Use of MCC-Based Motor Torque Measurements for Periodic Verification of Motor-Operated Valves

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EPRI Project Manager
J. Hosler

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

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ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

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CITATIONS

This report was prepared by

MPR Associates, Inc.
320 King Street
Alexandria, VA 22314

Principal Investigators
P. Damerell
J. Gratz
M. Frey

Crane Nuclear, Inc.
2825 Cobb International Blvd.
Kennesaw, GA 30152

Principal Investigator
W. Darmetko
D.Graf

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PRODUCT DESCRIPTION

This report develops, justifies, and validates a motor control center- (MCC-) based Motor Torque Periodic Verification (MTPV) method for torque-switch-controlled closing strokes of rising stem motor-operated valves (MOVs) with AC motors. The report details the evaluation of motor torque data obtained from electrical measurements at the MCC and covers the use of these (and other) measurements in MOV periodic verification (PV) testing.

Results and Findings

The MTPV method was validated against MOV test data from 15 in-plant MOVs. The validation included parallel test data (motor torque and direct thrust measurements) from baseline tests, as well as subsequent tests, to evaluate the performance of MTPV. In comparison to PV testing with stem thrust measurements, the validation showed the following:

- For 14 of the 15 MOVs, the predicted stem thrust at control switch trip (CST) (based on measured motor torque) deviated from the measured stem thrust by ± **(Content Deleted- EPRI Proprietary Information)** %. These variations were within the stated uncertainties for data analysis based on motor torque measurements.
- For one MOV, the change in motor torque at CST between tests exceeded the MTPV method acceptance criteria for periodic verification. Accordingly, the MTPV method indicated that the MCC-based tests for this MOV were insufficient to verify appropriate operational margin. Further engineering evaluation or an "at-the-valve" test would be required.

In addition to the validation analyses, the data from the 15 in-plant MOVs were evaluated to determine the potential effect of the MTPV methodology on MOV setup limits. In comparison to PV testing with stem thrust measurements, the MOV setup limit analyses showed:

- In the MTPV method, the setup lower limit is more restrictive (higher). The observed increase in the lower limit was as high as **(Content Deleted- EPRI Proprietary Information)** %.
- In the MTPV method, the setup mechanical upper limit is more restrictive (lower). The observed reduction in mechanical upper limit was as high as **(Content Deleted- EPRI Proprietary Information)** %.
- In the MTPV method, the setup motor torque capability (based on degraded voltage performance) is typically less restrictive (higher). The observed improvement ranged from **(Content Deleted- EPRI Proprietary Information)** %.

Based on these observations, the MTPV method is useful for MOVs that have an operational margin (margin to lower limit) and a margin against structural damage (margin to upper mechanical limit) of at least **(Content Deleted- EPRI Proprietary Information)** %. There is no constraint with regard to margin against motor torque capability, and in fact, use of MTPV is likely to improve margin in this category. Accordingly, the MTPV method may be a particularly good PV methodology for evaluation of MOVs whose setup is limited by motor torque capability at degraded voltage.

Challenges, Objectives

The objective of this work is to develop, justify, and validate a technique for conducting MOV PV tests using MCC-based motor torque measurements. Use of such methods is made more difficult by the need for justifying assumptions regarding potential uncertainties, including:

- Torque switch repeatability
- Stem factor uncertainty
- Rate-of-loading uncertainty
- Stem thrust measurement uncertainty
- Motor torque measurement uncertainty
- Actuator efficiency uncertainty
- Stem thrust inertia uncertainty

The report provides justification for a generic actuator efficiency uncertainty—a value that is not generally justified within plant MOV programs.

Applications, Value, and Use

The MTPV methodology is applicable to closing strokes of MOVs with rising stems, torque switch control, and AC motors. It can be used in lieu of a direct stem thrust measurement to periodically verify actuator output capability. Use of this method can result in significant cost savings when compared to "at-the-valve" testing.

EPRI Perspective

The MTPV methodology provides a cost-effective alternative to expensive "at-the-valve" testing to verify MOV actuator margins as recommended by Generic Letter 96-05. In combination with an effective preventive maintenance program, this methodology will help to ensure the operability of safety-related MOVs.

Approach

The MTPV method requires a baseline parallel test that includes MCC-based motor torque measurements and direct stem thrust measurements from sensors at the valve. Results from this test are used to determine the parameters needed to interpret data from subsequent PV tests where measurements are made only at the MCC. All testing (baseline and subsequent tests) is performed with no flow, pressure, or differential pressure in the pipe ("static" testing).

In this method, motor torque upper and lower limits are determined based on information from the baseline test. In subsequent tests, measured motor torque at CST is compared to these limits to verify that the MOV setup is acceptable and to quantify the margin for successful operation.

Uncertainties from several sources need to be considered in setting up the MTPV upper and lower limits. Most of these uncertainties are identified within existing plant MOV programs. This report includes analyses of in-plant MOV data to justify a value for actuator efficiency variation, which is an uncertainty that is not typically quantified by plants.

Keywords

Valves
Motor-operated valves
MCC-based motor torque measurement
Actuator margin verification
MOV periodic verification

ABSTRACT

This report develops, justifies, and validates a methodology for analysis and use of motor control center- (MCC-) based measurements (most important, measurement of motor torque) in a nuclear plant's periodic verification of motor-operated valves (MOVs). The method uses a baseline parallel test with simultaneous motor torque measurements (at the MCC) and stem thrust measurements (at the valve) to determine a relationship (MOV factor) between motor torque and stem thrust at control switch trip (CST). Upper and lower thrust limits are converted to motor torque limits using this calculated MOV factor and applying uncertainties as appropriate. Motor torque data from subsequent tests may be compared to these motor torque limits to verify adequate setup and to determine operational margin. This operational margin is consistent with margin as defined by the Joint Owners Group Periodic Verification Program.

Key elements of the methodology are justified using data from nuclear power plant MOV testing. In particular, a value for actuator efficiency uncertainty is justified based on motor torque data from 36 static tests of 11 MOVs.

The method is validated using data from tests of 15 MOVs at three nuclear power plants. For these MOVs, a second parallel test provided the necessary data to evaluate how well MCC-based measurements predict stem thrust. For 14 of the 15 MOVs, the predicted thrust at CST based on measured motor torque was consistent with the measured stem thrust at CST, considering measurement uncertainties. For one MOV, the change in motor torque at CST between tests exceeded the MTPV method acceptance criteria for MCC-based periodic verification. In practice, this result would indicate to the user either that the MOV setup had been changed or that there may be a problem with the MOV. In either case, further engineering evaluation or an "at-the-valve" test would be required to verify appropriate operational margin.

The method as described and justified in this report is applicable to torque-switch controlled closing strokes of rising stem MOVs with AC motors. Potential techniques for analysis of limit-switch controlled strokes using MCC-based measurements are discussed as well.

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EXECUTIVE SUMMARY

Historically, diagnostic testing of motor-operated valves (MOVs) for periodic verification (PV) has been conducted using "at-the-valve" tests. Although nuclear power plants have recognized the potential benefits of PV testing conducted at the motor control center (MCC), this technique is not widely used due to a lack of validated methods for use of MCC-based measurements in PV.

This report develops, justifies, and validates an MCC-based Motor Torque Periodic Verification (MTPV) method for torque-switch controlled closing strokes of rising stem MOVs with AC motors. The report details the evaluation of motor torque data obtained from electrical measurements at the MCC and covers use of these (and other) measurements in MOV PV testing. Currently, there are diagnostic vendors that offer the capability to measure motor torque at the MCC. Therefore, this report assumes that this MCC-based measurement is available with a justified accuracy and does not address the process of motor torque measurement. (For example, plants currently using diagnostic systems to measure motor power could apply the MTPV methodology as long as the recorded motor power data are converted to motor torque and measurement uncertainty is appropriately addressed.)

The MTPV method requires a baseline parallel test that includes MCC-based motor torque measurements and direct stem thrust measurements from sensors at the valve. Results from this test are used to determine parameters needed to interpret data from subsequent PV tests where measurements are made only at the MCC. All testing (baseline and subsequent tests) is performed with no flow, pressure, or differential pressure in the pipe (referred to as *static* testing).

In the MTPV method, motor torque upper and lower limits are determined based on information from the baseline test. In subsequent tests, measured motor torque at control switch trip (CST) is compared to these limits to verify that the setup of the MOV is acceptable and to quantify the margin for successful operation. This approach is analogous to current PV methods based on stem thrust measurements, where pre-determined thrust limits are used to evaluate measured thrust at CST.

Uncertainties from several sources need to be considered in setting up the MTPV upper and lower limits. Most of these uncertainties are identified within existing plant MOV programs. This report includes analyses of in-plant MOV data to justify a value for actuator efficiency variation.

The MTPV method was validated against MOV test data from 15 in-plant MOVs. The validation included parallel test data (motor torque and direct thrust measurements) from baseline tests, as well as subsequent tests, to evaluate the performance of MTPV. The validation showed that:

- For 14 of the 15 MOVs, the predicted stem thrust at CST (based on measured motor torque) deviated from the measured stem thrust by ± **(Content Deleted- EPRI Proprietary Information)** %. These variations were within the stated uncertainties for analysis of the data based on motor torque measurements.
- For one MOV, the change in motor torque at CST between tests exceeded the MTPV method acceptance criteria for periodic verification. Accordingly, the MTPV method indicated that the MCC-based tests for this MOV were insufficient to verify appropriate operational margin. In such a case, further engineering evaluation or an "at-the-valve" test would be required.

In addition to the validation analyses, the data from the 15 in-plant MOVs were evaluated to determine the potential effect of the MTPV methodology on MOV setup limits. In comparison to PV testing with stem thrust measurements, the MOV setup limit analyses showed the following:

- In the MTPV method, the setup lower limit is more restrictive (higher). The observed increase in the lower limit was as high as **(Content Deleted- EPRI Proprietary Information)** %.
- In the MTPV method, the setup mechanical upper limit is more restrictive (lower). The observed reduction in mechanical upper limit was as high as **(Content Deleted- EPRI Proprietary Information)** %.
- In the MTPV method, the setup motor torque capability (based on degraded voltage performance) is typically less restrictive (higher). The observed improvement ranged from **(Content Deleted- EPRI Proprietary Information)** %.

Based on these observations, the MTPV method is useful for MOVs that have an operational margin (margin to lower limit) and a margin against structural damage (margin to upper mechanical limit) of at least **(Content Deleted- EPRI Proprietary Information)** %. There is no constraint with regard to margin against motor torque capability, and in fact, use of MTPV is likely to improve margin in this category. Accordingly, the MTPV method may be a particularly good PV methodology for evaluation of MOVs whose setup is limited by motor torque capability at degraded voltage.

NOMENCLATURE

The nomenclature used in the Motor Torque Periodic Verification method is summarized below.

AF	application factor
CST	control switch trip
EFF	actuator efficiency
F_{MOV}	MOV factor
$F_{MOV, CST}$	MOV factor at CST
FS	stem factor
FS_{CST}	stem factor at CST
MARGIN	margin above required thrust at CST
MT	measured motor torque
MT_{HOTEL}	measured motor torque hotel load
$MT_{LL, CST}$	lower limit of motor torque at CST
$MT_{MAX, CST}$	measured maximum motor torque at CST
$MT_{MEAN, CST}$	measured mean motor torque at CST
$MT_{ML, CST}$	mechanical limit of motor torque at CST
$MT_{ML, CST (W/ UNC)}$	mechanical limit of motor torque at CST, including uncertainty
MT_{NOM}	nominal motor torque capability (motor start torque)
$MT_{REQ, CST}$	required motor torque at CST
$MT_{UL, CST}$	upper limit of motor torque at CST

MT_{VRED} — motor torque capability at reduced voltage

$MT_{VRED\,(W/\,UNC)}$ — motor torque capability at reduced voltage, including uncertainty

OAR — overall actuator ratio

ROL_{BIAS} — bias component of rate-of-loading

ROL_{RAND} — random component of rate-of-loading

TH — measured stem thrust

TH_{CST} — measured stem thrust at CST

TH_{MAX} — measured maximum stem thrust

$TH_{INERTIA}$ — stem thrust due to inertia, $(TH_{MAX} - TH_{CST})$

TH_{LL} — lower limit of stem thrust

TH_{ML} — mechanical limit of stem thrust

$TH_{P,\,CST}$ — predicted stem thrust based on measured motor torque at CST

$TH_{REQ,\,CST}$ — required stem thrust at CST

TH_{VRED} — thrust capability at reduced voltage

$TH_{VRED\,(W/\,UNC)}$ — thrust capability at reduced voltage, including uncertainty

TSR — torque switch repeatability

TQ_{CST} — measured stem torque at CST

U_{EFF} — actuator efficiency uncertainty/degradation

$U_{INERTIA}$ — inertial thrust uncertainty

$U_{MT,\,MEAS}$ — motor torque measurement uncertainty

U_{SF} — stem factor uncertainty/degradation

$U_{TH,\,MEAS}$ — stem thrust measurement uncertainty

U_{TOTAL}	total uncertainty
V_{NOM}	nominal voltage
V_{RED}	reduced voltage

COMMON CONVERSION FACTORS USED IN THIS REPORT

1 ft-lb = 1.36 N-m

1 ft-lb/lb = 0.31 N-m/N

1 inch = 2.54 cm

1 inch-lb/lb = 0.025 N-m/N

1 in-lb = 0.11 N-m

1 lb (force) = 4.45 N

1 psi = 6.89 kPa

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1 INTRODUCTION

1.1 Background

In 1989, the U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter 89-10, *Safety-Related Motor-Operated Valve Testing and Surveillance*, which required nuclear power plants to review and validate design basis requirements for safety-related motor-operated valves (MOVs) to ensure that these MOVs were capable of performing their required safety-related functions. To ensure continued reliability of safety-related MOVs, the NRC later issued Generic Letter 96-05, *Periodic Verification of Design-Basis Capability of Safety-Related Motor-Operated Valves*, which required facilities to develop a periodic verification (PV) program to address potential valve and/or actuator degradation.

One component of a successful PV program is regular diagnostic testing of MOVs. Historically, this type of testing has required access to the valve for installation of transducers and other equipment necessary to assess valve performance. This process is time consuming and limited by accessibility to the plant's MOVs. Although technologies are available that allow diagnostic testing to be performed from a remote location at the motor control center (MCC),[1] this type of diagnostic testing has not been implemented at many sites because justified and accepted methods for use of MCC-based testing within a PV program have not been defined.

1.2 Purpose

The purpose of this document is to develop and qualify a method of use for MCC based MOV diagnostic testing as an alternative, or a supplement, to "at-the-valve" diagnostic testing within nuclear plants' PV programs.

[1] Reference 1 provides a discussion of the use of MCC-based systems in plant MOV programs.

1.3 Scope

This document develops and justifies a method for evaluation of MCC-based test data called the Motor Torque Periodic Verification (MTPV) method. This report demonstrates how this methodology may be implemented within a nuclear plant's PV program. The scope of this document is as follows:

- Define the applicability, limitations, strengths, and weaknesses of the method.
- Define a step-by-step approach for use of the method to evaluate an MOV's current setup including:
  - Determination of MOV operational margin in accordance with the Joint Owners Group MOV Periodic Verification Program [2]
  - Evaluation of MOV setup against valve/actuator mechanical limits
  - Evaluation of MOV setup against reduced voltage motor capability
- Provide justification for key elements of the method and overall validation of the method based on plant MOV test data.
- Provide an example implementation of the method.

It is important to note that this document focuses on the evaluation of measured motor torque data as it pertains to an MOV's upper and lower setup limits. This document does not address how to measure motor torque from the MCC. Motor torque is assumed to be measured using a vendor-provided diagnostic system with a justified measurement uncertainty. Justification of motor torque measurement is the responsibility of the user (and the diagnostic equipment vendor) and is not included in this report.[2]

1.4 Report Organization

Section 2 details the applicability of the MTPV method and provides an overview of the methodology. Section 3 provides a step-by-step implementation of the method. Section 4 justifies key elements of the method, and Section 5 validates the method. An example implementation of the MTPV method is presented in Section 6, in both English and SI units. Section 7 of the report evaluates the potential effect of the MTPV method on typical MOV setup limits. References for this report are provided in Section 8.

[2] It is important to note that the MTPV method is independent of the specific methods used for determination of motor torque as long as the determined motor torque is expressed with an appropriate accuracy or uncertainty. For example, plants currently using diagnostic systems to measure motor power could apply the MTPV methodology as long as the recorded motor power data are converted to motor torque and measurement uncertainty is appropriately addressed.

Appendix A discusses potential MCC-based periodic verification methods for conditions outside the applicability of the MTPV method, including limit switch controlled strokes. Appendix B details several characteristics of MCC diagnostic systems that need to be considered for accurate data acquisition and analysis. Appendix C describes the general procedure for conversion of measured value uncertainties to upper and lower limit uncertainties. Appendix D describes justification for a value of actuator efficiency uncertainty, based on best available information.

2 METHOD DESCRIPTION

2.1 Applicability

The Motor Torque Periodic Verification (MTPV) method can be used for periodic verification of MOVs for the conditions listed below:

- Closing strokes
- Rising stem valves
- Torque switch controlled strokes
- AC motors

Use of the MTPV method beyond these conditions must be justified and validated by the plant.

Potential approaches for using MCC-based methods to evaluate opening strokes and valves with limit switch controlled strokes are presented in Appendix A; however, these approaches have not been validated. Plants that choose to use these approaches are responsible for justification and validation.

2.2 Overview

The MTPV method is an approach for comparing measurements of motor torque that are taken at the MCC to pre-determined limits to assess the operational margin of an MOV. The general procedure is similar to that used by plants for PV testing with direct thrust measurement methods:

1. Lower and upper "raw" limits are calculated.
2. Test equipment accuracy, torque switch repeatability, and other uncertainties are accounted for and used to develop "adjusted" limits.
3. Data are acquired from a test to verify that the measured values fall between the adjusted limits and to quantify the operational margin.

A graphical representation of the MTPV method is presented in Figure 2-1. A flow chart of the MTPV process is presented in Figure 2-2. The method shown in these figures is discussed below, and the detailed implementation of the method is discussed in Section 3 of this report.

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Figure 2-1
Motor Torque Periodic Verification Method Limits and Margin

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Figure 2-2
Motor Torque Periodic Verification Method Flowchart

For the MTPV method, raw lower and upper limits are based on existing stem thrust limits that plants have previously established as part of their MOV programs. These thrust limits are converted to raw upper and lower motor torque limits using an MOV Factor, defined below.

(Content Deleted – EPRI Proprietary Information) **Equation 2-1**

For each MOV utilizing the MTPV method, an initial baseline parallel test is required to obtain key parameters needed to establish the lower and upper MTPV limits. These parameters include:

- MOV Factor
- Motor Torque Hotel Load
- Inertial Thrust Component

A parallel test involves acquisition of simultaneous measurements at (1) the MCC, to determine motor torque and other data (for example, switch actuation), and (2) the MOV, to determine stem thrust (and possibly stem torque). Requirements for specific measurement parameters are provided in Section 3 of this report in Table 3-1. PV tests subsequent to the initial baseline test need only to obtain measurements at the MCC.

As with raw direct thrust limits, the resulting raw motor torque limits need to be adjusted appropriately for uncertainties to determine the *adjusted* upper and lower motor torque limits. These uncertainties may include (but are not limited to):

- Torque switch repeatability
- Thrust measurement uncertainty
- Motor torque measurement uncertainty
- Stem factor uncertainty
- Actuator efficiency uncertainty
- Inertial thrust uncertainty
- Rate of loading (ROL)

Further discussion of uncertainties is provided below. As shown in Figure 2-1, the window between the upper and lower motor torque limits is likely to be narrower than the window between stem thrust limits developed for direct thrust measurements. This difference is due to the additional uncertainties associated with the MTPV method, the most significant of which is motor torque measurement uncertainty.

During subsequent PV tests, the MCC-measured motor torque at control switch trip (CST) is compared to the upper and lower motor torque limits to ensure that the measured value is between these limits. If the measured motor torque at CST is greater than the lower limit, the valve has positive operational margin. The margin can then be quantified, and the resulting value fed back into the valve's PV program. If the measured motor torque at CST is less than the lower limit, then the valve does not have positive margin based solely on MCC testing. Accordingly, an alternative test (for example, at the valve) is needed to ensure positive margin.

After a baseline test is established for an MOV, this baseline can be used indefinitely going forward as long as the setup and general conditions of the MOV do not change significantly. The events listed below are judged to significantly alter the setup and conditions of a valve. Accordingly, if any of these events occur after the baseline test of record, the original baseline test is invalidated, and a new baseline parallel test needs to be performed:

- Change to torque switch setting
- Motor replacement
- Actuator refurbishment, gear ratio change, or replacement
- Valve replacement
- Change in stem lubricant (from one lubricant to another)

Additional details on specific elements of Figures 2-1 and 2-2 are provided below.

Hotel Load - (Content Deleted - EPRI Proprietary Information)

Packing/Parasitic Load – (Content Deleted - EPRI Proprietary Information)

Raw Required Thrust – (Content Deleted - EPRI Proprietary Information)

Mechanical Limit -- (Content Deleted - EPRI Proprietary Information)

MOV Factor – (Content Deleted - EPRI Proprietary Information) Equation 2-2

Inertia – (Content Deleted - EPRI Proprietary Information)

Reduced Voltage Motor Capability – (Content Deleted - EPRI Proprietary Information)

(Content Deleted - EPRI Proprietary Information) Equation 2-3

2.3 Uncertainties

The appropriate consideration of uncertainties is a key aspect of applying the MTPV method. Uncertainties are applied to the upper and lower MTPV limits rather than the measured motor torque from a test. This approach is equivalent to applying the uncertainties directly to the measured value, so long as the application is done correctly. Appendix C describes and justifies the approach used in the MTPV method to convert uncertainties normally applied to measured values so they can be applied to limits.

As shown in Figure 2-1, some uncertainty parameters can be applied to stem thrust limits or motor torque limits equivalently. In some cases, the uncertainty can be applied only to one side of the figure. Uncertainties may be stated as a random error (for example, % reading) or as a random error with a bias (for example, offset). Multiple random uncertainties should be combined into a single value using the square root of the sum of squares method. Additional discussion of uncertainty evaluation is provided below and in Section 3.

Torque Switch Repeatability - This value is typically provided by the actuator manufacturer and expressed as a random error. Torque switch repeatability should be considered in all MTPV uncertainty evaluations (for example, upper and lower limits) and can be applied directly to the raw stem thrust or equivalent raw motor torque.

Stem Factor Uncertainty - This value is determined by each plant and may represent a statistical evaluation of multiple valves. Stem factor uncertainty should be considered when determining the MTPV lower limit and structural upper limit (that is, it is not required for reduced voltage limit). Variation in stem factor may be different in one direction than in the other direction and a different stem factor uncertainty may be applied to the MTPV lower limit versus the structural upper limit, as appropriate. Stem factor uncertainty can be applied directly to the raw stem thrust or equivalent raw motor torque.

Rate of Loading (ROL) - The difference in the stem nut efficiency at CST between a static test and a DP test is attributed to the ROL effect. ROL can be determined by each plant, based on results from DP and static tests for a valve or similar valves, or an accepted industry method (for example, EPRI ROL Methodology) can be used. ROL should be considered only when determining the MTPV lower limit. It is conservative to **not** consider ROL in the MTPV upper limit. ROL can be applied directly to the raw stem thrust for the lower limit or to the equivalent raw motor torque for the lower limit.

Actuator Efficiency Uncertainty - This value may be determined by each plant and may represent a statistical evaluation of multiple valves. In lieu of determining a value from test data, an actuator efficiency uncertainty value of **(Content Deleted - EPRI Proprietary Information)** % (relative to measured value) may be used. This value is discussed in Section 4 and justified as best available data in Appendix D. Actuator efficiency uncertainty should be considered in both the lower and upper motor torque limits.

Measurement Uncertainty - This value is typically provided by the measurement system vendor and expressed as a random error. Measurement uncertainty should be considered in all MTPV uncertainty evaluations (for example, upper and lower limits); however, care must be taken in applying uncertainties properly to stem thrust limits and motor torque limits.

Inertial Thrust Uncertainty - Inertial thrust uncertainty may be determined by each plant and may represent a statistical evaluation of multiple valves. Inertial thrust uncertainty should be considered only in the MTPV structural upper limit (that is, it is not required for the reduced voltage upper limit nor for the MTPV lower limit). It can be applied directly to the raw stem thrust or equivalent raw motor torque.

3
METHOD IMPLEMENTATION

The following section outlines the approach for implementation of the MTPV method. The implementation approach describes the methods for:

- Analysis of baseline parallel test data
- Development of acceptable upper and lower motor torque limits
- Analysis of subsequent MCC-only test data, including determination of margin

3.1 Test Requirements

The MTPV method requires an initial (baseline) test that records data at both the valve and the MCC. This parallel test data is used to develop parameters that relate motor torque to stem thrust for the tested valve. Subsequent valve tests need only to obtain measurements at the MCC. The bulleted items below detail the required measurements, instrument calibration, instrument accuracy, and test sequence for both the baseline parallel test and subsequent MCC-only tests:

- The following information is required and should be collected prior to implementing the MTPV method:
  - Nominal motor torque capability (motor start torque)
  - Nominal motor voltage
  - Reduced motor voltage (under design basis conditions)
  - Minimum required stem thrust/torque
  - Actuator thrust rating
  - Valve thrust rating or maximum allowable thrust from weak-link analysis
  - Actuator torque rating
  - Uncertainties, including:
    - Motor torque measurement uncertainty
    - Stem thrust measurement uncertainty
    - Torque switch repeatability
    - Rate of loading

  - o Stem factor uncertainty/degradation
  - o Actuator efficiency uncertainty/degradation
  - o Inertial thrust uncertainty

- The baseline parallel test should include the following:
  - Measurements at the MCC to determine motor torque and other data (for example, switch actuation)
  - Measurements at the MOV to determine stem thrust and/or stem torque

Subsequent tests need only to obtain the measurements at the MCC to determine motor torque and other data (for example, switch actuation). See Table 3-1 for a summary of required test measurements for a baseline parallel test and subsequent tests.

Table 3-1
Required Measurements for Motor Torque Periodic Verification Method

Measurement	Baseline Parallel Test	Subsequent Tests
Stem thrust	Required	- -
Motor torque[a] (from MCC)	Required	Required
Current through or voltage across control switches (from MCC)	Required	Required
Stem torque	Recommended, but not required	- -

a. This "measurement" involves several individual measurements of currents and voltages at the MCC along with other measurements such as stator resistance that are processed to determine motor torque. See Appendix B of this report for additional discussion of MCC-based motor torque measurement systems.

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3.2 Step 1 – Evaluation of Baseline Parallel Test Data

The MTPV method requires an initial valve test (baseline test) that records data at both the valve and the MCC. These parallel test data are used to develop parameters that relate motor torque to stem thrust for the tested valve. Evaluation of baseline parallel test data is described below.

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Figure 3-1
Overlay of Measured Motor Torque (Bottom Trace) and Stem Thrust (Top Trace)

1.2 **(Content Deleted - EPRI Proprietary Information)**

1.3 **(Content Deleted - EPRI Proprietary Information)**

(Content Deleted - EPRI Proprietary Information)

Figure 3-2
Example 1 of Mean and Maximum Motor Torque at CST

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Figure 3-3
Example 2 of Mean and Maximum Motor Torque at CST

(Content Deleted - EPRI Proprietary Information)

Figure 3-4
Example 3 of Mean and Maximum Motor Torque at CST

1.4 (Content Deleted - EPRI Proprietary Information)

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Figure 3-5
Motor Torque Hotel Load (Bottom Trace – Motor Torque; Top Trace – Stem Thrust)

1.5 **(Content Deleted - EPRI Proprietary Information)**

1.6 **(Content Deleted - EPRI Proprietary Information)**

(Content Deleted - EPRI Proprietary Information) **Equation 3-1**

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Figure 3-6
Stem Thrust Due to Inertia

1.7 **(Content Deleted - EPRI Proprietary Information)**

(Content Deleted - EPRI Proprietary Information) **Equation 3-2**

3.3 Step 2 – Determination of Upper Motor Torque Limit

The Upper Motor Torque Limit is the most limiting (that is, lowest value) of the MOV mechanical limit and the reduced voltage motor torque capability (both adjusted for uncertainties). Upper Motor Torque Limit is determined as described below:

2.1 Determine the MOV motor torque mechanical limit, adjusted for uncertainties, as follows:

2.1.1 **(Content Deleted - EPRI Proprietary Information)**

2.1.2 **(Content Deleted - EPRI Proprietary Information)**

(Content Deleted - EPRI Proprietary Information) Equation 3-3

2.1.3 **(Content Deleted - EPRI Proprietary Information)**

(Content Deleted - EPRI Proprietary Information) Equation 3-4

2.1.4 Determine the adjusted motor torque mechanical limit as follows:

(Content Deleted - EPRI Proprietary Information) Equation 3-5

2.2 Determine the reduced voltage motor torque capability, adjusted for uncertainties, as follows:

2.2.1 **(Content Deleted - EPRI Proprietary Information)**

(Content Deleted - EPRI Proprietary Information) Equation 3-6

2.2.2 This reduced voltage motor torque needs to be adjusted to account for factors that tend to reduce or degrade actuator output thrust for a given motor output torque. The following factors should be considered:

(Content Deleted - EPRI Proprietary Information)

(Content Deleted - EPRI Proprietary Information) Equation 3-7

2.2.3 Determine the adjusted reduced voltage motor torque capability as follows:

(Content Deleted - EPRI Proprietary Information) Equation 3-8

2.2.4 **(Content Deleted - EPRI Proprietary Information)**

3.4 Step 3 – Determination of Lower Motor Torque Limit

The Lower Motor Torque Limit is based on the tested MOV's required thrust[3] (adjusted for uncertainties). Lower Motor Torque Limit is determined as described below.

3.1 **(Content Deleted - EPRI Proprietary Information)**

(Content Deleted - EPRI Proprietary Information) Equation 3-9

3.2 This required motor torque must be adjusted to account for factors that could reduce actuator output thrust. Typical factors include:

- Motor torque measurement uncertainty
- Stem thrust measurement uncertainty
- TSR
- Rate of loading
- Stem factor uncertainty/degradation
- Actuator efficiency uncertainty/degradation

(Content Deleted - EPRI Proprietary Information)

(Content Deleted - EPRI Proprietary Information) Equation 3-10

(Content Deleted - EPRI Proprietary Information)

3.3 Determine the Lower Motor Torque Limit ($MT_{LL, CST}$) as follows:

(Content Deleted - EPRI Proprietary Information) Equation 3-11

3.5 Step 4 – Evaluation of MCC-Only Test Data

As described in Step 1, the MTPV method requires an initial valve test (baseline parallel test) that records data at both the valve and the MCC. After a baseline test is established for an MOV, this baseline can be used indefinitely as long as the setup and general conditions of the MOV do not change significantly. Subsequent valve tests need only to obtain measurements at the MCC. Evaluation of subsequent MCC-only test data is described below.

[3] The design basis required thrust should consider design packing load and parasitic loads. Thrust measurements in the baseline parallel test should be used to verify that these design packing/parasitic loads bound the measured data.

4.1 **(Content Deleted - EPRI Proprietary Information)**

4.2 **(Content Deleted - EPRI Proprietary Information)**

4.3 (Content Deleted - EPRI Proprietary Information)

(Content Deleted - EPRI Proprietary Information)

Figure 3-7
No-Load Torque and Hotel Load from MCC-Only Test

4.4 (Content Deleted - EPRI Proprietary Information)

(Content Deleted - EPRI Proprietary Information)

Figure 3-8
Comparison of Measured Motor Torque to Setup Limits for MCC-Only Test

4.5 (Content Deleted - EPRI Proprietary Information)

4.6 (Content Deleted - EPRI Proprietary Information)

4.7 **(Content Deleted - EPRI Proprietary Information)**

4.8 Determine the operational margin for the valve as follows:

(Content Deleted - EPRI Proprietary Information) Equation 3-12

The margin from Equation 3-12 should be used by the plant as the "as tested" margin within the plant's PV program. For example, test frequency may be dependent on this margin.

4
METHOD JUSTIFICATION

This section discusses and justifies key elements of the MTPV method.

4.1 Mean and Maximum Motor Torque

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(Content Deleted - EPRI Proprietary Information)

Figure 4-1
Measured Motor Torque Near CST – Example with Significant Oscillations

(Content Deleted - EPRI Proprietary Information)

Figure 4-2
Measured Stem Thrust Near CST for Example Corresponding to Figure 4-1

4.1.1 Use of Mean Motor Torque at CST to Determine MOV Factor

(Content Deleted - EPRI Proprietary Information)

4.1.2 Comparison of Maximum Motor Torque at CST to Upper Motor Torque Limit

(Content Deleted - EPRI Proprietary Information)

4.1.3 Comparison of Mean Motor Torque at CST to Lower Motor Torque Limit

(Content Deleted - EPRI Proprietary Information)

4.2 Acceptable Changes in Motor Torque at CST Between Tests

(Content Deleted - EPRI Proprietary Information)

4.3 Actuator Efficiency Uncertainty

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5
METHOD VALIDATION

This section provides a validation of the MTPV method using *in situ* plant test data from 15 MOVs. Table 5-1 provides a general description of each MOV.

Table 5-1
MOV Descriptions

MOV	Manufacturer and Valve Type	Valve Size (inches)	Actuator	Motor
MOV 1	Anchor Darling Flex Wedge Gate	4	Limitorque SMB-00	Reliance 5 ft-lb, 3400 RPM, 460 V
MOV 2	Anchor Darling Globe	1	Limitorque SMB-000	Reliance 5 ft-lb, 1700 RPM, 575 V
MOV 3	Anchor Darling Flex Wedge Gate	8	Limitorque SMB-00	Reliance 10 ft-lb, 3400 RPM, 460 V
MOV 4	Velan Globe	4	Limitorque SMB-00	Reliance 15 ft-lb, 1700 RPM, 575 V
MOV 5	Velan Globe	4	Limitorque SMB-00	Reliance 15 ft-lb, 1700 RPM, 575 V
MOV 6	Velan Globe	4	Limitorque SMB-00	Reliance 15 ft-lb, 1700 RPM, 575 V
MOV 7	Walworth Flex Wedge Gate	4	Limitorque SMB-00	Reliance 25 ft-lb, 1700 RPM, 460 V
MOV 8	Velan Flex Wedge Gate	3	Limitorque SMB-00	Reliance 25 ft-lb, 1700 RPM, 575 V
MOV 9	Velan Flex Wedge Gate	3	Limitorque SMB-00	Reliance 25 ft-lb, 1700 RPM, 575 V
MOV 10	Copes Vulcan Double Disc	14	Limitorque SMB-0	Reliance 25 ft-lb, 1700 RPM, 460 V
MOV 11	Velan Flex Wedge Gate	3	Limitorque SMB-00	Reliance 25 ft-lb, 1700 RPM, 575 V
MOV 12	Velan Flex Wedge Gate	3	Limitorque SMB-00	Reliance 25 ft-lb, 1700 RPM, 575 V
MOV 13	Velan Flex Wedge Gate	3	Limitorque SMB-00	Reliance 25 ft-lb, 1700 RPM, 460 V
MOV 14	Anchor Darling Double Disc	14	Limitorque SMB-0	Reliance 25 ft-lb, 1700 RPM, 460 V
MOV 15	Anchor Darling Double Disc	14	Limitorque SMB-0	Reliance 15 ft-lb, 3400 RPM, 460 V

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5.1 Summary of Validation Results

Each validation case used measured stem thrust and motor torque data from multiple parallel tests of the same MOV. From MOVs with available test data, 15 MOVs met the applicability requirements described in Section 2 and had motors covered by the vendor accuracy statement for the motor torque diagnostic equipment. The parallel tests for these MOVs were separated by operating time periods ranging from 16 months to 5 years.

Validation of the method is based on a comparison of Measured Thrust at CST to Predicted Thrust at CST based on measured Motor Torque. This comparison is made for results obtained in the second test. This validation approach does not determine or confirm an *absolute* accuracy for the MTPV method because there is no standard reference measurement (measured stem thrust has an associated measurement uncertainty). However, a correlation between thrust determined with the MTPV method and stem thrust measured directly validates use of the MTPV method in lieu of direct stem thrust measurement. A summary of the results of the validation is provided in Table 5-2 and Figures 5-1 through 5-4.

Table 5-2
Measured Thrust vs. Predicted Mean Thrust Based on Measured Motor Torque

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Table 5-2 (continued)
Measured Thrust vs. Predicted Mean Thrust Based on Measured Motor Torque

(Content Deleted - EPRI Proprietary Information)

(Content Deleted - EPRI Proprietary Information)

Figure 5-1
Comparison of Predicted Mean Thrust at CST (Based on Measured Motor Torque) to Measured Stem Thrust at CST, Including Measurement Uncertainty (MOVs 1–5)

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Figure 5-2
Comparison of Predicted Mean Thrust at CST (Based on Measured Motor Torque) to Measured Stem Thrust at CST, Including Measurement Uncertainty (MOVs 6–10)

(Content Deleted - EPRI Proprietary Information)

Figure 5-3
Comparison of Predicted Mean Thrust at CST (Based on Measured Motor torque) to Measured Stem Thrust at CST, Including Measurement Uncertainty (MOVs 11–15)

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Figure 5-4
Graphical Comparison of Predicted Mean Thrust at CST (Based on Measured Motor Torque) to Measured Stem Thrust at CST

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5.2 Validation Approach

As discussed above, the MTPV method was validated based on measured stem thrust and motor torque data from two sets of parallel tests for each of 15 MOVs. An outline of the validation approach is detailed below.

1. Analysis of baseline parallel test data to determine MOV Factor
2. Analysis of second parallel test data to calculate predicted thrust based on measured motor torque from second test and MOV Factor (determined from baseline test)
3. Comparison of direct stem thrust measurements with stem thrusts calculated from motor torque measurements

Table 5-3 summarizes selected design and setup information for the 15 MOVs used in the method validation. A sample validation demonstrating the approach described above is included in this report for MOV 8.

Table 5-3
MOV General Information

Parameter	MOV 1	MOV 2	MOV 3	MOV 4	MOV 5	MOV 6	MOV 7
Valve mfr/size/type	Anchor Darling 4" FWG	Anchor Darling 1" Globe	Anchor Darling 8" FWG	Velan 4" Globe	Velan 4" Globe	Velan 4" Globe	Walworth 4" FWG
Stem diameter (in)	1.000	0.625	1.250	1.375	1.375	1.375	1.250
Stem pitch (in)	0.333	0.167	0.333	0.250	0.250	0.250	0.250
Stem lead (in)	0.667	0.167	0.667	0.500	0.500	0.500	0.500
Actuator type/size	SMB-00	SMB-000	SMB-00	SMB-00	SMB-00	SMB-00	SMB-00
Overall ratio	63.0	52.0	63.0	55.8	55.8	55.8	30.0
Stem Factor (ft-lbs/lb)	0.0148	0.0073	0.0163	0.0179	0.0179	0.0179	0.0142
Motor start torque (ft-lbs)	5	5	10	15	15	15	25
Nominal Voltage (Volts)	460	575	460	575	575	575	460

Parameter	MOV 8	MOV 9	MOV 10	MOV 11	MOV 12	MOV 13	MOV 14	MOV 15
Valve mfr/size/type	Velan 3" FWG	Velan 3" FWG	Copes Vulcan 14" DD	Velan 3" FWG	Velan 3" FWG	Velan 3" FWG	Anchor Darling 14" DD	Anchor Darling 14" DD
Stem diameter (in)	1.125	1.125	1.750	1.125	1.125	1.125	1.750	1.625
Stem pitch (in)	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333
Stem lead (in)	0.667	0.667	0.333	0.667	0.667	0.667	0.333	0.667
Actuator type/size	SMB-00	SMB-00	SMB-0	SMB-00	SMB-00	SMB-00	SMB-0	SMB-0
Overall ratio	52.2	52.2	78.8	49.0	49.0	49.0	78.8	89.8
Stem Factor (ft-lbs/lb)	0.0170	0.0170	0.0148	0.0170	0.0170	0.0156	0.0148	0.0187
Motor start torque (ft-lbs)	25	25	25	25	25	25	25	15
Nominal Voltage (Volts)	575	575	460	575	575	460	460	460

5.3 Sample Validation Analysis for MOV 8

5.3.1 Analysis of Baseline Parallel Test Data

As discussed in the Validation Approach above, the baseline parallel test data was analyzed in accordance with the MTPV method to **(Content Deleted - EPRI Proprietary Information).**

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Figure 5-5
MOV 8 - Baseline Test Measured Thrust (Top Trace) and Motor Torque (Bottom Trace)

(Content Deleted - EPRI Proprietary Information)

Figure 5-6
MOV 8 - Baseline Test Zeroing of Measured Thrust Trace

(Content Deleted - EPRI Proprietary Information)

Figure 5-7
MOV 8 - Baseline Test Measured Thrust Inertia

(Content Deleted - EPRI Proprietary Information)

Figure 5-8
MOV 8 - Baseline Test Measured Torque Hotel Load (Top Trace – Stem Thrust; Bottom Trace – Motor Torque)

(Content Deleted - EPRI Proprietary Information)

Figure 5-9
MOV 8 - Baseline Test Mean and Maximum Motor Torque at CST

Table 5-4 summarizes the motor torque and stem thrust data from the analysis of the baseline parallel test.

Table 5-4
MOV 8 - Baseline Parallel Test Data

(Content Deleted - EPRI Proprietary Information)

The MOV Factor at CST is calculated based on the measured stem thrust and motor torque in accordance with Equation 3-2, as follows:

(Content Deleted - EPRI Proprietary Information)

As expected, Figure 5-10 shows that thrust calculated based on the mean motor torque at CST and the MOV Factor (determined above) is equivalent to the measured thrust at CST (the MOV Factor was derived from measured thrust and mean motor torque at CST). Also as expected, the magnitude of the thrust calculated based on the maximum motor torque at CST is greater than the measured thrust.

(Content Deleted - EPRI Proprietary Information)

Figure 5-10
MOV 8 - Baseline Test Calculated Thrust Based on Measured Motor Torque vs. Measured Thrust

5.3.2 Analysis of Second Parallel Test Data

The second parallel test data was analyzed similarly to the baseline parallel test to determine Mean and Maximum Motor Torque at CST. The overlay of the measured stem thrust and motor torque from the second parallel test is shown in Figure 5-11. Figure 5-12 depicts the determination of the Mean and Maximum Measured Motor Torque. The data from the analysis are listed in Table 5-5.

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Figure 5-11
MOV 8 - Second Parallel Test Measured Thrust (Top Trace) and Motor Torque (Bottom Trace)

(Content Deleted - EPRI Proprietary Information)

Figure 5-12
MOV 8 - Second Parallel Test Mean and Maximum Motor Torque at CST

Table 5-5
MOV 8 - Second Parallel Test Data

(Content Deleted - EPRI Proprietary Information)

Based on the values listed in Table 5-5, the predicted thrust at CST is calculated using the following equation:

(Content Deleted - EPRI Proprietary Information)

These calculated mean and maximum thrust values are listed in Table 5-6 and depicted in Figure 5-13.

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Figure 5-13
MOV 8 - Second Parallel Test Predicted Thrust Based on Measured Motor Torque vs. Measured Thrust

Table 5-6
MOV 8 - Second Parallel Test Predicted Thrust Based on Measured Motor Torque

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6 APPLICATION OF METHOD

In this example, a baseline parallel test and a subsequent PV test (MCC-only test) have been performed on the subject MOV approximately three years apart. The example illustrates how the MTPV method can be used to demonstrate that the MOV maintained positive margin. At the end of this section, the example is summarized in SI units.

6.1 Summary of MOV Data and Test Results

Tables 6-1 through 6-6 provide information used in the MTPV method.

Table 6-1
Valve, Actuator, and Motor Data

Parameter	Value
Valve mfr/type/size	Anchor Darling 14" DD
Stem diameter (in)	1.750
Stem pitch (in)	0.333
Stem lead (in)	0.333
Actuator type/size	SMB-0
Overall ratio	78.8
Motor start torque (ft-lbs)	25
Motor speed (rpm)	1700
Nominal voltage (volts)	460
Reduced voltage (volts)	441.14

Table 6-2
Valve Setpoint Data

Parameter	Value	Comments
Minimum required thrust (lbs)	7,707	
Mechanical thrust limit (lbs)	33,600	Based on actuator thrust rating (140% of actuator rating per Limitorque Technical Update 92-01)

Table 6-3
Baseline Parallel Test Data

	Motor Torque (in-lbs)		Stem Thrust (lbs)
Hotel load	2.8		
Torque switch trip	Mean: 70.2	Max: 72.0	16,168
Final			17,738
Inertia			1,570

Table 6-4
Periodic Verification, MCC-Only Test Data

	Motor Torque (in-lbs)	
Hotel load	0.7	
Torque switch trip	Mean:74.4	Max: 81.5

Table 6-5
MTPV Method Uncertainties

Parameter	Value	Comments
Torque switch repeatability	5%	As stated by the actuator manufacturer
Actuator efficiency uncertainty	**(Content Deleted - EPRI Proprietary Information)**	Value justified in Appendix D of this report
Inertial thrust uncertainty	5%	Based on plant data
Stem factor uncertainty	0%	Based on plant data
Rate of loading	10% bias + 0% random error	Based on plant data
Motor torque measurement uncertainty	9.3% of reading + 2.5% of full scale	As stated by the motor torque diagnostic system vendor. "Full scale" is the motor start torque.
Stem thrust measurement uncertainty	10.05% of reading + 400 lbs	As stated by the stem thrust diagnostic system vendor.

The uncertainties listed in Table 6-5 are based on application of these uncertainties to the measured motor torque or stem thrust. However, the MTPV methodology applies these uncertainties to the upper and lower motor torque limits. As such, these uncertainties need to be expressed in terms of a percentage of the upper and lower limits. Appendix C of this report details the process of converting measured value uncertainties to upper and lower limit uncertainties. The converted uncertainties are shown in Table 6-6.

Table 6-6
MTPV Method Uncertainties as Applied to Upper and Lower Motor Torque Limits

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6.1.1 Data Analysis

6.1.1.1 Step 1 – Evaluation of Baseline Parallel Test Data

Steps 1.1 through 1.5 of the method are depicted in Figures 6-1 through 6-4 below. The data from these plots are listed in Table 6-3.

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Figure 6-1
Baseline Test Measured Thrust (Top Trace) and Motor Torque (Bottom Trace)

(Content Deleted - EPRI Proprietary Information)

Figure 6-2
Baseline Test Mean and Maximum Motor Torque at CST

(Content Deleted - EPRI Proprietary Information)

Figure 6-3
Baseline Test Motor Torque Hotel Load (Top Trace – Stem Thrust; Bottom Trace – Motor Torque)

(Content Deleted - EPRI Proprietary Information)

Figure 6-4
Baseline Test Stem Thrust Due to Inertia

The Stem Thrust due to inertia ($TH_{INERTIA}$) is determined in accordance with Equation 3-1, as follows:

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The MOV Factor at CST is calculated based on the measured stem thrust and motor torque in accordance with Equation 3-2, as follows:

(Content Deleted - EPRI Proprietary Information)

6.1.1.2 Step 2 – Determination of Upper Motor Torque Limit

6.1.1.2.1 Mechanical Motor Torque Limit

The unadjusted valve/actuator thrust mechanical limit (TH_{ML}), is the lesser of (a) Actuator Thrust Rating, (b) Valve Thrust Rating, and (c) Actuator Torque Rating. For this example, the Actuator Thrust Rating was determined to be the most limiting value for the mechanical limit.

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6.1.1.2.2 Reduced Voltage Motor Torque Capability

The unadjusted reduced voltage motor torque is determined in accordance with Equation 3-6.

(Content Deleted - EPRI Proprietary Information)

The total uncertainty is calculated in accordance with Equation 3-7.

(Content Deleted - EPRI Proprietary Information)

And, the Reduced Voltage Motor Torque Capability is determined in accordance with Equation 3.8.

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6.1.1.2.3 Upper Motor Torque Limit

The Upper Motor Torque Limit ($MT_{UL, CST}$) is set equal to the most limiting of the adjusted motor torque mechanical limit and the adjusted reduced voltage motor torque capability.

(Content Deleted - EPRI Proprietary Information)

6.1.1.3 Step 3 – Determination of Lower Motor Torque Limit

The Lower Motor Torque Limit is based on the tested valve's required thrust. The required thrust at control switch trip ($TH_{REQ, CST}$) is converted to the unadjusted required motor torque at control switch trip ($MT_{REQ, CST}$), using Equation 3-9.

(Content Deleted - EPRI Proprietary Information)

The total uncertainty is calculated in accordance with Equation 3-10.

(Content Deleted - EPRI Proprietary Information)

And, the Lowers Motor Torque Limit is determined in accordance with Equation 3-11.

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6.1.1.4 Step 4 – Evaluation of MCC-Only Test Data

Figure 6-5 shows the measured motor torque from the PV (MCC-only) test. Lines denoting the Upper and Lower Motor Torque Limits have been added to the plot to show that the measured motor torque at CST falls within the acceptable motor torque range.

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Figure 6-5
MCC-Only Test Measured Motor Torque

Figure 6-6 shows a zoomed plot near the beginning of the valve stroke and identifies motor torque hotel load.

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Figure 6-6
MCC-Only Test Motor Torque Hotel Load

Figure 6-7 shows a zoomed-in plot of the measured motor torque curve, near CST. Trend lines indicating mean motor torque and maximum motor torque are also depicted in the figure.

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Figure 6-7
MCC-Only Test Mean and Maximum Motor Torque at CST

The measured motor torque is evaluated against the following acceptance criteria.

MCC Test Acceptance Criterion:

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Finally, the margin for the valve is determined in accordance with Equation 3-12.

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6.2 Summary of Sample Problem in SI Units

The sample problem above was originally evaluated using English units of measure. A summary of the pertinent data from this problem in SI units is included below.

Table 6-7
Valve Setpoint Data – SI Units

Parameter	Value	Comments
Minimum required thrust (N)	34,296	
Maximum CST thrust (N)	149,520	Based on actuator thrust rating (140% of actuator rating per Limitorque Technical Update 92-01)

Table 6-8
Baseline Parallel Test Data – SI Units

	Motor Torque (N-m)		Stem Thrust (N)
Hotel load	0.3		
Torque switch trip	Mean: 7.7	Max: 7.9	71,948
Final			78,934
Inertia			6,986

Table 6-9
Periodic Verification, MCC-Only Test Data (9/02) – SI Units

	Motor Torque (N-m)	
Hotel load	0.1	
Torque switch trip	Mean: 8.2	Max: 9.0

Table 6-10
MTPV Method Key Parameters – SI Units

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7 EFFECT OF MTPV METHOD ON TYPICAL MOV SETUP

The general procedure for determining MOV setup limits based on motor torque measurements in the MTPV method is analogous to that used for determining setup limits based on stem thrust measurements in current PV methods. However, the application of data uncertainties to these limits is dependent on the parameter measured during MOV testing (that is, stem thrust or motor torque). As such, the motor torque setup limits for an MOV are different than just a simple factor times the MOV's analogous thrust limits. This section of the report examines the potential effects of the MTPV methodology on an MOV's setup window by comparing upper and lower limits based on measured stem thrust with upper and lower limits based on measured motor torque.

It should be noted that these comparisons used the 15 MOVs considered in the validation of the MTPV methodology (Section 5). Evaluation of upper and lower limits in this analysis is performed in accordance with guidance in Section 3 of this report. In use of the MTPV method at plants, data uncertainties will be accounted for and applied in accordance with individual plant procedures, which likely differ from the procedures used in this analysis. Nonetheless, the general trends discussed below will be consistent regardless of the specific procedures followed.

7.1 Summary of Results

The 15 MOVs used in the MTPV method validation were evaluated to determine the potential effect of the MTPV method on an MOV's upper and lower setup limits. Upper and lower limits based on measured thrust were determined with consideration of uncertainties typically used in industry (measurement uncertainty, stem factor uncertainty, rate of loading, etc.). Upper and lower limits based on measured motor torque were determined in accordance with guidance in Section 3 of this report, with consideration of similar uncertainties. The motor torque limits were then converted to thrust limits using the MOV factor (determined from the baseline test data).

7.1.1 Mechanical Upper Limit

The mechanical upper limit is the lesser of the actuator thrust rating, the valve thrust rating, and the actuator torque rating (converted to thrust using the stem factor). In the MTPV method, this limit is lower (that is, more restrictive) than that determined using direct stem thrust measurements. This reduction in the mechanical limit is due to the higher measurement uncertainty for motor torque compared to stem thrust. The observed reduction in mechanical upper limit ranged from **(Content Deleted - EPRI Proprietary Information)** for the 15 MOVs. Figures 7-1 and 7-2 show two examples.

In these two cases, the mechanical upper limit was reduced by **(Content Deleted - EPRI Proprietary Information),** respectively.

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Figure 7-1
Comparison of Setup Windows for MOV 1 (Stem Thrust vs. Motor Torque Measurements)

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Figure 7-2
Comparison of Setup Windows for MOV 2 (Stem Thrust vs. Motor Torque Measurements)

7.1.2 Reduced Voltage Upper Limit

The reduced voltage limit is based on motor output torque capability under conditions of reduced voltage. Because the MTPV method directly measures motor output torque, there are fewer parameter uncertainties to apply to the limit than if measured thrust is used. In addition, calculation of this limit expressed as a stem thrust value was performed with the Limitorque sizing equation [.6], using conservative design values for stem factor and actuator efficiency. Determination of reduced voltage limit with the MTPV method was performed using the baseline test MOV Factor, which is determined directly from the test data and inherently incorporates the actual stem factor and actuator efficiency. Accordingly, the reduced voltage upper limit in the MTPV method is typically higher (that is, less restrictive) than the limit determined using methods that directly measure stem thrust. The observed improvement ranged from **(Content Deleted - EPRI Proprietary Information)** shown in Figure 7-1 and Figure 7-2, the improvement **(Content Deleted - EPRI Proprietary Information),** respectively.

7.1.3 Lower Limit

The lower limit is based on the MOV minimum required thrust. In the MTPV method, this limit is higher (that is, more restrictive) than that determined using direct stem thrust measurements. This increase in the lower limit is due to the higher measurement uncertainty for motor torque compared to stem thrust. The observed increase in the lower limit ranged from **(Content Deleted - EPRI Proprietary Information)** % for the 15 MOVs. For the examples in Figure 7-1 and Figure 7-2, the increase in lower limit is **(Content Deleted - EPRI Proprietary Information)** %, respectively.

7.1.4 Setup Window

The upper and lower limits discussed above define an MOV's setup window. Comparisons of the magnitudes of these setup windows for two MOVs (for limits determined using stem thrust measurements vs. limits determined using motor torque measurements) are graphically depicted in Figure 7-1 and Figure 7-2. Specifically, the window is the open space between the lower bar and the lesser of the two upper bars.

As shown in the figures, the setup window between the mechanical upper limit (left upper bar) and the required thrust lower limit (lower bar) is smaller in the MTPV method than the setup window determined using direct stem thrust measurements. However, the setup window between the reduced voltage upper limit (right upper bar) and the lower limit is larger in the MTPV method. This improvement is due to a reduction in the uncertainty of the reduced voltage limit (see the discussion above in Section 7.1.2, Reduced Voltage Upper Limit). Note that in Figure 7-1, where the window (based on measured stem thrust) is controlled by the reduced voltage upper limit (right upper bar), application of the MTPV method produces an overall improvement in the setup window. In other words, the open space between the lower bar and the lesser of the upper two bars increases when the MTPV method is used. Conversely, in Figure 7-2, the mechanical upper limit controls the window, and use of the MTPV method reduces the available window. As such, the MTPV method would be most beneficial for an MOV that is limited by motor capability at reduced voltage.

8 REFERENCES

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A

MCC-BASED TESTING BEYOND THE APPLICABILITY OF THE MTPV METHOD

The MTPV method is a quantitative method for PV of closing strokes of MOVs with rising stems, torque switch control, and AC motors. It can be used in lieu of a direct stem thrust measurement to verify adequate setup and margin for successful operation. Although not evaluated in this report, other MCC-based methods could be used for periodic verification of limit-switch-controlled strokes. These other potential methods are discussed in this appendix.

A.1 Evaluation of Limit-Switch-Controlled Closing Strokes

Application of MCC-based methods to MOVs with limit-switch-controlled closing strokes is affected by the fact that these MOVs typically do not demonstrate, during static operation, their ability to develop thrust or torque above their required values. MOVs with limit-switch-controlled closing strokes are generally considered to have positive margin if their stem thrust/torque output capability under worst-case conditions (including reduced motor voltage) is greater than the required thrust/torque. Typically, both of these parameters are calculated values and are not dependent on measurements during tests. Required thrust/torque typically includes a static running load component and a dynamic component. The dynamic component is established through DP testing, calculation methods, grouping data, or other means. The static component consists primarily of packing load. MCC testing could potentially be used to verify the static component of required thrust/torque to ensure that when combined with the dynamic component, the output capability of the MOV is not challenged. This quantitative evaluation would need to be validated by the user. In addition, MCC testing could be used to qualitatively assess valve actuation (for example, stroke time, limit-switch trip, etc.).

A.2 Evaluation of Limit-Switch-Controlled Opening Strokes

Evaluation of limit-switch-controlled opening strokes based on MCC measurements can be affected by the ability of the MCC diagnostic equipment to accurately quantify motor torque during unseating. Application of MCC methods to wedge gate valves and parallel gate valves or globe valves with limit-switch-controlled opening strokes is discussed below.

A.2.1 Wedge Gate Valves

For rising-stem wedge gate valves with AC motors, the peak motor torque for the opening stroke occurs at unwedging. This event coincides with a rapid transient in motor torque and may be difficult to accurately quantify. Filtering algorithms typically used by diagnostic software may dampen or mask the unwedging peak. Plants should discuss the capability of their MCC diagnostic system to measure unwedging motor torque with their equipment vendor.

However, given accurate motor torque data during unseating, MCC-based methods could be justified and validated to quantify unseating thrust/torque for limit-switch-controlled opening strokes of rising-stem wedge gate valves with AC motors. Similar to the method for torque switch controlled closing strokes, an MOV factor should be determined based on a baseline parallel opening stroke test.[4] The MOV factor should be determined at the peak unseating thrust at unwedging. If the measured unseating load is used directly (or adjusted) to determine required unseating load, then this measured result would need to be compared to the actuator capability limit (based on reduced voltage capability or mechanical upper limit as appropriate). Margin could also be calculated for this comparison.

Alternatively, if the unseating load is strictly a calculated value, then determination of acceptability and margin is governed by calculation and is independent of measurements during tests. In such a case, the MCC-based test could serve simply as a qualitative assessment of valve actuation (for example, confirm that unseating occurs, confirm stroke time and limit-switch actuation, etc.).

A.2.2 Parallel Gate Valves and Globe Valves

Application of MCC-based methods to the opening strokes of parallel gate valves and globe valves is affected by the fact that these valves do not exhibit an unwedging peak and, typically, do not demonstrate during static operation their ability to develop thrust or torque above their required values. These MOVs are generally considered to have positive margin if their stem thrust/torque output capability under worst-case conditions (including reduced motor voltage) is greater than the required thrust/torque. Typically, both of these parameters are calculated values and are not dependent on measurements during tests. Required thrust/torque typically includes a static running load component and a dynamic component. The dynamic component is established through DP testing, calculation methods, grouping data, or other means. The static component consists primarily of packing load. MCC testing could potentially be used to verify the static component of required thrust/torque to ensure that when combined with the dynamic component, the output capability of the MOV is not challenged. This quantitative evaluation would need to be validated by the user. In addition, MCC testing could be used to qualitatively assess valve actuation (for example, stroke time, limit-switch trip, etc.).

[4] The opening stroke MOV factor should **not** be assumed to be equivalent to the closing stroke MOV factor.

B
MCC-BASED DIAGNOSTIC SYSTEM REQUIREMENTS

Use of the MTPV method for periodic verification of MOVs is dependent upon the capability of the MCC diagnostic equipment. This appendix details several characteristics of MCC diagnostic systems that should be considered for accurate data acquisition and analysis.

B.1 Steady-State vs. Transient Motor Output Torque

Periodic verification of MOVs requires analysis of data acquired during steady-state operation (that is, running region) and data acquired during rapidly changing load conditions (for example, valve seating/unseating). Steady-state motor output torque can be calculated by measuring the input power, subtracting any losses, and converting the remaining motor power to electric torque. However, some of these losses are a function of motor speed, which varies under transient conditions. Also, acceleration of the motor's rotating mass during load transients contributes additional torque (inertial torque) to the motor shaft. Therefore, an MCC-based diagnostic system must consider the relationship between input power and motor output torque for both steady-state and transient conditions.

B.2 No-Load Motor Torque

Motor torque measurements should be zeroed at the condition where the motor is spinning, but not turning any gearing. This condition is the "no-load motor torque." As shown in the motor torque plots in Sections 3, 5, and 6 of this report, no-load motor torque is often indistinguishable in analysis of test data due to signal noise during the motor start transient. Therefore, an MCC diagnostic system should account for no-load torque so that it is not included in "measured" motor torque (that is, the diagnostic system should correctly zero the measured motor torque data).

B.3 Filtering Techniques

Motor current and voltage data acquired with diagnostic equipment will inevitably contain some noise and distortion. An MCC diagnostic system may use filtering to reduce undesirable noise and distortion without unacceptably altering the underlying data. In general, the filtering technique should not significantly time-shift the underlying data nor excessively attenuate the signal. This second point is of particular concern because the motor current, power, and torque data at CST occurs at a time very close to a rapid transition from the maximum motor torque value to zero. A user should be knowledgeable of the capabilities and limitations of the filtering techniques used by their MCC diagnostic system.

B.4 Diagnostic System Validation

An MCC diagnostic system should be validated and verified to calculate motor torque to within its stated uncertainties. The validation and verification (V&V) process should meet the requirements of the plant's quality assurance program. This V&V process should include the following:

- The diagnostic equipment used to acquire the electrical data
- The motor torque model used to convert electrical data to motor output torque
- The software used to implement the motor torque model and any associated calculations

B.5 Diagnostic Equipment Calibration

The diagnostic equipment used to acquire data should be calibrated in accordance with the plant's quality assurance program.

C APPLICATION OF UNCERTAINTIES TO SETPOINT LIMITS

In the MTPV method, measured motor torque is compared to upper and lower limits to determine valve operability and margin. As discussed in the methodology, these comparisons need to account for uncertainties for items such as test equipment uncertainty, rate-of-loading (ROL), stem factor uncertainty, torque switch repeatability (TSR), and actuator efficiency uncertainty. The MTPV method accounts for these uncertainties by adjusting the upper and lower motor torque limits to define a "window" of operability for the MOV. As such, these uncertainties need to be expressed in terms of a percentage of the upper and lower limits.

Dependent on an individual plant's procedures, the uncertainties discussed above may originally be expressed in terms of a percentage of measured thrust/torque. In this case, these uncertainties need to be converted to uncertainties expressed in terms of upper and lower limits, prior to use in the MTPV method. This appendix describes the general procedure for conversion of measured value uncertainties to upper and lower limit uncertainties.

C.1 Conversion of Measured Value Uncertainty to Lower Limit Uncertainty

(Content Deleted - EPRI Proprietary Information)

C.2 Conversion of Measured Value Uncertainty to Upper Limit Uncertainty

(Content Deleted - EPRI Proprietary Information)

D
ACTUATOR EFFICIENCY UNCERTAINTY

The MTPV method accounts for the following uncertainties or possible degradation mechanisms:

- Measurement Uncertainty
- Torque Switch Repeatability (TSR)
- Stem Factor Uncertainty
- Rate of Loading (ROL)
- Actuator Efficiency Uncertainty
- Inertial Thrust Uncertainty

Values for measurement uncertainty, TSR, stem factor uncertainty, and ROL can be based on vendor information or plant-unique test information. However, it is unlikely that information regarding actuator efficiency uncertainty is widely available. As such, a justified value for actuator efficiency uncertainty is discussed below.

The analyses in this appendix justify use of an actuator efficiency uncertainty of **(Content Deleted - EPRI Proprietary Information)** % based on available MOV test data. This value should be considered "best available information."

D.1 Justification of Actuator Efficiency Uncertainty

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E
TRANSLATED TABLE OF CONTENTS

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

Electric Power Research Institute (EPRI)

產品說明

挑戰與目的

本作業的目的是要開發、證明和驗證一種技術方法，以使用 MCC 馬達扭力測量法進行 MOV PV
測試。由於需要針對可能的不確定度證明假設，因此使用這種技術方法會變得較為困難，這些不確定度包括：

- 扭力極限開關的重現性
- 閥桿係數不確定度
- 加荷速率不確定度
- 馬達扭力測量不確定度
- 制動器效率不確定度
- 閥桿推力慣性不確定度

閥桿推力測量不確定度
本報告將提供一般制動器效率不確定度的證明，此數值通常不會在廠房 MOV
計劃中說明。

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产品说明

挑战与目的

本项目的目的是开发、证明和验证一种技术方法，以便使用 MCC 马达扭力测量法进行
MOV PV
测试。由于需要针对可能的不确定性证明假设，因此使用这种技术方法会变得较为困难，这些不确定性包括：

- 扭力极限开关的重现性
- 阀杆系数不确定性
- 加载速率不确定性
- 马达扭力测量不确定性
- 制动器效率不确定性
- 阀杆推力惯性不确定性

阀杆推力测量不确定性

本报告将提供一般制动器效率不确定性的证明，此数值通常不会在工厂 MOV
计划中说明。

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DESCRIPTION DU PRODUIT

Défis et objectifs

L'objectif de ce travail est de développer, de justifier et de valider une technique de réalisation de test sur valve motorisée (MOV) PV en utilisant les mesures de couple moteur basées sur le centre de commande de moteur (MCC). L'utilisation de ces méthodes est compliquée par le besoin d'hypothèses qui justifient les incertitudes potentielles, dont :

- La répétabilité du limiteur de couple
- L'incertitude du facteur corps de valve
- L'incertitude de la vitesse de mise en charge
- L'incertitude de la mesure du couple moteur
- L'incertitude de l'efficacité de l'actionneur
- L'incertitude de l'inertie de la poussée du corps de valve

L'incertitude de la mesure de poussée du corps de valve Le rapport apporte une justification de l'incertitude de l'efficacité d'un actionneur générique. Cette valeur n'est pas généralement justifiée au sein des programmes de valves motorisées d'usine (MOV).

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製品の説明

課題および目的

本書は、MCCベースのモータートルク測定値を用いたMOV PV検査実行に必要な技術の開発、その正当性立証および妥当性確認を目的としている。かかる方法の使用は、下記のような潜在的不定性に関する仮定が正当であることを立証する必要があるため、より難しいものとなっている。

- トルクスイッチ再現性
- ステム要因による不定性
- 負荷率による不定性
- モータートルク測定値による不定性
- アクチュエータ効率性による不定性
- ステム慣性推力による不定性

ステム推力測定値に関する不定性：本報告では一般的アクチュエータ効率性による不定性が正当であることを立証する。プラントMOVプログラム内では通常その正当性は立証されていない値である。

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DESCRIPCIÓN DEL PRODUCTO

Retos y objetivos

El objeto de este trabajo es el de desarrollar, justificar y validar una técnica para realizar pruebas de válvula motorizada PV usando mediciones del par motor con base en el Centro de Control del Motor (CCM). La utilización de dichos métodos se hace aún más difícil debido a la necesidad de justificar algunas suposiciones sobre posibles incertidumbres, entre las cuales figuran las siguientes:

- Repetibilidad del interruptor de empuje
- Incertidumbre del factor del vástago
- Incertidumbre de velocidad de carga
- Incertidumbre de medición del par motor
- Incertidumbre de rendimiento del accionador
- Incertidumbre de inercia del empuje del vástago

Incertidumbre de medición del empuje del vástago Este informe justifica la incertidumbre de rendimiento del accionador genérico—un valor que generalmente no se justifica dentro de los programas de válvulas motorizadas.

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