PROTEC Z

High Frequency Transient Surge Suppressors

For protection of medium voltage motors, generators and dry type transformers

- Eliminates interturn insulation failures
- Extends the life of machine insulation
- Eliminates multiple pre- strike and re-strike transients associated with vacuum and other switchgear
- Provides comprehensive insulation co-ordination at all practical surge Magnitudes and rise-times

Reduces direct & indirect costs of insulation failure and SAVES MONEY

Introduction

Every year huge losses are incurred by end-users as a result of insulation failures of medium voltage motors and dry – type transformers.
The cost of insulation failure includes:

- Costs of removing failed equipment from service and for re-installation after repair.
- Costs of transportation to and from the site.
- Direct repair costs.
- Costs of downtime and lost production (or disruption to production).

Owing to the nature and duty normally associated with medium voltage motors and dry-type transformers, the indirect costs are often significantly higher than the direct repair costs.

PROTEC Z is a unique high frequency transient overvoltage surge suppressor for the protection of motors and transformers from steep wave-front, short rise-time, high magnitude, spikes, surges and other transient overvoltage's, generated by switching, lightning and other sources.

The protective characteristics of PROTEC Z provide comprehensive insulation co-ordination with both the CIGRë and IEEE motor impulse voltage withstand characteristics at all practical surge magnitudes and rise-times.

PROTEC Z completely eliminates multiple pre-striking and re-striking (re-ignition) transients associated with vacuum and other switchgear.

Suitable for both switchgear panel and motor / transformer terminal box mounting, PROTEC Z provides an easy-to-apply, compact and low cost solution to the extremely expensive problem of motor and transformer insulation failures.

Steep Wave-front Surges

A steep fronted surge comprises a step change in voltage or current (without reference to earth), with rise-time in order of 0.1 – 2µs.

Steep wave-front travelling waves are injected into a cable during the process of switching of motors and transformers, when a pre-strike or re-strike occurs across the closing or opening contact gap of the switch.

Because the motor or transformer load surge impedance is invariably high with respect to the cable surge impedance, the steep wave-fronts are reflected and refracted at the load terminals.

Refraction causes the magnitude of steep voltage wave-fronts to almost double when the wave-front impinges on the load terminals.

During switching, reflection of pre-strike current wave-fronts causes high frequency current zeros in the contact gap of the switch. Arc extinction occurs in switchgear capable of interrupting at this high frequency current zeros, and subsequent re-strikes result in the generation

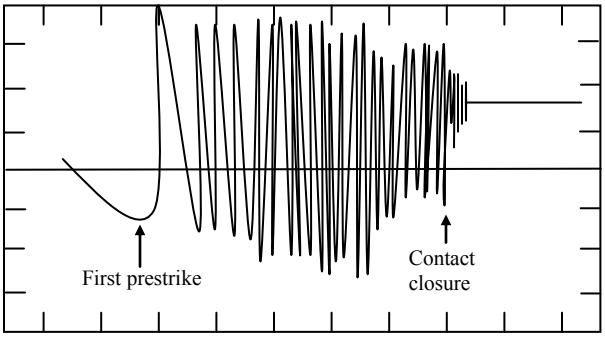


Fig.1
Multiple pre-striking during routine motor switch-on (without PROTEC Z suppressor fitted)

of multiple pre-striking and multiple re-striking transients. Thus, refraction and reflection of steep wave-fronts, caused by mismatch of the cable and load surge impedances, is central to the generation of the severe multiple pre-striking and multiple escalating re-striking switching transients associates with vacuum and other switchgear. (*Fig.1 & 2).*

Other switching transients can also occur, such as current chopping and virtual current chopping transients. The former is normally not severe because the voltage transient generated is not steep fronted, and the normal chopping currents of

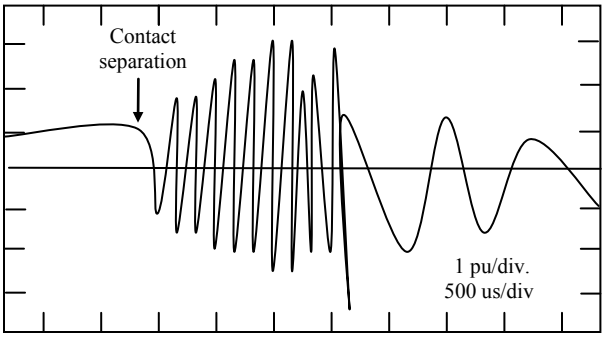


Fig.2
Multiple re-striking (re-ignitioning) during interruption of a motor starting current i.e. stalled tripping (without a PROTEC Z *surge suppressor fitted)*

Medium voltage switchgear are not high. The latter is extremely severe and cannot be tolerated by motors and dry-type transformers in any circumstances.

Steep wave-front surges on medium voltage power systems may also result from direct lightning strikes, from flash –overs across insulators, or from induced surges caused by lightning and other atmospheric discharges.

Motor Insulation Impulse Withstand Levels

The ability of motors and dry-type transformers to withstand steep wave-front switching, lightning and other

transient overvoltage phenomena is the lowest of all equipment generally connected to a three phase power system.

The surge withstand ability of motors and dry-type transformers decreases with decreasing impulse wave-front rise-times (i.e. with steeper wave-fronts) because a steep wave-front surge does not distribute itself evenly over the motor / transformer winding, but stresses the line-end coils more. The steeper the surge wave-front, the more the stressing of the interturn insulation of the line-end coils.

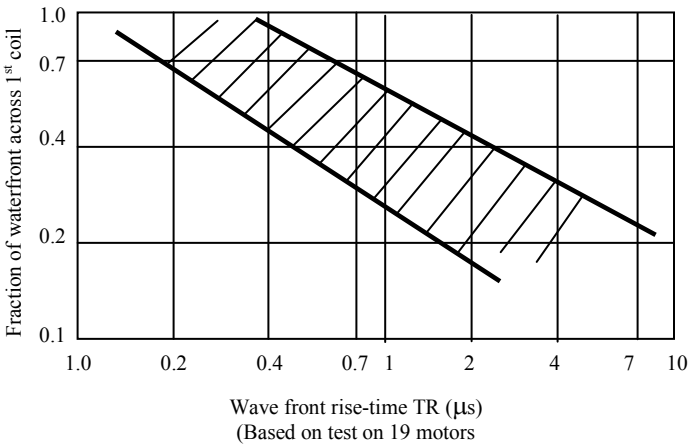


Fig.3
Percentage of voltage wave-front appearing across line-end coil as a function of rise-time – Reference 5

This contrasts with the protective characteristics of power surge arresters, which exhibit an increasing (or at best, a constant) sparkover / residual voltage characteristic for steeper impulse wave-fronts. Therefore it is impossible for power surge arresters to provide adequate insulation coordination at all practical impulse magnitudes and rise-times.

In addition, power surge arresters provide protection with respect to earth, or between phases, whereas steep wave-front surges are step changes in voltage without reference to earth (often crossing earth potential) which stress the interturn insulation of the line-end coils of motors and dry-type transformers. (See Fig. 1 and 2).

In service, there is an inevitable and unpredictable degradation of motor and transformer insulation as a result of the effects of temperature, vibration, shrinkage of insulation (resulting in loosening of a coil within a slot and subsequent chafing), environmental and atmospheric conditions, the number, magnitude and rise-times of transient over voltages applied to the motor, etc.

There are no international standards which lay down requirements regarding MV motor insulation impulse withstand levels, either at the point of manufacture or over the intended service life of the motor.
However, the CIGRë Working group 13.02 and the IEEE Working group on the Impulse Strength of AC rotating machines give some guidance as to what can be expected in practice. The IEEE curve takes the effects of ageing into account. (Fig.4).

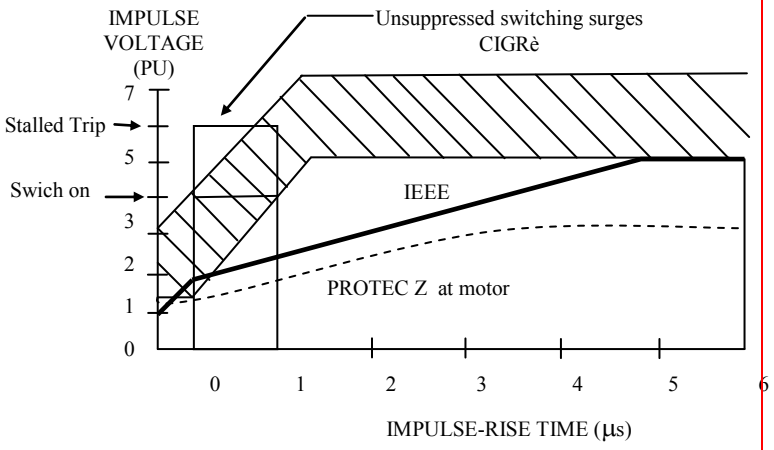


Fig.4
Impulse withstands levels of medium voltage motors, showing unsuppressed switching surge magnitudes and rise-times, and insulation co-ordination provided by PROTEC Z*.*

It is well documented that routine motor switch-on operations can result in surges of to 4pu with rise of 0,1 - 6μs, and stalled tripping operations can result in surges of 5 – 6pu with rise times of 0,1 - 1μs.
Note 1pu = √2 / √3 x VL-L. These surges are significantly higher than the motor withstand levels given by the IEEE and CIGRè curves. (Fig. 4).

How PROTEC Z Works

The PROTEC Z surge suppression is a unique voltage and frequency dependent cable terminating network comprising capacitors, resistors and zinc oxide (ZnO) non –linear arresters. *(Fig.5)*
Under normal mains frequency conditions, the impedance of the capacitive elements is very high, effectively

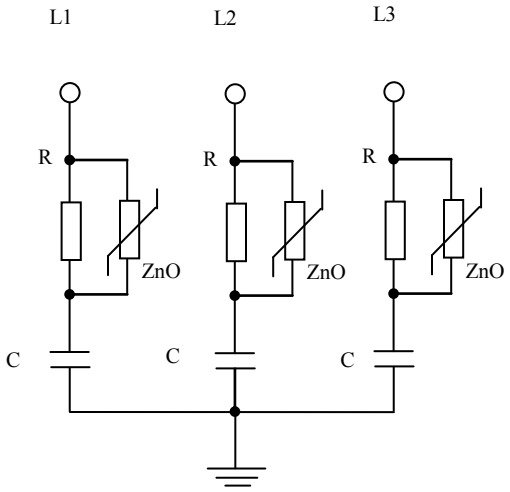


Fig. 5
The PROTEC Z circuit and technique

"disconnecting" the resistive components from the system and minimizing heat dissipation and stressing of these elements.

Under high frequency transient conditions, the impedance of the capacitive elements is low with respect to the resistive elements, effectively "inserting" the resistive components in the power system as a network.

For cable termination resistors having a value of Zc ≤ R ≤ 3 Zc (where Zc is the cable surge impedance) voltage refraction and reflection of steep wave-fronts is minimized, voltage doubling is avoided, and high frequency re-strike current zeros in the switch are eliminated. This eliminates multiple pre-striking and re-striking transients associated with vacuum and other switchgear. *(Fig. 6 & 7).*

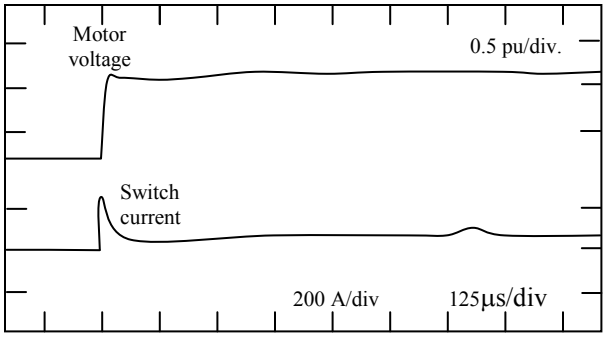


Fig. 6
Clean switch on of motor with PROTEC Z *surge suppressor fitted, showing eliminationof multiple pre-striking*

Under high magnitude steep wave-front conditions, the ZnO arresters (having a knee-point voltage of 1 – 2 pu) "trigger" ,providing a very low resistance in series with the capacitive elements. Therefore, a suitably low absolute limit is provided to the magnitudeof a steep wave-front at the load terminals, and that portion of a steep wave-front which exceeds this limit is sloped to a value within the IEEE recommended motor insulation withstand levels.

The cable surge impedance Zc is independent of cable length, and does not vary widely for different cable types and sizes. Therefore , a resistance value of 30 ohms for the PROTEC Z suppressors, satisfying the condition Zc ≤ R ≤ 3 Zc, is suitable for virtually all installations, and is independent of cable length, motor size and voltage.

The value of the capacitive elements is optimized to minimize the heat dissipation and stressing of the resistive elements under normal mains frequency conditions while still performing its function as a "frequency dependent switch" and as a "wave sloping capacitor" under high frequency transient conditions.

With the PROTEC Z circuit , ZnO gapless non-linear arresters, with a clamping voltage low enough to protect the interturn insulation of the line-end coils (ie less than 2pu, where 1 pu =√2 / √3 x V L-L, can be used, because the voltage across the non-linear elements is negligible under normal mains frequency operating conditions.

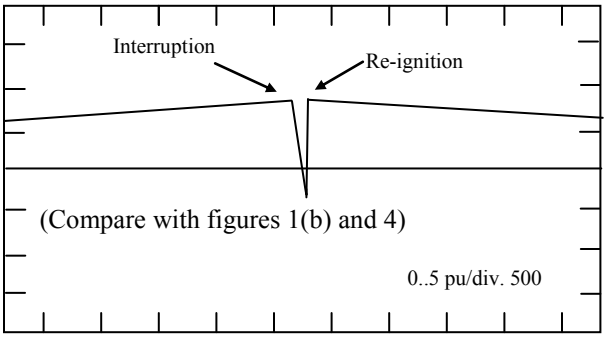


Fig. 7
Single re-striking during interruption of motor starting current with a PROTEC Z *surge suppressor fitted, showing elimination of multiple escalating re-striking*

User Benefits provided by Protec Z

- *PROTEC Z* halves the magnitude of steep wave-front surges impinging on the load terminals by providing a matched cable terminating impedance under transient conditions, thereby eliminating refraction of steep wave-front surges (ie eliminates voltage doubling effects).

- PROTEC Z eliminates multiple pre-striking and re-striking transients associated with vacuum and other switchgear, by eliminating reflections of the pre-strike and re-strike current wave-fronts, and thus preventing high frequency current zeros in contact gap of the switch.

- PROTEC Z provides suitably low absolute limit to the magnitude of steep wave-fronted surges that may impingle on the load terminals, and slopes that portion of the steep wave-front which exceeds this limit.

- PROTEC Z provides comprehensive insulation co-ordination, at all practical steep wave-front surge magnitudes and rise-times, within the motor impulse withstand levels recommended by the IEEE and CIGRë curves.

- PROTEC Z protects new motors and dry-type transformers throughout their service life by reducing the magnitude, rise-time and frequency of occurrence of steep wave-fronts impinging on the load terminals.

- PROTEC Z extends the life of motor and dry-type transformers insulating if retro-fitted to existing motors in service.

- PROTEC Z saves money by eliminating losses incurred as a result of insulation failures of motors and dry – type transformers, in terms of both direct repair costs as well as cost of down-time leading to lost or disrupted production.

Product Features of *PROTEC Z*

- **Compact**
  PROTEC Z is compact enough to be fitted within most motor / transformer terminal enclosures or switchgear panels.

- **Low Cost**
  PROTEC Z offers an unparalleled price / performance ratio.

- **Easy to apply**
  PROTEC Z suppressors may be selected from a catalog with no detailed engineering required.

- **Motor/transformer mounting and switchgear panel mounting versions.**
  PROTEC Z suppressors are available for both motor/transformer mounting (M type) and panel mounting (P type).

- **PROTEC Z Compact.**
  PROTEC Z compact auto ranging from 2kV to 6.6kV

- **Single phase and three phase versions.**
  PROTEC Z suppressors are available as both single phase or three phase versions. Single phase versions are suitable for installing in phase segregated terminal enclosures.

- **Class 1 Division 2 Certification (ExN, non sparking).**
- As standard PROTEC Z surge suppressors can be ordered certified for use in potentially flammable atmospheres (Class 1 Divisions 2 locations), temperature classes T1 to T5, to SABS 970-1971 (amended).

- **Safety Switch.**
  All PROTEC Z units are equipped with a safety switch for protection of staff and assets.

- **Easy to install.**
  PROTEC Z suppressors may be mounted in any orientation, and convenient mounting brackets or clamps are provided. (See dimensions drawing).

- **Model range.**
  Only four colour coded models covering from 2kV to 13,8kV, machine mount and panel mount

Applications

PROTEC Z suppressors have been installed in large quantities in the following industries and applications:

- Fans
- Pumps
- Compressors
- Mills
- Crushers
- Refrigeration machines
- Motor-generator sets
- Mine winders
- Conveyors
- Underground and surface mini-substations and mobile substations
- Generators
- Power station auxiliaries
- Arc furnaces
- Induction furnaces

Available Types

PROTEC Z type:

PROTEC Z LV – 400V to 690V

PROTEC Z HV – 2KV to 25KV panel or machine mount 3-phase and single phase versions available.

Compact machine mount 3-phase versions available from 2KV to 6.6KV.

Installation

PROTEC Z surge suppressors may be installed in any orientation (including upside down) on the machine side of the associated medium voltage motor / generator / transformer switch, in the following positions (in order of preference from a surge protection point-of-view):

- In the motor/generator/transformer terminal box, connected from each phase to earth.
- Cabled to the motor/generator /transformer terminal box via a 3 core cable (25mm² minimum), plus earth conductor (in accordance with local regulations).
- In line with the motor / generator / transformer supply cable, shunt connected from each phase to earth.
- In the associated motor / generator / transformer switch panel, connected from each phase to earth. Convenient mounting brackets are provided.

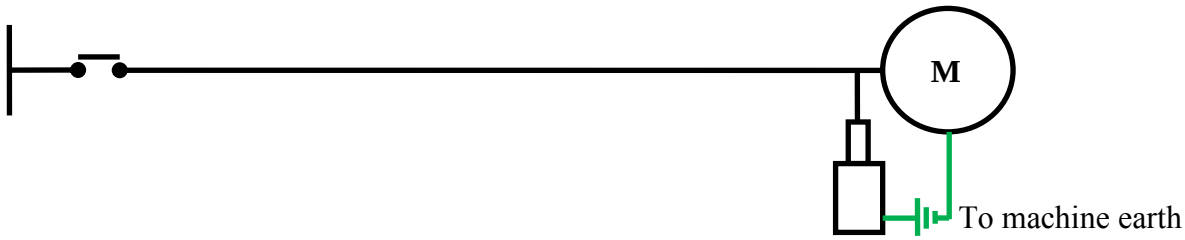
(Refer to the dimension drawings).

In the case of *PROTEC Z* surge suppressor with porcelain bushings, care should be taken to use flexible connections to the bushings to avoid vibrations or shock, in transportation and service, from being transmitted to the bushings. In addition, care should be taken not to over tighten the nuts on the bushings and earth studs (maximum 20 Nm).

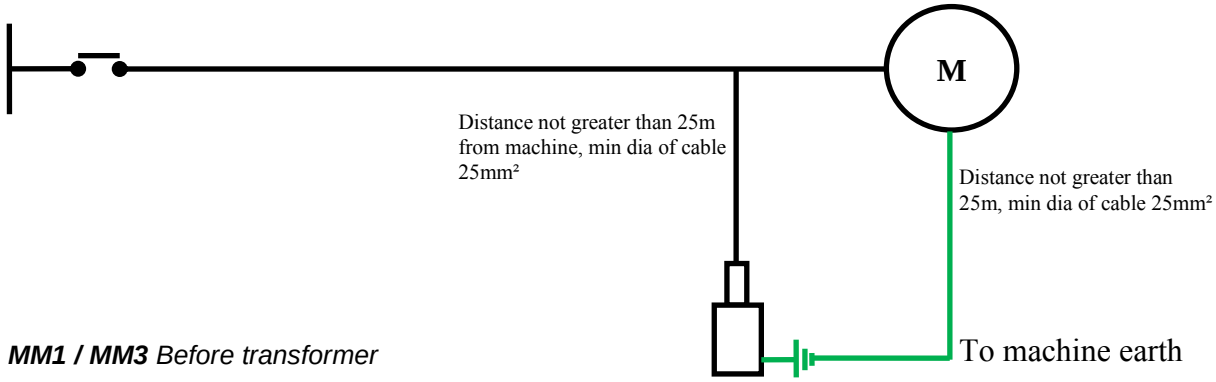
In the case of *PROTEC Z* surge suppressors with flexible insulated connections leads, the leads can be cut to length to suit the application, but should not be extended.

PREFERRED CONNECTIONS

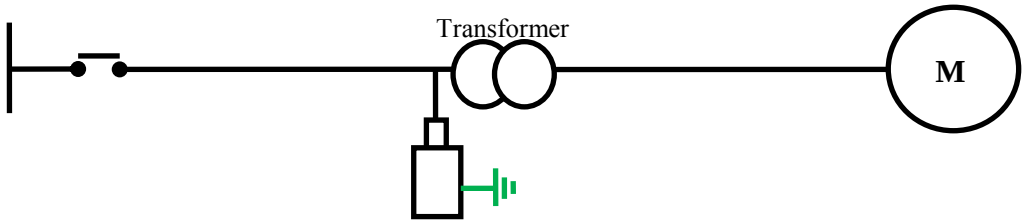
1. ***MM1 / MM3*** *As close to the machine as possible* (Maximum length 1 meter)



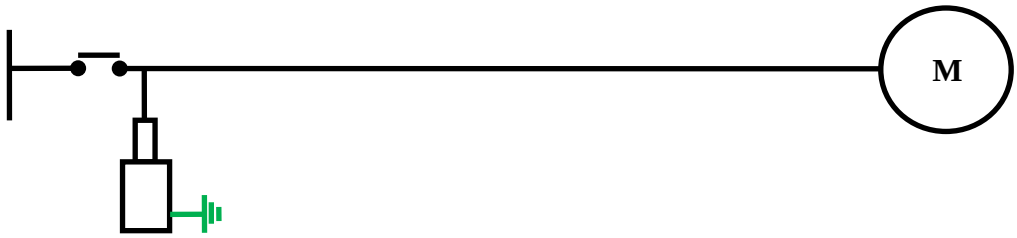
2. ***MM3 -*** *Impedance matching*



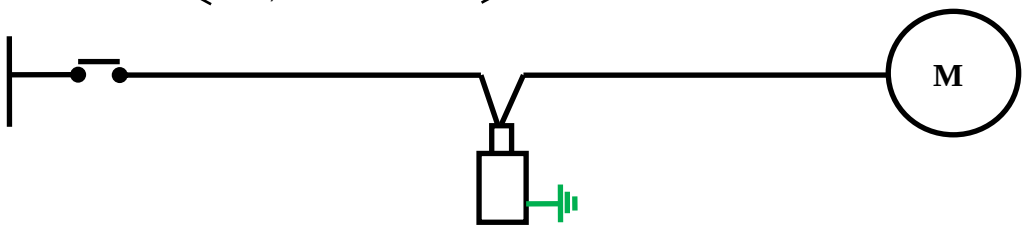
3. ***MM1 / MM3*** *Before transformer*



4. ***PM3 –*** *Panel mount*



5. ***PM3*** *if cable is* ⩽*15m,* ***MM3*** *if cable is* ⩾*15m*



PROTEC Z types and main specifications

Voltage	Machine Mounting	Panel Mounting	BIL	Frequency Hz	THD(V) %
400 v	LV 400	N/A	N/A	50/60	10
690 v	LV 690	N/A	N/A	50/60	10
2 – 6.6kV	MM3C-(2-6.6kV)	N/A	45	50/60	10
2 – 8 kV	MM3-(2-5kV)	PM3-(2-8kV)	75	50/60	10
5 – 8 kV	MM3-(5-8kV)	N/A	75	50/60	10
5 – 13.8kV	N/A	MM3-(5-13.8kV)	95	50/60	10
5 – 13.8kV	MM3-(5-13.8kV)	N/A	95	50/60	10
13.8 – 17.1kV	MM1-(13.8-17.1kV)	N/A	125	50/60	10
17.6 – 25kV	MM1-(17.6-25kV)	N/A	125	50/60	10

Higher THD(V) versions can be designed