

# **VARIABLE SPEED DRIVES** **AND MOTORS**

## **Motor Insulation and PWM Inverter Drives**



ASSOCIATION FOR  
INSTRUMENTATION, CONTROL, AUTOMATION



ROTATING ELECTRICAL  
MACHINES ASSOCIATION

*Developed by the joint GAMBICA/REMA Working Group*

# VARIABLE SPEED DRIVES AND MOTORS

## Motor Insulation and PWM Inverter Drives

### INTRODUCTION

This user guide provides information to enable the correct matching of low voltage induction motors up to 690V and PWM inverters with respect to motor insulation.

The guide was produced by a working group of GAMBICA (Variable Speed Drives Group) and REMA, which are the associations for variable speed drive and electric motor manufacturers respectively. It is based on a review of published literature on the subject and a variety of test results and practical experience of member companies.

Variable speed a.c. drives are used in ever-increasing numbers because of their well-known benefits for energy efficiency and for flexible control of processes and machinery using low-cost readily available maintenance-free a.c. induction motors. While the connection of a motor to an inverter supply is straightforward, some basic considerations are necessary to ensure trouble free long-term operation.

Insulation performance is one of the considerations required in engineering variable speed drive solutions. Following these guidelines gives the user confidence in the final selection.

For readers requiring a more in-depth understanding, Technical Report No1 'Motor Insulation Performance Under PWM Inverter Operation' is available from GAMBICA or REMA.

### SUMMARY

- ◆ Motor winding insulation experiences higher voltage stresses when used with an inverter than when connected directly to the a.c. mains supply.
- ◆ The higher stresses are dependent on the motor cable length and are caused by the fast rising voltage pulses of the drive and transmission line effects in the cable.
- ◆ For supply voltages less than 500V a.c. most standard motors are immune to these higher stresses.
- ◆ For supply voltages over 500V a.c. a motor with an enhanced winding insulation system is required. Alternatively, additional components can be added to limit the voltage stresses to acceptable levels.

## Motor Insulation and PWM Inverter Drives

### MOTOR SELECTION

#### For supply voltages less than 500V a.c.

- ◆ Select a standard motor from REMA manufacturers (see back page). No further insulation considerations are necessary for PWM inverters.
- ◆ For motors from other suppliers, where the motor cable length exceeds 10m, the pulse withstand capability should be established by reference to the supplier. The permitted voltage/rise-time characteristic should equal or exceed curve A shown in the graph.

#### For supply voltages in the range 500V - 690V a.c.

- ◆ Select a motor with an enhanced insulation system available from REMA manufacturers. The additional cost of the enhanced insulation is typically 10 - 20% of the standard motor cost. No further insulation considerations are necessary for PWM inverters.
- ◆ For motors from other suppliers, the pulse withstand capability should be established by reference to the supplier. The permitted voltage/rise time characteristic should equal or exceed curve B shown in the graph.

#### Notes:

- i) Motor frame size selection must be appropriate for the application and duty.
- ii) Insulation requirements may be affected by the application specific notes overleaf.

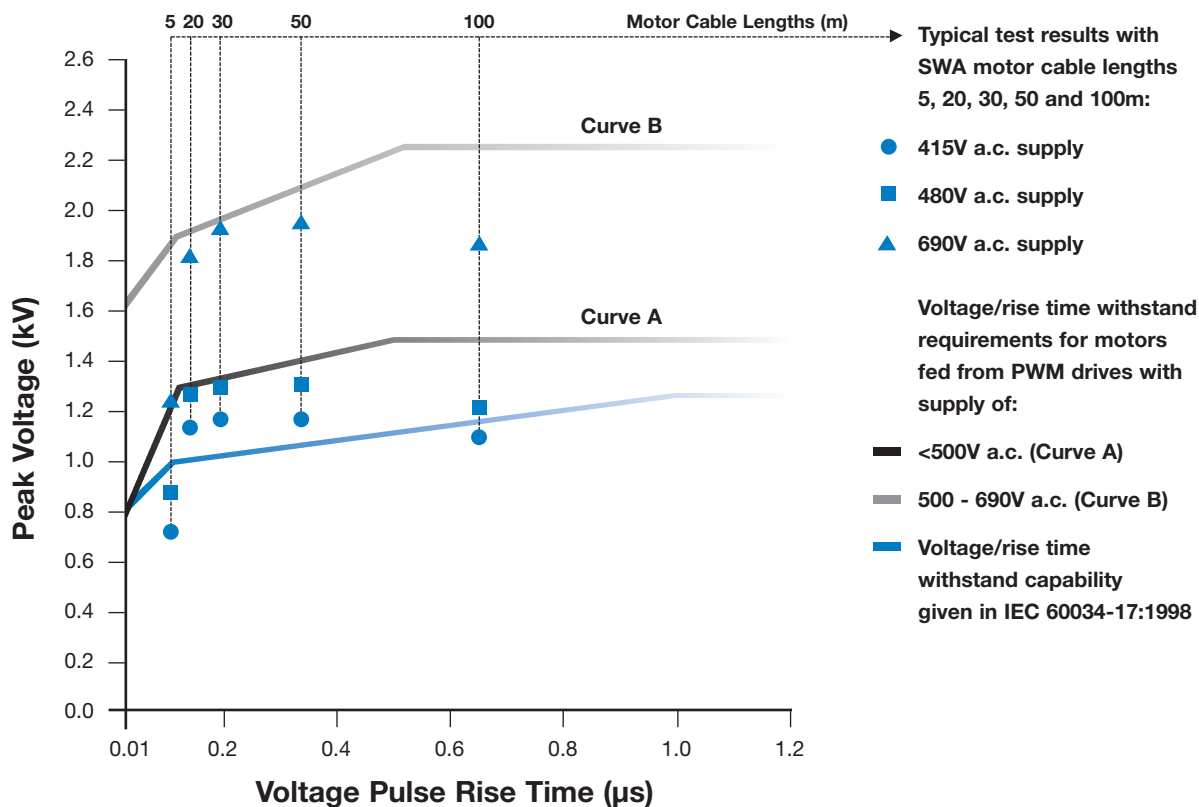
## ALTERNATIVE APPROACH

### Use Additional Preventative Methods

It may not be possible to follow the above recommendations - for example because the drive is to be retro-fitted to an existing motor, or data is not available for the motor concerned. In these cases an additional preventative measure is recommended - options are shown in the table on the right and the relative merits should be discussed with the drive supplier.

If special measures such as drive output reactors or filters are to be used for other reasons e.g. to limit the capacitance charging currents associated with motor cables or to reduce ripple currents, then no further special precautions are usually required.

## MOTOR PULSE WITHSTAND CHARACTERISTIC CURVES PEAK VOLTAGE/RISE TIME



- Notes: i) Motor pulse withstand requirements on 415V supply generally exceed the minimum capability specified in IEC 60034-17.  
 ii) Pulse risetime is in accordance with the IEC 60034-17 definition.  
 iii) These curves are based on the practical experience of GAMBICA and REMA members.

## TYPICAL RELATIVE COSTS - DRIVES AND PREVENTATIVE MEASURES (MOTOR = 100%)

RATING	DRIVE	PREVENTATIVE MEASURE			
		OUTPUT INDUCTOR	OUTPUT dv/dt FILTER	SINUSOIDAL FILTER	MOTOR TERMINATION UNIT
2.2kW, 415V	350%	75%	440%	330%	170%
75kW, 415V	220%	15%	100%	150%	10%
250kW, 415V	120%	5%	65%	110%	3%
160kW, 690V	150%	15%	40%	N/A	4%
250kW, 690V	140%	15%	40%	N/A	2%
500kW, 690V	140%	15%	35%	N/A	1%
POWER CIRCUIT OUTLINE					

# APPLICATION SPECIFIC NOTES

## **Applications with 'long' cable lengths**

The definition of 'long' depends on the drive rating and type, and may vary between 50m for lower power drives and 500m for higher powers - refer to manufacturers technical documentation. For these applications, new factors are introduced and the drive supplier should be consulted.

## **Drive switching strategies**

Some drive types use control strategies which could allow bipolar switching. These systems could theoretically double the motor peak voltage stress. GAMBICA inverter manufacturers implement control mechanisms to inhibit bipolar switching. If in doubt the drive or motor supplier should be consulted.

## **Frequent or continuous braking duty**

Where the drive spends a large part of its operating time in braking mode, the effect is similar to increasing the supply voltage by up to 20% and this should be taken into consideration - e.g. treat a 400V application as if it was supplied with 480V.

## **Active front end**

For drives with PWM active front ends (regenerative and/or unity power factor), the effective supply voltage is increased by around 15% and this should be taken into consideration e.g. treat a 480V application as if it was supplied with 550V.

## **Hazardous area approval**

The application of inverters to 'Ex' motors may invalidate the hazardous area certification - refer to the motor manufacturer.





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GAMBICA is the Association for Instrumentation, Control, Automation and has a group profile for suppliers of Variable Speed Drives

REMA is the Rotating Electrical Machines Association representing manufacturers of rotating electrical machines, other than turbine type machines, traction motors or machines for the use in aircraft.

The greatest care has been taken to ensure the accuracy of the information contained in this guide, but no liability can be accepted by GAMBICA, REMA or their members, for errors of any kind.

**Always refer to your Drive and Motor Suppliers if in doubt about correct matching**

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