MOTOR PROTECTION

This publication is intended only as a brief guide to protection of large electric motors; GEC ALSTHOM Protection & Control offer one of the widest ranges of equipment in this important field, and further details or advice will gladly be given on request.

Instantaneous Earth Fault Protection

Motors of more than about 50 h.p. supplied from earthed systems should be protected against earth faults to reduce damage and accident risk, particularly those not fitted with differential protection. Sensitivity of high speed electromagnetic devices is limited by unbalance in the current transformers caused by starting surges and is usually about 20% of full load rated current. A suitable unit is incorporated in most thermal relays.

High rupturing capacity fuse links also protect against earth faults, but with less sensitivity.

A Type VME relay is recommended for protection against earth rotor faults.

Differential Protection

Machines fitted with differential protection require current transformers at each end of each winding so that the current entering a winding can be compared in the relay with the current leaving the winding, ensuring minimum fault damage by immediate clearance of all stator faults.

This is normally fitted to machines of 1000 h.p. and above, especially those not otherwise protected against earth faults. Circulating current differential relays (e.g. Type CAG34 or FAC) are recommended because they give faster operating times and better discrimination than the biased type. Where current transformer characteristics differ widely, however, biased differential relays (e.g. Type DDG) should be used.

Transverse differential protection against inter-turn faults can be provided easily only where the stator windings are divided into two or more circuits; the same considerations apply regarding choice of relays.

Overload and Stalling Protection

It is not possible to make simple rules for overload protection because the protection used depends on factors such as the type of load, starting arrangements, and overload capacity of the motor.

As examples, a standard size mass-produced motor may be larger than necessary for its load and can be completely protected against overloads by a simple electromagnetic oil-dashpot-delayed device operating at say 115% of full load current. A motor which is designed for a particular load runs at its maximum rating continuously, and will require an accurate and sensitive thermal relay for adequate protection. Likewise, it may be necessary to protect a very small motor with a thermal relay so that an important load can be maintained under overload conditions to within close limits of the motor's endurance.

Protecting a motor with a high-inertia load and long starting time (e.g. a fan) is especially difficult when direct-on-line starting is employed because the motor approaches its thermal limit during the starting period and the difference between the starting condition and the stalling condition is not great. The overshoot of the protective device determines the accuracy with which it can discriminate between start and stall conditions. Oil dashpot electromagnetic devices have little overshoot; however, when thermal devices with appreciable overshoot are used it may be necessary to use an additional stalling relay. Type CTM thermal relays have a quick response and small overshoot, so that separate stalling protection is rarely necessary. Versions of the CTM relay are available for protecting motors constructed to withstand prolonged starting times at high torques.

Instantaneous High-set Overcurrent Protection

This reduces fault damage and is recommended in addition to overload protection for all large motors. Instantaneous high-set units can usually be included in thermal overload relays; electromagnetic oil-dashpot-delayed devices may incorporate an instantaneous high-set trip or can be backed up with high rupturing capacity fuse links.

For direct-on-line starting motors, ordinary instantaneous high-set overcurrent units protect only against cable faults and terminal flashovers because of the very high settings required to clear the starting surge. Windings can be protected by introducing a time delay during starting and using a lower setting; for example, the positive sequence high-set instantaneous overcurrent unit used in

Type CTM relays is delayed about four cycles and can be set down to four times full load rated current, protecting almost the whole of the stator winding instantaneously.

Unbalance Protection

Unbalance or negative phase sequence protection shall always be given. Rotor heating due to unbalanced currents is a function of the negative sequence component of the line current, so a thermal negative sequence relay will give the most accurate protection. The Type CTM relay is one of the few thermal relays which takes full account of negative sequence heating, and has a characteristic given by $k = (I_1^2 + 6I_2^2 - 1)t$ where I_1 is the positive sequence component and I_2 the negative sequence component of the motor current; 6 is a design constant.

When a motor is stalled due to loss of one phase, the heating is concentrated in one part of the rotor and may be very rapid. Many motors have been lost from this cause but an instantaneous negative sequence unit gives complete protection.

Protection Against Restoration of Supply

Synchronous machines must be protected against this condition because it is unlikely that they will remain in step with the supply after an interruption. Induction motors are adequately protected by the no-volt release on the starter because motor terminal voltage falls rapidly on loss of supply.

A synchronous machine driving a high torque load slows down rapidly on loss of supply and can be protected by a sensitive underfrequency relay, e.g. Type FMG. When deceleration on loss of supply is small, the rise in terminal voltage (approximately 30% depending on regulation) can be used to operate on overvoltage relay, and an inverse time relay Type VDG11 is usually recommended.

Polyphase reverse-power or under-power relays (Type WCD) can be used as alternatives where power reversal does not occur under normal operating conditions.

By applying the d.c. field to a synchronous motor at the instant when maximum synchronising power is available, synchronous motors can be started or re-started automatically under full load conditions. The Type VTM synchronising relay operates to close the field circuit breaker at any selected slip frequency as the slip current passes through zero.

Reverse Phase Sequence

In applications such as conveyor drives and rotary converters it is sometimes necessary to protect against reverse phase sequence to ensure that the machine rotates in the correct direction.

An inverse time relay such as the Type VDM gives both reverse phase sequence and undervoltage protection.

Bearing Failures

Motors up to about 500 h.p. usually have ball or roller bearings and failure causes stalling almost immediately. With large machines using sleeve bearings, a defective bearing is indicated by temperature rise and vibration, with little rise in motor current. Overload devices thus give no protection but a temperature sensing device embedded in the bearing gives adequate warning.

Loss of Synchronism and Field Failure in Synchronous Motors

Synchronous machines subjected to sudden mechanical overloads should be protected against loss of synchronism, which can also be caused by a reduction of field current or supply voltage. Where overloads are known to be of short duration a loss of synchronism relay can be arranged to disconnect the field supply only, so that the machine runs as an induction motor during the overload. A relay such as the type VTM will re-synchronise the machine automatically.

Field failure protection should be provided for synchronous machines larger than about 500 h.p. which are not fitted with loss of synchronism protection; this prevents overheating of the rotor after continuous operation as an induction motor. An undercurrent relay in the field circuit gives satisfactory protection. Very accurate discrimination against unstable conditions is given by a Type YCGF mho relay at the machine terminals.

Damper winding thermal protection may be used as an alternative to field failure protection if the machine is required to run for long periods as an induction motor.

Any motor protection problems referred to our Protection Engineering Department at St. Leonards Works will receive detailed attention.

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