Preliminary Analysis of Western Interconnection Disturbances 1999-2010

Are we getting better?

Introduction:

This paper is meant to address the question: "Are we getting better?" with respect to reliability in the Western Interconnection. The question is often asked at industry meetings, but there is little in the way of an answer to date.

Background:

The original NERC was formed on June 1, 1968, by the electric utility industry to promote the reliability and adequacy of bulk power transmission in the electric utility systems of North America. NERC's mission states that it is to "ensure that the bulk power system in North America is reliable." NERC oversees eight regional reliability entities and encompasses all of the interconnected power systems of the contiguous United States, Canada and a portion of Baja California in Mexico. NERC's major responsibilities include working with all stakeholders to develop standards for power system operation, monitoring and enforcing compliance with those standards, assessing resource adequacy, and providing educational and training resources as part of an accreditation program to ensure power system operators remain qualified and proficient. NERC also investigates and analyzes the causes of significant power system disturbances in order to help prevent future events.

With the passage of the Energy Policy Act of 2005, an "Electric Reliability Organization" was created to develop and enforce compliance with mandatory reliability standards in the U.S. This non-governmental, "self-regulatory organization" was created in recognition of the interconnected and international nature of the bulk power grid. In 2006, NERC applied for and was granted this designation. The Electric Reliability Act of 1967, passed due to the political pressure and fallout from the 1965 blackout, was a significant turning point in the arena of electric reliability in North America. Initially, ten regional reliability councils were created by groups of interconnected power systems, which collectively covered the entire footprints of the major North American interconnections.

Today, NERC's standards are mandatory and enforceable throughout the 50 United States and several provinces in Canada. Entities in the U.S. found to be in violation of a standard can be subject to fines of up to $1 million per day per violation.

The Data:

The Western Electricity Reliability Council (WECC) collects data on Bulk Electric System disturbances (generation and load outages due to events at the bulk electric system level). The present data set (July 2011) contains information on 204 disturbances. The reasons for these disturbances are categorized and there were 15 root cause reasons included in the data – which are shown below with the number of times each occurred.

1. Human Error - 30

2. Power System Condition - 37
3. Lightning - 26
4. Failed AC Substation Equipment - 34
5. Weather - 18
6. Fire - 3
7. Environmental - 15
8. Failed Protective System Equipment - 3
9. EMS Malfunction - 5
10. Vandalism, Terrorism or Malicious Acts - 5
11. Foreign Interference - 5
12. Failed AC Circuit Equipment - 6
13. Unknown - 1
14. Contamination - 2
15. Vegetation – 1

The Entity involved (e.g. SDGE, CISO, PPA, APS, etc.) are also included with the data set. There is also data on generation lost and load lost for each of the 204 events.

Data Analysis:

A regression analysis was performed to analyze the data. The variable to be explained – which included lost generation in one model and lost load in a separate model – can be modeled by analyzing which of the disturbance reasons can "explain" the lost generation / lost load. The disturbance reasons were converted to independent variables using the "dummy variable" approach – where the variable shows a 1 if it was involved in the individual event, and a 0 otherwise.

To answer the question: "Are we getting better?" A 16^{th} independent variable – the year – was included to complete the master independent variable set. If the year of the event has a negative sign and a significant t-statistic – the answer to the question is yes. The negative sign indicates that as the year gets larger (time passes), the generation loss / load loss becomes less – holding other factors constant.

In models of this type – cross sectional analysis - statisticians generally tolerate very low R-Squared statistics, and believe that t-statistics above 1 are statistically significant.

Separate models were developed for Lost Load and Generation Lost.

Dependent Variable = Lost Load

After eliminating independent variables with t-statistics under .5 – the following regression analysis was obtained:

Regression Statistics	
Multiple R	0.281668
R Square	0.079337
Adjusted R Square	0.056088
Standard Error	370.824
Observations	204

ANOVA

	df	SS	MS	F
Regression	5	2346254	469250.7	3.412473
Residual	198	27227070	137510.5	
Total	203	29573323		

	Coefficients	Standard Error	t Stat	P-value
Intercept	22377.89	16569.18	1.350573	0.178374
Fire	191.663	92.13311	2.080283	0.038787
Environmental	569.5707	216.6319	2.62921	0.00923
Failed Protective System Equipment	127.2816	100.1862	1.27045	0.205415
Failed AC Circuit Equipment	351.1594	154.2818	2.276091	0.023911
Year	-11.0668	8.264831	-1.33903	0.182097

Conclusion – *the year has a negative sign and a t-statistic greater than one. The answer to the question: "Are we getting better?" would be "yes."*

Dependent Variable = Lost Generation

After eliminating independent variables with t-statistics under .5 – the following regression analysis was obtained:

Regression Statistics	
Multiple R	0.388911
R Square	0.151252
Adjusted R Square	0.125401
Standard Error	775.1423
Observations	204

ANOVA

	df	SS	MS	F
Regression	6	21093577	3515596	5.851081

Residual	197	1.18E+08	600845.6	
Total	203	1.39E+08		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	45523.74	34815.49	1.307571	0.192543
Failed AC Substation Equipment	265.5066	150.3186	1.766292	0.078896
Fire	775.3925	195.1707	3.972894	9.96E-05
Environmental	446.3955	453.7106	0.983877	0.326383
Failed Protective System Equipment	246.5077	211.6419	1.16474	0.245533
Failed AC Circuit Equipment	1407.127	323.9177	4.344089	2.24E-05
Year	-22.5158	17.36464	-1.29665	0.196269

Conclusion – *the year has a negative sign and a t-statistic greater than one. The answer to the question: "Are we getting better?" would be "yes."*

Analysis of Transmission Availability Data - TADS data:

The input data to the TADS analysis was summarized data – where the 2161 outages from 2008 and 2009 were obtained in summarized form – but disaggregated for analysis purposes using the averages in the summarized data. Only Sustained Outages were analyzed.

The final model was:

Multiple R	0.723431347
R Square	0.523352914
Adjusted R Square	0.520690081
Standard Error	24.50578298
Observations	2161

ANOVA

	df	*SS*	*MS*	*F*
Regression	12	1416345.308	118028.7757	196.5399023
Residual	2148	1289945.742	600.5333996	
Total	2160	2706291.05		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	10269.78616	2137.984792	4.803488876	1.66693E-06
Year	-5.11797706	1.064608877	-4.807377777	1.63518E-06

Failed AC Substation Equipment	81.40635067	1.89636453	42.92758559	2.968E-291
Weather, excluding lightning	13.95686674	1.558188812	8.957108817	7.0507E-19
Fire	39.44879613	2.051415813	19.23003415	3.63348E-76
Failed AC Circuit Equipment	11.64518098	1.950328258	5.970882562	2.75385E-09
Foreign Interference	2.813205048	2.909624595	0.96686186	0.33372194
Power System Condition	11.93804443	2.918539338	4.090417518	4.46477E-05
Environmental	134.8417437	11.00434696	12.25349802	2.04297E-33
Failed AC/DC Terminal Equipment	11.9491133	8.829267101	1.353352794	0.176085351
200-299 kV	18.89324563	6.388813288	2.957238658	0.003137942
300-399 kV	7.929490004	6.470165457	1.225546712	0.220503657
500-599 kV	9.133675921	6.449768435	1.416124627	0.156884007

Again, the sign on the year variable is negative and the t-statistic is above 1 indicating statistically significant year over year progress.

Additional Considerations:

This analysis is preliminary and could no doubt greatly benefit from analysis by a professional statistician, and cleansing of the data set. In addition, the outages were instantaneous amounts and a duration component was not included. Also, the Entity involved in each event was not included as an explicitly modeled component which might also improve results.

In the Lost Load Model – the coefficient on the year variable is only -11 – indicating that the level of progress is 11 MW per year, against an average of 235 MW per lost load. Over the entire data set of 11 years – there were 48,015 lost MW or 4365 MW per year – a rate of progress of 5% per year.

For the 48,015 lost MW over the 11 year period – assuming an outage duration of 3 hours and a Value of Lost Load of $5000 per MWh – the cost is about $720 million or $65 million per year.

With respect to the TADS data – the analysis was limited to 2008 and 2009 and summarized data. The analysis would greatly benefit using more years of data and non-summarized data as input to the analysis. The year over year improvement of 5 hours per sustained outage, is statistically significant, and is fairly large compared to the average of 21.6 hours per outage.

Although the answer to the question: “Are we doing better?” seems to be “yes” – a related and unanswered question is: “Is it worth it?” Given that the cost to customers of bulk electric system outages in the Western Interconnect is in the range of $65M per year and that just NERC compliance activities alone far exceed that number – another unanswered question might be asked: “Are we going about this correctly?”