# CONSULTANTS MANUAL

## Principles and Engineering Application

### INTRODUCTION

The major causes of motor failures are:
- **insulation degradation**
- **electrical problems**
- **mechanical problems**

Excellent devices are readily available to provide warning of, or protection against electrical problems such as overload, phase loss, etc.; and mechanical problems such as misalignment, vibration and bearing wear.

For some industries, the **major** cause of motor breakdown is insulation degradation when the motor is idle. For these industries, periodic testing with a Megger™ Tester does not provide a practical and efficient method of protection against production loss caused by motor failures. Only continuous monitoring will do that.

Intermittent operation of electrical motors creates extreme temperature changes of the motor's winding. These changes along with mechanical vibrations leading to insulation cracks, later contaminated by air pollution resulting in degradation of the electrical insulation.

Until the MotoSafe Monitor was introduced, **automatic** warning of impending insulation problems was **not available**. MotoSafe devices provide continuous monitoring of insulation resistance with automatic early warning of possible insulation failure.

The relationship between motor age, dielectric strength and insulation resistance, with the ranges covered by MotoSafe and by high voltage Megger Testers, is shown below.

In the MotoSafe monitor range, the motor has already lost its dielectric strength and its insulation resistance is low so it is not necessary to use a high-test voltage to obtain reliable readings. In fact, for safety a low-test voltage is desirable for continuous monitoring. The MotoSafe test voltage is 24V. D.C., current limited to 30 microamperes, to make it intrinsically safe.

**DEGRADATION SPECTRUM OF MOTOR INSULATION**

← Low voltage **MotoSafe** Range →

← MEGGER TESTING RANGE →

DIELECTRIC STRENGTH

| NEW MOTOR | EXCELENT | GOOD | INADEQUATE | DANGER |
|---|---|---|---|---|
| > 1000 MEG. | 1000 – 100 MEG. | 100 – 10 MEG. | 10 – 1 MEG. | 1 – 0 MEG. |

INSULATION RESISTANCE

→ MOTOR AGE INCREASING →

Fig. 1 illustrates that probability of motor failure increases with insulation resistance deteriorating. The time to complete failure of the motor decreases with insulation resistance failing into the Risk Zone. The probability of recovery of the motor at a low cost (without rewinding) also decreases with the insulation resistance failing below the minimum operating range. The minimum operating level of the insulation resistance differs depending on the motor operating voltage and application.

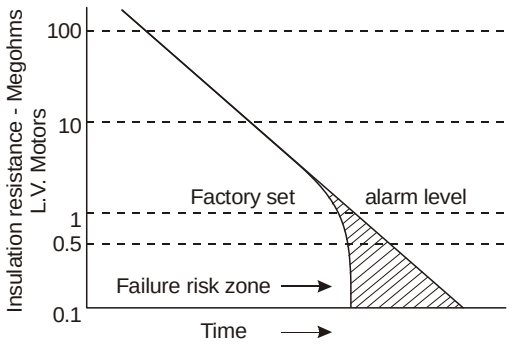


Fig. 1

## PRINCIPLE OF OPERATION

When the motor is idle, the windings are connected, through precision series resistors, Rs, and an isolation relay contact, to a regulated voltage source (see Fig. 2).

The precision resistor and the motor winding insulation resistance form a voltage divider, so the voltage across the motor windings is a function of the insulation resistance. This voltage is monitored by a comparator and when it falls below the comparator reference voltage the alarm relay is activated.

ALARM SETTINGS: Many variables in the motor operating conditions affect the choice of alarm setting, so it is difficult to choose a single, universally acceptable, level for early warning. However the minimum operating level of 1 Megohm per 1kV line voltage is recommended.

Fig. 3 Shows the general consensus, based on practical experience, that if the motor is operated for a long time after the insulation level has fallen to 0.5 Megohm, the insulation level will continue to deteriorate and will be practically impossible to recover it, regardless of any preventative maintenance efforts. It also shows that an alarm level of 1 Megohm gives practically a 100% chance of recovery, using simple procedures.

## DESCRIPTION

Fig. 4 Shows the block diagram of a basic low voltage MotoSafe Insulation Monitor. Other types are available which differ in detail.

**Terminals 1 & 2:** Control Power input through an internal isolating transformer to a power supply producing stabilized 24V DC for the sensing circuitry. Units for DC control power are available using an external DC-to-DC converter.

The sensing circuitry based on a high sensitive comparator able to work with low currents.

**Terminals 6 & 3:** the 24V D.C. measuring voltage is injected into the motor windings via terminal 6 (Sense) and 3 (Ground) through a measuring resistance. The measuring circuit measures the voltage across the resistor to monitor the insulation resistance when the motor is not energized.

**Isolation Terminals 6 & 8** are connected to sense whether the motor is energized or not. If it is, the isolation circuit triggers the internal isolation relay, isolating the monitor from the motor windings. The isolation circuit is designed to accept AC or DC voltage, 24 to 600 Volts.

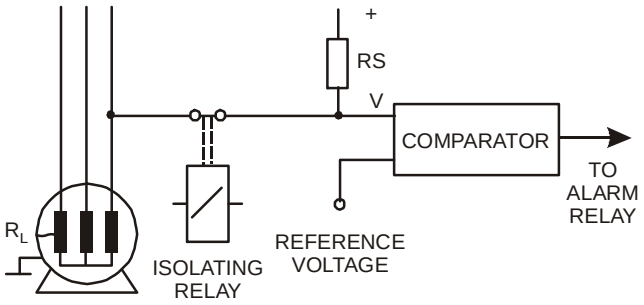


Fig. 2 Principle of operation

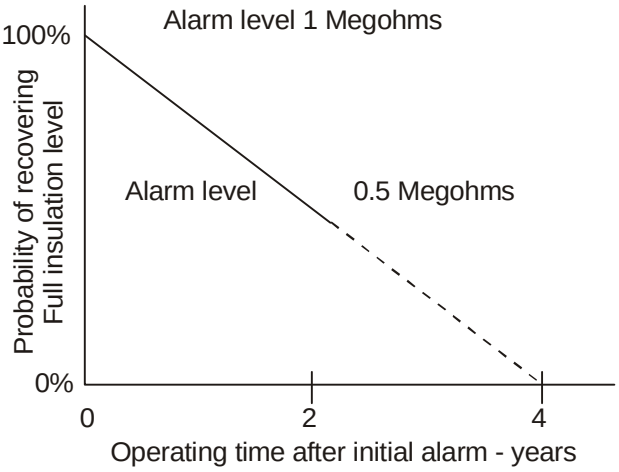


Fig 3 Alarm Setting v. Probability of Recovery Low Voltage Motors

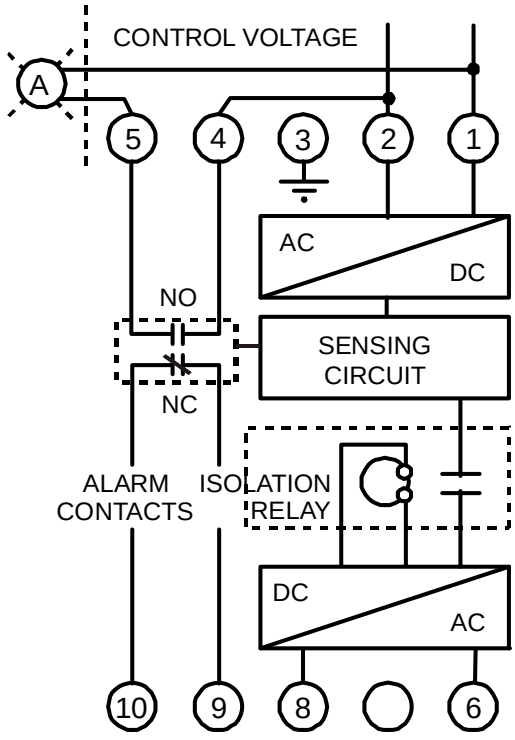


Fig. 4 Typical MotoSafe Block Diagram

**Terminals 4 & 5 and 9 & 10:** are dry contacts of the alarm relay rated 5 amps, 250V AC, resistive. When the insulation resistance falls to the preset alarm level, the sensing circuit operates the alarm relay. Contacts may be used to operate external alarm devices as well as for remote alarm indication through an existing PLC network.
Relay contacts may be wired for start prevention. While in alarm the motor may be restarted by switching the unit to a lower alarm level.

**Alarm Settings:** On the monitor faceplate, a slide switch offers several alarm settings. It should be set to the highest setting initially and switched to a lower setting when the unit alarms. A short interval between alarm level changes indicates rapid insulation deterioration. Schedule preventive maintenance when the unit alarms at the lowest setting.
The unit incorporates a local alarm indicator on the face panel.

## BASIC APPLICATION PRINCIPLES FOR MOTORS UP TO 600V

The MotoSafe Insulation Monitor senses the insulation level of a motor when the motor is **not** energized. It can be used with **all types** of motor starters if the following three simple rules are followed.

1. When it is not energized, the motor must be completely isolated from the supply and ground.

***Note:*** *all motors controlled by the conventional electromagnetic starters meet this condition.*

2. If the motor is controlled by a solid-state starter, there must be an electromagnetic contactor between the solid state starter and the supply.

***Note****: The solid state starter by itself does* ***not*** *isolate the motor from the supply.*

3. The isolation circuit must sense the state of the motor (whether it is connected to the supply). In order to provide that the voltage should be applied to the isolation terminals of the monitor while the motor is energized.

***Note****: For applications such as direct on-line the isolation terminals may be connected directly to the motor windings. For soft start drives, variable speed drives and other applications with an intermediate controller the isolation contactor coil, running light or main contactor coil on the load side could be used as an isolation voltage source. In these applications the monitor with separated sense and isolation inputs should be used (see Fig. 6).*

Typical applications and MotoSafe terminals 6 & 8 (model M603IND) connections are as follow:

**Direct-on-line** and **Autotransformer:** to any two phases on the load side of the main contactor.

**Reversing motor:** to any two phases on the load side of either contactor

**DC motors:** same as AC motors with solid state starter (see Fig. 6)

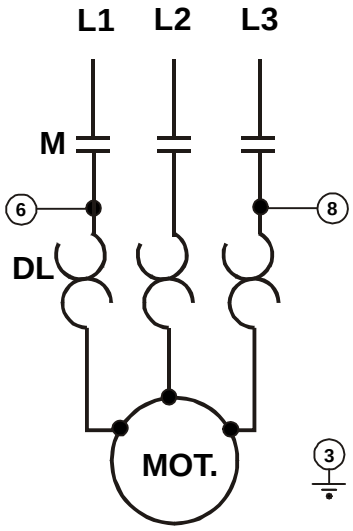


Fig. 5 Direct-on-line Starter – MotoSafe connection

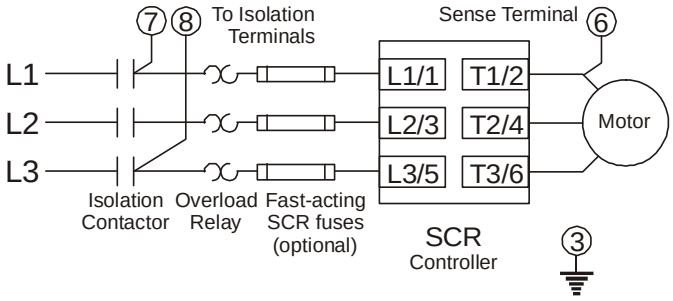


Fig. 6 Solid State Starter with Isolation Contactor – MotoSafe (model M603INDS) Connection

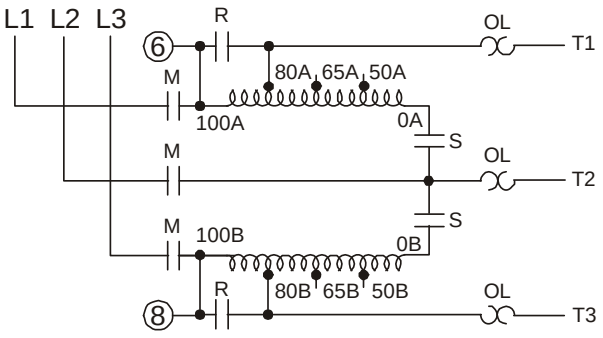


Fig 7. Autotransformer starter

**Delta – Star:** to any two phases on the load side of the main contactor; since the windings are disconnected from each other when the motor is off-line, special connector should be used in order to monitor all motor phases

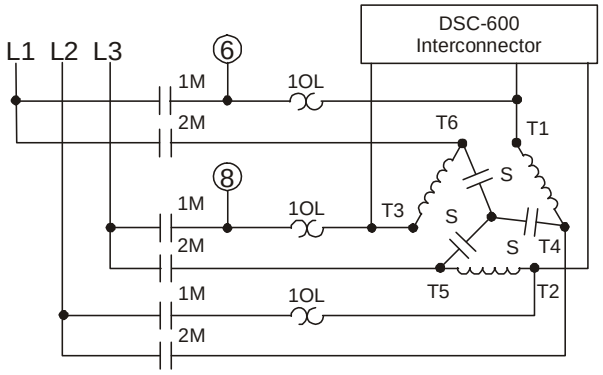


Fig. 8. Star-Delta starter

**Multispeed, Separate Winding:** consider as individual motors, use a MotoSafe monitor for each speed; connect each as Direct-on-Line.

**Multispeed, Same Winding:** to any phase on the load side terminals of the Slow Speed contactor

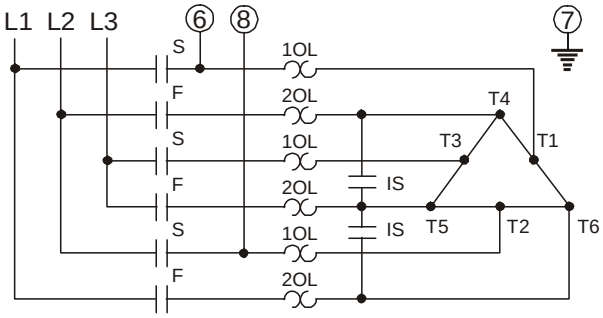


Fig. 9 Multi-speed, same winding

**Slip Ring Motor:** for the stator, to any two phases on the load side of the contactor. For the rotor, connect the sense terminal 6 of an additional monitor to any slip ring phase

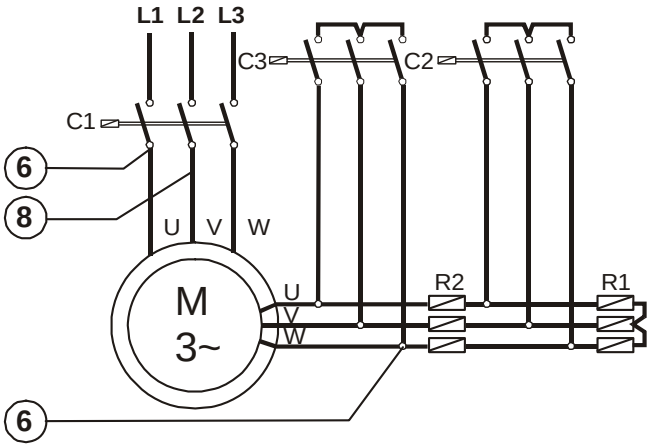


Fig. 10 Slip Ring motor

**Multiple Motor Installation:** for multiple motors controlled by several contactors installed in one starter enclosure the "Multi-Channel" monitor MCM603INDE recommended that is capable of monitoring up to 8 motors running on the neutral grounded supply. Connect the sense terminal of each channel to any phase of the motor.

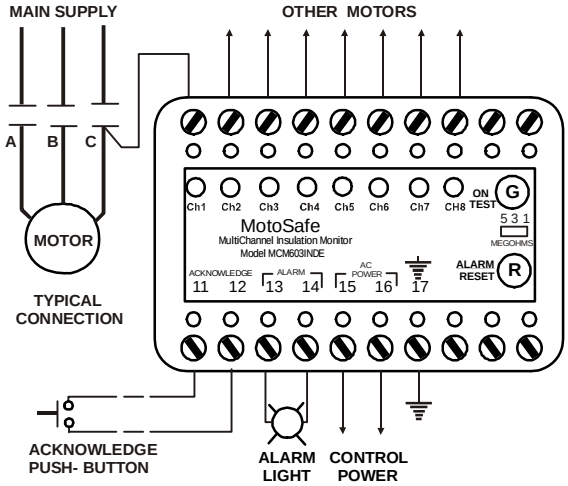


Fig. 11. Multiple motor monitor

## BASIC APPLICATION PRINCIPLES FOR GENERATORS

The MotoSafe Insulation Monitor can be applied to all 3-Phase generators, if the generator neutral is isolated when the generator is idle.

***Note:*** the generator breaker should be a four-pole unit, with the forth pole breaking the neutral. Alternatively, a correctly rated, single-pole contactor may be used to isolate the neutral.

A MotoSafe Insulation Monitor with separated sense and isolation inputs such as M603INDS is recommended for monitoring generators. The sense terminal can be connected to any phase of the generator and the source of the isolation signal should be provided to make sure that monitor is connected to the generator only when it is isolated from the ground and loads and is not exited.

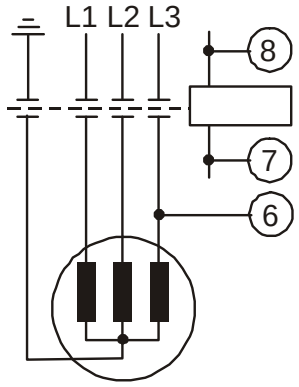


Fig. 12. Generator
Basic application principle

## BASIC APPLICATION PRINCIPLES FOR HIGH VOLTAGE MOTORS

The MotoSafe Insulation Monitor for High Voltage Motors is the same in principle as the unit for Low Voltage motors, with the following additional features.

1) Time Delay: As many H.V. Motors are fitted with line-to-ground capacitors, the sensing circuit has an optional 7 minute delay, to allow time for the capacitor to discharge
2) The unit has circuitry for forced discharge of residual voltage.
3) Remote Test & Reset: Terminals are provided for a remote “Test” and “Reset” buttons.

However, as the MotoSafe device is installed in the low voltage (L.V.) instrument compartment of the H.V. starter, the way it is installed is different from installations for L.V. motors.

INTERMEDIATE RESISTOR BLOCK (IRB)

As the L.V. MotoSafe device monitors winding insulation resistance, it can be connected to any point on the winding. For H.V. motors, the neutral point is preferred for safety. An artificial neutral is created by joining three 10 Megohm resistors in star configuration. It is mounted in the H.V. compartment and connected to the motor terminals. The star point forms a safe, convenient, low voltage connection point for the MotoSafe device. (Fig. 13)

To eliminate the hazard to personnel, the connection between the Intermediate Resistor Block in the high voltage compartment and the MHV monitor unit in the low voltage compartment of the motor control gear, is current limited by the high internal impedance of the Intermediate Resistor Block to a maximum of 1.25 milliamperes, i.e. 25% of the mandated GFCI trip level. This maximum current flows through the “Sense” line (the neutral conductor of the Intermediate Resistor Block) to “Sense” terminal of the MHV monitor unit only if it is shorted to ground when a ground fault exists on one phase of the motor supply.

When the motor is idle, the three resistors are effectively in parallel and in series with the winding insulation resistance, thus adding 3.33 Megohms to the apparent value. The calibration of the MotoSafe device compensates for this, so the alarm levels correspond to actual insulation resistance values.

This method of connection complies with all applicable codes and is approved by CSA and UL. When the Intermediate Resistor Block is installed inside the High Voltage compartment, fuses are not required.

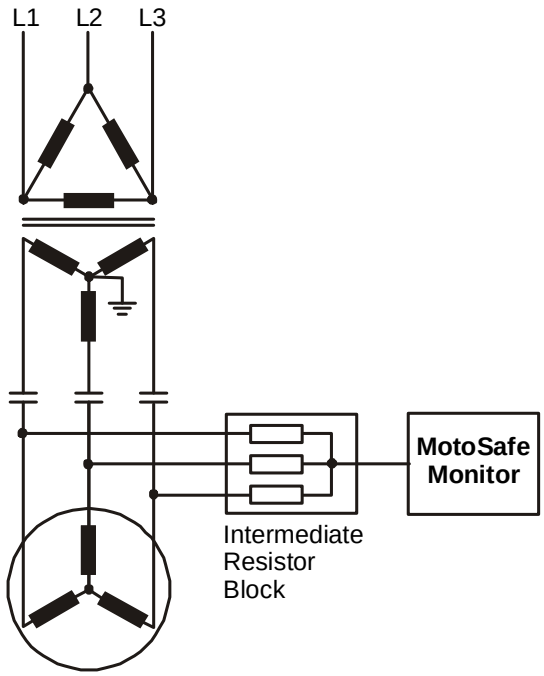


Fig. 13 High Voltage Transformer Coupled Motor

TRANSFORMER COUPLED HIGH VOLTAGE MOTORS

If the motor is transformer-coupled the MotoSafe Insulation Monitor can only be installed if one of the following conditions is met:

1) There is a contactor between the motor and the transformer, or
2) The transformer secondary is not grounded, or
3) A correctly rated one pole contactor is installed to isolate the grounding resistor from the neutral.

*Every IRB bears a serial number and is tested at 225% of its rated line voltage for one minute by an independent test laboratory, to meet CSA and UL requirements.*

## OTHER APPLICATIONS

The MotoSafe product was developed to meet the well-defined need to monitor idle motors in adverse conditions to warn of insulation deterioration, but it has many other applications, i.e. whenever insulation sits idle but must be effective when needed, a MotoSafe Insulation Monitor can eliminate untimely failures.

Some such applications are:

- Airport runway lighting circuits
- Standby power systems for firepumps
- Air conditioning systems during the off season
- Standby pumps for water and sewage systems
- Hospital emergency power systems
- Buried standby power distribution cables

## GENERAL NOTES

The design of MotoSafe Insulation Monitor ensures that any component failure in the unit will not affect the normal operation of the motor gear.

The low voltage MotoSafe Insulation Monitor (MG600 type) will withstand the high voltage applied by a Megger™ Tester to 1000V D.C. and the MHV type withstands DC voltages up to 2500V with the control power turned off. If higher testing voltages are required, the "Sense" terminal of the monitor should be disconnected from the tested equipment.

The enclosure of the MotoSafe Insulation Monitor is made of self-extinguishing plastic and all terminals are completely shrouded, for safety.

Provision for DIN-rail mounting is included on the back of the unit. When installed as instructed, the unit will withstand shock testing to Spec Mil No. S901C (U.S. Navy).

"TEST" and "RESET" buttons on the face of the unit permit routine testing of the MotoSafe Insulation Monitor.

To ensure that the external wiring has been done correctly, a Test Resistor is provided. It consists of a 100 Kilohm resistor attached to 12 inches of # 18 a.w.g. wire and it should be used to ground the motor winding temporarily when the installation procedure has been completed. This is done to simulate a low phase-to-ground insulation condition.

A flashing visual alarm unit is provided in the installation kit. Using a neon lamp instead of an incandescent lamp ensures long life and the life is further extended as the lamp is flashed instead of being permanently "ON". Note also that the alarm only operates when the motor insulation falls to the preset level.

The visual alarm unit is drip-proof and may be used where regulations permit. Other types of visual alarm units may be used, if desired. A self-adhesive "WARNING" and "Explanatory" labels are provided.

All units have a provision for remote alarm indication that could be used for start prevention when the alarm is activated, to activate an external device or wired to the PLC I/O. Some units have analog output for actual insulation resistance value reading that may be connected to a pannel metter or the PLC I/O.

To ensure quality of installation, insulated crimp-on wire terminals and wire ty-wraps provided in the installation kit.

## INSTALLATION KIT

The MotoSafe Insulation Monitor is shipped complete with an installation kit. This kit contains all of the material and hardware required for a typical retrofit application in a motor starter enclosure. If the "Installation Instructions" are followed, the installation will be completed quickly, in a workmanlike, reliable, fashion.

The kit contains the following items:

- **Installation instruction**
- **DIN-rail mounting bracket**
- **Self-tapping mounting screws**
- **Flashing visual alarm unit**
- **Sufficient hook-up wire for a typical installation**
- **Crimp-on wire terminals**
- **Plastic cable ties**
- **Self-adhesive "Warning" and "Instruction" labels**
- **A Test Resistor**

***Installation Instruction and Product Brochure for all models may be found at [www.msegroup.net](http://www.msegroup.net)***