NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

ERO Enterprise Endorsed Implementation Guidance

Compliance Implementation Guidance
Real-time Assessment Quality of Analysis

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RELIABILITY | ACCOUNTABILITY




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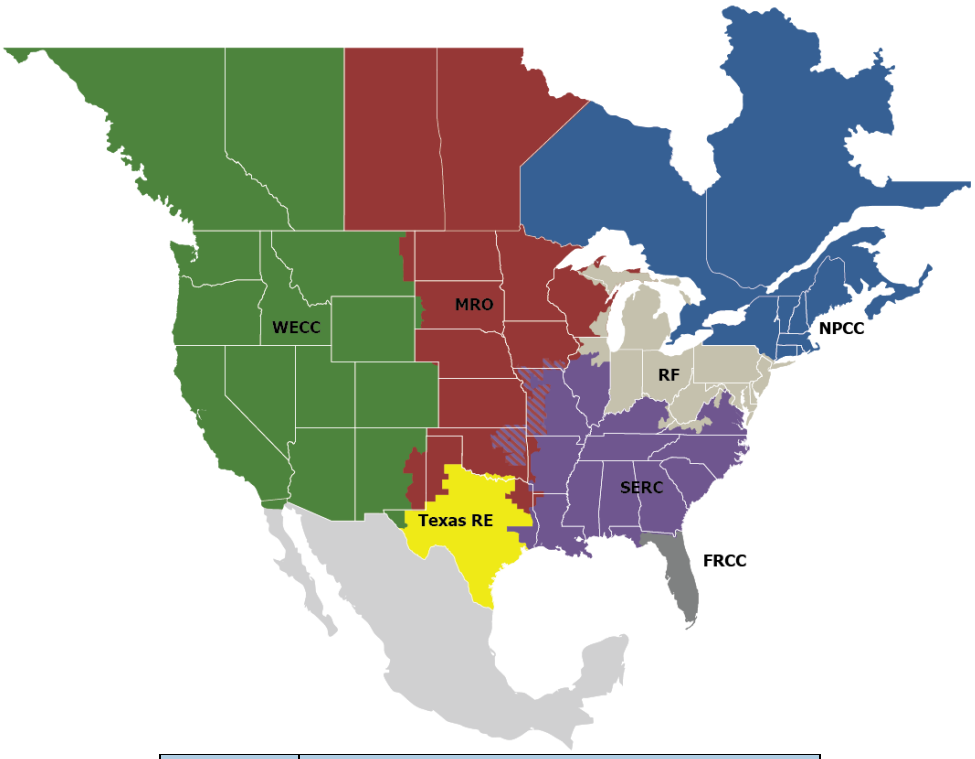
Preface

The vision for the Electric Reliability Organization (ERO) Enterprise, which is comprised of the North American Electric Reliability Corporation (NERC) and the seven Regional Entities (REs), is a highly reliable and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

The North American BPS is divided into seven RE boundaries as shown in the map and corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Region while associated Transmission Owners/Operators participate in another.



FRCC	Florida Reliability Coordinating Council
MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

Chapter 1: Background

1.1 Preamble

Implementation Guidance provides examples or approaches to illustrate how registered entities could comply with standards that are vetted by industry and endorsed by the Electric Reliability Organization (ERO) Enterprise. The examples provided in this Implementation Guidance are not all inclusive, as there are likely other methods for complying with a particular standard requirement. The ERO Enterprise's endorsement of an example means the ERO Enterprise Compliance Monitoring and Enforcement Program (CMEP) staff will give these examples deference when conducting compliance monitoring activities. Registered entities can rely upon the example and be reasonably assured that compliance requirements will be met with the understanding that final compliance determinations will depend on individual facts, circumstances, and system configurations. [1]

- Guidance documents cannot change the scope or purpose of the requirements of a standard.
- The contents of this guidance document are not the only way to comply with a standard.
- Compliance expectations should be made as clear as possible through the standards development process, which should minimize the need for guidance after final ballot approval of a standard.
- Forms of guidance should not conflict.
- Guidance should be developed collaboratively and posted on the NERC website for transparency.

1.2 Purpose

The purpose of this guidance document is to assist NERC registered entities in establishing a common understanding of the practices and processes surrounding the quality of analysis used in completion of a Real-time Assessment as applied in NERC Standards TOP-010-1(i), Requirement R3 and IRO-018-1(i), Requirement R2.

Specific objectives of this guidance document are to provide guidance on methods to meet compliance requirements surrounding the quality of analysis used in completion of a Real-time Assessment (RTA) including alternatives to advanced EMS applications.

1.3 Scope

This guidance document applies to Transmission Operators (TOPs), Reliability Coordinators (RCs), and applicable supporting entities' quality of analysis used in completion of a Real-time Assessments in accordance with NERC Standards TOP-010-1(i), Requirement R3 and IRO-018-1(i), Requirement R2.

> ***TOP-010-1(i)***
>
> ***R3.*** *Each Transmission Operator shall implement an Operating Process or Operating Procedure to address the quality of analysis used in its Real-time Assessments. The Operating Process or Operating Procedure shall include:*
>
> > ***3.1.*** *Criteria for evaluating the quality of analysis used in its Real-time Assessments;*
> >
> > ***3.2.*** *Provisions to indicate the quality of analysis used in its Real-time Assessments; and*
> >
> > ***3.3.*** *Actions to address analysis quality issues affecting its Real-time Assessments.*
>
> ***M3.*** *Each Transmission Operator shall have evidence it implemented its Operating Process or Operating Procedure to address the quality of analysis used in its Real-time Assessments as specified in Requirement R3. This evidence could include, but is not limited to: 1) an Operating Process or Operating Procedure in electronic*

[1] Source: http://www.nerc.com/pa/comp/Resources/ResourcesDL/Compliance_Guidance_Policy_FINAL_Board_Accepted_Nov_5_2015.pdf

or hard copy format meeting all provisions of Requirement R3; and 2) evidence the Transmission Operator implemented the Operating Process or Operating Procedure as called for in the Operating Process or Operating Procedure, such as dated operator logs, dated checklists, voice recordings, voice transcripts, or other evidence.

IRO-018-1(i)

R2. *Each Reliability Coordinator shall implement an Operating Process or Operating Procedure to address the quality of analysis used in its Real-time Assessments. The Operating Process or Operating Procedure shall include:*

2.1. *Criteria for evaluating the quality of analysis used in its Real-time Assessments;*

2.2. *Provisions to indicate the quality of analysis used in its Real-time Assessments;*

and

2.3. *Actions to address analysis quality issues affecting its Real-time Assessments.*

M2. *Each Reliability Coordinator shall have evidence it implemented its Operating Process or Operating Procedure to address the quality of analysis used in its Real-time Assessments as specified in Requirement R2. This evidence could include, but is not limited to: 1) an Operating Process or Operating Procedure in electronic or hard copy format meeting all provisions of Requirement R2; and 2) evidence the Reliability Coordinator implemented the Operating Process or Operating Procedure as called for in the Operating Process or Operating Procedure, such as dated operator logs, dated checklists, voice recordings, voice transcripts, or other evidence.*

1.4 Overview

Real-time Assessments are utilized by TOPs and RCs to maintain situational awareness of the Bulk Electric System (BES). There are many methods, information sources, tools and applications available to complete an RTA. For a more detailed look at how to complete an RTA, please utilize the Compliance Implementation Guideline for Real-time Assessments.

Individual entities may elect to perform RTAs in different ways depending on the availability of advanced EMS applications or complexity of their individual TOP or RC areas. Thus, different methods are available to complete the quality of analysis of an RTA. For entities without advanced in-house analysis tools which directly support the completion of an RTA, the use of third-party tools or applications may be an option and therefore, the method chosen to assess its quality of analysis will depend on an entity's approach to perform an RTA. This document has been created to assist TOPs and RCs in assessing what methods, practices, tools, and information may be utilized to meet compliance with the aforementioned standards.

1.5 NERC Defined Terms

Real-time Assessment (RTA)	An evaluation of system conditions using Real-time data to assess existing (pre-Contingency) and potential (post-Contingency) operating conditions. The assessment shall reflect applicable inputs including, but not limited to: load, generation output levels, known Protection System and Remedial Action Scheme status or degradation, Transmission outages, generator outages, Interchange, Facility Ratings, and identified phase angle and

equipment limitations. (Real-time Assessment may be provided through internal systems or through third-party services.)

1.6 Commonly Used Terms Within This Document

Note: These definitions are not found in or intended to be included in the NERC Glossary of Terms. These particular definitions are identified to ensure a common industry understanding of how they are applied solely within this paper.

Best Practice	Continuously evolving technique, method, or process that delivers an outcome with minimal problems or complications. Best Practices are often used for benchmarking and represent an outcome of repeated and contextual user actions.[2]
Energy Management System (EMS)	A system of computer-aided tools used by System Operators to monitor, control, and optimize the performance of the generation and/or transmission system. The computer technology is also referred to as SCADA/EMS or EMS/SCADA. Besides SCADA (Supervisory Control and Data Acquisition), other EMS applications can include alarm processing, network applications (which includes State Estimation), Power Flow, Contingency analysis (CA), security analysis (SA), and data historians. Data acquisition typically includes data that is received from RTUs or data links.
Power Flow (PF)	An application that allows the user to study various configurations of the electrical system model to calculate the voltages and flows in the system. PF typically uses a Newton Raphson / Gaussian Seidel method for solution.
Real-time Contingency Analysis (RTCA)	An application used to predict electrical system conditions after simulating specific contingencies. It relies on a base case from a state estimator or power flow case.
State Estimator (SE)	An application that calculates the current state of the electrical system (the voltage magnitudes and angles at every bus) using a network model and telemetered measurements. The purpose is to provide a consistent base case of Real-time system conditions for use by other network applications programs, such as power flow and Contingency analysis. SE typically uses a weighted least squares statistical method for solution.
Third Party advanced EMS network application results	Third party service provider collecting real-time data, maintaining a network model, and providing advanced EMS network application results for one or more TOP. Results are then used by the TOPs to conduct an RTA.

[2] Source: https://www.techopedia.com/definition/14269/best-practice

Chapter 2: RTA Quality Analysis

2.1 Purpose of an RTA

Current NERC standards TOP-001-4 and IRO-008-2 require RCs and TOPs to perform a Real-time Assessment (RTA) at least once every thirty minutes. The standards' requirements specify the minimum compliance measures for an RTA to reduce reliability risks. System Operators assess risks to the reliability of the BES by monitoring System Operating Limits (SOL) and Interconnection Reliability Operating Limits (IROL), system operating conditions such as loads, generation, system topology, automatic protection schemes, and equipment limitations such as safe operating limits, phase angles, etc. In order to make an accurate assessment of the reliability risks to the system, adequate situational awareness of current and potential system conditions is necessary. For the System Operator to have an appropriate level of situational awareness, the maximum interval between two consecutive RTAs must not exceed 30 minutes.

2.2 RC and TOP RTA Quality of Analysis

In performing the requirements to complete an RTA, RCs and TOPs may utilize various types of analyses, such as monitoring branch flows and bus voltages against established limits in SCADA and/or SE, monitoring projected post-contingency conditions against appropriate limits using RTCA or other off-line studies, voltage stability analysis and/or transient stability analysis based on off-line study results, or real-time voltage stability analysis and transient stability analysis tools. The results of these analyses provide valuable situational awareness that give applicable entities the ability to analyze real-time and potential future system reliability issues. The quality of the analysis determines the usefulness of the Real-time Assessment to provide appropriate situational awareness.

Since System Operators are highly dependent on RTA analysis tools to provide adequate situational awareness, it is extremely important for System Operators and other responsible support personnel to recognize when analysis tools are not performing properly and potentially producing erroneous results. For example, if a potential RTA analysis tool such as SE solves with excess mismatch or with unreasonably low voltages at a bus in the model, the resulting calculated flows in SE may not be accurate and could potentially impact the quality of the results in downstream applications such as RTCA, voltage stability analysis, or transient stability analysis. The requirements R3 of TOP-010-1(i) and R2 of IRO-018 (i) pertaining to analysis quality are designed to address this issue.

Each TOP or RC may utilize various analysis methods and criteria to assess the quality of analysis performed by tools in an RTA. Depending on the nature and size of an individual TOP or RC, a set of criteria that may be appropriate for one TOP or RC may not be appropriate for another TOP or RC. Requirements R3 of TOP-010-1(i) and R2 of IRO-018 (i) leave it up to the individual TOP or RC to develop and individualize their own Operating Process or Operating Procedures as appropriate to suit their unique operating systems, which includes the capability of their analysis tools. For example, an RC or TOP may have a set of criteria for monitoring the solution quality for RTCA (e.g., number of unsolved contingencies, solution time, etc.) while others may utilize a different set of criteria (e.g., average number of power-flow iterations to reach solution).

RCs and TOPs are also required to establish the criteria and provisions to indicate RTA quality to address quality for both automated Real-time tools normally used to perform the analysis as well as offline tools that may be used in performing analysis as part of an RTA. For example, a TOP or RC may utilize an in-house RTCA solution as a primary tool to perform contingency analysis. However, if RTCA is not functioning properly, the RC or TOP will need to utilize another tool to perform their contingency analysis. In this scenario, RCs and TOPs shall include quality criteria and provisions to indicate the quality of all primary and secondary analysis tools that are used in performing an RTA. Similarly, entities that normally rely on a third party RTA must identify applicable criteria and provisions to indicate quality within Operating Processes and Procedures to meet R3 of TOP-010-1(i) and R2 of IRO-018 (i) requirements. Requirements R3 of TOP-010-1(i) and R2 of IRO-018 (i) do not require the analysis quality indication to be provided to System Operators (as is the case for requirements related to Real-time data quality in R1 of TOP-010-1(i) and R1 of IRO-018-1(i)) because at times the analysis results are monitored by personnel other than System Operators, such

as Operations Support Personnel. A particular RC or TOP may decide to show the analysis results and associated quality information to their System Operators but the standard leaves it up to the entity to determine who needs to see the analysis results to and how to address quality issues.
Once criteria have been defined, the standard requires the RCs and TOPs to show the analysis results to appropriate personnel and take appropriate corrective actions if criteria violations are discovered in the analysis. Entities may also choose to set EMS alarms, send emails, or provide automated messaging to personnel expected to respond to analysis quality issues.

Compliance related evidence gathering is critical in order to demonstrate compliance to the aforementioned standard requirements. To maintain evidence that an entity implemented their Operating Procedures or Operating Processes to address analysis quality issues, RCs and TOPs can utilize said processes or procedures, screenshots from their EMS systems, System Operator logs, archived logs generated by the EMS (from SCADA, SE, RTCA, etc.), voice recordings or other such documentation. The next section describes the type of evidence that could be utilized to demonstrate compliance in more detail.

Chapter 3: Compliance Implementation and Evidence

3.1 Examples of Operating Scenarios and Compliance Evidence

Table 3.1 identifies analysis tools that entities may use when completing an RTA. For the different tools, examples of criteria and provisions that can be used to evaluate quality of RTA analysis are also listed in Table 3.1. Note that the analysis tools are neither exclusive nor exhaustive in demonstrating whether an entity is meeting its compliance obligations pertaining to performing RTAs and addressing associated quality analysis. Other techniques or methods may be utilized depending on an entity's individual circumstances.

Table 3.1 has eight categories identified for analysis tools.

Analysis Tool 1 - Health of Remedial Action Schemes and Protection Systems

Table 3.1: Criteria for Evaluating and Indicating the Quality of an RTA	
Criteria for Evaluating:	**EMS displays and alarms**
Analysis Tool 1 - Health of Remedial Action Schemes and Protection Systems	
Receiving telemetered values	EMS displays and alarms
Monitor status of RAS and/or protection system to ensure they are functioning as expected	
Analysis Tool 2 - EMS SCADA and Alarm Applications	
Processes are running and updating with real-time data	Summary display of health indicators ("Dashboard" displays)
Monitoring for RTU Failure	System generated emails (either native or with an email alert tool)
Monitoring for ICCP Link and Dataset Failures	Alarm Displays
Monitoring for Metering differences	Alarm Notifications
Monitoring for Measurement values are within the acceptable range.	Quality Codes
Bus mismatch derived from SCADA (when sufficient SCADA data is available)	
MW flow from SCADA comparisons on lines that are measured on both ends (flow absolute values should be "close")	
Analysis Tool 3 - State Estimator (SE)	
Monitor the Number of solution iterations	Summary display of health indicators ("Dashboard" displays)
Monitor real-time or normalized performance index trending	Alarms (visual and/or audible)
Monitor bus mismatch	Displays listing all items that meet the criteria
Monitor for measurement anomalies	Quality codes
Monitor solution status, including: Time elapsed since last solution, Non-convergence of SE,SE failure	Trends of performance index, normalized performance index, solution time, solution iterations, etc.
Monitor SE measurement consistency check	Continuous monitoring of the production systems 24 X 7 including display of high residual anomalies. Email notifications to Operations Support Personnel
Monitor abnormal SE solution voltages	
Monitor number of islands in solution	
Monitor quality and refresh time of real-time input data.	
Analysis Tool 4 - Real-time Contingency Analysis (RTCA)	
Monitor contingency solution information (invalid, solved, not-solved, violations, etc.)	Summary display of health indicators

Table 3.1: Criteria for Evaluating and Indicating the Quality of an RTA	
Criteria for Evaluating:	**EMS displays and alarms**
Monitor Solution Performance: Time elapsed since last solution, Performance index, RTCA failure, Number of unsolved contingencies, execution time of current solution.	Real-time SCADA alarms (visual and/or audible)
Monitor the Number of solution iterations	Continuous monitoring of the production systems 24 X 7
Analysis Tool 5 - Use of off-line Security Analysis Tools (representative of Real-time system conditions)	
Compare results to Real-time data	Application logs
Compare to last known results	Application solution performance (to review application performance pertaining to solution time, average number of iterations, number of unsolved, etc.
Monitor abnormal solution voltages	Violation summary
Verify Interchange Schedules vs solved Interchange values	Review the abnormal voltage page to assess solution performance
Verify topology for BES Facilities	Tie-line and Company Summary
Verify SPS/RAS status	Review bus summary display or single lines match real-time data
Verify generator and synchronous condenser status and output	Match the SPS/RAS status within the off-line tool.
Verify DC line status and output	
Verify phase shifter status and output	
Verify BES bus voltages	
Analysis Tool 6 - Real-time Voltage Stability Analysis	
Ensure application is running at pre-determined intervals	Real-time alarms, Bus VAR margins
Application produces a valid solution (This includes monitoring for partial solution and unsolved contingencies as well)	RTVSA output display or output files RAS summary Zero or low VAR margins Low bus voltages
Model contains sufficient modeling footprint to accurately simulate necessary voltage and RAS related contingencies	Valid RTVSA limit indicated by: Accurate RAS information Bus VAR margins Bus voltages
Application uses correct assumptions with respect to transfer calculations	
Analysis Tool 7 - Real-time Transient Stability Analysis	
Ensure application is running at pre-determined intervals	Transient stability tool display or output files: RAS summary Transient stability criteria violations
Application produces a valid solution (This includes monitoring for partial solution and unsolved contingencies as well)	
Model contains sufficient modeling footprint to accurately simulate necessary contingencies	
Application uses correct assumptions with respect to transfer calculations	
Application uses correct dynamic data	

Table 3.1: Criteria for Evaluating and Indicating the Quality of an RTA	
Criteria for Evaluating:	**EMS displays and alarms**
Valid transient stability results indicated by: Accurate RAS information Transient stability criteria	
Analysis Tool 8 - In House Applications	
Servers hosting the application are working properly	Verify that application is running in real-time when reviewing results (view interface and logs if necessary)
Application is getting the required ICCP /RTU data	Verify data, via applicable displays, are in an acceptable state
Transfer limit provided by the tool matches the operating guidelines	

3.2 Actions to Address Quality Issues affecting Real-time Assessments

Entities are required to monitor the quality of an RTA 24/7 and if they are unable to resolve an issue, Operation Support Personnel (on-call operations, EMS, IT, etc.) may be notified to assist in the resolution. External entities should be contacted as deemed appropriate for addressing data quality issues which are external to the applicable entity. The actions taken by the aforementioned individuals to address quality issues and the associated evidence to save for compliance are listed in Table 3.2 below.

Table 3.2 identifies actions that entities may take to address the quality of an RTA. For the different actions, examples of how to demonstrate evidence of compliance are included. The actions and examples of compliance are neither exclusive nor exhaustive in demonstrating whether an entity is meeting its compliance obligations pertaining to performing RTAs and addressing associated quality analysis. Other techniques or methods may be utilized depending on an entity's individual circumstances.

Table 3.2: Actions to Address the Quality of an RTA	
Actions to Address Quality	**Evidence of Compliance Examples**
Notification of field personnel or other support personnel to address erroneous readings from the field	Dated logs, dated checklists, voice recordings, voice transcripts, or other evidence.
Manually change digital or analog values to known good values or use backup data readings	Dated logs, dated checklists, voice recordings, voice transcripts, EMS historian data, emails, or other evidence.
Verifying model information, data and issue corrections as necessary Notification of support staff if status or incorrect flow values are identified	Dated logs, dated checklists, voice recordings, voice transcripts, EMS historian data, emails, or other evidence.

3.3 Best Practices

Table 3.1 above provides specific examples of criteria that can be used to evaluate and indicate the quality of a Real Time Assessment given the various analysis tools used by RCs and TOPs. While this table is by no means an exhaustive list of all possible criteria, it does provide general direction with respect to what is considered reasonable criteria for the evaluation of quality.

In developing a process or procedure to address the quality of analysis used in its RTA, RCs and TOPs could also consider the following Best Practices:

1. Use and monitor multiple criteria to evaluate quality. For example, a TOP may choose to use the number of unsolved or partially solved contingencies to indicate quality of RTCA or RTCA solution completion time as a

metric to indicate analysis quality. Ideally, using both number of unsolved or partially solved contingencies as well as RTCA solution completion time provides a more robust assessment of RTCA solution quality.

2. Leverage advanced network tools to perform an RTA. Examples of advanced network tools are: State Estimation (SE), Real-time Contingency Analysis (RTCA), Voltage Stability Analysis, and Transient Stability Analysis. When integrated into EMS production systems, the real-time monitoring capability of these applications facilitates the evaluation of solution quality. Table 3.1 identifies some examples of the type of monitoring capability that can be leveraged with these tools to assess quality.

3. Develop a composite performance index for advanced network tools based on a number of inputs that have the potential to impact the quality of solution from these tools. One approach to establishing a performance index is shown in Figure 3.1 where multiple performance factors for SE and RTCA advanced network tools are evaluated and aggregated into one overall composite performance index. The individual factors may include: a) The current performance value for the factor, b) Historical based threshold using engineering judgement, c) Other possible attributes such as weight and limits for the factor. Note that each performance index factor and the overall methodology should be periodically reviewed and appropriately updated if needed. The intent of periodic review is to mitigate false positives while identifying all legitimate quality events.

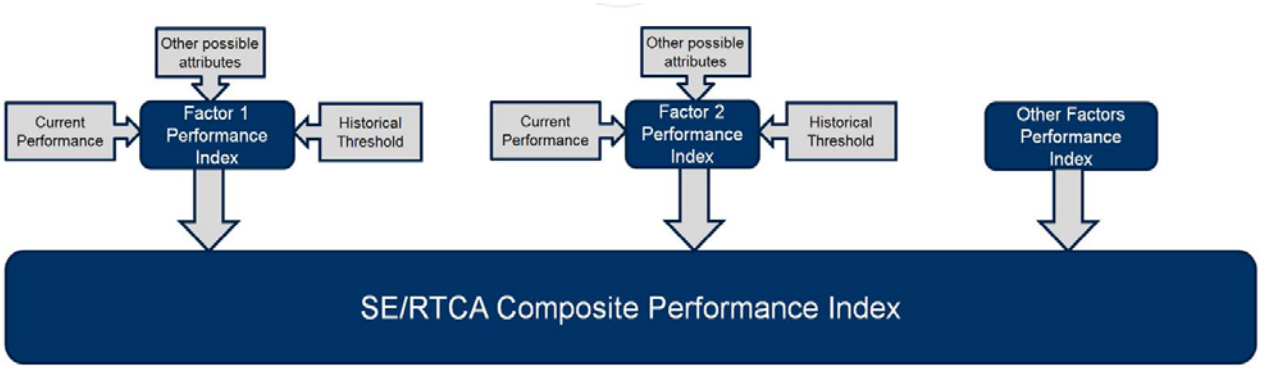


Figure 3.1: Performance Index

4. Consider developing alarms for real-time operators and support personnel expected to respond to analysis quality issues. Entities may use warning alarms generated by the monitoring provision tools to assess quality impact levels (low to severe). Such indicators may be used to assess when quality is inadequate and actions are needed to mitigate and alleviate analysis issues. Additionally, warnings may be used in the following ways:

   a. Severe quality warnings may be derived using statistical analysis such as greater than three σ.

   b. Less severe quality warnings may be derived using statistical analysis such as greater than two σ.

   Significant warnings may be used to trigger immediate engineering support staff action, such as when SE or RTCA severe quality warning exceed an identified time period.

5. Develop pre-emptive actions to address quality issues which could include system generated emails or alerts regarding SE/SA solution status or other quality metrics that are sent out to applicable Operations Support Personnel. This process may aid in detection and mitigate quality issues contributing to EMS network application issues.

6. Since a TOP or an RC may be running various different types of analyses, setting up a dashboard tool that consolidates analysis quality metrics from various different types of analyses into a single display provides enhanced situational awareness as to the status of RTA tools. An example is a “traffic light” graphic to display RTA quality warnings or potential quality flags.

Chapter 4: Entities Utilizing a Third Party to Provide Advanced EMS Network Applications Results

An entity that utilizes a third party to provide advanced EMS network application results remains responsible to assure the quality of those results used in their Real Time Assessment. This may be done as described in Sections 2 & 3 above, with the entity ensuring the third party service provider makes adequate data available to the client entity to evaluate advanced EMS network application results or other applicable analysis tools listed in Table 3.1. Criteria and provisions outlined in Table 3.1 are applicable to all registered entities responsible to comply with R3 of TOP-010-1(i) and R2 of IRO-018 (i) regardless of whether a third party completes the RTA associated quality assessment or the entity performs the analysis. Best Practice methods defined within Section 3.3 can also be used to help validate third party advanced EMS network application solutions or analysis tools.