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SCR-Regenerative Ac Drive

Using a regeneration controller with adjustable-frequency drives to return energy to the Ac power line was once considered too costly. Now, line regeneration joins the more common schemes as available method for controlled deceleration and applications requiring retarding torque. When a load becomes overhauling, the load turns the rotor faster than its synchronous speed. The motor acts as an alternator, converting mechanical energy to electrical energy. If we add an adjustable-frequency drive into the equation, the synchronous speed can be at any operating speed. The synchronous speed of an Ac motor is proportional to the applied frequency. For example, a four-pole motor operating at 60-Hz power has a synchronous speed of 1,800 rpm. At 30 Hz has a synchronous speed of 900 rpm. A typical example of a regenerative load application is a crane. In the hoist mode the motor receives its energy, by rectify the incoming Ac power into a filtered Dc bus section, then the power device in the inverter section modulates this Dc voltage into variable-voltage and variable-frequency Ac power to raise the motor. In this mode the Ac lines are supplying the energy required to lift the load. When traveling downward, however, the motor acts as an alternator, now converting the mechanical energy into electrical energy back into the Dc bus.

Most adjustable-frequency drives have only a **one-way street**; the rectifier section can only deliver power to the Dc bus. No provision exists for transferring energy from the inverter section back to the power line. The reason is that most adjustable-frequency drives use **uni-direction Ac-to-Dc rectifier**, typically consisting of a diode or SCR bridge rectifier. This makes economic sense, because the majority of the applications require motoring only. When an overhauling load is encountered, the problem is due to the fact that the Dc-to-Ac inverter section is **bi-directional**, enabling motor counter voltage (energy) to flow back through this **bi-directional** inverter section to increase the Dc bus voltage. However, the typical **uni-direction Ac-to-Dc rectifier** section can't return the energy to the Ac lines. Should an overhauling load condition occur, the drive would trip on over-voltage, to protect from exceeding the allowable voltage limits. (Fig. 1)

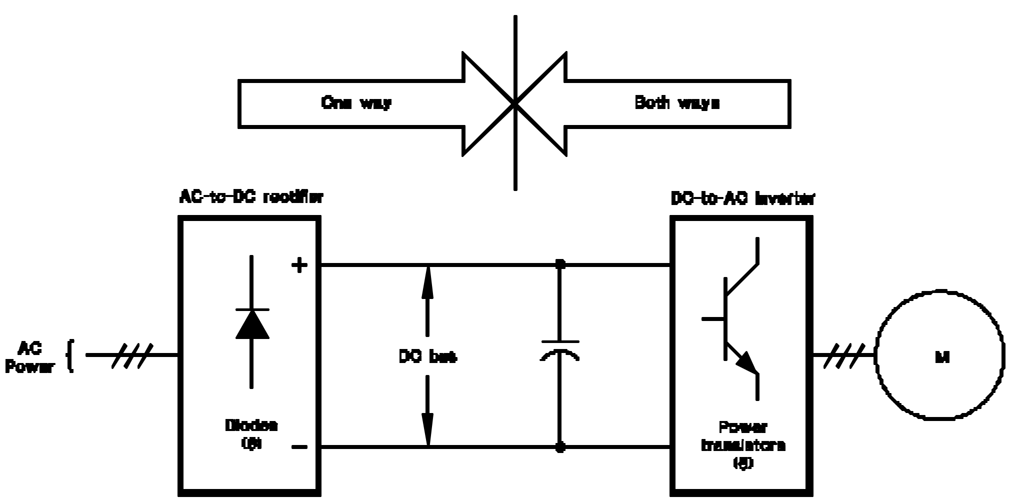


Fig. 1 Typical nonregenerative ASD with pulse-width modulated

Voltage Transients:

Another condition that will cause the constant Dc bus voltage to increase is voltage transients, the momentary increase in the line voltage forces current through the rectifier and into the filter capacitors. If more energy flows through the rectifier than is removed by the motor load, an over-voltage condition results.

Dynamic Braking:

The term dynamic braking is often used to describe the resistive braking module that is used in both Ac and Dc drives. The requirements for applying braking resistors to the Ac and Dc drives systems differ greatly. But in short they both provide braking torque with a stop command.

Ac drive applications, requiring braking option consists of an electronic switch and power resistor. The electronic switch is sometime called the braking transistor or a brake chopper. Ac drive braking kits may also include Dc bus fusing, thermostats, and a means to disconnect the resistors from the drive during over temperature conditions. Braking resistors may be used to dissipate regenerative energy during either speed changes or stops. It is usually not appropriate or cost effective to use dynamic braking for continuous duty. When used for those applications the dissipated heat results in excessive temperatures for the control cabinet or control room. Line regeneration modules, which are typically 95% efficient, provide a more cost-effective solution.

Line Regeneration Options:

Line regenerative options provide a cost-effective alternative to resistive braking option, especially for continuos regenerative applications. There are three primary technologies that are available.

1. Synchronous PWM rectifier (Fig .2)
2. Current Source Inverter CSI (Fig. 3)
3. Regenerative 6-pulse SCR rectifier (Fig .4)

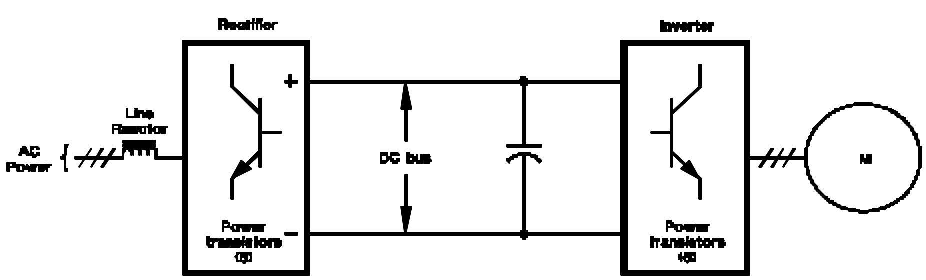


Fig. 2- Synchronous rectifier PWM Inverter

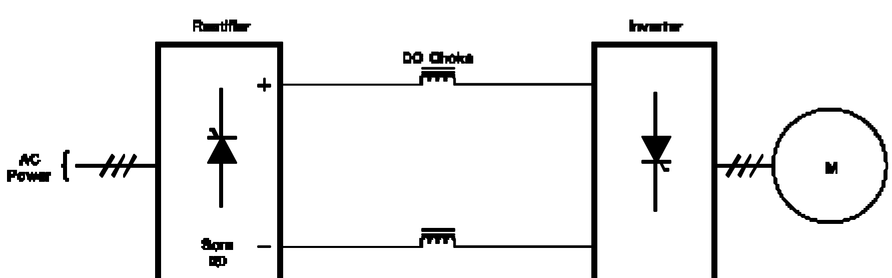


Fig. 3: Current source inverter (CSI)

Principle of Operation for the HMS-R:

During motoring and standby condition the input diode rectifier section functions in the normal manner providing a 660 Vdc supply to the Dc bus from a 460 Vac supply. During regeneration the Dc bus voltage rises and exceeds the voltage produced by the SCR bridge causing the current to be forced into the HMS-R bridge, and inverted back onto the main supply via the auto-transformer. The HMS-R may be enabled continuously. If this option is selected there will be a certain amount of current circulating between the rectifier bridge and the SCR bridge. This is because the SCR bridge, produces less opposing voltage when the current is discontinuous. This current will depend on the value of the Dc chokes, because these determine the size of the discontinuous pulses. With the values recommended the circulating current will be approximately 10 -15% of full load current and will not normally be a problem. The circulating current may be largely avoided by inhibiting the HMS-R when regeneration is not required.

It is also recommended to delay the energizing of the HMS-R upon power up. This can be accomplished by using the "Run "or "Lower" contact to enable the HMS-R.

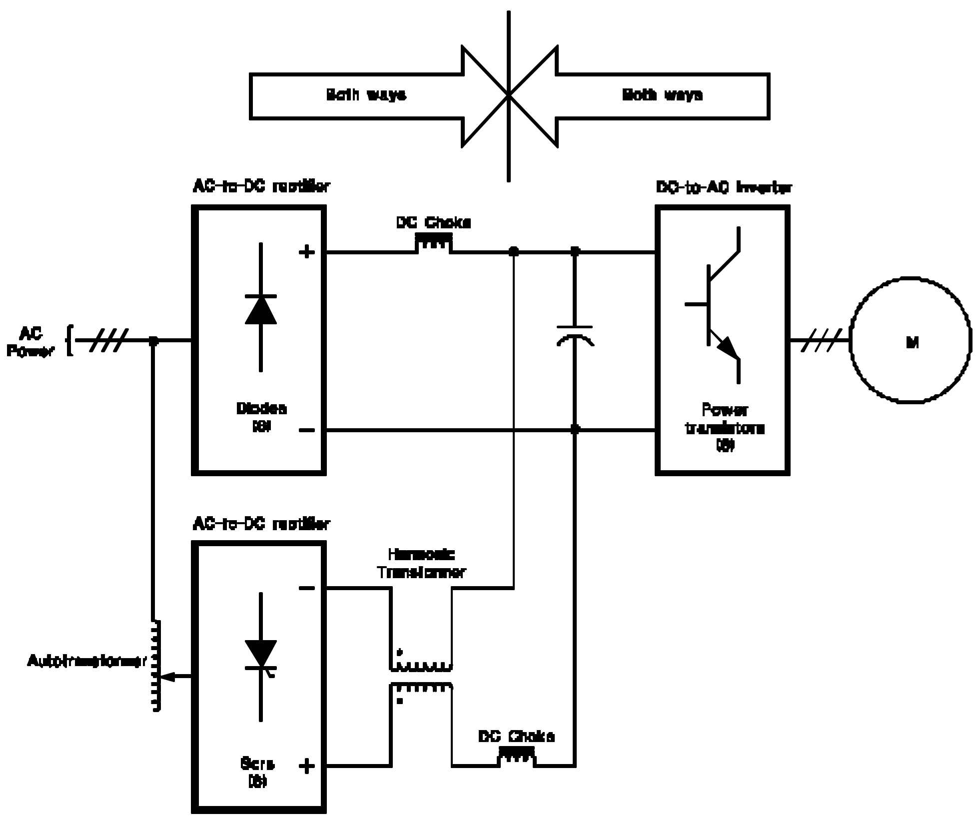


Fig. 4 SY6-R thyristor regenerative controller

Sizing for the Application:

Except for applications like unwinders, the magnitude of the regenerative torque is generally less than the motoring torque. Therefore, the rating of the regenerative module is less than motoring unit. This is because friction and windage increase the power needed for acceleration, and they decrease the magnitude of the regenerative torque. Naturally, the amperage rating of the regenerative module is equal to or smaller than the main inverter section based on the worst-case requirements.

Typically referred to as an **HMS-R**, the Stevens Drives, Inc. reverse-connected six-pulse phase controller can be used with any Adjustable Speed Drive. A common practice is to connect an auto-transformer or isolation transformer to the **HMS-R** converter bridge. The reason for the auto-transformer is to raise the line voltage to an acceptable line voltage for the phase-controlled bridge (SCR) to operate with the normal Dc bus voltage of an ASD. Also to guard against inverting faults, this is an unwelcome phenomenon that occurs when the Dc bus voltage exceeds the peak of the sine wave Ac line voltage. This can cause a reverse-bridge SCR to remain in conduction while a forward-bridge SCR conducts, resulting in phase-to-phase short circuit. To avoid this, the reverse-rectifier (**HMS-R**) is connected to a higher voltage source.

The **HMS-R** system uses a single quadrant phase-controlled bridge to absorb power when required from the Dc bus and returns it to the Ac input.

The input rectifier, filter chokes and Dc bus capacitors may already be present in the standard Ac drive module. The components that must be added consist of the following:

1. **HMS-R** reversed **6**-pulse phase controlled bridge and associated firing circuit

2. **Auto-transfomer** steps up the supply voltage by 20 % from 480V to 575V.

3. **Dc Chokes** are provided to limit the 360 Hz ripple from rising, from the un-smoothed voltage produced by the rectifier and the SCR bridge.

4. **Harmonic Transformer:** This component is a small transformer with low voltage, high current windings. Its purpose is to prevent the circulation of triple harmonics.

5. **Fuse**: High-speed semiconductor line fuses must be supplied with the HMS-R. Rated at least 700Vac. Along with 1000Vac Mov. and a Suppression card.

Test Procedure on the HMS-R

The following is a list of equipment used to perform the following test reports. Using the motor test stand of the 40 Hp Ac motor coupled to the 40 Hp Dc motor. (Fig. 5)

Qty 1 50 Hp, AC inverter.

Qty 1 HMS-R61-6 rated at 61 amps Dc.

Qty 1 45Kva, Auto-transformer rated at 55 amps continuous

Qty 1 Harmonic Transformer 87:87 Volts at 63 amps continuous.

Qty 1 1.5mh.DC Choke rated 62 amps continuous.

Qty 1 Dc 12 Regenerative drive.

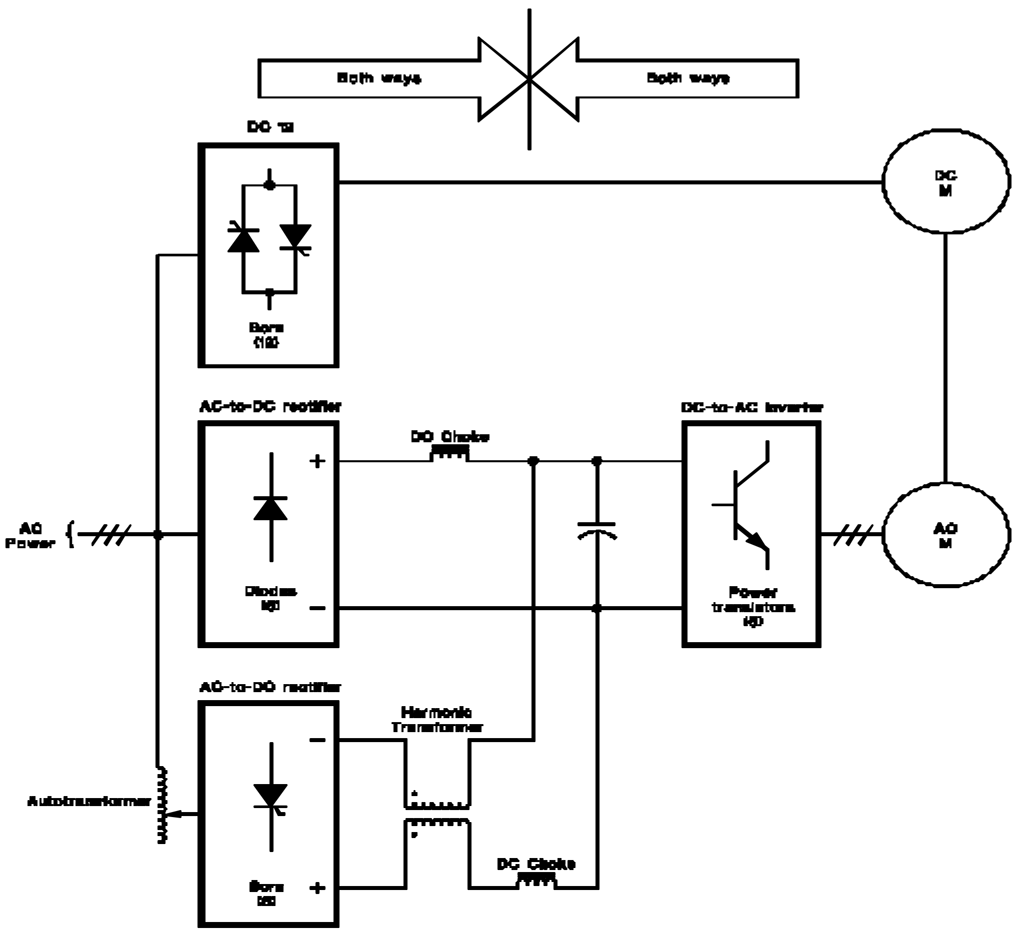
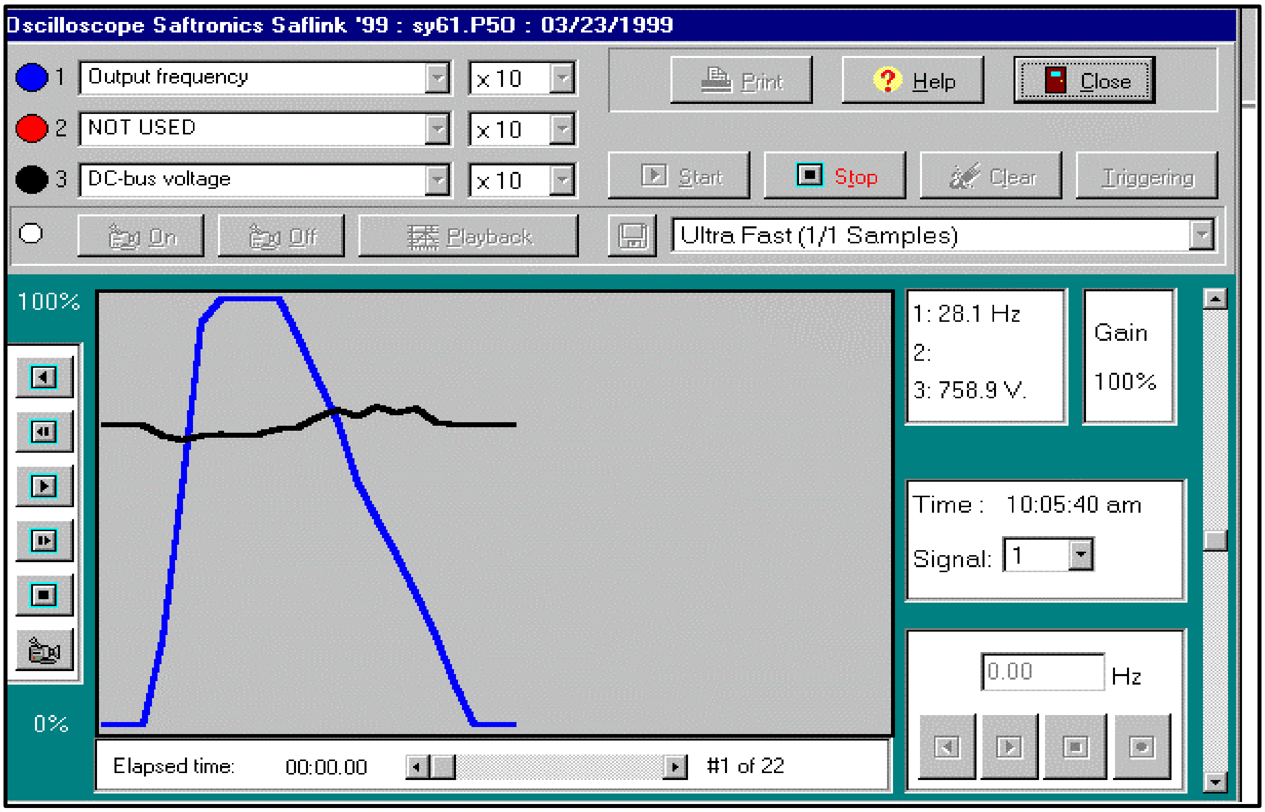


Fig. 5- AC-DC test stand

Test #1 Standard Inverter used without the HMS-R connected.

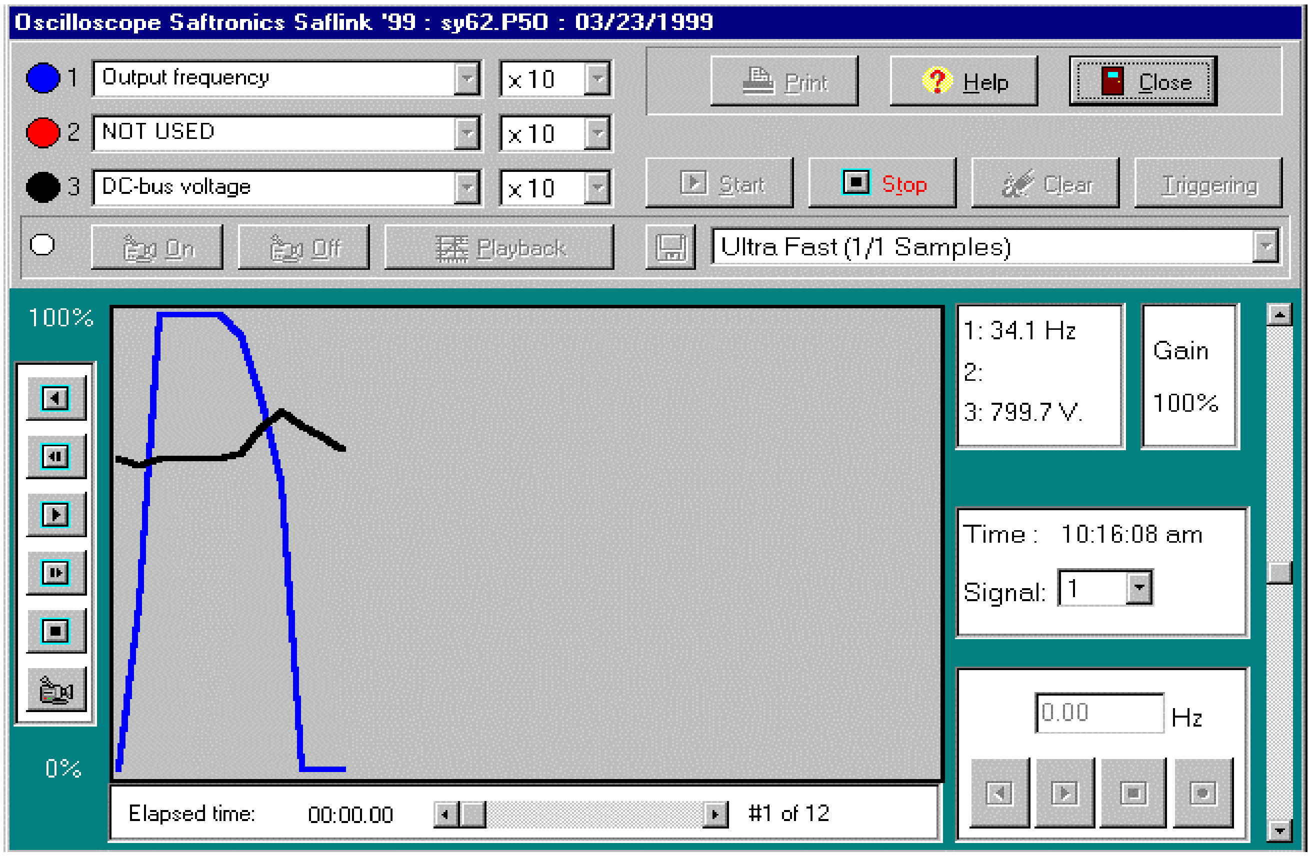
Objective: To find the minimum deceleration time without causing an over-voltage trip. The HMS-R controller for line regeneration was disabled. Fig 6



The object was to run the 40 Hp Ac motor up to full speed and find the minimum deceleration rate that would not cause an over-voltage trip to the inverter. The motor test stand of a 40 Hp Ac motor coupled with a 40 Hp Dc motor was ramped up to maximum speed with a 5 seconds acceleration time. The Dc motors inertia is acting as a light load driven by the Ac motor. The Dc motor inertia will add to the Ac rotor inertia on deceleration. With a stop command and with a rate of 20 seconds the drive did not trip on an over-voltage. It is important to note that the stall function was enabled. With this feature you can see that the deceleration time was extend out to the 20 seconds to prevent the over-voltage trip. The Dc bus voltage indicated above did not exceed the level of 758.9 Vdc. Notice how the Dc Bus voltage goes low on the acceleration, as more energy is being removed from the Dc bus then what the line can supply on acceleration. Once the set speed is reached the Dc bus voltage would have settled in at the line supply, but the stop command was given to decelerate to 20 seconds. Again note the deceleration time is controlled to prevent over-voltage automatically.

Test #2: Standard Inverter used without the HMS-R connected.

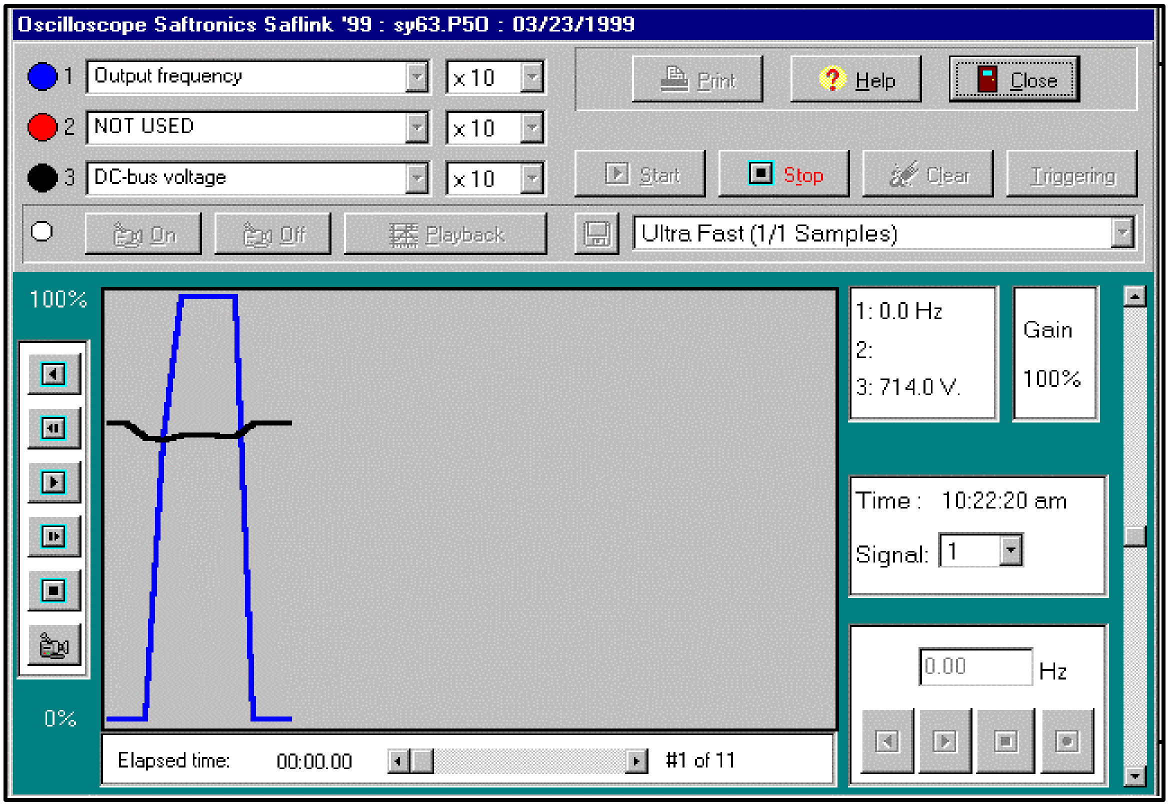
Objective to find the maximum deceleration time to cause an over-voltage trip The HMS-R controller for line regeneration was disabled. Fig 7



The object was to run the 40 Hp Ac motor up to full speed and find the maximum deceleration rate that would cause an over-voltage trip to the inverter. The motor test stand of a 40Hp Ac motor coupled with a 40 Hp Dc motor was ramped up to maximum speed with a 5 seconds acceleration time. The Dc motors inertia is acting as a light load driven by the Ac motor. The Dc motor inertia will add to the Ac rotor inertia on deceleration. With a stop command and with a time of 19 seconds the drive did trip on an over-voltage. It is important to notice that the stall function was disabled in this test. So as not to extend the deceleration time out automatically to the 20 seconds to prevent the over-voltage trip as it did in previous test. The Dc voltage of 799.7 Vdc indicated above is the maximum voltage that caused the drive to trip on over-voltage trip. At the voltage trip point the inverter faulted removing the motor counter voltage (energy) from flowing back through this **bi-directional** inverter section to increase the Dc bus voltage. However, the inverter now with the load disconnected continued on its deceleration ramp to zero.

Test #3: Standard Inverter used with the HMS-R connected.

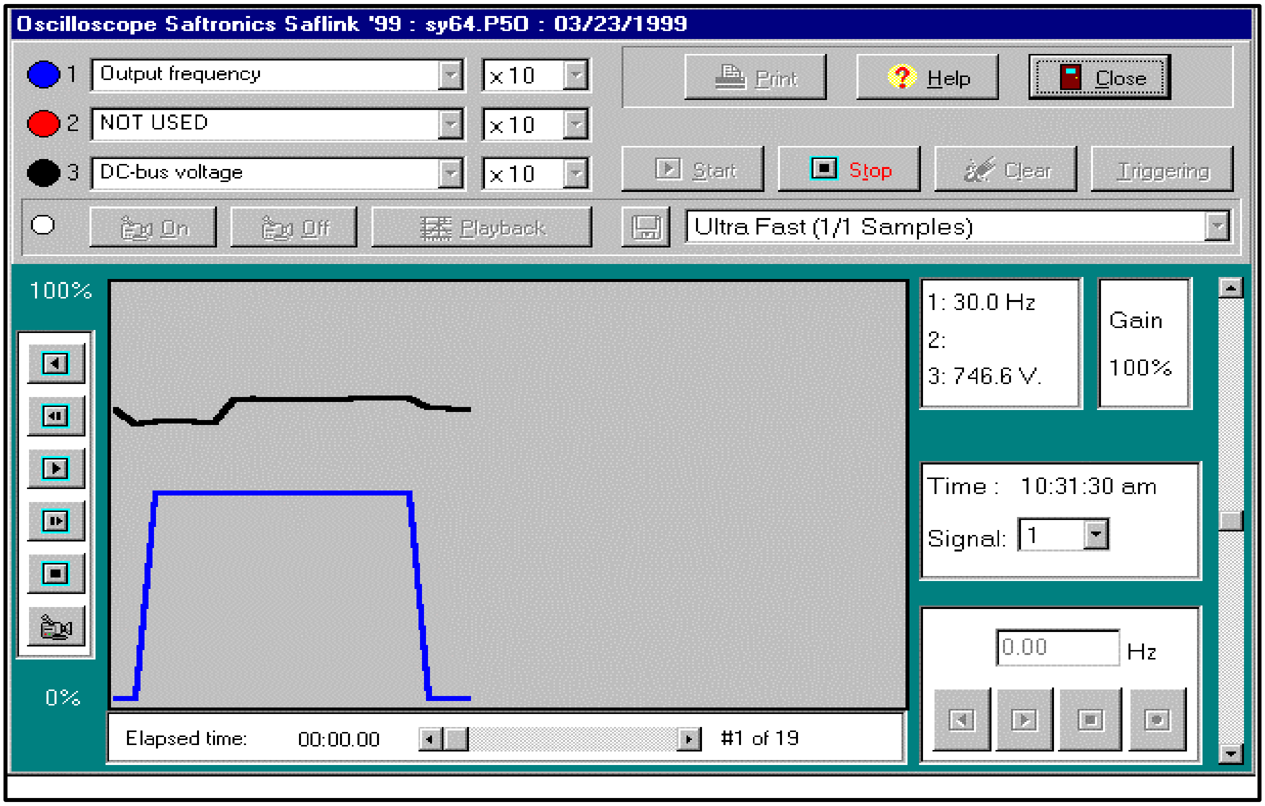
Objective is to decelerate the motor to a stop in 0.2 seconds with the use of an HMS-R controller for line regenerative. Fig 8



The object was to run the 40 Hp Ac motor up to full speed and find the minimum deceleration rate that doesn't cause an over-voltage trip to the inverter. The motor test stand of a 40Hp Ac motor coupled with a 40 HP Dc motor was ramped up to maximum speed with a 5 seconds acceleration time. The Dc motor acting as a light load driven by the Ac motor. The Dc motor inertia will add to the Ac rotor inertia on deceleration. With a stop command and with a rate of 0.2 seconds the drive did not trip on an over-voltage. It is important to notice that the stall function was disabled. The voltage indicated below is the maximum voltage.

Test #4: Standard Inverter used with the HMS-R connected.

Objective to create an overhauling load on the Ac motor and to show the continuous line regeneration using an HMS-R controller. Fig 9



The object was to run the 40 Hp Ac motor up to 50 % of maximum speed and run the Dc motor at 100 % speed to over-haul the Ac motor. The Ac motor becomes overhauling, when the Dc motor turns the AC motor faster than its synchronous speed. The motor acts as an alternator, converting mechanical energy to electrical energy. This allows the motor counter voltage (energy) to flow back through this **bi-directional** inverter section to increase the Dc bus voltage. During regeneration the Dc bus voltage rises and exceeds the voltage produced by the SCR bridge causing the current to be forced into the HMS-R bridge, and inverted back onto the main supply via the auto-transformer (wave-form fig.11&12 shows the line current and line voltage on one phase). Notice the Dc bus voltage was clamped at 746.6 Vdc when the Dc motor was overhauling the Ac motor. The waveform above shows as in the previous test that the Dc bus voltage goes down on acceleration. When the speed set point was reached the Dc bus voltage settled in at the line supply, until the Dc motor overhauled the Ac causing the Dc bus to rise to 746.6 Vdc.

Single Phase Line Wave-forms

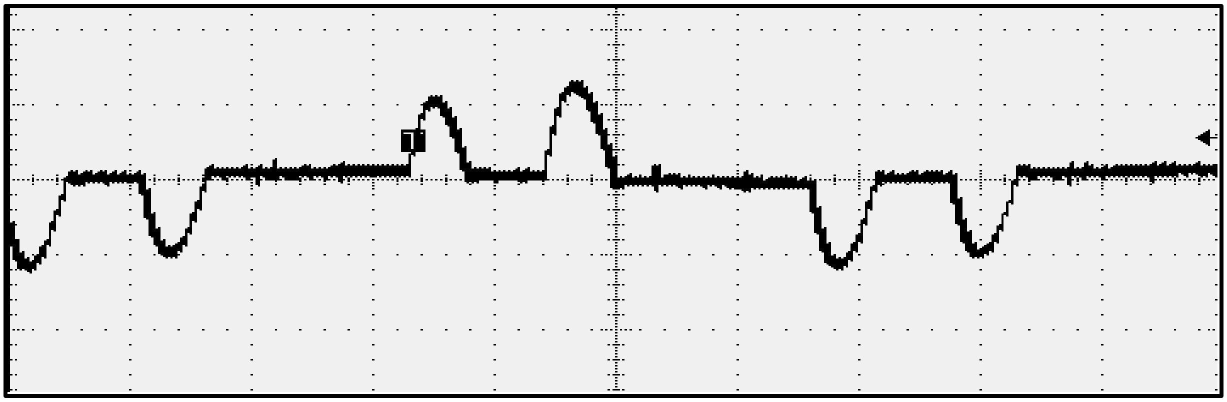


Fig. 10. Current waveforms showing a current of 6.9 amps when the 40Hp Ac motor is coupled to the freewheeling 40 Hp Dc motor.

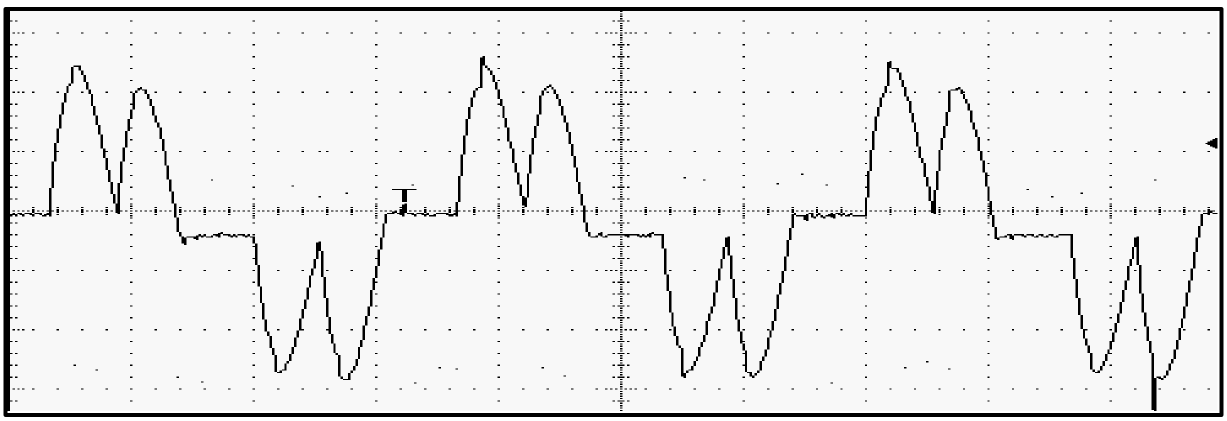


Fig. 12 . Current Waveforms showing the current of 31.9 amps when the 40Hp Ac motor coupled with a 40 HP Dc motor overhauling the AC motor.

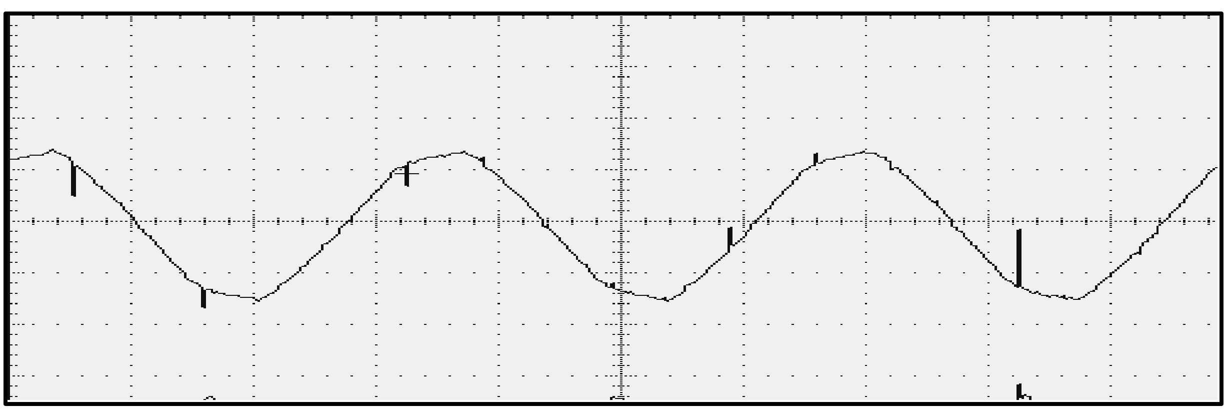


Fig. 13. Voltage Waveforms showing the line voltage when the 40Hp Ac motor coupled with a 40 Hp Dc motor overhauling the ac motor. Regenerating line currents of 31.9 amps.