Baird Substation Condition Assessment Distribution Capacity and Voltage Regulation

November 18, 2011

By: System Integrity

The United Illuminating Company
Electric System Work Center
801 Bridgeport Avenue
Shelton, CT 06484-471

Table of Contents

Executive Summary:

Due to its age (approximately 45 years old), Baird 115/13.8 kV Substation has been identified as an aging infrastructure risk which requires condition assessment to determine any potential issues which may affect its operation or performance indices.

In this report, the capacity and voltage regulation conditions of Baird Substation have been assessed based on the forecasted substation's peak loads from the refreshed Ten Year Load Forecast of (2011-2020). No capacity deficiencies have been identified at the substation level throughout the ten year planning horizon. However, low voltage issues have been identified on circuits as the peak load on the substation grows. Possible solutions are, utilizing a seasonal adjustment to the No-Load tap changer on the transformers, utilizing field voltage regulators and capacitor banks to support the voltage on the feeders, perform distribution load transfers to reduce the load on the substation's transformers and feeders and then reduce the voltage drop on their impedances, replace the existing transformers with others equipped with Load Tap Changer (LTC) to help improving the delivered voltage through active tap adjustments as the load varies.

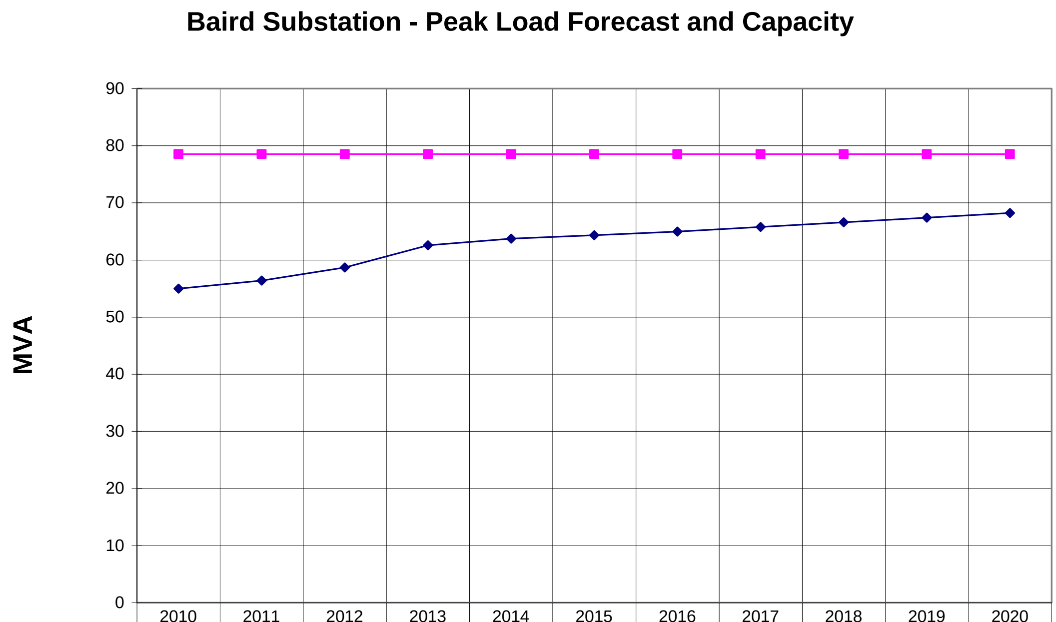
These solutions will be discussed in this report with preliminary commentary. However, further investigations would be required later in the solution phase of this study to verify the feasibility of each solution. This phase of the study is mainly concerned with identifying any existing or future capacity or voltage regulation issues.

1. Distribution Capacity Assessment

Baird Substation has two Westinghouse 116/13.8 kV 36/48/60 MVA no-load tap changing transformers manufactured in 1963. The firm rating of the substation is 78.52 MVA based on the last rating update of October 12, 2005. All outgoing feeder positions from the substation are currently utilized.

1.1 Substation- Level Capacity Assessment :

In order to evaluate the substation capacity, Scenario A from the Ten Year Peak Load Forecast (2011-2020) study was used. In this scenario, the forecasted annual peak load of the substation is weather normalized based on 90/10 weather conditions. Also, it assumes that 100% of the screened new economic development loads are added to the forecasted peak with no load reduction due to Demand Side Management (DSM) policies or Distributed Generation (DG) resources. The assumption is to account "from a planning perspective" for the inherent uncertainty associated with the DSM responses and the availability of the DG resources. The substation's forecasted peak load is applied against its firm rating through the Ten-Year planning horizon as shown in Figure 1.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Firm Rating	78.52	78.52	78.52	78.52	78.52	78.52	78.52	78.52	78.52	78.52	78.52
Peak Load	54.97	56.39	58.68	62.57	63.72	64.32	64.97	65.79	66.58	67.40	68.20
Capacity Factor	70.0%	71.8%	74.7%	79.7%	81.2%	81.9%	82.7%	83.8%	84.8%	85.8%	86.9%

Figure 1: Baird Substation - Peak Load Forecast and Capacity

The results of Baird Substation's capacity assessment at the substation level shows that no capacity deficiency is predicted for the substation within the ten year planning horizon. Also, it worth noting that, Barnum substation represents a good candidate to pick-up some of Baird substation's loads, if needed to address voltage regulation issues. Barnum substation has 35 MVA of available capacity (per 2011 load levels) and it falls geographically in a close proximity to Baird substation circuits which makes it feasible to transfer loads between both substations.

2. Voltage Regulation Assessment

The Baird Substation's 116/13.8 kV transformers are not equipped with a Load Tap Changer (LTC). Hence, automatic voltage regulation capability at the substation is not available. The output voltage at the 13.8 kV bus is assumed to be nominally 13.8 kV for this analysis. Also, the 13.8 kV as the primary distribution voltage will be equivalent to 1.0 per unit. This per unit base voltage is equivalent to 120 V on the secondary side of the distribution transformers. Under normal operating conditions, the voltage regulation limits for the voltage delivered to the end use customer (at the meter point of connection) are +3% for high voltage and -5% for low voltage (8% bandwidth). This means that the delivered voltage to the customer at the meter point should not go higher than 123.6 V or lower than 114 Volts on a 120 Volt basis. It is assumed that the voltage drop on the distribution transformer, secondary wires, and the service drop wires to the customer's meter is 3%. Since the total voltage drop allowed from the substation's bus to the customer is 5%, therefore, the allowed voltage drop on the primary wire or cable from the substation's bus to the distribution transformer should not exceed 2%. This means that the voltage on the primary wires (delivered to the distribution transformer) should not go below 117.6 V. This assumption is used for Baird as it is known that it lacks active voltage regulation capability to boost the bus voltage above its nominal voltage 13.8 kV.

This voltage regulation analysis is analyzing the low voltage conditions expected to occur as the load on the substation's grows. Table 1 shows the annual growth rates for Baird's forecasted peak load during the period 2010-2015.

Table 1: Peak Load growth rates for Baird Substation

Year	2010	2011	2012	2013	2014	2015
Peak Load (MVA)	54.97	56.39	58.68	62.57	63.72	64.32
Growth Rate		2.57%	4.07%	6.63%	1.83%	0.94%

Based on the data provided by the Transmission Planning Department from the Voltage Stability Analysis, the more load to flow through the Baird Substation transformer the more voltage drop through the transformer impedance and the lower the voltage on the 13.8 kV side of the transformer.

The Transmission Planning Department has provided the Power-Voltage analysis (PV analysis) simulating the transmission system with the load increasing at Baird's bus by 0.1 MW increment per step increase. Two cases were simulated, one at unity power factor at Baird's bus and another at 0.995 power factor which is the power factor used for system planning and in the load forecast study. In this analysis, the case with the power factor of 0.995 was used. Also, at each power factor, the normal operating conditions and the case of contingency (T1/L1) condition were simulated. The contingency case (T1/L1) represents the case when one of the substation's transformers and one of the transmission lines feeding the substation are out of service. In case of losing one transformer, the plan is to close the bus tie and have all the substation's load fed by the other transformer. Table 2 shows the results of the PV analysis. This table shows the simulated voltages on the high and low sides of the transformers at each loading level under normal operating conditions and under l1/T1 contingency.

Table 2: Results of Baird's PV-analysis using PSS/E

Load Scaling - PV Analysis (Model Entry Data)									0.995 Power Factor Case			
Load Level	Customer Load					Capacitors	Net	% Compensation	No Contingency		T1/L1 Contingency	
	%	P	Q	MVA	PF	Q	PF		@115kV Bus	@13.8kV Bus	@115kV Bus	@13.8kV Bus
	80.60%	44.00	27.18	44.21	0.851	-22.88	0.995	52%	116.66	13.71	116.45	13.35
	82.43%	45.00	27.80	45.21	0.851	-23.40	0.995	52%	116.66	13.70	116.44	13.33
	84.26%	46.00	28.41	46.22	0.851	-23.92	0.995	52%	116.65	13.69	116.43	13.31
	86.10%	47.00	29.03	47.22	0.851	-24.44	0.995	52%	116.65	13.69	116.42	13.29
	87.93%	48.00	29.65	48.23	0.851	-24.96	0.995	52%	116.64	13.68	116.41	13.26
	89.76%	49.00	30.27	49.23	0.851	-25.48	0.995	52%	116.64	13.67	116.40	13.24
	91.59%	50.00	30.88	50.24	0.851	-26.00	0.995	52%	116.64	13.67	116.38	13.22
	93.42%	51.00	31.50	51.24	0.851	-26.52	0.995	52%	116.63	13.66	116.37	13.19
	95.26%	52.00	32.12	52.25	0.851	-27.04	0.995	52%	116.62	13.66	116.36	13.17
	97.09%	53.00	32.74	53.25	0.851	-27.56	0.995	52%	116.62	13.65	116.34	13.14
	98.92%	54.00	33.36	54.26	0.851	-28.08	0.995	52%	116.61	13.64	116.33	13.11
Base Load (2011 Peak Load)	100.00%	54.59	33.72	54.85	0.851	-28.39	0.995	52%	116.61	13.64	116.32	13.10
	100.75%	55.00	33.97	55.26	0.851	-28.60	0.995	52%	116.61	13.63	116.31	13.08
	102.58%	56.00	34.59	56.27	0.851	-29.12	0.995	52%	116.60	13.63	116.30	13.06
	104.41%	57.00	35.21	57.27	0.851	-29.64	0.995	52%	116.60	13.62	116.29	13.03
	106.25%	58.00	35.83	58.28	0.851	-30.16	0.995	52%	116.59	13.61	116.27	13.00
	108.08%	59.00	36.44	59.28	0.851	-30.68	0.995	52%	116.59	13.61	116.26	12.96
	109.91%	60.00	37.06	60.29	0.851	-31.20	0.995	52%	116.58	13.60	116.24	12.93
	111.74%	61.00	37.68	61.29	0.851	-31.72	0.995	52%	116.57	13.59	116.22	12.90
	113.57%	62.00	38.30	62.30	0.851	-32.24	0.995	52%	116.57	13.58	116.21	12.86
	115.41%	63.00	38.91	63.30	0.851	-32.76	0.995	52%	116.56	13.58	116.19	12.83
	117.24%	64.00	39.53	64.30	0.851	-33.28	0.995	52%	116.56	13.57	116.17	12.79
	119.07%	65.00	40.15	65.31	0.851	-33.80	0.995	52%	116.55	13.56	116.15	12.75
	120.90%	66.00	40.77	66.31	0.851	-34.32	0.995	52%	116.54	13.55	116.13	12.72
	122.73%	67.00	41.39	67.32	0.851	-34.84	0.995	52%	116.54	13.54	116.11	12.68
	124.56%	68.00	42.00	68.32	0.851	-35.36	0.995	52%	116.53	13.54	116.09	12.63
	126.40%	69.00	42.62	69.33	0.851	-35.88	0.995	52%	116.53	13.53	116.07	12.59
	128.23%	70.00	43.24	70.33	0.851	-36.40	0.995	52%	116.52	13.52	116.05	12.55
	130.06%	71.00	43.86	71.34	0.851	-36.92	0.995	52%	116.51	13.51	116.03	12.50
	131.89%	72.00	44.47	72.34	0.851	-37.44	0.995	52%	116.51	13.50	116.01	12.45
	133.72%	73.00	45.09	73.35	0.851	-37.96	0.995	52%	116.50	13.49	115.99	12.40

The CymDist application was used to model and analyze the circuits from Baird Substation at different feeder loading and bus voltage conditions. The growth rates from Table 1 were applied to the feeder loads of 2010 to forecast the weather normalized loads for the years 2011-2015. Also, the corresponding bus voltages from Table 2 were applied to the feeders' source nodes. Under normal operating conditions, if the voltage on the primary sections of any circuit should go below 2% (less than 117.6 V on a 120 V base), it would be identified as a low voltage condition. Under T1/L1 contingency, if the voltage on the primary sections of any circuit should go below 5.3% (less than 113.6 V on a 120 V base), it would be identified as a low voltage condition

Table 3 shows the simulation results of the voltage drop analysis and presents the worst voltage on each circuit (by 2015 most of the circuits are exhibiting low voltage condition). In case of contingency (T1/L1), the service voltage delivered at the customer's meter is allowed to go as low as 110 V before it should be considered as low voltage condition (According to the Public Utilities Regulator Authority (PURA)

emergency voltage limit of 110 V based on ANSI C84.1-2006 voltage range B). After accounting for the assumed 3% voltage drop on the distribution transformer, secondary wires, and the service drop wires, then the voltage on the primary wires should not go below 113.6 V. Table 4 shows the simulation results of the voltage drop analysis in this contingency case (with the load levels of 2011 all circuits will experience voltages lower than what is allowed by the ANSI standard above for T1/L1 contingency).
Both tables (3 and 4) are illustrating the circuits exhibiting voltage lower than the threshold determined by the operating conditions. For normal operating conditions, the threshold for low voltage on the primary wires is 117.6 V. While, under contingency operating conditions (T1/L1) the threshold for the low voltage is 113.6 V.

2.1 Potential Solutions to Address The Voltage Regulation Issue

In the table below, a list of potential distribution solutions to address the voltage regulation issue under normal operating conditions and L1/T1 contingency is presented along with comments on its feasibility or its expected impact. However, further investigations are required in the solution study in order to conclude the best solution.

Solution	Normal Operating Conditions	L1/T1 Contingency
Utilizing seasonal adjustments to the No-Load tap changer on the transformers. The transformers are equipped with five steps tap changer. Each step is 2.5% with total voltage regulation capability of +/-5%. (This solution may not be the optimum as it does not address the low voltage condition which violates the ANSI limits in the case of L1/T1 contingency)	In this study, boosting the voltage with 2.5% and 5% was simulated in CymDist. Fortunately, this action was able to eliminate the low voltage concerns during the forecast ten years under normal operating conditions.	The simulations showed that all feeders would still exhibit low voltage below th ANSI limits under this contingency conditions even with 5% boosting on the transformers' taps (starting from 2011 load levels). This can be explained when considering the significantly low voltage delivered on the low side of one transformer as it carries the total load of the substation per the PV analysis (see Table 2)
Utilizing Distribution load transfers to reduce the total load on the substation.	This solution requires further investigation to identify the potential load transfers. This solution may be utilized in conjunction with the first solution to help reducing the load on the transformers and then reducing the resulting voltage drop on their impedances.	

	However, this solution would result in de-rating the substation and not being able to fully utilize its current capacity just to avoid low voltage issues and the violation of the ANSI voltage limits in the case of L1/T1 contingency (given that this violation exists currently with the loading levels of 2011, see Tables 2 and 4)
Utilize field voltage regulators and capacitor banks to support the voltage	This solution requires further investigation to identify the optimum locations for the placement of the voltage regulator and the capacitor banks.
Replacing the transformers with others equipped with LTC	This solution should address the low voltage issues under normal operating conditions and under the contingency L1/T1. However, more cost-benefit analyses are required along with investigating the other solutions above in order to determine the feasibility of this solution.

Table 3: Results of the voltage drop analysis – Normal Operating Conditions @ 0.995 P.F.

	2010		2011		2012		2013		2014		2015	
Circuit ID	Low Voltage Status	Worst Voltage (V)	Low Voltage Status	Worst Voltage (V)	Low Voltage Status	Worst Voltage (V)	Low Voltage Status	Worst Voltage (V)	Low Voltage Status	Worst Voltage (V)	Low Voltage Status	Worst Voltage (V)
2630		118.17		118.07		117.88	☑	117.59	☑	117.49	☑	117.40
2631		118.45		118.36		118.18		117.91		117.82		117.73
2632	☑	117.42	☑	117.30	☑	117.07	☑	116.72	☑	116.61	☑	116.51
2633	☑	117.26	☑	117.14	☑	116.90	☑	116.54	☑	116.42	☑	116.32
2634	☑	115.71	☑	115.55	☑	115.25	☑	114.76	☑	114.61	☑	114.49
2635	☑	117.32	☑	117.20	☑	116.96	☑	116.61	☑	116.49	☑	116.39
2636		118.59		118.50		118.32		118.06		117.97		117.89
2637	☑	115.14	☑	114.95	☑	114.62	☑	114.09	☑	113.92	☑	113.79
2638	☑	117.44	☑	117.33	☑	117.10	☑	116.75	☑	116.63	☑	116.53
2639		117.62	☑	117.51	☑	117.29	☑	116.95	☑	116.84	☑	116.74
2640		117.70	☑	117.59	☑	117.38	☑	117.05	☑	116.94	☑	116.84
2641	☑	117.22	☑	117.09	☑	116.86	☑	116.49	☑	116.37	☑	116.27
2642	☑	116.32	☑	116.17	☑	115.89	☑	115.46	☑	115.32	☑	115.20
2643	☑	116.58	☑	116.44	☑	116.18	☑	115.77	☑	115.64	☑	115.53
2644	☑	114.61	☑	114.41	☑	114.06	☑	113.49	☑	113.31	☑	113.17
2645		118.46		118.37		118.19		117.92		117.83		117.74

Table 4: Results of the voltage drop analysis – Contingency Case of (T1/L1) @ 0.995 P.F.

	2010		2011	
Circuit ID	Low Voltage Status	Worst Voltage (V)	Low Voltage Status	Worst Voltage (V)
2630	☑	113.46	☑	112.92
2631		113.75	☑	113.22
2632	☑	112.67	☑	112.11
2633	☑	112.51	☑	111.94
2634	☑	110.89	☑	110.28
2635	☑	112.57	☑	112.00
2636		113.89	☑	113.37
2637	☑	110.28	☑	109.64
2638	☑	112.70	☑	112.14
2639	☑	112.88	☑	112.33
2640	☑	112.97	☑	112.41
2641	☑	112.46	☑	111.89
2642	☑	111.52	☑	110.92
2643	☑	111.80	☑	111.22
2644	☑	109.73	☑	109.08
2645		113.76	☑	113.23