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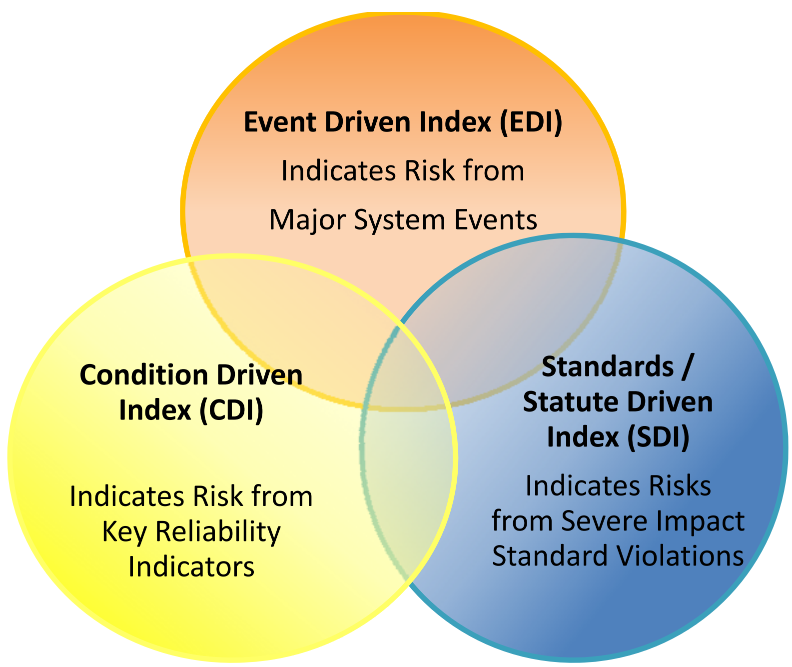
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

# Integrated Reliability Index Concepts

The development of an integrated reliability index aims to inform, increase transparency, and quantify the effectiveness of risk reduction and/or mitigation actions. The goal is to provide the industry meaningful trends of the bulk system performance and guidance on how they can improve reliability and support risk-informed decision making.

Under the direction of the Operating Committee (OC) and Planning Committee (PC), the Reliability Metrics Working Group (RMWG) has developed a portfolio of eighteen (18) Adequate Level of Reliability (ALR) metrics.[1] At its March 2011 meeting, the Operating Committee (OC) and Planning Committee (PC) approved the Severity Risk Index (SRI)[2] calculation and supported the development of an Integrated Reliability Index (IRI), which can be constructed based on the risk model illustrated in Figure 1. This model attempts to capture the "universe of risk" and links that risk calculation to the reliability of the bulk power system.

Figure 1 – Risk Model for Bulk Power System




1 http://www.nerc.com/docs/pc/rmwg/RMWG_AnnualReport6.1.pdf

2 http://www.nerc.com/docs/pc/rmwg/Integrated_Bulk_Power_System_Risk_Assessment_Concepts_Final.pdf

**Event Driven Index (EDI) –** The Event Driven Index (EDI) provides a basis for prioritization of events based on bulk power system integrity, equipment performance, and/or engineering judgment. The event severity indicators can serve as a high value risk assessment tool. Stakeholders can use the tool to measure the severity of these events and evaluate disturbance history. The relative severity ranking of events considers both the occurrence of an event and its impact, in order to quantify the event risk to reliability. The index EDI increases if the risk value associated with significant events is reduced over a trending period. The EDI calculation and metric aggregation are described in Appendix A.

**Condition Driven Index (CDI) –** Condition Driven Index (CDI) focuses on a set of measurable system conditions to assess bulk power system reliability. These reliability indicators identify factors that positively or negatively impact reliability and are early predictors of the risk to reliability from condition based ALR metrics. A collection of these indicators measures how far reliability performance is from desired outcome, and if the performance is heading or trending in the preferred direction. The index CDI increases if the risk value associated with key reliability metrics covering major risk factors to reliability is reduced over a trending period. The CDI calculation and metric aggregation are described in Appendix B.

**Standards/Statute Driven Index (SDI) –** The Standards/Statute Driven Index (SDI) measures improvement in compliance with Reliability Standards.[3] The violations included in SDI all have high Violation Risk Factors (VRFs) and were rated as potentially severe reliability impacts. Based on these two dimensions, known unmitigated violations are weighted and normalized over the number of applicable registered entities subject to a particular standard requirement. The index increases if the compliance improvement is achieved over a trending period. The CDI calculation and metric aggregation are described in Appendix C.

As this time, the IRI is intended to be used as a historical measure, neither a real-time, nor forward-looking performance score. As such, the index is calculated using actual field data.[4] The value of the IRI can be calculated based on the assessed risk of the above three components and their relative weightings, as shown in Equation 1 below:

$$IRI = w_E \times EDI + w_C \times CDI + w_S \times SDI \qquad (1)$$

where:

$w_E$ = weighting of event component;
$EDI$ = normalized Event Driven Index;
$w_C$ = weighting of metric component;
$CDI$ = normalized Condition Driven Index;
$w_S$ = weighting of standard compliance component;
$SDI$ = normalized Standards Driven Index;
$IRI$ = Integrated Reliability Index for a specific period.

[3] Detailed standards/statute-driven indicators can be viewed at http://www.nerc.com/filez/pmtf.html.

[4] From a real time or forward-looking point of view, one can also create other indices linking real-time or forecast variables and factoring in probabilities. As the industry gains experience with this backward-looking metric it will continue to consider whether certain real-time or forecast metrics are valuable indicators of the reliability of the bulk power system.

The value of IRI will range from 0 to 100, and can be aggregated at various levels of detail, including at the NERC, Interconnection or Regional levels. The three weights can be adjusted as we learn more and gain experience after one to two years of trending. At this time it is suggested that a weighting of

$$IRI = \frac{1}{2} \times EDI + \frac{1}{4} \times CDI + \frac{1}{4} \times SDI \qquad (2)$$

is used initially as the EDI reflects actual experiences of the power system while CDI and SDI are more reflective of risks to the power system.

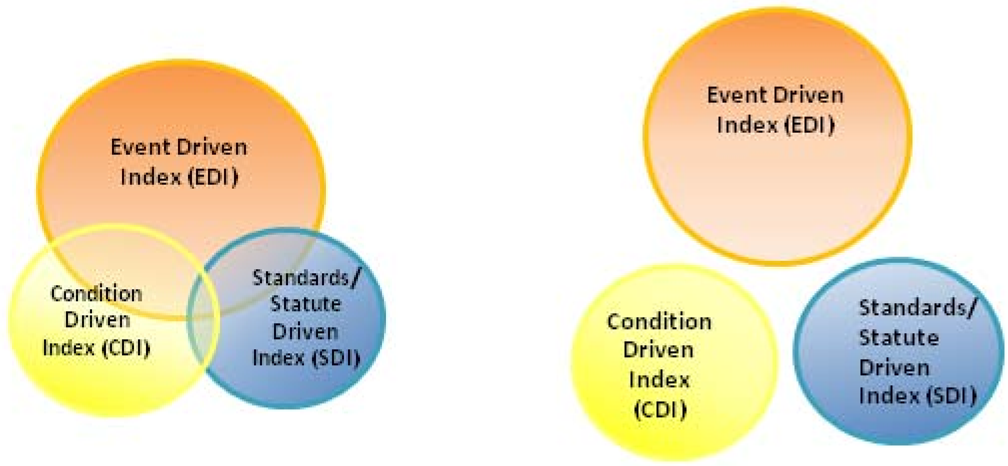
The following factors are to be considered when developing each of the IRI components:

- Cover majority of risks
- Show a consistent link to reliability
- Consider randomness and independence
- Should understand the degree to which any of the three indices may relate to other indices

Conceptually, the components might be considered as “success rates” for events experienced (as measured by EDI), condition performance (as measured by CDI), and compliance history (as measured by SDI). Components should be measurable for specific time periods of interest, such as quarterly or annually.

Another important concept is the extent to which the IRI measures the intersection or the union of risks within the bulk powers system. At this time, there appears to be benefit in shrinking the size of the populations (or weightings) for CDI and SDI. Also, currently the equation reflects the addition of risks, rather than the measurement of any of the unions (and increased weightings) of each of the components of the IRI. This concept is shown graphically in Figure 2. Depending upon the model preferred, the equation and relevant indices should be modified appropriately.

Figure 2 – Union IRI or Intersecting IRI




**IRI Index Components**

As discussed previously IRI is intended to be a composite metric which integrates several forms of individual risks to the bulk power system. Upon their factoring and weighting a lagging indicator will be developed on a quarterly or annual basis. At this time three component indices are being considered. Each of these components is discussed in greater detail below. It is important to caution that since they range across many stakeholder organizations, these concepts are developed as starting points for continued study and evaluation. Additional supporting materials are found in the Appendices as much of the individual indices calculations and supporting trend information is in a formative state.

**Sample Integrated Reliability Index (IRI) Calculation**

At this time, the RMWG believes some form of blended weighting may serve to start to populate IRI characteristic curves at a high and generic level. Based upon feedback from stakeholders, this approach may change, or as discussed further below, weighting factors may vary based on periodic review and risk model update. The RMWG will continue the refinement of the IRI calculation and consider other significant factors that impact reliability (e.g., intentional and controlled load-shedding); further, it will explore developing mechanisms for enabling ongoing refinement which should be influenced by a wide set of stakeholders.

RMWG recommends the Event Driven Index (EDI) be weighted the highest (50%) since events actually occurred, indicating how system was performing. The Condition Driven Index (CDI) and Standards/Statute Driven Index (SDI) are weighted 25% each since they are indicators of potential risks to BPS reliability. Using Equation 3, IRI can be calculated as follows:

$$IRI = 0.50 \times EDI + 0.25 \times CDI + 0.25 \times SDI \qquad (3)$$

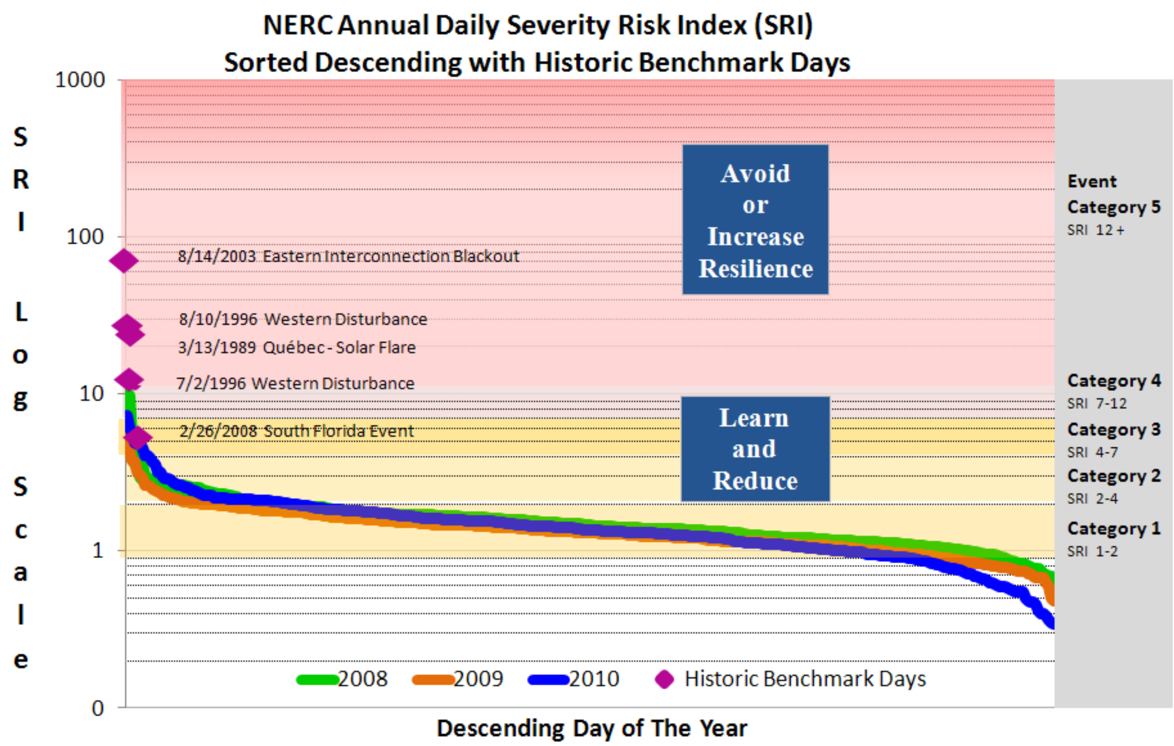
# Appendix A – Event Driven Index (EDI) Calculation

**Event Driven Index (EDI)**

The event severity risk index (SRI) was developed to measure relative severity ranking of events based on event occurrence rate and their impact to the bulk power system. Impact can be among multiple dimensions such as load (as a proxy for customers) or loss of facilities (such as generators, transmission lines, substations or communications facilities). These measures provide a quantitative approach to determine which events have more impact on bulk power system reliability. In other words, the metrics are an integrated measurement system, which classifies an event's impact on each of the components that are critical to the holistic performance of the bulk power system.

Figure 3 plots the 2008-2010 NERC SRI performance, including historic benchmark events using the approved SRI formula. The impact considers load loss and duration, AC transmission circuit and generation losses occurred from recorded events, including weather and other natural events. The load loss and duration data were gathered from EOP-004[5] and OE-417[6] reports. The daily generation and AC transmission circuit outages were obtained from GADS (Generating Availability Data System) and TADS (Transmission Availability Data System), respectively. The event category[7] and its associated severity risk range are also shown in Figure 3.

Figure 3 – NERC 2008-2010 Severity Risk Index versus Historic Benchmark Days




5 http://www.nerc.com/files/EOP-004-1.pdf
6 http://www.eia.doe.gov/cneaf/electricity/forms/instfor417.pdf
7 http://www.nerc.com/docs/eawg/Event_Analysis_Process_Field_test_DRAFT_102510-Clean.pdf

The EDI component is derived from RMWG's Severity Risk Index (SRI) values[8] and can be computed as follows:

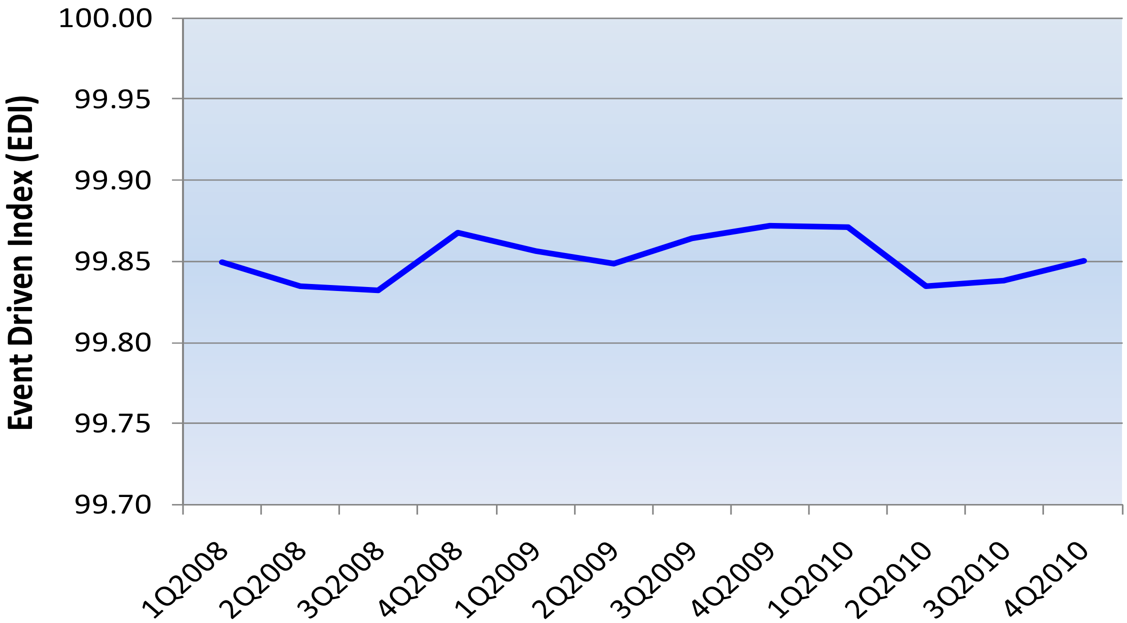
$$EDI = \frac{Duration\ in\ Days - \sum SRI}{Duration\ in\ Days} \qquad (4)$$

where the SRI is a daily Severity Risk Index and the duration is a specific time period of interest, such as quarterly or annually. The value of EDI will range from 0 and 100

Based on the SRI values in Figure 3 and Equation 4, quarterly EDI trending for the past three years is presented in Figure 4.

No significant EDI trend changes are observed from 2008 to 2010.

Figure 4 – NERC 2008-2010 Event Driven Index by Quarter




[8] http://www.nerc.com/docs/pc/rmwg/Integrated_Bulk_Power_System_Risk_Assessment_Concepts_Final.pdf

# Appendix B – Condition Driven Index (CDI) Calculation

In 2009, the RMWG developed the S.M.A.R.T criteria[9] (Specific, Measurable, Attainable, Relevant and Tangible), shown in Table 1, as the ranking process providing a consistent approach to identify a high ranking subset of metrics.

Table 1 – SMART Method and Rating (*SMART Score = Sum of Ratings for S, M, A, R, and T)

| Table 1 – SMART Method and Rating* | | | | | |
|---|---|---|---|---|---|
| Rating | **S - Specific/Simple**<br><br>• Be easily understood and not driven by commercial factors (i.e. tariff)<br>• Identify factors that positively or negatively impact reliability<br><br>• Address reliability problems and solutions | **M - Measurable**<br><br>• Be easily measured with regularly collected information<br><br>• Measure past and current reliability<br><br>• Measure progress in ensuring reliability<br><br>• Measure effectiveness of reliability standards and enforcement programs | **A - Attainable**<br><br>• The industry can provide the right resources (i.e. funding, time and ability) to improve reliability<br><br>• Reliability will be measurably improved | **R - Relevant**<br><br>• Linked to reliability goals<br><br>• Provide meaningful information<br><br>• Provide feedback for improving the Reliability Standards | **T - Tangible/Timely**<br><br>• Reflect current top priority issues and possess a sense of urgency<br><br>• Identify reliability gaps and point to existing standards that need to be modified or new standards that need to be developed |
| **3** | • Defined in a NERC Standard<br><br>• Not driven by commercial factors<br><br>• Addresses specific reliability issues | • Easily measured and reported regularly<br><br>• Historical data exists at REs and/or NERC and is currently required in NERC Standard<br><br>• Directly measure effectiveness of standard and enforcement programs | • Compelling business case suggests good chance of being approved through business planning and tariff approval processes<br><br>• Reliability improvements will be easily seen | • Direct link to reliability goals<br>• Focus on failures and possible solutions or improvements<br><br>• Provide direct feedback for improving the Reliability Standards | • Directly links to current top priority reliability issues and possess a sense of urgency<br><br>• Clearly identifies reliability gaps and points to standard improvement needs |
| **2** | • Defined within the industry<br><br>• Not driven by commercial factors<br><br>• Addresses reliability issues | • Easily measured and reported on occasions<br><br>• Some historical data exists at REs and/or NERC and is currently required in NERC standard<br><br>• Measure effectiveness of standard and enforcement programs in a long run | • Additional resources will be required and have a reasonable chance of being approved through business planning and tariff approval processes<br><br>• Reliability improvements will be apparent within a reasonable period of time (months) | • Some link to reliability goals<br><br>• Not directly focus on failures and possible solutions or improvements<br><br>• May provide feedback for improving the Reliability Standards in a long run | • Some link to current top priority reliability issues<br><br>• May reveal reliability gaps in a long run |
| **1** | • Defined somewhere<br><br>• May have some commercial factors<br><br>• May relate to reliability issues | • Easily measured and not reported<br><br>• Some historical data exists at REs and/or NERC<br><br>• No link to effectiveness of standard and enforcement programs | • Significant resources will be required well beyond normal business planning and tariff approval levels<br><br>• Reliability improvements will only marginal, or evident over an extended period of time (years) | • No link to reliability goals<br><br>• Not Focus on failures and possible solutions or improvements<br><br>• Not tied to a standard improvement | • No link to current top priority reliability issues and does not possess a sense of urgency<br><br>• Does not identify reliability gaps. |

9 http://www.nerc.com/docs/pc/rmwg/RMWG_Metric_Report-09-08-09.pdf

RMWG recommends using a combination of Relevant and Tangible ratings of each metric as weighting factors. Table 2 lists each metric's Relevant and Tangible scores[10] and combined metric weighting factors.

Table 2 – CDI Metric Weighting Factor (WF) and Trend Rating (TR)

| ALR | Description | Relevant | Tangible | WF | 2010 Performance Trend | Trend Rating |
|---|---|---|---|---|---|---|
| 1-3 | Planning Reserve Margin | 2 | 3 | 5 | Slight Improvement | 4 |
| 1-4 | BPS Transmission Related Events Resulting in Loss of Load | 3 | 3 | 6 | Slight Improvement | 4 |
| 1-5 | System Voltage Performance | 3 | 2 | 5 | No Data | 0 |
| 1-12 | Frequency Response | 3 | 2 | 5 | No Data | 0 |
| 2-3 | Activation of Under Frequency Load Shedding | 2 | 2 | 4 | Inconclusive | 3 |
| 2-4 | Average Percent Non-Recovery DCS | 3 | 3 | 6 | Inconclusive | 3 |
| 2-5 | Disturbance Control Events Greater Than Most Severe Single Contingency | 2 | 2 | 4 | Slight Improvement | 4 |
| 3-5 | Interconnection Reliability Operating Limit/ System Operating Limit (IROL/SOL) Exceedance | 3 | 3 | 6 | New Data | 0 |
| 4-1 | Automatic Transmission Outages Caused by Protection System Misoperations | 3 | 3 | 6 | Inconclusive | 3 |
| 6-1 | Transmission Constraint Mitigation | 3 | 2 | 5 | New Data | 0 |
| 6-2 | Energy Emergency Alert 3 (EEA3) | 3 | 3 | 6 | Slight Improvement | 4 |
| 6-3 | Energy Emergency Alert 2 (EEA2) | 3 | 3 | 6 | Slight Improvement | 4 |
| 6-11 | Automatic Transmission Outages Caused by Protection System Misoperations | 3 | 2 | 5 | Inconclusive | 3 |
| 6-12 | Automatic Transmission Outages Caused by Human Error | 3 | 2 | 5 | Inconclusive | 3 |
| 6-13 | Automatic Transmission Outages Caused by Failed AC Substation Equipment | 3 | 2 | 5 | Inconclusive | 3 |
| 6-14 | Automatic Transmission Outages Caused by Failed AC Circuit Equipment | 3 | 2 | 5 | Inconclusive | 3 |
| 6-15 | Element Availability Percentage (APC) | 2 | 2 | 4 | New Data | 0 |
| 6-16 | Transmission System Unavailability on Operational, Planned and Auto Sustained Outages | 2 | 2 | 4 | New Data | 0 |

10 http://www.nerc.com/filez/Approved_Metrics.html

To integrate individual metrics with differing units of measure, the five common trend ratings (TR) were identified to quantify each metric performance level, shown in Table 2. These five ratings range from 1 to 5. If no metric data trend is yet available, the trend rating is assigned 0. The significant improvement trend has the highest rating of 5, and other trend ratings, as listed below:

$$\begin{aligned} TR\quad &= 5 \text{ for Significant Improvement,} \\ &= 4 \text{ for Slight Improvement,} \\ &= 3 \text{ for Neutral or Inconclusive,} \\ &= 2 \text{ for Slight Deterioration, and} \\ &= 1 \text{ for Significant Deterioration.} \\ &= 0 \text{ for New Data or No Data} \end{aligned}$$

The individual metric contribution can be computed as

$$Metric\ Contribution = Weighting\ Factor \times Specific\ Trend\ Rating \qquad (5)$$

The value of metric contribution will range from 0 to 100. The CDI aggregates each metric contribution as a weighted average by relative importance. For example, SMART ratings of the above five metrics serves as their importance values in the CDI equation below:

$$CDI = \frac{\sum(100 - Metric\ Contribution) \times Metric\ SMART\ Rating}{\sum SMART\ Score} \qquad (6)$$

# Appendix C – Standards/Statute Driven Index (SDI)

The RMWG recommends using the Reliability Impact Statement (RIS) and Violation Risk Factor[11] (VRF) as selection criteria to identify the subset of standard requirements to be included in the SDI. RIS is the assessment of risk to the bulk power system when a requirement is violated, as determined by the Regional Entity. The three RIS levels are minimal impact, moderate impact and severe impact. The factors included in the RIS are

- Time Horizon
- Relative size of the entity
- Relationship to other entities
- Possible sharing of responsibilities
- Voltage levels involved
- Size of generator or equipment involved
- Ability to project adverse impacts beyond the entity's own system

"Failure to maintain vegetation clearance could cause or exacerbate a cascading outage" is an example of severe impact; "lack of regular maintenance and testing could result in misoperations" is an example of moderate impact; "the entity is conducting training, but its training program did not include a plan for the initial operator training" is an example of minimal impact.

Based on the above criteria, the twenty-six standard requirements in Table 3 were identified from NERC's 3-year compliance database as having a severe RIS and high VRF.

Table 3 – Standard Requirements* Included in SDI

| Standard | Req. | Standard | Req. | Standard | Req. | Standard | Req. | Standard | Req. |
|---|---|---|---|---|---|---|---|---|---|
| EOP-001-0 | R1. | FAC-009-1 | R1. | PER-002-0 | R3. | PRC-005-1 | R2. | TOP-004-2 | R1. |
| EOP-003-1 | R7. | IRO-005-2 | R17. | PER-002-0 | R4. | TOP-001-1 | R3. | TOP-004-2 | R2. |
| EOP-005-1 | R6. | PER-001-0 | R1. | PRC-004-1 | R1. | TOP-001-1 | R6. | TOP-006-1 | R6. |
| EOP-008-0 | R1. | PER-002-0 | R1. | PRC-004-1 | R2. | TOP-001-1 | R7. | TOP-008-1 | R2. |
| FAC-003-1 | R1. | PER-002-0 | R2. | PRC-005-1 | R1. | TOP-002-2 | R17. | VAR-001-1 | R1. |
| FAC-003-1 | R2. | | | | | | | | |

*Requirements are identified from the NERC compliance database where their violations have severe RIS.

[11] http://www.nerc.com/page.php?cid=2|20|285

By applying a similar aggregation as EDI, the SDI can be calculated as

$$SDI = 100 - \sum \frac{w_V \times N_V}{N_R} \qquad (7)$$

where:
$SDI$ = integrated standard compliance index for a specific period;
$w_v$ = weighting of a particular requirement violation;
$N_V$ = number of known unmitigated violations for the selected requirement;
$N_R$ = number of registered entities who are required to comply with the selected requirement.

Assuming an equal weighting ($w_V$) for all requirements, Figure 5 provides the quarterly SDI trends for past three years.

Figure 5 – NERC 2008-2010 SDI Trend by Quarter

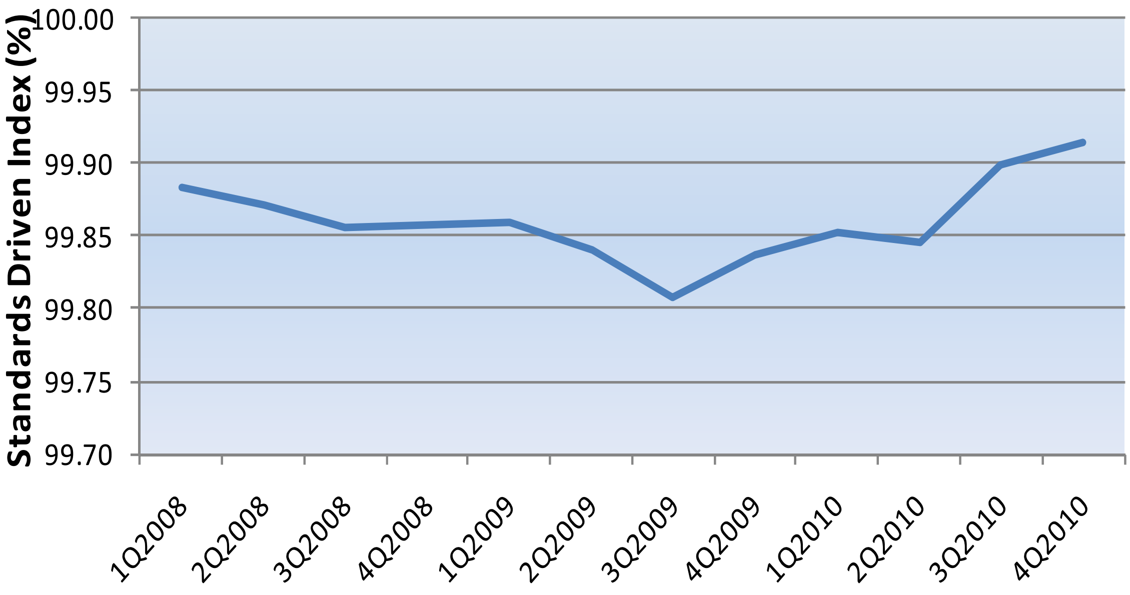



Figure 5 provides the quarterly SDI trends for past three years, indicating the risk due to known severe impact violations has decreased, and the industry has achieved a higher reliability level through standards compliance since third quarter 2009.