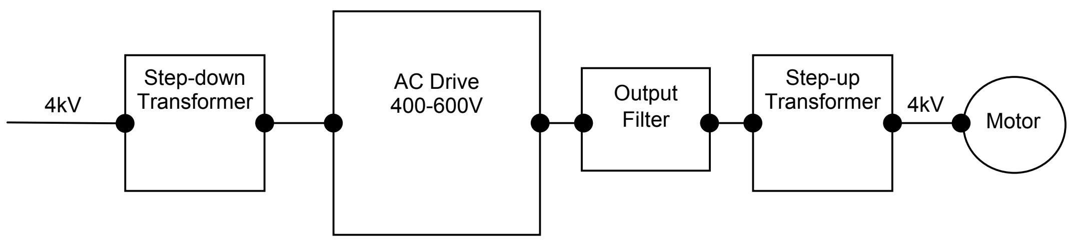
Application Note

Guidelines For The Use Of 400-600 Volt AC Drives In Medium Voltage Applications

Applicable Product: AC Drives



Subject: Step-Up XFMR	Product: AC Drives	Doc#: AN.AFD.08
Title: GUIDELINES ON THE USE OF OUTPUT FILTERS FOR STEP-UP APPLICATIONS		

INTRODUCTION

PWM AC drives have successfully been applied to medium voltage applications. In some cases, a low voltage AC drive, typically 460 or 600 volt is used in conjunction with step-down and step-up transformers on the input andoutput, respectively. This document is meant to provide basic guidelines in the application of AC drives and output filters for step-up transformer applications. The observations made here can be extended to the use of output filters without step-up transformer as well. The proper selection and use of sinusoidal output filters in step-up applications can result in lower motor and transformer stresses. The recommendations discussed in this article should be kept in mind while applying output filters. These basic precautions and guidelines, when adhered to, will yield optimum performance of the AC drive/filter/transformer combination.

OUTPUT FILTER DESCRIPTION

A filter designed for step-up transformer applications filter consists of three single-phase reactors (one for each phase) and capacitors connected in a wye configuration on the load side of the reactors. The component values are selected to filter the AC drive's PWM waveform at a particular carrier frequency (typically the AC drive default carrier frequency). By filtering, or "stripping", the PWM waveform, the issues associated with the high dv/dt are no longer of concern because the waveform applied to the transformer and motor becomes sinusoidal. The sinusoidal waveform no longer has the sharp edges associated with the PWM waveform. Therefore, the AC drive is unlikely to interact with the stray capacitance in the system, resulting in lower peak voltages, less leakage current, and lower stress on the transformer and motor insulation system.

INPUT/OUTPUT TRANSFORMER DESCRIPTION

The input step-down transformer is used to step down the voltage to the AC drives input voltage rating. Since this transformer is operating with nominal incoming voltage and frequency (i.e. 460 V @ 60Hz), a standard transformer design is usually adequate with only the harmonic content being of concern.
The output step-up transformer is used to increase the voltage back to a level as required by the motor.
The output step-up transformer should be a 3-phase transformer with delta-connected primary and wye-connected secondary. The neutral on the secondary-side should be grounded. The output transformer should have a grounded shield between the primary and secondary windings.

MITIGATING EFFECTS OF POWER DEVICE SWITCHING IN INPUT AND OUTPUT TRANSFORMERS

The Effect of Harmonics on Input Step-down Transformers

The additional heating due to the non-linear current flow associated with the AC drive's input diode bridge rectifier is generally managed by using an properly sized transformer with an appropriate K-Factor rating. The K-Factor rating indicates the transformers ability to tolerate the additional losses (heating) associated with the non-linear waveform. Harmonics are a significant concern when applying input step-down transformers to an AC drive. To reduce the impact of harmonics, in such cases a 12-pulse (3-winding) step-down transformer is recommended.

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The Effect of DC Components in the AC Drive's Output PWM

AC drive PWM voltage waveforms can create DC components that will be applied to the output step-up transformers. All AC drive PWM patterns have some amount of voltage mismatch between the positive half and the negative half of the output fundamental frequency. Heating and saturation may result from the PWM waveform of the AC drive and the DC component often associated with such a waveform.
The output filter is not designed to filter such resultant DC components in the AC drive's output voltage waveforms. Standard output step-up power transformers are generally not equipped to handle DC components. The engineers at Yaskawa Electric America in cooperation with Hammond Transformers have developed special transformers with air-gaps to handle certain amount of DC components. These specially designed transformers are recommended for use with output filters. In cases where this is not possible, it is recommended to set the AC drive's Hunting Prevention Gain parameters to a lower value (or disable). This has been identified as a factor that can influence the DC component in the output voltage waveform.

The Effect of dv/dt Stresses on the Motor and Output Transformer

The AC drive will apply a PWM waveform to the output transformer. A voltage peak associated with high dv/dt is experienced through the use of the AC drive's IGBT switching devices. The high dv/dt stresses the insulation in both the transformer and motor. The dv/dt may interact with the stray capacitance in the system, resulting in nuisance AC drive tripping and/or voltage "ringing". The dv/dt may also cause shaft voltages that may lead to premature motor bearing failure. An output filter between the AC drive and the output transformer is recommended to mitigate dv/dt stresses to both the motor and output transformer.

GUIDELINES FOR THE AC DRIVE, OUTPUT FILTER AND MOTOR

AC Drive Guidelines

V/F Motor Control Method with Speed-Search

V/F control is the preferred motor control method for step-up applications. However, implementing a V/F motor control method in conjunction with speed-search can be detrimental to the operation of the output filter due to resulting large current surges. The output filter components may cause the AC drive to improperly sense motor speed when starting into a rotating motor. Thus, if speed search is desired, it will be necessary to use the drive in V/F control method (w/ PG fdbk). The user should implement a "V/F with PG feedback" motor control method if speed-search is absolutely required. If PG feedback is unavailable, speed-search may be enabled only if the AC drive's torque limit is set to 125% or lower.

Open-loop and Closed-loop Vector Motor Control

Open-loop and closed-loop vector motor control should not be employed when the AC drive has an output filter. Though the parameter tuning may proceed smoothly during installation, the sudden current surges that are expected in a tightly tuned control loop may cause drive system instability. This instability can cause permanent damage to the AC drive and may potentially harm the filter capacitors. Furthermore, due to the presence of a large filter inductor in the output, fast torque and speed response from the AC drive are not possible. This may saturate the drives control loops and result in undesirable current surges.

Carrier Frequency 2.0kHz or Less

The recommended Yaskawa output filter design requires that the AC drive have an output carrier frequency of 2.0kHz or above. Variable carrier frequencies starting at values lower than 2.0kHz should be avoided. AC drive carrier frequencies below 2.0kHz can cause large circulating currents (at low fundamental output frequency) and create excessive power loss and heating in the output filter inductors. Higher carrier frequency will result in better output filter performance.

Motor Guidelines

Reducing Motor Shaft Voltages

A properly selected transformer can provide the advantage of reducing motor shaft voltages and increased bearing life. A transformer with a wye secondary results in sinusoidal line-neutral voltages and eliminates common mode voltage and hence shaft voltage. Shaft voltage with high dv/dt in medium voltage motors can cause premature failure of the bearings. Step-up transformers having delta-connected primary and delta-connected secondary or wye-connected primary and wye-connected secondary should be avoided. Using a step-up transformer with a wye secondary will take maximum advantage of the sinusoidal output filter from common mode voltage viewpoint.

Motor Overload Protection

The output filter will create additional current flow on the output of the AC drive. Experience has shown that when using the AC drive's ***fan cooled motor overload curve,*** the additional currents may cause nuisance motor overload faults while operating at lower motor speeds. It is recommended that the AC drive's ***blower cooled motor overload curve*** be used to accommodate the additional current flowing through the filter.

Output Filter Guidelines

Output Filter Inductor Cooling

Cooling fans are recommended to eliminate hot spots near the core and windings of the single-phase inductors. Door mounted fans blowing air directly across the inductors have been used to eliminate any hot spots. Fans positioned to blow ambient air across the inductors is recommended. Simply exhausting the warm air from the filter may not be sufficient. Fan life will be extended using this method. If the output filter is contained within the drive enclosure, additional enclosure fans may be required for the proper ventilation as the losses in the filter may approach 3% of the rated capacity of the motor.

Output Filter Inductor Thermal Switch

The inductor over-temperature switch should be wired to shutdown the AC drive in case of over temperature (due to fan failure, excessive current, low carrier, etc.). The AC drive's ***external fault multifunction input*** can be used with the thermal switch to shutdown the AC drive. An interposing relay is recommended to reduce the possibility of stray currents caused by the magnetic fields around the inductors from reaching the microprocessor-based AC drive.

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RECOMMENDATION

Yaskawa recommends using an output filter to filter the PWM waveform when applying PWM AC drives to medium voltage sinewave applications through the use of step-up transformers. A mutli-faceted approach containing AC drive settings, proper transformer selection and PWM filter precautions is suggested. This is based on Yaskawa field experience and extensive lab research. Following the guidelines in this paper will result in more successful use of 400-600 volt class AC drives in medium voltage applications.