Human Performance Guide for Knowledge-Based Work

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Preface

Midwest Reliability Organization (MRO) is dedicated to its vision to maintain and improve the quality of life through a highly reliable regional bulk power system.

MRO operates as a cross-border Regional Entity and is headquartered in Saint Paul, Minnesota. The MRO Region covers roughly one million square miles spanning the provinces of Saskatchewan and Manitoba, and all or parts of the states of Illinois, Iowa, Minnesota, Michigan, Montana, Nebraska, North Dakota, South Dakota and Wisconsin. The region includes more than 130 organizations that are involved in the production and delivery of electricity to more than 20 million people. These organizations include municipal utilities, cooperatives, investor-owned utilities, transmission system operators, a federal power marketing agency, Canadian Crown Corporations, and independent power producers.

MRO’s primary responsibilities are to: ensure compliance with mandatory reliability standards by entities who own, operate, or use the interconnected, international Bulk Power System; conduct assessments of the grid’s ability to meet electricity demand in the region; and analyze regional system events.
Introduction

The North American Electric Reliability Corporation (NERC) 2015 State of Reliability Report challenges entities to reduce protection system misoperations. MRO identified human performance as a component of protection system misoperations and therefore, improved human performance can play a role in the reduction of protection system misoperations and improve reliability.

This human performance guide addresses human performance techniques for knowledge-based work to prevent errors and reduce incidents. Registered Entities in the MRO Region can use this paper as a starting point to develop their own human performance policies and procedures. This paper focuses on high risk level knowledge-based work to reduce impact of an event through human performance techniques such as organizational controls, tools, and oversight.

Registered Entities should apply these human performance techniques in connection with the recommendations discussed in the MRO Protection System Misoperations document addressing Overcurrent Relay, Directional Comparison Blocking, and Direct Transfer Trip schemes. Use of these techniques should increase as the risk of the activity increases.

Good internal controls are critical to a reliable transmission grid. The NERC 2015 State of Reliability Report challenges entities to reduce protection system misoperations including incorrect settings and design, and communication failures. The MRO Region has identified human performance and misoperations as focus areas to reduce risk to the Bulk Electric System (BES) in the MRO Region. One of the leading causes of misoperations is incorrect settings or logic errors so it is clear that improved human performance can reduce misoperations and improve reliability.

This paper focuses on internal controls to reduce errors from knowledge-based work that potentially can have the greatest adverse impact on reliability, safety, and economic performance. This includes latent or in-process errors which are more subtle than active errors committed by operators and craft personnel because they can go undetected for years, resulting in hidden defects in equipment or documentation. The latency characteristic of engineering and other knowledge-based errors limits feedback, awareness, and opportunities to catch and prevent them.

Purpose

This human performance guide promotes techniques for knowledge-based work to prevent both latent and active errors that can cause reduced system reliability, safety concerns, equipment damage, financial impacts, or environmental incidents.

Incorporating internal controls into work processes will help identify, catch, minimize, or prevent active or latent errors from occurring. This guide is developed for engineering and other knowledge-based work. At the end of this guide, additional general information is given regarding human performance error precursors, controls, tools, oversight, and industry references.

This paper supports the Protection System Misoperations document written by the MRO Protective Relay Subcommittee (PRS) and is written by the MRO Operating Committee.
Scope

This paper provides guidance on knowledge-based work to help Registered Entities in the MRO Region develop their own human performance policies and procedures to:

1. Establish training requirements
2. Identify performance indicators used to measure effectiveness
3. Implement an observation program to monitor and reinforce human performance
4. Identify when and how to use various human performance tools
Roles and Responsibilities

Recommendations for human performance roles and responsibilities for Registered Entities in the MRO Region are:

Leadership:
1. Promote the use of human performance policy/tools including routine review.
3. Reinforce the proper use of the human performance tools through observation and coaching.
4. Participate in human performance training and serve as a role model for employees.

Knowledge Workers (May include engineers, project managers, designers, engineering aids, others):
3. Participate in incident investigations, develop and complete corrective actions.
Risk Assessment

The primary focus of this guide is for high risk knowledge-based work. High, medium, and low risk levels are defined based on risk management probability and severity and these levels should not be directly correlated to NERC CIP Impact Rating or Violation Security Levels (VSL).

**High risk** is defined as:
1. High probability of occurrence and medium/high severity
2. May include knowledge-based performance modes
3. May include all BES facilities

Based on the NERC 2015 Annual State of Reliability Report and items identified by the Protection System Misoperations document, the following are examples of high risk in the area of protection systems:
1. Overcurrent Relaying Schemes
2. Directional Comparison Blocking Schemes
3. Direct Transfer Trip Schemes

**Medium risk:**
1. Low-to-medium probability of occurrence and a medium incident severity
2. May include rule-based performance modes
3. May directly impact customers through momentary disruptions or loss of service

**Low risk:**
1. Low probability of occurrence with low incident severity
2. May include skill based performance modes
3. May include drawing archive, project close out, database entry
Application of Human Performance Techniques

It is necessary to understand the anatomy of an event and to avoid, when possible, error precursors which increase event probability. Error precursor examples include items such as time pressure, distractions, fatigue, and frustration. Registered Entities can prevent and mitigate the impact of an event through various human performance techniques. Use of the following techniques needs to increase as the risk of the activity increases.

1. Organizational Controls
   a. Engineered- human machine interface, interlocks, effective without human interaction
   b. Administrative- policy, procedure, training, work management, rely on human judgement
   c. Cultural- values, beliefs, attitude, accountability (blame/complain or own/solve, investigation team, corrective actions, improvement)
2. Tools- Pre-job brief, self/peer check, drawing review checklist, wire check, relay settings calculation check list, staff experience
3. Oversight- Self assessment, observation, performance indicators (clock reset)

Many techniques identified to reduce misoperations fall under human performance which plays a key role both in preventing protection system misoperations and in implementing effective corrective actions after they occur to prevent similar future incidents. Examples from the Protection System Misoperations document and other sources where human performance techniques can be applied include:

1. NERC cause code trends - to determine areas of focus for maximum impact.
2. One of the leading causes of misoperations - incorrect settings or logic errors.
3. Updating short circuit models for accuracy to reflect current topology, sources and mutual impedances all of which can impact settings.
4. Designing security into schemes that use communications channels susceptible to transients such as power line carrier or audio tone (e.g., leased phone line or microwave). Dual channel voting schemes can be used.
5. Proper scheme design and commissioning to verify all inputs, outputs, and proper relay equipment interfaces to other equipment including communication scheme equipment.
6. Timely and accurate drawings, as-built drafting, and archive close out process.
7. Following system events, knowledge workers should participate in incident investigations to establish a clear root cause and develop and complete corrective actions. Corrective actions need to address and mitigate the true root cause for the event under investigation. Further, a review for similar schemes on your system should be made and corrective actions applied to each applicable scheme.
Anatomy of an Event

Events are typically triggered by human action, but seldom does a single failure alone lead to an event. Most often, failure results from a combination of latent organizational weaknesses, error precursors, and flawed barriers and defenses that have been aligning over time to create an error-likely situation. No one individual issue seems to be significant; yet, when all of the individual components merge, the event is initiated and the consequences are realized.
Error Precursors

Error precursors are unfavorable prior conditions that increase the probability for error during a specific action (error-likely situations). An error-likely situation typically exists when the demands of the task exceed the capabilities of the individual, or when work conditions aggravate the limitations of human nature. Error-likely situations are also known as error traps.

<table>
<thead>
<tr>
<th>TASK DEMANDS</th>
<th>WORK ENVIRONMENT</th>
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</thead>
<tbody>
<tr>
<td>Time Pressure</td>
<td>Poor Location Atmosphere</td>
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<tr>
<td>Heavy Workload</td>
<td>Confusing Displays or Controls</td>
</tr>
<tr>
<td>Simultaneous Tasks</td>
<td>Personality Conflicts</td>
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<td>Repetitive Actions</td>
<td>Distractions or Interruptions</td>
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<tr>
<td>Interpretation Requirements</td>
<td>Unexpected Equipment Conditions</td>
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<tr>
<td>Irreversible Actions</td>
<td>Lack of Alternative Indication</td>
</tr>
<tr>
<td>Unclear Goals, Roles or Responsibilities</td>
<td>Hidden System/Equipment Response</td>
</tr>
<tr>
<td>Lack of or Unclear Standards</td>
<td>Changes or Departure from Routine</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>INDIVIDUAL CAPABILITIES</th>
<th>HUMAN NATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illness</td>
<td>Stress</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Complacency</td>
</tr>
<tr>
<td>Lack of Knowledge or Proficiency</td>
<td>Inaccurate Risk Perception</td>
</tr>
<tr>
<td>Imprecise Communication Habits</td>
<td>Mental Shortcuts/Assumptions</td>
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<tr>
<td>Indistinct Problem Solving Skills</td>
<td>Frustration</td>
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<tr>
<td>New Techniques Not Used Before</td>
<td>Habit Patterns</td>
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<tr>
<td>Unfamiliarity with Task/First Time</td>
<td>Imprecise Communication Habits</td>
</tr>
<tr>
<td>Unsafe Attitudes</td>
<td>Limited Short Term Memory</td>
</tr>
</tbody>
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Preventing Events and Mitigating Consequences

Preventing events from occurring or mitigating their consequences involves a twofold strategic approach for improving human performance:

- Manage controls that help identify and eliminate latent organizational weaknesses
- Anticipate, prevent, catch, and recover from active errors where work is being done

Controls for Managing Latent Organizational Weaknesses

Latent organizational weaknesses are, by definition, conditions that exist prior to an event. They can degrade barriers and defenses and also promote error precursors. The elimination of hazards or error traps altogether is the most effective way to ensure an environment in which work can be conducted safely, efficiently, and reliably.

Engineered, administrative, and cultural controls work together to provide defense-in-depth, and better allow individuals to anticipate, prevent, catch, and recover from errors that cause significant events.
**Engineered Controls**
The human-machine environment provides opportunities to help control error. Design of human-machine interfaces should consider likely methods of human error and the potential for consequences. Examples of these controls include:

- Elimination of unnecessary human-machine interactions.
- Implementation of interlocks and error-tolerant designs used to “mistake-proof” human-machine interactions, especially those which risk significant systems and critical components.
- Adjusting or manipulating the habitability or accessibility of the physical work environment.

The most reliable Engineered Controls require no operational or maintenance supports to remain effective, eliminating dependence on human involvement.

**Administrative Controls**
Administrative controls can be used in the absence of, or in conjunction with Engineered Controls to assist in controlling the opportunities for error. Examples of administrative controls include:

- Policies that describe what affected employees should and should not do for subjects that are considered critical to the organization.
- Step-by-step procedures that describe when, how, and by whom individual steps or tasks should be completed, especially for tasks or activities considered critical to the organization.
- Training and qualification processes that establish physical, psychological, educational, and proficiency requirements for assigned duties of a given position.
- Work management processes that establish how work is initiated, prioritized, planned, scheduled, and staffed.

These controls rely on human judgment, training, and initiative; consequently, they are not as reliable as Engineered Controls on their own.

**Cultural Controls**
Organizational culture comprises a set of shared values, beliefs, and attitudes that characterize the choices and behaviors of individual members of the organization. These types of controls are less tangible, but just as important to success. Examples of Cultural Controls include:

- Values that are both well communicated and demonstrated for the organization. For example, when production and safety conflict, it must be communicated and demonstrated that production does not take precedence over safety.
- Beliefs (or perceptions) tend to drive individual attitudes and behaviors. Improving human performance requires the belief that: absolutely safe environments do not exist, there is no such thing as a “routine” task or activity, and people are fallible.
- Attitudes are how an individual feels toward an object or subject. Uneasiness toward fallibility, a questioning attitude, and a conservative approach are all attitudes that promote safe and error-free behaviors.

**Tools for Reducing Active Error**
Workers cannot rely solely on management and controls to identify and remove error precursors, fix flawed barriers, and correct latent organizational weaknesses. Error prevention tools promote worker engagement and help workers maintain positive control of work situations. In general, error prevention tools should be used as applicable to the work being performed and may be applied as shown in the table below. The specific tool used should be tailored to the work activities of a particular work group and higher risk activities should use a more enhanced or detailed implementation of the tools.
<table>
<thead>
<tr>
<th>ERROR PREVENTION TOOL</th>
<th>HIGH RISK</th>
<th>MEDIUM RISK</th>
<th>LOW RISK</th>
</tr>
</thead>
<tbody>
<tr>
<td>TASK PREVIEW</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>PRE-JOB BRIEF</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>TWO-MINUTE DRILL</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>TIMEOUT/STOP WORK</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>SELF-CHECK/PEER-CHECK</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>PROCEDURE USE &amp; ADHERENCE</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>THREE-PART COMMUNICATION</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>TURNOVER</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>POST-JOB REVIEW</td>
<td>X</td>
<td>X</td>
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</tbody>
</table>

**Oversight Controls**

The nature of latent conditions is such that they will not self-reveal; these conditions must be discovered. Oversight controls provide opportunities to identify specific vulnerabilities or performance gaps, take actions to address those issues, and verify that they have been resolved. Possible controls may include:

- Self-assessments that compare present performance for a given work activity to the expected performance (based on standards).
- Behavior observations where the quality and effectiveness of work preparation and work practices can be reviewed, and where results can be recorded and trended to help identify and build upon strengths, and to identify and resolve weaknesses.
- Performance indicators and monitoring allow for the identification of undesirable trends. They must measure what is important, not just what is easy to measure.

Examples include:

- Event-free days (number of days since last event)
- Number of errors or near misses or concerns reported
- Observation results (using a standard scoring system)
- Employee perception (based on on-going surveys)
- Re-work (amount of re-work vs. total work completed)
Additional Reference Materials

For detailed information on Human Performance including additional human performance tools, access the following information:

**DOE Human Performance Improvement Handbook Vol 1** -

**DOE Human Performance Improvement Handbook Vol 2** –