

# Different Types of Methods to Recover Regenerative Energy Replacing Conventional Dynamic Braking Of Variable Frequency Drive

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**Abstract -** The Variable Frequency Drive (VFD) is most used drive now a days in industries. But the conventional VFD has some energy loss as the dynamic braking is used in it. There are some different types of methods in how to use and convert the regenerate energy when motor acts as a generator and this energy can be saved rather than dissipating as heat in the dynamic braking. Some methods are shown in this paper.

**Index Terms -** Variable Frequency Drive (VFD), Dynamic Braking (DB), Hertz (Hz)

## I. INTRODUCTION

The drive is a general term responsible for controlled motion with specific start/stop and matched torque properties as required by the process, keeping input energy level at most minimum level while keeping efficiency to be the best one; in other words minimizing the losses. The drive could be alone or a combination of mechanical, hydraulic, pneumatic, electrical motors combined with control elements like gearbox, belts and pulley drives, chain drives, throttle valve, pressure regulator, and electronic systems with analog/digital controls. Almost 80% industrial motions are achieved by asynchronous induction motor. Thereby there is increasing population of AC digital drives replacing DC drives and simplifying mechanical drives [1].

A Variable Frequency Drive (VFD) is a simply a motor controller that drives an electric motor, generally a three phase squirrel cage induction motor, by varying the frequency and voltage supplied to the electric motor. VFD are also called with different types of names such as **variable speed drive, adjustable speed drive, adjustable frequency drive, AC drive, micro-drive and inverter**. The VFD is controlled by the frequency (Hz) which is proportional to the speed of the motor. As the frequency is increased the speed of the motor increases and vice-versa. The Variable Frequency Drive (VFD) industry is growing rapidly and it is now more important than ever for technicians and maintenance personnel to keep VFD installations running smoothly. Variable Frequency Drives (VFD) change the speed of motor by changing voltage and frequency of the power supplied to the motor. In order to maintain proper power factor and reduce excessive heating of the motor, the name plate volts/hertz ratio must be maintained[4].

The main task of Variable Frequency Drive are:

1. The VFD are used to stepless speed control of squirrel cage induction motors mostly used in process plants due to its ruggedness and maintenance free long life.
2. VFD control speed of motor by varying output voltage and frequency through sophisticated microprocessor controlled electronics device.
3. VFD consists of Rectifier and inverter units. Rectifier converts AC in DC voltage and inverter converts DC voltage back in AC voltage.

## II. OPERATION OF VFD AND THE BRAKING

There are mainly three different sections in the VFD named as: The three phase rectifier (which contains three legs of diode), the DC bus (consists of filter unit and braking unit) and the three phase inverter (consists of three legs of IGBTs).

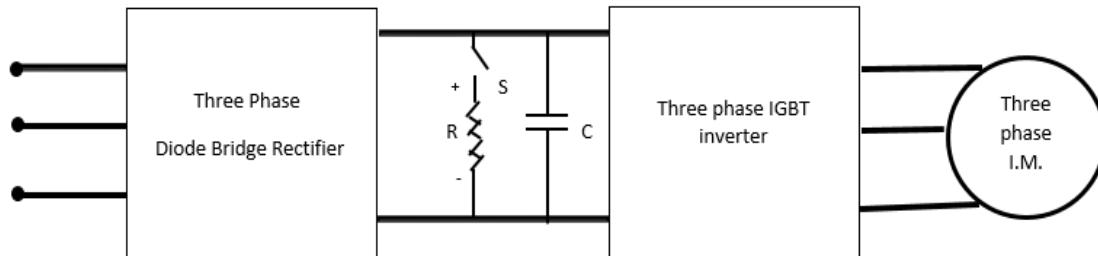


Fig 1 The Variable Frequency Drive (VFD)

The three phase ac supply is given to the rectifier section where ac is converted to DC and this DC voltage is generally about 650V. The DC voltage is then filtered out and the harmonics are removed. The DC voltage is converted to ac voltage through the three phase inverter and induction motor is connected to it which runs. The controlling section is in the inverter where frequency is changed and the speed changes.

The reasons why motor works as a generator:

1. Quickly decelerating a high inertia load (flywheel, mechanical arm)
2. Controlling the speed of a load moving vertically downward (hoist, declining conveyor)
3. A sudden drop in load torque occurs (machining/drilling operation or an industrial saw)
4. The process requires repetitive acceleration and deceleration to a stop (indexing)
5. Controlling the speed (tension control) of an unwind application
6. Running motors can be brought to a halt quickly without any mechanical tear. After the supply has been cut-off

When the motor works as a generator, the energy from the stator is flow back to the DC bus through the inverter section. In the DC bus, if the voltage rises above some level of the voltage, the braking chopper turns ON and the resistor connected to braking chopper in series, where the excess energy gets dissipated in the form of heat. Hence the motor gets stop slowly. This method is called dynamic braking of VFD. This method is generally used in the current period in industries. Fig 1 shows conventional dynamic braking of VFD. Dynamic braking (DB) is typically used for applications that require frequent or rapid braking, especially of heavy (high inertia) loads. However, many such applications could also be candidates for regenerative converters.

The waste heat generated by DB often creates the need for additional cooling and air-conditioning. A regenerative unit will save the customer energy and money by eliminating that waste heat and returning that energy back to the AC line. Implementing a regenerative unit in the system will allow for a smaller cooling system (HVAC), offsetting the up-front cost of the regenerative unit, and reducing the demand on the cooling system. One regenerative unit can feed several drives connected on common DC bus and optimize energy consumption by recovering excess regenerative energy not used by the drives.

### **III. METHODS TO RECOVER REGENERATIVE ENERGY**

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There are mainly three different types of methods to recover the regenerative energy of the VFD when it works as a generator:

1. Snubber resistor braking
2. Line regeneration control
3. Synchronous rectifier control

#### **Snubber Resistor control**

Snubber Resistor Braking kits use a transistor and circuitry that “turns on” at a predetermined DC bus voltage, which is set below the AC drive’s trip point. At this voltage level the energy is transferred to a resistor (or group of resistors) where the energy is burned off as heat. Some AC drives already include a built-in braking transistor and only require the addition of a resistor kit. Snubber resistor braking kits are a lower cost solution compared to line regeneration controls or synchronous rectifier controls. Snubber braking resistors, however, require cool down time, which make them less suitable for highly cyclical operations such as frequent, repetitive starts and stops. Line regeneration controls or synchronous rectifier controls are more suitable for these applications.

#### **Line Regeneration control**

Line Regeneration Controls use a set of transistors, which pulse “on” at a predetermined DC bus voltage set below the AC drive’s trip point. At this voltage level the energy is transferred directly back to the AC power source. Line regeneration controls can operate in a continuous mode up to the transistor current rating[3]. Their ability to regenerate power back to the power source also makes them an energy saving device. Over time this energy savings can offset the higher cost of these controls. As shown in Fig 2. the regenerative module converts the excess energy from the DC bus to three phase ac power and pass it to the source back thus saves the energy.

If we go back to the three-phase bridges mentioned earlier, we get some insight into how a Regenerative Brake works. The IGBT bridge inside the regenerative Converter is connected in parallel with the diode bridge of the drive. When one of the diodes in the drive’s diode bridge is forward biased, the diode in the same relative position in the IGBT bridge is also forward biased. Remember that the two bridges are basically connected at the DC bus and the AC line terminals[6].

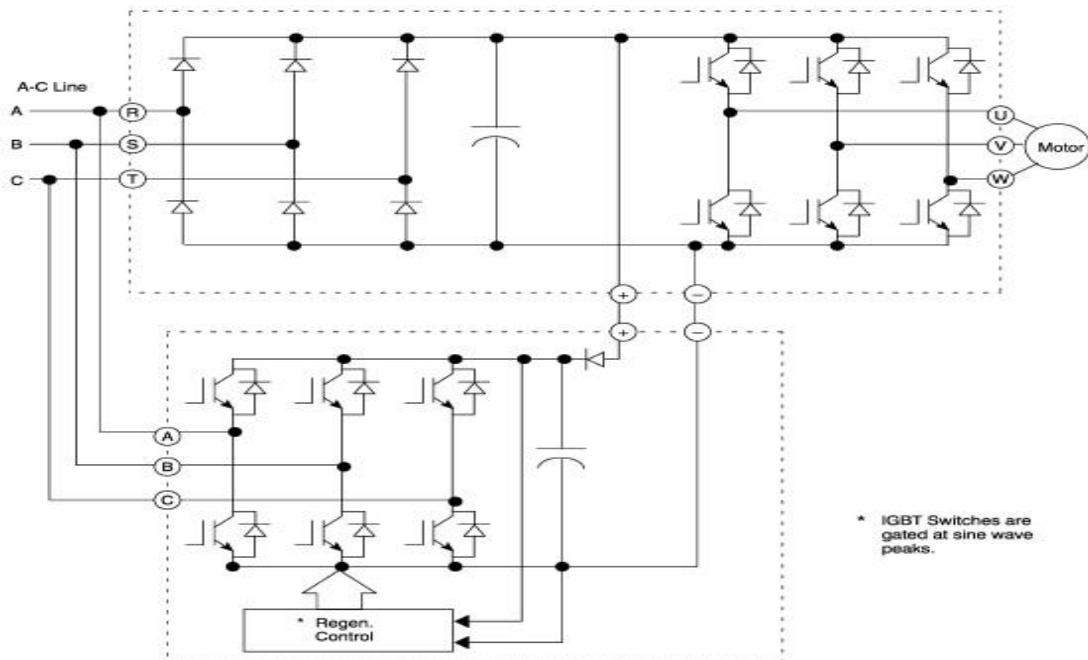


Fig 2 Line Regeneration Control

#### Synchronous rectifier control

Synchronous Rectifier Controls can be used either as line regeneration controls or as AC line voltage to DC voltage converters for powering the DC bus of an AC drive. This is the newest technology which can be the ultimate solution of a regenerative drive. The circuit of this consists of two IGBT bridges with both of them controlled by PWM as shown in Fig 3. The converter bridge gating is synchronized to the A-C line. The resulting input currents are nearly sinusoidal with 5<sup>th</sup> and 7<sup>th</sup> harmonics are removed which we see in diode bridge converter[3].

In the motoring mode, the IGBT converter bridge works with a resonant tuned input line reactor and DC bus capacitor as a boost converter to create DC bus voltage. This intermediate voltage is higher than that created by a conventional diode bridge rectifier. In the regenerative mode, the IGBT bridge feeds width-controlled pulses of the excess C bus voltage maximizing input power factor. The synchronous PWM rectifier may be tuned to create a leading power factor, compensating for other lagging loads in the system[3].

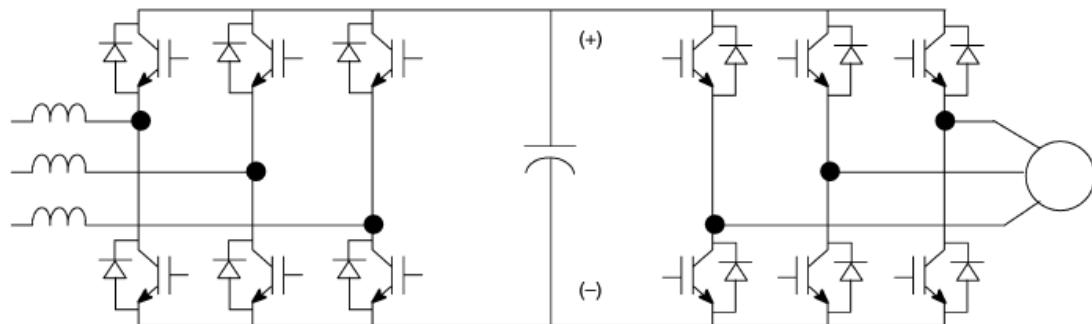


FIG 3 Synchronous Rectifier Control

#### IV. APPLICATIONS OF REGENERATIVE AC DRIVE

- Overhauling loads
- High inertia loads
- Machine requiring fast deceleration
- Flywheels
- Vacuum pumps
- Locomotives
- Cranes and hoists
- Elevators
- Drums/ kilns
- Injection molding machines, etc

#### V. CONCLUSION

The above discussion states that the conventional braking of VFD can be replaced by different methods to recover regenerative energy of the motor. Of all the three methods, the synchronous rectifier control method is best as it has lower cost and high efficiency. Also the cost of the energy losing can be reduced with this implementation.

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