A SOLID STATE CONTACTOR FOR USE IN 60 Hz, 3 ϕ SERVICE*

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Summary. A solid-state step-start contactor using back-to-back thyristors has been developed at NAL. The unit described here employs water-cooled thyristors designed to switch 3 phase 500A rms at 480V, 60 Hz. The thyristors are turned on by a rectified 50 kHz carrier signal transmitted to the thyristor gate circuit via a specially developed high-isolation transformer that prevents the impulse noise on the 480V line from affecting the logic-level control circuits. A 3-phase current sensor and a solid-state interlock and status-monitor display unit form an integral part of the contactor. DTL compatible logic-level signals are used to control the contactor from local or remote positions and to display and monitor the status of the interlocked variables. These principles appear to be quite applicable to contactors designed for lower or higher power levels.

Introduction

There is a need to connect large pieces of electrical equipment, in a step-start manner, to and from the 480V, 3 phase, 60 Hz line. The specific case is a high current dc power supply used to tune the resonators of the NAL Booster accelerator from 30 to 53 MHz. A brief description of the power supply follows. The power input to the supply is 480V, 3 phase, 60 Hz. Thyristors on the secondary side of the step-down transformer are used to rectify and control the output current from approximately 40 to 2500A at a 15 Hz rate, in response to a computer controlled waveform. An active filter in shunt with the load is used to keep the current and the voltage ripple to 0.1% of output.

These requirements lead to a large number of transistors which have to operate continuously for long periods of time, unattended except for the status monitoring computer. In case of a component failure it is advantageous to disconnect the supply from the 480V power line in one power line cycle to limit the extent of component damage.

This paper describes the power line contactor, current sensors and alarm sensors which belong in the same set functionally because they act together to protect the equipment under fault conditions. Now that reliable solid state devices of required power levels are available commercially, it is a good engineering practice to assemble the protective components into a compact package which can be produced and tested independently of the equipment in which it will be used. The solid state contactor (SSC) described in this paper is such a package. The performance and some design details are included.

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Results

Operation to Date. To date, 30 units have been produced and installed in the power supplies. Out of 30, 10 have been operational for approximately 2 months, while 3 have been used in the laboratory for about 10 months. There have been no failures and the results to date have been most satisfactory.

Description of the Solid State Contactor, SSC. The solid state contactor consists of 4 functional parts: the thyristor switch assembly shown in Fig. 1, a control unit, and 50 kHz Oscillator with its dc power supply, and the 3 phase current sensor.

Operation. The SSC can be operated locally by manually operating the appropriate push switches or remotely by applying the appropriate control signals, Logic 0 = 0 volts, and Logic 1 = 5V. the 2 main control functions are "Contactor Closed" and the "Contactor Open". If the operating conditions are normal, that is, control power is on and all currents and the temperatures are normal, actuating the Contactor Closed function closes the contactor in 2 steps. In step 1, the circuit between the 480V power line and the load is connected through the 1st set of thyristors in series with a 1.6 ohm, 800 watts resistors. These resistors limit the inrush current due to transformer saturation to a value no greater than the maximum operating current. At step 2, the 1st set is turned off and the 2nd set is turned on without current interruption. This achieves the contactor on state which persists until the appearance of an off command, or an actuation of the alarm sensors.

At the turn-off command, the 1st set of thyristors is gated off, while the 2nd set is gated on for 0.1 sec. At initiation of the OFF command, the 1st set conducts until the current in each thyristor commutates off, whereupon the second set of thyristors conducts, again until current zero.

Principles of Operation

The nucleus of the SSC is a thyristor operated under maximum reliability conditions. The thyristors, of hockey-puck construction, are mounted in a water cooled heat sink in pairs. A selenium surge suppressor bridging each pair of thyristors guards against accidental turn on by power line transient voltage. Reliable firing under the given conditions of temperature, load and anode voltage, is assured by a rectified 50 kHz square wave carrier current to the gate electrodes. This carrier is coupled to the thyristor by an isolation transformer that does not conduct damaging power line transients to the logic level integrated circuits. There are no parts in the gating circuitry that could not well be designed for any power level needed.

The simplicity of the SSC can be observed from Fig. 2. The transmission of the 50 kHz carrier current to six thyristor gates is controlled by transistor Q1 operated as a switch. If the Q1 is conducting, the thyristors are ON and vice-versa. A latch circuit, consisting of an OR gate G1 and an AND gate G2, followed by a buffer transistor Q2, controls the state of Q1. If all alarm sensors are normally low, the ON control can be actuated, producing a negative-going pulse at the input of 1 of Q1 and latching it in the high condition, corresponding to the ON state for Q2, Q1 and the thyristors. If any of the alarm sensors is in a high condition, Q2 cannot be latched on. Initiations of the OFF command or an opening any alarm sensor unlatches Q2 and opens the thyristors. Because the SSC can be set to open at any line current from zero to maximum, it therefore serves as a circuit breaker as well as a contactor.

Bibliography

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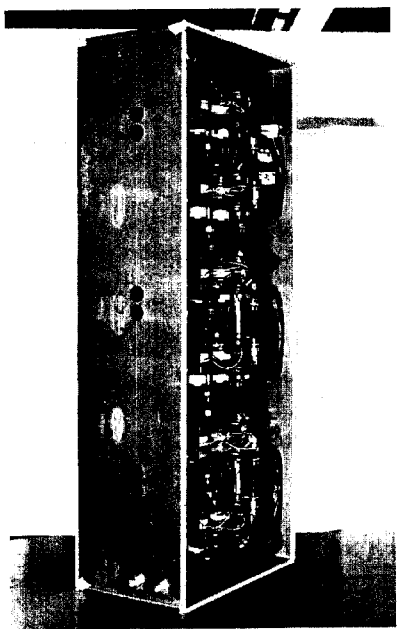

Fig. 1. Thyristor Switch Assembly

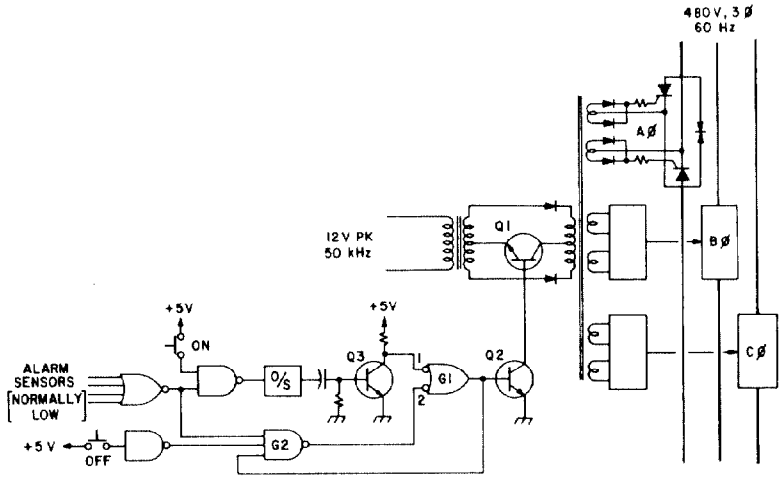

Fig. 2. Simplified Diagram of the Solid State Contactor