THE ADVANCED SMART STARTER SYSTEM- HTLC

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Abstract -The High Torque Low Current (HTLC) Starter is the new innovative motor soft starter system. This is a motor starting method for high inertia loads using a low voltage drive with input and output transformers to control motor torque and limit current when starting a medium/high voltage motor. The HTLC is a solution to motor starting problems where Direct on Line (DOL) or "Across the Line" starting is not feasible due to high in-rush current causing problems on the distribution system or where a reduced voltage starter cannot provide enough torque to achieve breakaway and accelerate the motor to full speed. The main features of HTLC starter system are reduction of starting inrush current from 600% to 10% and over 60% breakaway torque available during starting, significantly less costly than a fully rated VFD and multiple motors can be started from a single HTLC. The standard Synchronous motor, those designed for Line Supply and fixed speed, have brushless dc excitation and use built in induction motor features for starting. For the soft or weak line condition (allowed current <100%) the > 400% Direct On Line current will be unacceptable. Reducing the voltage will reduce the starting torque in proportion to the voltage squared, so there may not be enough torque. The HTLC system utilizes a VFD to ramp up the voltage and frequency from start to 100% speed. The relatively poor induction motor characteristics (small cage & high slip) prevent the synchronous motor from achieving good torque efficiency. The great benefit of the synchronous motor (with variable stator frequency) is that torque is proportional to the product of the stator and excitation flux.

Keywords-HTLC, Synchronous Motor, Starters, Protection, Relays Starting Torque, Starting Current

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1 INTRODUCTION

The HTLC (High Torque Low Current) Starter is motor starting method for high inertia loads using a low voltage drive with input and output transformers to control motor torque and limit current when starting a medium/high voltage motor. The HTLC is a solution to motor starting problems where Direct on Line (DOL) or "Across the Line" starting is not feasible due to high in-rush current causing problems on the distribution system or where a reduced voltage starter cannot provide enough torque to achieve breakaway and accelerate the motor to full speed developed from the combined experience of Converteam, one of the world's leading manufacturers of large VFD's and drives systems, this unique soft-starter is aimed primarily at the Oil and Gas industry for starting medium/high voltage compressor motors. The HTLC starter solves these problems with a combination of innovative engineering and power electronics application and design know how.

2 THEORY OF OPERATION

The HTLC is equipped with an input isolation transformer to change the Medium Voltage supply to a low voltage level, typically 690 Volts. The VFD is chosen to deliver the current needed to start the motor and connected load. An output transformer, connected as an auto-transformer, is used to change the voltage back to the same level as the utility supply. The motor is supplied with the proper voltage and current to accelerate it from rest to the frequency of the electrical supply grid. The auto-transformer uses three resistors connected in series with the windings at low frequencies to add impedance to the circuit and limit the transformer saturation current. As the frequency increases the resistors are removed from the circuit and the transformer then operates normally.

The VFD operates at its own variable frequency and will not be in synchronism with the grid when the motor reaches full speed. In order to match the grid frequency the inverter will typically run at a frequency slightly above the grid so that the VFD and the grid will match the phase rotation and can accommodate any variations in the supply frequency. The HTLC contains a synchronizing relay that determines when the two are frequency and phase matched.

When the match is detected a signal is sent to close the bypass circuit breaker or contactor in the Medium Voltage Switchgear.

Once the breaker closes the inverter load will increase as it is still running at a frequency slightly higher than the supply but still in parallel with it. At this point the HTLC Output Circuit Breaker will open, the drive will shut off and the motor is then operated solely from the utility supply. The HTLC input power can be removed at this point, as the starter is no longer required. A typical HTLC schematic is shown in Fig.1

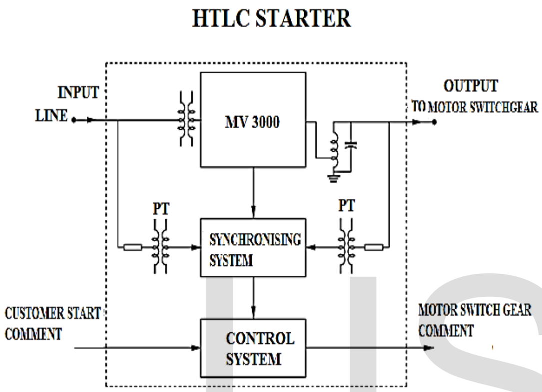

Fig.1 A typical HTLC

On a medium voltage supply the HTLC would be fed by a separate fused disconnect or contactor arrangement. A single HTLC starter can be sequenced to start multiple motors off a common bus. A separate isolating contactor is required for each motor to be started. Shown in Fig.2

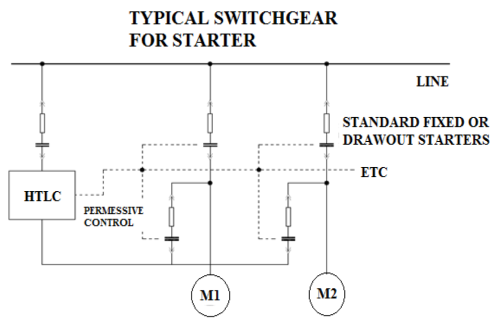

Fig.2.HTLC with multiple motors

3 HTLC WITH SYNCHRONOUS MOTOR

The standard Synchronous motor those designed for Line Supply and fixed speed have brushless dc excitation and use built in induction motor features for starting. For the soft or weak line condition (allowed current <100%) the > 400% Direct On Line current will be unacceptable. Reducing the voltage will reduce the starting torque in proportion to the voltage squared so there may not be enough torque. The HTLC system utilizes a VFD to ramp up the voltage and frequency from start to 100% speed. For a typical induction motor this allows a very effective motor utilization achieving near 1 per unit torque / current at all speeds.

The relatively poor induction motor characteristics (small cage & high slip) prevent the synchronous motor from achieving good torque efficiency. For a given motor the ratio of Torque / Stator current is maximum of 0.4 at 90% speeds (10% slip). Even with the benefit of a VFD providing the maximum torque efficiency at all speeds the value of 0.4 would mean we need > 100% stator current for 44% breakaway torque. The great benefit of the synchronous motor (with variable stator frequency) is that torque is proportional to the product of the stator and excitation flux. If excitation can be 100% the required stator current for 44% torque reduces to 44% or less. This solution requires an AC exciter.

3.1 Starting Sequence with HTLC

Motor at zero speed, the exciter supply applies voltage to the synchronous motor's AC Exciter. Main field current is applied through the rectifier and the Exciter control loops are now satisfied (balanced 3 phase currents above minimum and below overload) in Fig.3. Field current is regulated to 100%. HTLC autotransformer is energized with resistance in 3 neutral connections. This allows very low frequency (even zero) with a limit to transformer saturation current. In this mode the VFD controller injects a current source (rated VFD current) which pulls the motor in step and accelerates as the frequency increases to ~ 5%. Around 5% speed (and frequency), a significant voltage is required for the current source (neutral

resistor and motor impedance in series). A contactor shorts out the neutral resistor. Since the controller is in "current source mode" no change or step is realized by motor, but VFD voltage decreases due to shorted neutral. The VFD control system switches to Synchronous Motor Vector Control. The inner loop controls current amplitude and phase to maintain stability to accelerate the motor and load to higher speeds. The outer loop checks motor voltage versus speed (should follow a linear volts per hertz to rated volts) and outputs a field current reference for Exciter. Effectively these control loops will achieve a VFD current providing for torque and field current providing for VARS.
As the system approaches rated full speed;

- The frequency will be approaching 50Hz (controlled by vector control)
- The voltage will be motor rated voltage (controlled by field adjustment)
- The stator Power Factor will be unity (controlled by vector control)
- The Synchroscope / Synch check relay will close the transfer contact to initiate LINE BREAKER CLOSE with motor, HTLC and LINE all in parallel, line current will be small (HTLC is supplying the motor)
- Once HTLC OUTPUT BREAKER opens the LINE will pick up the motor current
- Exciter is controlled from the HTLC processor.

By operator choice the exciter will maintain unity power factor within the motor limits or will maintain constant field current. The motor continues running as normal with the stator connected to the LINE and the Exciter controlled by the HTLC. Once the motor has started and synchronized the VFD is now out of the circuit, with the stator connected to a fixed frequency and voltage supply.

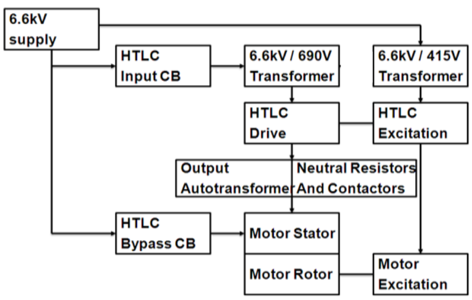

Fig.3 Synchronous motor with HTLC block diagram

This is the main application of the HTLC starter. The connection of the synchronous motor with HTLC was mainly implemented in the industrial application .here the machines were high rated machine and the overall parameters are in kilo volt or mega volt. The main supply of the industries will be very high because of the capacity of the plants are different. The application tells the use of the HTLC with a synchronous motor in a high voltage capable industry. The motor continues running as normal with the stator connected to the LINE and the Exciter controlled by the HTLC. Once the motor has started and synchronized the VFD is now out of the circuit, with the stator connected to a fixed frequency and voltage supply. The connection diagram was shown in the Fig. 4

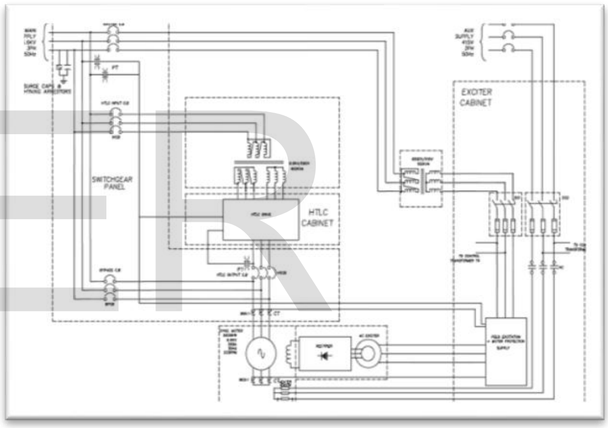

Fig.4 HTLC with synchronous motor layout

4 SIMULATION RESULTS

SCADA stands for Supervisory Control And Data Acquisition. It generally refers to an industrial control system: a computer system monitoring and controlling a process. The SCADA analysis output for HTLC starter is shown in Fig.5 the window page, six graphs are shown. All the X axis are time and Y axis shows the voltage, current, torque, power factor, speed, frequency, each graph shows the relation and can understand the result of particular starter.

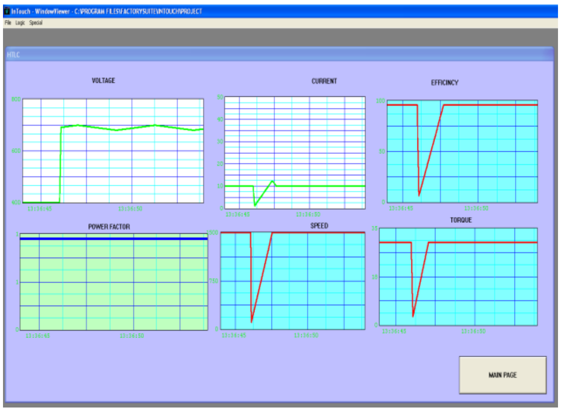

Fig.5.HTLC Simulation

In this graphs the starter input voltage is much larger but in industrial basis it is convenient. The starting current of the HTLC was much lower than the conventional starters. The starting torque present in the system is higher and it helps to attain the speed rated at the starting itself. The HTLC attain near unity power factor so the overall system performance is increased. Then the efficiency of the motor will be increased. The performance of the HTLC with synchronous motor is much better than the other conventional type starters and the motor attain synchronous speed during the starting. But in the other starters the motor acts as a variable speed drive.

5 RESULT & CONCLUSIONS

The HTLC soft starter thus is used for the smooth starting of synchronous motors. We need to understand why or when to use the HTLC starter:

- On weak power systems
- At the end of long T lines
- Power company voltage restrictions
- Power company flicker specifications
- High inertia loads
- When we can’t afford VFD losses or cost

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The advantage of using HTLC starter over VFD starter or DOL starter has already been discussed. The protection methods employed in HTLC starter are also of great importance in order to avoid system failure or plant shutdown. Thus the HTLC starter is useful in energy saving and has reduced cost, making it a favourable method of starting.

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