PRELIMINARY SIZING AND PERFORMANCE EVALUATION OF MEDIUM-VOLTAGE MOTOR STARTING SYSTEMS

VarStec Power Solutions
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Abstract - Large medium-voltage motors can impose severe voltage sag during starting, reducing motor terminal voltage and available accelerating torque. MotorVAR applies switched reactive compensation during the starting interval to support voltage locally and reduce the reactive burden on the upstream system. This paper presents a practical preliminary method for evaluating MotorVAR-assisted starts using steady-state impedance and voltage-divider calculations. Direct-on-line, reduced-voltage soft starter, captive transformer, and line-reactor configurations are reviewed. The method is intended for early-stage screening, preliminary kvar selection, voltage-sag estimation, starting torque evaluation, and development of an initial equipment scope before final dynamic study or project-specific verification.

Index Terms - motor starting, MotorVAR, voltage sag, reactive compensation, induction motor, reduced-voltage soft starter, captive transformer, starting torque.

I. INTRODUCTION

VarStec's MotorVAR is a medium-voltage motor starting capacitor bank designed to enable reliable starting of large induction and synchronous motors while maintaining acceptable system voltage and motor terminal voltage during starting. Compared to traditional starting methods such as Reduced-Voltage Soft Starters (RVSS) and Adjustable Speed Drives (ASD/VFDs), MotorVAR provides a simpler, more robust, and more cost-effective solution. Built entirely from proven, off-the-shelf components, it introduces no steady-state harmonics, does not require a climate-controlled E-House, and eliminates the need for synchronous bypass switchgear and complex transfer schemes.

The purpose of this VarStec Engineering Brief is to explain the fundamentals of the MotorVAR concept and present practical methods for calculating its performance across a range of system configurations. The focus is on the steady-state impedance calculations used to evaluate voltage performance, starting torque margin, reactive power requirements, and upstream system impact during motor starting. Understanding these relationships allows the engineer to properly size the MotorVAR system, develop an accurate preliminary equipment scope, and establish a sound basis for project pricing and final design.

II. WHY IT MATTERS

Starting large medium-voltage motors can impose severe voltage sags on both the plant electrical system and the utility supply. High locked-rotor current flowing through the source and transformer impedance can depress the voltage at the motor terminals and at upstream buses to unacceptable levels. Because motor starting torque varies with the square of the applied voltage, even a moderate reduction in terminal voltage can produce a significant loss of available accelerating torque. The result can be prolonged acceleration, failure to start, excessive heating, or unacceptable disturbance to other connected equipment.

Traditional methods used to reduce motor starting current, such as line reactors, autotransformer starting, RVSS units, and ASD/VFD systems, each involve tradeoffs in cost, complexity, performance, or equipment scope. Some reduce current by reducing motor voltage, which may further limit starting torque. Others introduce added system complexity, additional equipment interfaces, harmonic considerations, environmental requirements, or bypass and transfer arrangements that increase cost and design burden.

MotorVAR addresses the motor starting problem from a different direction. By supplying reactive power locally during the starting interval, it reduces the reactive current drawn from the upstream system and helps support voltage at the motor bus. This allows the motor to develop more starting torque while reducing the magnitude of voltage sag seen by the rest of the electrical system. The performance of a MotorVAR-assisted start can be predicted using simple steady-state impedance and voltage-divider methods. In practical application, these methods are organized in the VarStec MotorVAR Sizing Tool (visit www.varstec.com/resource-hub/technical-downloads/) described in the next section.

III. THE VARSTEC MOTORVAR SIZING TOOL AND STARTING CONFIGURATIONS

The VarStec MotorVAR Sizing Tool is a practical preliminary engineering tool used to evaluate induction and synchronous motor starting performance and develop a preliminary MotorVAR rating across several common system configurations. Rather than relying on a complex dynamic model at the early design stage, the tool applies steady-state impedance and voltage-drop methods to estimate the key performance parameters that govern feasibility and preliminary sizing.

The tool is organized into separate worksheets by starting configuration. For each case, the user enters the basic system inputs, including utility source strength, step-down transformer data, motor data, and the applicable MotorVAR rating. Where required, the tool also incorporates optional equipment such as an RVSS, a starting reactor, or a captive transformer. The results are presented in a structured format that compares the unassisted motor start to the MotorVAR-assisted case and summarizes the effect on starting current, motor terminal voltage, bus voltage sag, and approximate starting torque.

A. Simple Configuration: DOL + MotorVAR

The simple configuration worksheet evaluates a direct-on-line motor start with and without MotorVAR applied at the motor bus. This is the most basic MotorVAR application and is the starting point for preliminary screening. The sheet compares the baseline unassisted motor start to the MotorVAR-assisted case and shows how the capacitor bank reduces the voltage sag on the network and improves motor starting performance.

B. MotorVAR + RVSS Configuration

This worksheet evaluates applications in which MotorVAR is used together with a Reduced-Voltage Soft Starter. It includes the baseline unassisted case, a MotorVAR-only case with the RVSS bypassed, and the combined MotorVAR + RVSS case. This allows the engineer to compare the benefit of MotorVAR alone with the combined MotorVAR + RVSS arrangement.

This configuration is especially useful where an existing RVSS installation cannot provide sufficient starting torque for reliable motor acceleration. In these cases, MotorVAR, applied in coordination with the RVSS, supports voltage during the starting interval and can improve motor terminal voltage and available starting torque.

C. Captive Transformer Configuration

This worksheet is intended for systems in which the motor is supplied through an additional captive transformer. In this case, the tool evaluates the effect of that added series impedance on both the unassisted and MotorVAR-assisted start. It is useful where voltage must be reviewed not only at the motor terminals, but also at the captive transformer primary, the upstream secondary bus, and the primary source. It is also well suited for systems with multiple medium-voltage distribution levels, such as plants with both 4.16 kV and 13.8 kV buses.

D. MotorVAR + Line Reactor Configuration

This worksheet evaluates applications where a starting reactor is used with MotorVAR. It includes the baseline unassisted case, a MotorVAR-only case with the reactor bypassed, and the combined MotorVAR + reactor case. This allows the engineer to compare the tradeoff between additional current limitation and any corresponding reduction in motor terminal voltage and starting torque.

Taken together, these worksheets provide a consistent framework for screening the most common MotorVAR applications. They allow the engineer to quickly compare alternatives, identify the likely MotorVAR rating, and determine whether a simple MotorVAR solution is sufficient or whether additional starting equipment should also be considered.

IV. CONCLUSIONS

MotorVAR provides a practical and robust way to improve the starting performance of large medium-voltage motors by supporting voltage during the starting interval and reducing the reactive burden placed on the upstream system. Because its preliminary performance can be evaluated using straightforward steady-state impedance and voltage-drop methods, the engineering is transparent, fast, and well suited for early-stage screening and equipment sizing.

The VarStec MotorVAR Sizing Tool applies these methods in a structured format that allows the engineer to evaluate common starting arrangements, including direct-on-line, RVSS-assisted, reactor-assisted, and captive-transformer applications. In only a few minutes, multiple design approaches can be reviewed and compared to estimate MotorVAR rating, voltage sag, motor terminal voltage, and approximate starting performance.

Just as importantly, MotorVAR is not a one-size-fits-all solution. Each application should be engineered as a VarStec System-Fit™ solution based on the specific utility strength, transformer impedance, motor characteristics, voltage requirements, and starting objectives of the project. For engineering support, application review, and a quotation for a MotorVAR system, contact VarStec Power Solutions.

V. REFERENCES

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VI. VITAE

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