison of Regeneration Converters.

In variable frequency drives under regenerative condition all three above said converters has good energy saving

capability. Instead of wasting the regenerated power simply as heat loss in external resistor circuit. The converter circuit said in first section multiple VFD connection is but low input current harmonics is present and medium level installation space is required. The best low-cost solution is sinusoidal PWM converter which has utility good utility cost saving using Regenerative braking and multiple VFD connection is possible similar to first converter. The best solution may differ if extra benefits such as low current harmonics and unity power factor are also important, The matrix converters is another fair solution which require less space comparing to other two regeneration converter units and multiple VFD connection is not possible and matrix converter is a product that has both regeneration converter and VFD capabilities inherently. The table compares regeneration power units.

**Table -1:**

Item	Regenerative converter	SPWM converter	Matrix converter
Utility cost saving by regenerative braking	Good	Good	Good
Low input current harmonics	None	Good	Good
Multiple VFD connection	Yes	Yes	No
Initial cost including VFD	Good	Fair	Good
Input power factor improvement	None	Good	Good
Installation space including VFD	Medium	Large	Small

### 3. CONCLUSIONS

There is huge amount of energy is wasting in variable frequency drives when a regeneration take place, By using brake chopper and external resistor arrangement the excessive regenerative power is simply wasted as heatloss. It can be found that from energy saving calculation almost 50% of energy is wasted as simply heatloss. By using Regenerative converters this excessive regenerative power can be feedback to the grid. For multiple VFD connections the converters explained in first and second section is good choice but in overall performance matrix converter is more efficient choice.

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