GE Power Systems

Report to:

New York Independent System Operator

Assessment of Short-Circuit Analysis for the Class 2001Cost Allocation Studies

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Foreword

This document was prepared by General Electric International, Inc. through its Power Systems Energy Consulting (PSEC) in Schenectady, NY. It is submitted to New York Independent System Operator (NYISO) as record of work.

The purpose of this report is to review the cost allocation studies for the Class Year 2001, with a particular focus the short circuit analysis, to determine if it is in accordance with the requirements of Attachment S to the NYISO tariff.

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1. Purpose

The purpose of this evaluation was to review the short circuit portions of the baseline and reliability assessment studies on which the equipment cost allocation was later based, and to advise NYISO as they determine the System Upgrade Facilities Cost Allocation for action by the NYISO Operating Committee..

The evaluation includes:

- A review of the system data employed to calculate short circuits
- A review of the short circuit calculations derived from that data
- An estimate of cost allocation factors for the proposed System Upgrade Facilities
- The application of the cost allocation formula to the proposed System Upgrade Facilities based on the evaluated short circuit studies

Information provided for the evaluation was:

1. "Con Edison Service Area Year 2001 Annual Transmission Baseline Assessment" Report. (Con Ed ATBA Report)

2. "Long Island Power Authority (LIPA)
   Annual Transmission Baseline Assessment (ATBA)
   Annual Transmission Reliability Assessment (ATRA) 2001 Class year" report.

3. Power Technologies (PTI) PSS/E computer program ASCII data files for Class 2001 studies. (baseline, non mitigation, and mitigation cases)

4. Con-Edison Fault Current Management Plan, June 2001 report.

2. Summary of Conclusions

The following is a summary of conclusions regarding GE PSEC's review the NYISO Class 2001 ATBA/ATRA cost allocation.

1. The short circuit calculations performed by ConEd conform to the methodologies established for use on their system.

2. The short circuit report provided by LIPA does not provide enough detail to infer the methodology employed in assessing the application of circuit breakers or to understand the application conditions determined for individual breakers other than whether they are applied within their ratings.

3. Parallel calculations of short circuit currents, documented elsewhere in this report, from the ConEd and LIPA data yield essentially identical symmetrical bus short circuit current magnitudes. However, these calculations reveal a few instances in which disagreements exist on individual breaker duty assessments.

4. The equipment cost allocation based on the existing ATBA and ATRA studies is reasonable.

System Data Employed to Calculate Short-Circuit Duties

The data for the Con Edison and the LIPA was examined. Both data sets were in Power Technologies (PTI) PSS/E format. It was noted that some of the generator subtransient (X"d) reactances in the short circuit data set were different from the values of generator reactances specified in the corresponding power flow data set. This is to be expected since the power flow and stability representation of generators would likely use the respective unsaturated subtransient reactances, X"di, whereas the saturated subtransient reactances, X"dv, is required for short circuit calculations. It was not possible to tell from the supplied data if saturated subtransient reactances were used for all generators.

A few discrepancies were noted in the short circuit data. The modifications to the data files as listed below were made prior to performing an independent set of short circuit current calculations using the non-mitigation and mitigation case data files for class year 2001:

1. The connection to the Bowline 3 units was modified to have it connect into the Ladentown 345 kV station and tapped into the Lovett to W. Nyack circuit and a transformer between the Bowline 138-kV and 345-kV circuits.

2. Some generators were represented with zero resistance. These data entries were modified to include typical resistance values. Each zero resistance machine with a reactance greater than 1.0 per unit was assigned a resistance value based on a component X/R ratio of 50. All other zero resistance generators were assigned a resistance based on an X/R ratio of 125. The X/R ratio of 50 is typical of machines about 50-MVA, while an X/R ratio of 125 is typical for machines larger than 100-MVA.

3. A few instances were found in which the branch impedance data had zero values for resistance. Each zero resistance branch with a reactance less than 0.0005 per unit was assigned a resistance of 0.0001 per unit. Each zero resistance branch with a reactance greater than 0.0050 per unit was assigned a per unit resistance corresponding to a component X/R ratio of 60. This would be typical for transformers larger than 100-MVA. Zero resistance lines between 0.0005 and 0.0050 were assigned a resistance equal to X/10.

The detailed evaluations of the 2001 Class studies discussed below indicate that the impact of these data issues in the immediate case is negligible.

3. Breaker Ratings in the LIPA, ATBA, and ATRA Reports

The breaker evaluations in both the Long Island and Con Edison studies examine only the symmetrical ratings of breakers. The first-cycle, peak or close and latch ratings of breakers were not evaluated. This conclusion was based on the observation that the breaker evaluation tables listed only one set of breaker ratings. This is consistent with the classical methodology as currently implemented in the NYISO/Con-Ed studies.

4. Methodology Employed for Breaker Duty Calculations

The Con Edison report described the methodology and assumptions used in their calculations. The methodology used by LIPA was not described in their study report. Both reports mentioned individual breaker duties (IBD), however, neither report included a detailed description of the procedures employed in IBD evaluations.

4.1 Con Edison Fault Duty Calculation Methodology

Per Con Edison's Criteria given in Appendix A of the "Service Area Year 2001 Annual Transmission Baseline Assessment" report. It states that the nameplate rating (in kiloamperes) of any breaker at each of its Bulk Power Transmission Facilities (69 kV and above) should not be exceeded by the fault currents generated by the most severe fault as defined below. The methodology employed in calculating fault currents includes the following:

- All generating units in service
- All transmission feeders in service
- All series reactors in service
- Loads, shunts, and line capacitance not represented
- Pre-fault flat-start power flow representation (e.g. unity operating voltages, unity transformer tap ratios, etc)
- Generators are represented by their direct-axis subtransient reactance at rated voltage (X"dv), which ensures that breaker fault duty levels are determined for the instant immediately after the occurrence of the fault, when generator current contribution (into the fault) is at its maximum level.

The short circuit analysis is performed for the system conditions above defined for the following three types of faults, at each Bulk Power Substation:

a. Three phase-to-ground faults

b. Double phase-to-ground faults

c. Single phase-to-ground faults

Fault currents are calculated for all substations on the Consolidated Edison Bulk Power System. These are symmetrical values and represent the sum of the currents flowing into each substation, as a result of a fault. Further analysis is then performed to determine the short circuit currents that to which individual breakers will be exposed, but only at those stations where total fault currents have increased beyond their respective nameplate rating (i.e., this additional analysis is not performed for buses where the calculated short circuit currents are within the listed breaker ratings.

The breaker to be evaluated always interrupts ***after*** every other breaker with an equal voltage rating, but always ***before*** any other breaker with a lower voltage rating.

Representing all generators and lines in service adds conservatism to the calculation and is appropriate. Using an assumed 1.0 PU pre-fault bus and internal driving voltage may not be universally conservative but is consistent with normal industry practice. The tabulation of short-circuit results in the ConEd reports listed current magnitudes to the nearest ten amperes. While the software program can give an answer with greater precision, this is not necessary since breaker ratings are given to the nearest kiloampere. The impedance data in the supplied file was given to five places after the decimal point. Overall, the precision of the calculations is consistent with the expected de minimis standard of 100 amperes.

Two generators modeled in the ConEd system were spot checked against the machine design data sheets. The subtransient reactance values (X"dv) in these data sets were in agreement with the respective manufacturer's design data.

It is judged that the short-circuit modeling used by ConEd results in acceptable values of symmetrical fault currents and is conformant with their stated criteria.

4.2 LIPA Fault Duty Calculation Methodology

The LIPA short circuit study provided for this review gave very little information on the data and methodology used in the evaluation. The assessment appeared to be based only on the interrupting rating of circuit breakers and the tabulation of short-circuit was expressed in percent of breaker rating. A numerical tabulation of breaker ratings and calculated fault currents was not included. While percent rating is useful in determining if a breaker is marginal or over-dutied, it is not possible to infer from this limited information if substitution of a higher rated breaker would correct problems disclosed by the analysis, or if system redesign is needed. Numerical values of breaker rating and fault current need to be given to make the table more useful. The results were given to the nearest 0.01% of the breaker rating which is approximately 20 amperes.

5. Overview of the Baseline System Fault Currents

The conclusions in the 'Con Edison Service Area Year 2001 Annual Transmission Baseline Assessment' (ATBA) were verified with independent calculations as shown in Table SC-1a and SC-1b. Of interest were the ATBA tables 1 and III. The small differences between the values calculated by ConEd and the current magnitudes calculated for this review and listed in tables SC-1a and SC-1b are attributable to the data changes on the Bowline circuit and the addition of circuit resistance to the representation of transformers and generators.

In each instance in which the calculated short circuit currents exceeded breaker ratings (noted for emphasis as shaded entries in the table), an individual breaker duty (IBD) calculation was made to further understand the duties imposed on breakers. The results of these IBD studies were then noted in the table as either "OK" or "Over". Note that IBD analysis resolved many of the duty questions that surfaced in the Baseline and 2001 Non-Mitigation cases, and the proposed Mitigation plan (in combination with IBD analysis) resulted in no instances in which short circuit duties exceeded reported breaker ratings.

To provide the reader additional information on individual breaker duties, detailed results of the IBD studies have been tabulated in the Appendix, Table App-1.

The IBD calculations for Sherman Creek disclosed a duty exactly equal to the 40kA breaker rating. Since the rating is not exceeded, this situation must be interpreted as an acceptable application.

The short circuit calculations done for this assessment support the breaker replacement at Astoria East and Greenwood identified in the ATBA. The data listed for East 13th Street showed breaker F5 with a 40-kA rating. The other three breakers identified as requiring replacement could not be specifically identified but were presumed to have similar ratings. East River substation is to have twelve breakers rated variously at 40, 42 or 50-kA replaced with 63-kA breakers. However, some of the 50-kA breakers appear to be within their IBD rating and may not need to be replaced based on the short circuit evaluation.

Table SC-1a – Short-Circuit Bus Current Based on PSS/E File 'Baseline.raw','Class2001nomitplan.raw','Class2001mitplan.raw'

Zero Resistance in file changed to definite values

No	BUS	Bus kV.	Base Line				Year 2001 Nonmitigation			Year 2001 Mitigation			
			Bkr Sym. kA	Fault Type	Sym kA	Individual Breaker Duty	Fault Type	Sym kA	Individual Breaker Duty	Bkr Sym. kA	Fault Type	Sym kA	Individual Breaker Duty
8	Buchanan N.	345	40	3-Ph	30.10		3-Ph	32.16		40	3-Ph	31.22	
9	Buchanan S.	345	40	3-Ph	41.07	OK	3-Ph	44.67	Over	40	3-Ph	42.17	OK
12	Dunwoodie	345	63	3-Ph	62.70		3-Ph	67.50	Over	63	3-Ph	53.11	
18	Farragut	345	63	LLG	62.71		LLG	67.57	Over	63	LLG	55.73	
22	Fresh Kills	345	63	LLG	24.75		LLG	24.58		63	LLG	24.31	
24	Goethals N.	345	40	LLG	23.96		LLG	23.81		40	LLG	23.55	
25	Goethals S.	345	63	L-G	24.35		L-G	24.21		63	L-G	23.98	
26	Gowanus N.	345	40	LLG	19.55		LLG	19.46		40	LLG	19.23	
27	Gowanus S.	345	40	LLG	19.67		LLG	19.58		40	LLG	19.35	
29	Ladentown	345	63	3-Ph	40.84		3-Ph	50.14		63	3-Ph	48.94	
32	Millwood	345	63	3-Ph	48.88		3-Ph	52.36		63	3-Ph	47.25	
39	Pleasant Valley	345	63	3-Ph	40.06		3-Ph	41.02		63	3-Ph	39.59	
41	Rainey	345	63	LLG	61.60		LLG	66.52	Over	63	LLG	53.97	
45	Ramapo	345	40	3-Ph	43.90	OK	3-Ph	54.97	Over	63	3-Ph	53.89	
48	Sprain Brook	345	63	3-Ph	63.58	OK	3-Ph	68.62	Over	63	3-Ph	54.33	
165	Poletti	345	63	LLG	47.17		LLG	49.74		63	LLG	43.36	
438	West 49 St	345	63	LLG	57.52		LLG	61.56		63	LLG	48.59	
839	East Fishkill	345	63	3-Ph	39.23		3-Ph	40.22		63	3-Ph	38.67	

Table SC-1b – Short-Circuit Bus Current Based on PSS/E File ‘Baseline.raw’,’Class2001nomitplan.raw’,’Class2001mitplan.raw’

Zero Resistance in file changed to definite values

No	BUS	Bus kV.	Base Line				Year 2001 Nonmitigation			Year 2001 Mitigation			
			Bkr Sym. kA	Fault Type	Sym kA	Individual Breaker Duty	Fault Type	Sym kA	Individual Breaker Duty	Bkr Sym. kA	Fault Type	Sym kA	Individual Breaker Duty
62	Astoria E	138	45	L-G	51.24	Over	L-G	78.36	Over	63	L-G	51.41	
159*	Astoria E-E	138	-	-	-	-	-	-	-	63	L-G	52.75	
64	Astoria W	138	45	LLG	41.21		LLG	46.93	Over	63	L-G	29.90	
66	Buchanan	138	40	3-Ph	15.67		3-Ph	15.81		40	3-Ph	15.68	
70	Corona N	138	45	LLG	49.97	OK	LLG	71.89	Over	45	LLG	47.34	OK
160	Corona S	138	-	-	-	-	-	-	-	63	LLG	48.29	
72	Dunwoodie N	138	40	LLG	33.35		LLG	34.42		40	3-Ph	32.11	
73	Dunwoodie S	138	40	LLG	31.56		LLG	32.42		40	LLG	30.44	
78	E 13 St	138	40	LLG	44.60	Over	LLG	48.99	Over	63	L-G	46.74	
82	E 179 St	138	63	LLG	47.53		LLG	54.98		63	LLG	42.55	
89	Fox Hills	138	40	LLG	35.11		LLG	32.83		40	LLG	32.71	
91	Fresh Kills	138	40	LLG	37.77		LLG	35.90		40	LLG	35.77	
94	Greenwood	138	45	LLG	57.54	Over	LLG	49.28	Over	63	LLG	48.98	
102	Hell Gate 6	138	63	LLG	42.24		LLG	48.27		63	LLG	28.85	
106	Hudson Ave	138	40	3-Ph	37.82		3-Ph	39.07		40	3-Ph	38.95	
108	Jamaica	138	40	LLG	46.47	OK	LLG	49.10	OK	40	LLG	48.99	OK
114	Millwood	138	20	3-Ph	19.23		3-Ph	19.44		20	3-Ph	19.20	
129	Queensbridge	138	40	LLG	40.35	Over	LLG	45.82	Over	40	LLG	29.53	
134	Sherman Crk	138	40	LLG	42.74	OK	LLG	48.12	Over	40	LLG	38.87	
139	Vernon E.	138	40	LLG	32.37		LLG	31.07		40	LLG	29.98	
140	Vernon W.	138	40	LLG	30.59		LLG	32.14		40	L-G	31.17	
151	East River	69	40	L-G	50.62	Over	L-G	51.13	Over	50	L-G	50.66	OK

* Bus 159 at Astoria E will be created by installation of the phase-shifting transformer proposed in the mitigation plan.

6. Overview of the Non-Mitigated Class 2001 System Fault Currents

The addition of the Class year 2001 projects increases the duty on the Con Edison substations. The entries in tables SC-1a and SC-1b that exceed the respective breaker ratings are shaded. The values listed in these tables are in agreement with Table VI of the Con Ed ATBA Report, except for the insignificant differences due to the Bowline circuit change and the added circuit resistance. The following substations have high symmetrical current duty conditions.

345-kV	**138-kV**
Buchanan S.	Astoria E
Dunwoodie	Astoria W
Farragut	Corona N
Rainey	E 13 St
Ramapo	Greenwood
Sprainbrook	Queensbridge
	Sherman Crk
	East River (69-kV)

7. Overview of the Mitigated Class 2001 System Fault Currents

Tables SC-1a and SC 1b provide a comparison of the Baseline, non-mitigation, and mitigation cases. For the individual breaker duties refer to table App-1 in the appendix to this report.

The symmetrical fault currents listed in Tables SC-1a and SC-1b, and Table VI of the Con Ed ATBA Report are in agreement except for the small and explainable differences due to the Bowline circuit change and the added circuit resistance.

The proposed short circuit mitigation plan, when examined using individual breaker duty analysis, shows that the duties on all circuit breakers will be lower than the respective breaker ratings.

8. Review Of Cost Allocation For System Upgrade Facilities

GE PSEC has reviewed the cost allocation strategy currently envisioned by NYISO and the market participants for the Class Year 2001 projects. Our review focused on the anticipated costs for the Fault Current Mitigation Plan (FCMP) equipment and installation, determination of transmission owner responsibilities and lastly, the distribution of those costs amongst the market participants. We find, overall, that the implementation of the method as contained in the tariff (Attachment "S" of the OATT) is reasonable and fair. There are instances in which the estimates of equipment and labor costs for the proposed remediation are higher than one would expect based on experience in other locations; the estimated costs may be reasonable, and providing additional detail to support those estimates would resolve any concern. However, it is the actual cost that is ultimately of concern since that is the value that will be shared between the participants, and providing a conservative estimate assures that no one is surprised later.

The beginning of the review focused upon the project and project component costs published by as Table V of the Con Ed ATBA Report in addition to a document (entitled "Class 2001 – Fault Mitigation Plan Breakdown of Cost Estimates") made available to the project team by NYISO staff.

The cost allocation of system upgrade facilities with respect to short circuit issues is rather straightforward. It simply states that all projects in a class year will contribute on a pro-rata basis to the financial requirements of a project in accordance with its contribution to the system issue, in this case the generation of short circuit currents. This is subject of course, to the de minimis standard of 100 amperes.

This review resulted in the following observations:

1. While there are some minor variations in cost estimates, in general it appears that costs for outdoor breakers replacements were calculated using the factors listed in the table below.

Breaker	Equipment Cost	Installation	Cost Total
69-kV	$200 K	$200 K	$400 K
138-kV	$300 K	$200 K	$500 K
345-kV	$550 K	$200 K	$750 K

The equipment cost components listed in this table are higher than the authors of this report would expect to see for conventional outdoor SF_6 breakers based on recent project experience. Costs for replacement gas insulated installations would be more expensive than indicated in this table, but it does not appear than any GIS installations will be affected in the required system upgrades. The costs that will ultimately be shared among the responsible market participants will be the actual costs of system upgrade projects, so it is presumed that the approach taken by Con Ed has been to generate conservative estimates in order to assure that actual costs come in below the levels that market participants are led to expect by the Class 2001 Cost Allocation analysis.

2. Essentially no detail is provided in support of the cost estimates. It is presumed that "installation" includes foundations and bus connections (both material and labor). It is also presumed that since the objective is to replace breakers with equipment having higher short circuit ratings, the existing relays will be reused and therefore the only cost attributable to relaying is the labor and miscellaneous material associated with reconnecting the breaker trip and close circuits.

3. One factor that is driving the installation component of costs is labor. It is generally known that doing anything in New York City is expensive, but additional supporting information would be beneficial.

4. The East River 69 kV breakers were included in both table V of the Con Ed FCMP (in satisfaction of a need based on the 80% ICAP rule) and Table I of the ATBA. Detailed analysis of the cost assignment reveals that the costs associated with these breakers are fully assigned to Con Ed; therefore, the appearance of these breakers in the ATBA table does not represent an inappropriate cost assignment to other market participants.

For the current analysis, the higher short-circuit fault duties on the Con Edison system and facilities due to the Class 2001 project were evaluated based on each project. Table FC-1 gives the change in amperes while Table FC-2 give the change in percent of total change.

The influence of each Class 2001 project was evaluated in the following method. The database for the no mitigation condition was used with all the Class 2001 generation and step-up transformers in service. The highest of the three-phase, line-to-line-ground, and line-ground fault was noted for each substation in column 4 of table FC-1a. Next, each project was individually removed and new short-circuit values were calculated. The highest of the three-phase, line-to-line-ground, and line-ground fault was noted and compared to the limiting short-circuit type given in the base condition. The change in fault amperes at critical 138 and 345-kV buses are shown in Table FC-1a and FC-1b. The sum of the change in fault currents for all projects was determined and used to calculate the percentage factors given in Table FC2a and FC2b. As per Attachment S, these factors were used to allocate costs of the required higher rated breakers and reactors needed to reduce the short-circuit currents.

The abbreviated headings in Tables FC-1 and FC-2 are for the following projects.

ANP = Four ANP generators to Ramapo 345-kV Substation.

ER = One generator to East 13th Street substation and one generator to East River.

Key = Two generators for Keyspan to Rainey 345-kV substation.

Bow = Four generators for Bowline 3 to W. Haverstraw substation.

NYPA = Three generator for NYPA Poletti connected to Astoria E.

AST G2 = One generator to Astoria E.

SCSE = Six SCSE generators to Astoria E.

PAT2g = Two NYPA GT's connected to Gowanus.

PAT2v = Two NYPA GT's connected to Vernon W.

PathG1 = Two NYPA GT's connected to Hell Gate #1.

PathG4 = Two NYPA GT's connected to Hell Gate #4.

PARkF = One NYPA GT connected to Fox Hills.

PATKK = One NYPA GT connected to Kent Tap.

As the Class 2001 projects are added to the system, the existing generator fault current contribution may be reduced. For example, for a fault at Dunwoodie, the amount of fault current from the existing Astoria generators will be reduced due to the new machines at Astoria and Hell Gate.

The change in fault current due to a project was compared to the 'Con Edison Cost Allocation Based on 100A. De-minimus Rule-Class year 2001' a preliminary table developed by Con Edison per request of TPAS dated 12/14/2001. The change in currents and percentages are similar between the GE and the above referenced table.

Additionally, this evaluation was based upon each project's contribution to the largest magnitude fault using the symmetrical values of fault current only. In our (GE PSEC) evaluation, circuit breaker classification of within limits versus overdutied is a binary event (either it is overdutied or it is not).

Table FC-1a – 345-kV Substation Change in Maximum Short-Circuit Amperes for each Project

Initial Condition - All Projects in service (Column 4). Amps change from the highest of the 3-phase, line-line-ground, line-ground fault shown.

Bus No	Name	kV	Highest bus duty, amperes	Delta Amps from No Mit, No added Gen column												
				ANP	ER	Key	Bow	NYPA	AST G2	SCSE	PAT2g	PAT2v	PathG1	PathG4	PARkF	PATKK
8	BUCHAN N	345	32158	1208	53	77	519	22	4	16	2	7	10	10	1	1
9	BUCHAN S	345	44669	1379	134	195	1537	56	9	41	6	17	27	27	3	3
12	DUNWODIE	345	67501	1062	809	1222	797	342	56	253	36	104	163	163	18	20
18	FARRAGUT	345	67569	647	1566	1843	475	255	43	193	45	112	117	117	23	24
22	FR KILLS	345	24579	20	16	36	13	10	1	5	93	14	4	4	59	37
24	GOETHL N	345	23809	20	17	37	13	10	1	5	84	13	4	4	52	34
25	GOETHL S	345	24211	17	19	35	11	8	1	4	78	11	3	3	51	30
26	GOW N	345	19461	16	15	31	11	8	1	4	58	10	3	3	34	24
27	GOW S	345	19584	16	14	30	11	8	1	4	58	10	3	3	34	24
29	LADENTWN	345	50141	3962	77	111	5066	31	5	23	4	10	15	15	2	2
32	MILLWOOD	345	52363	1193	273	397	1136	115	19	84	12	34	55	55	6	7
39	PL VAL	345	41020	348	71	105	251	30	5	22	3	9	14	14	2	2
41	RAINEY	345	66516	636	1225	2142	472	262	41	184	43	125	122	122	21	24
45	RAMAPO	345	54966	7708	80	114	3068	32	5	23	4	10	15	15	2	2
48	SPRN BRK	345	68620	1174	830	1201	886	353	57	257	37	104	170	170	18	20
165	POLETTI	345	49739	338	906	927	249	128	22	98	23	57	57	57	12	13
438	W 49 ST	345	61564	610	1210	1379	455	226	37	165	34	88	106	106	17	19
839	E FISHKL	345	40225	374	77	115	245	32	5	24	3	10	15	15	2	2

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Table FC-1b – 138-kV Substation Change in Maximum Short-Circuit Amperes for each Project

Initial Condition - All Projects in service (Column 4). Amps change from the highest of the 3-phase, line-line-ground, line-ground fault shown.

Bus No	Name	kV	Highest bus duty, amperes	Delta Amps from No Mit, No added Gen column												
				ANP	ER	Key	Bow	NYPA	AST G2	SCSE	PAT2g	PAT2v	PathG1	PathG4	PARkF	PATKK
62	AST-EAST	138	78364	13	2	21	10	8008	5055	18425	2	11	275	275	1	1
64	AST-WEST	138	46931	37	-186	58	28	3585	84	372	20	206	753	753	8	15
66	BUCHANAN	138	15812	64	7	10	40	3	0	2	0	1	1	1	0	0
70	CORONA	138	71887	13	4	21	10	6038	3889	14675	2	10	203	203	1	1
72	DUN NO	138	34417	68	41	94	51	254	24	105	4	24	169	169	2	3
73	DUN SO	138	32416	62	44	88	47	188	18	79	4	19	127	127	2	2
78	E 13 ST	138	48985	110	4379	303	81	43	7	32	7	18	20	20	4	4
82	E 179 ST	138	54980	69	-86	103	52	2468	192	845	16	137	1830	1830	6	11
89	FOXHLS 1	138	32834	6	-61	11	4	16	1	4	642	54	4	4	384	265
91	FR KILLS	138	35897	7	-50	14	5	15	1	4	551	48	4	4	572	226
94	GRENWOOD	138	49280	12	-167	24	9	43	2	9	2020	158	11	11	760	865
102	HG 5 & 6	138	48267	41	-168	63	31	3568	96	427	19	195	871	871	7	14
106	HUDSON E	138	39068	25	32	43	18	242	149	666	2	5	16	16	1	1
108	JAMAICA	138	49098	24	32	45	18	553	343	1494	2	5	29	29	1	1
114	MILLWOOD	138	19439	84	12	18	62	5	1	4	1	2	2	2	0	0
129	QUEENSBG	138	45823	35	-198	54	27	3572	76	339	20	197	670	670	8	14
134	SHM CRK	138	48124	58	-62	84	44	1766	140	620	12	101	1265	1265	5	9
139	VERNON E	138	31068	16	-1260	38	12	179	6	27	67	155	41	41	25	36
140	VERNON W	138	32135	13	-679	30	9	177	6	25	66	2083	39	39	25	70
151	E RIVER	69	51126	21	8734	68	16	8	1	6	1	4	4	4	1	1

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Table FC-2a – 345-kV Substation Weighed in Maximum Short-Circuit Amperes for each Project

Initial Condition - All Projects in service (Column 4). Amps change from the highest of the 3-phase, line-line-ground, line-ground fault shown.

Bus No	Name	KV	Sum of Amps Chg	Percent of Total Change from No Mit, No added Gen column- highest fault type												
				ANP	ER	Key	Bow	NYPA	AST G2	SCSE	PAT2g	PAT2v	PathG1	PathG4	PARkF	PATKK
8	BUCHAN N	345	1930	62.6	2.7	4.0	26.9	1.1	0.2	0.8	0.1	0.4	0.5	0.5	0.1	0.1
9	BUCHAN S	345	3434	40.2	3.9	5.7	44.8	1.6	0.3	1.2	0.2	0.5	0.8	0.8	0.1	0.1
12	DUNWODIE	345	5045	21.1	16.0	24.2	15.8	6.8	1.1	5.0	0.7	2.1	3.2	3.2	0.4	0.4
18	FARRAGUT	345	5460	11.8	28.7	33.8	8.7	4.7	0.8	3.5	0.8	2.1	2.1	2.1	0.4	0.4
22	FR KILLS	345	312	6.4	5.1	11.5	4.2	3.2	0.3	1.6	29.8	4.5	1.3	1.3	18.9	11.9
24	GOETHL N	345	294	6.8	5.8	12.6	4.4	3.4	0.3	1.7	28.6	4.4	1.4	1.4	17.7	11.6
25	GOETHL S	345	271	6.3	7.0	12.9	4.1	3.0	0.4	1.5	28.8	4.1	1.1	1.1	18.8	11.1
26	GOW N	345	218	7.3	6.9	14.2	5.0	3.7	0.5	1.8	26.6	4.6	1.4	1.4	15.6	11.0
27	GOW S	345	216	7.4	6.5	13.9	5.1	3.7	0.5	1.9	26.9	4.6	1.4	1.4	15.7	11.1
29	LADENTWN	345	9323	42.5	0.8	1.2	54.3	0.3	0.1	0.2	0.0	0.1	0.2	0.2	0.0	0.0
32	MILLWOOD	345	3386	35.2	8.1	11.7	33.5	3.4	0.6	2.5	0.4	1.0	1.6	1.6	0.2	0.2
39	PL VAL	345	876	39.7	8.1	12.0	28.7	3.4	0.6	2.5	0.3	1.0	1.6	1.6	0.2	0.2
41	RAINEY	345	5419	11.7	22.6	39.5	8.7	4.8	0.8	3.4	0.8	2.3	2.3	2.3	0.4	0.4
45	RAMAPO	345	11078	69.6	0.7	1.0	27.7	0.3	0.0	0.2	0.0	0.1	0.1	0.1	0.0	0.0
48	SPRN BRK	345	5277	22.2	15.7	22.8	16.8	6.7	1.1	4.9	0.7	2.0	3.2	3.2	0.3	0.4
165	POLETTI	345	2887	11.7	31.4	32.1	8.6	4.4	0.8	638.2	0.8	2.0	2.0	2.0	0.4	0.5
438	W 49 ST	345	4452	13.7	27.2	31.0	10.2	5.1	0.8	8.4	0.8	2.0	2.4	2.4	0.4	0.4
839	E FISHKL	345	919	40.7	8.4	12.5	26.7	3.5	0.5	0.2	0.3	1.1	1.6	1.6	0.2	0.2

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Table FC-2b – 138-kV Substation Weighed in Maximum Short-Circuit Amperes for each Project

Initial Condition - All Projects in service (Column 4). Amps change from the highest of the 3-phase, line-line-ground, line-ground fault shown.

Bus No	Name	kV	Sum of Amps Chg	Percent of Total Change from No Mit, No added Gen column- highest fault type												
				ANP	ER	Key	Bow	NYPA	AST G2	SCSE	PAT2g	PAT2v	PathG1	PathG4	PARkF	PATKK
62	AST-EAST	138	32099	0.0	0.0	0.1	0.0	24.9	15.7	0.3	0.0	0.0	0.9	0.9	0.0	0.0
64	AST-WEST	138	5733	0.6	-3.2	1.0	0.5	62.5	1.5	1.4	0.3	3.6	13.1	13.1	0.1	0.3
66	BUCHANAN	138	129	49.6	5.4	7.8	31.0	2.3	0.0	24.8	0.0	0.8	0.8	0.8	0.0	0.0
70	CORONA	138	25070	0.1	0.0	0.1	0.0	24.1	15.5	3.4	0.0	0.0	0.8	0.8	0.0	0.0
72	DUN NO	138	1008	6.7	4.1	9.3	5.1	25.2	2.4	0.4	0.4	2.4	16.8	16.8	0.2	0.3
73	DUN SO	138	807	7.7	5.5	10.9	5.8	23.3	2.2	0.5	0.5	2.4	15.7	15.7	0.2	0.2
78	E 13 ST	138	5028	2.2	87.1	6.0	1.6	0.9	0.1	0.2	0.1	0.4	0.4	0.4	0.1	0.1
82	E 179 ST	138	7473	0.9	-1.2	1.4	0.7	33.0	2.6	5.7	0.2	1.8	24.5	24.5	0.1	0.1
89	FOXHLS 1	138	1334	0.4	-4.6	0.8	0.3	1.2	0.1	49.9	48.1	4.0	0.3	0.3	28.8	19.9
91	FR KILLS	138	1401	0.5	-3.6	1.0	0.4	1.1	0.1	106.6	39.3	3.4	0.3	0.3	40.8	16.1
94	GRENWOOD	138	3757	0.3	-4.4	0.6	0.2	1.1	0.1	0.1	53.8	4.2	0.3	0.3	20.2	23.0
102	HG 5 & 6	138	6035	0.7	-2.8	1.0	0.5	59.1	1.6	5.6	0.3	3.2	14.4	14.4	0.1	0.2
106	HUDSON E	138	1216	2.1	2.6	3.5	1.5	19.9	12.3	51.0	0.2	0.4	1.3	1.3	0.1	0.1
108	JAMAICA	138	2576	0.9	1.2	1.7	0.7	21.5	13.3	1.0	0.1	0.2	1.1	1.1	0.0	0.0
114	MILLWOOD	138	193	43.5	6.2	9.3	32.1	2.6	0.5	13.0	0.5	1.0	1.0	1.0	0.0	0.0
129	QUEENSBG	138	5484	0.6	-3.6	1.0	0.5	65.1	1.4	0.1	0.4	3.6	12.2	12.2	0.1	0.3
134	SHM CRK	138	5307	1.1	-1.2	1.6	0.8	33.3	2.6	0.0	0.2	1.9	23.8	23.8	0.1	0.2
139	VERNON E	138	-617	-2.6	204.2	-6.2	-1.9	-29.0	-1.0	0.0	-10.9	-25.1	-6.6	-6.6	-4.1	-5.8
140	VERNON W	138	1903	0.7	-35.7	1.6	0.5	9.3	0.3	0.0	3.5	109.5	2.0	2.0	1.3	3.7
151	E RIVER	69	8869	0.2	98.5	0.8	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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References

[1]. IEEE Standard C37.010-1999 - Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

[2] IEC 60909-1, Technical Report, Short-circuit Current Calculation in Three-phase A.C. Systems, Part 1, Factors for the calculation of short-circuit currents in three-phase alternating current. systems according to IEC-909, 1991.

[3] A Practical Guide to Short-Circuit Calculations, (book) August 2001, Conrad St. Pierre

Appendix

The short-circuit analysis was done ASPEN OneLine software using the PSS/E database converted to ASPEN format. The buses of interest were assigned to an area of '99' to allow restricting the printout. The 'Batch' short-circuit processing mode was used for a summary and a detailed printout. For the individual breaker analysis, the line out option was used.

The printout of the result for the Baseline, non-mitigation, and mitigation follow.

Summary 3-Phase, LLG and LG faults

BaseLine	Page C-1
Non-Mitigation	Page C-4
Mitigation	Page C-7

Detailed 3-Phase, LLG and LG faults

BaseLine	Page C-10
Non-Mitigation	Page C-100
Mitigation	Page C-187

Line out Summary 3-Phase, and LG faults

BaseLine	Page C-279
Non-Mitigation	Page C-289
Mitigation	Page C-299

Line out Detailed - LLG faults

BaseLine	File 'BASE_LLG.pdf'
Non-Mitigation	File 'NMIGR2_LLG.pdf'
Mitigation	File 'MIGR2_LLG.pdf'

The tables below document the results of individual breaker duty (IBD) studies. IBD calculations were made only for those instances in which the total bus duty listed in Tables SC-1a and SC-1b exceeded the ratings of the lowest-rated circuit breaker at the substation bus. IBD calculations were not performed, and table entries were omitted, in instances in which the ratings of individual breakers were not exceeded by the calculated total bus duties.

Entries in these tables that exceed the ratings of respective circuit breakers have been shaded for emphasis. Note that this detailed analysis discloses that all instances of excess breaker duty are addressed and resolved by the proposed short circuit mitigation program.

Table App-1(a): Detailed results of individual breaker duty analysis

No	BUS	Bus kV.	Base Line					Year 2001 Nonmitigation			Year 2001 Mitigation				
			Bkr	Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Bkr	Sym. kA Rating	Fault Type	Sym kA	Bkr Sym kA
9	Buchanan S.	345	1	40	3-Ph	41.07	36.87	3-Ph	44.67	40.47	1	40	3-Ph	42.17	37.97
			3	40			36.87			40.47	3	40			37.97
			5	40			35.70			38.92	5	40			37.39
			6	40			35.70			38.92	6	40			37.39
12	Dunwoodie	345	3	63				3-Ph	67.50	67.26					
			4	63						67.26					
			5	63						64.88					
			6	63						65.35					
			7	63						64.88					
			8	63						65.35					
18	Farragut	345	1E	63				LLG	67.57	67.57					
			1W	63						67.57					
			2E	63						67.57					
			2W	63						67.57					
			3E	63						67.57					
			3W	63						67.57					
			4E	63						67.57					
			4W	63						67.57					
			5E	63						67.57					
			5W	63						67.57					
			6E	63						67.57					
			6W	63						67.57					

Table App-1(b): Detailed results of individual breaker duty analysis

No	BUS	Bus kV.	Base Line					Year 2001 Nonmitigation			Year 2001 Mitigation				
			Bkr	Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Bkr	Sym. KA Rating	Fault Type	Sym kA	Bkr Sym kA
18	Farragut #	345	7E	63						67.35					
			7W	63						67.57					
			8E	63						67.35					
			8w	63						67.57					
			9E	63						67.57					
			9W	63						67.57					
			10E	63				LLG	67.57	67.57					
			10W	63						67.57					
			11E	63						66.90					
			11W	63						66.44					
41	Rainey #	345	1E	63						66.17					
			1W	63						66.38					
			2E	63						63.39					
			2W	63						64.84					
			3E	63						64.84					
			3W	63				LLG	66.52	64.84					
			4E	63						64.23					
			4W	63						64.84					
			6E	63						65.06					
			7E	63						65.06					
			7W	63						64.81					

Could not identify all computer branch connections to breaker locations shown on Dwg 900 (Jun 19, 2000)

Table App-1(c): Detailed results of individual breaker duty analysis

NO	BUS	Bus kV.	BASE LINE					YEAR 2001 NONMITIGATION			YEAR 2001 MITIGATION				
			BKR	SYM KA	FAULT TYPE	BUS SYM KA	BKR SYM KA	FAULT TYPE	BUS SYM KA	BKR SYM KA	BKR	SYM. KA RATING	FAULT TYPE	SYM KA	BKR SYM KA
41	Rainey #	345	8E	63				LLG	66.52	66.17					
			8w	63						66.38					
			9E	63						66.17					
			9W	63						66.38					
45	Ramapo	345	T-1500	40	3-Ph	43.90	39.95	3-Ph	54.97	54.33					
			T-77-94	40	3-Ph	43.90	38.66	3-Ph	54.97	49.62					
48	Sprain Brook	345	RN2	63	3-Ph	63.58	62.85	3-Ph	68.62	67.89					
			RN3	63			62.8.5			67.89					
			RN4	63			62.85			67.89					
			RN5	63			62.85			67.89					
			RN6	63			62.85			67.89					
			RS3	63			62.94			67.79					
			RS4	63			62.94			67.79					
			RS5	63			62.94			67.79					
			RS6	63			62.94			67.79					
			RNS2	63			62.94			67.79					
			RNS3	63			62.16			68.75					
			RNS4	63			62.25			66.85					
			RNS5	63			62.24			67.14					
			RNS6	63			62.80			67.58					

Could not identify all computer branch connections to breaker locations shown on Dwg 900 (Jun 19, 2000)

Table App-1(d): Detailed results of individual breaker duty analysis

No	BUS	Bus kV.	Base Line					Year 2001 Nonmitigation			Year 2001 Mitigation				
			Bkr	Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Bkr	Sym. KA Rating	Fault Type	Sym kA	Bkr Sym kA
62	Astoria E #	138	1E	45	L-G	51.24	48.07	L-G	78.36	78.26					
			1W	63			$			75.30					
			2W	45			48.07			78.27					
			2E	63			$			78.27					
			3E	63			$			78.27					
			3W	63			$			78.27					
			4E	63			$			75.60					
			4W	63			$			78.27					
			5E	63			$			78.26					
			5W	63			$			78.27					
			6E	63			$			78.26					
			6W	63			$			78.27					
			7E	63			$			75.30					
			7W	63			$			75.60					
			8E	63			$			78.27					
			8W	63			$			75.60					
			BT	45			24.83			78.27					
			GTB23	63			$			78.27					
70	Corona	138	BT	45	LLG	49.97	44.87	LLG	71.89	60.72	BT	45	LLG	47.34	44.61
78	E 13 St	138	F5	40	LLG	44.60	40.62	LLG	48.99	44.89					

\# Cannot identify on ConEd drawing 900 (Jun 19, 2000) breakers to SCS and NY PAG generators, highest duty given.
$ Breaker rating greater than bus duty, IBD not calculated.

Table App-1(e): Detailed results of individual breaker duty analysis

No	BUS	Bus kV.	Base Line					Year 2001 Nonmitigation			Year 2001 Mitigation				
			Bkr	Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Bkr	Sym. KA Rating	Fault Type	Sym kA	Bkr Sym kA
94	Greenwood	138	4S	45	LLG	57.54	54.79	LLG	49.28	46.35					
			BT	45			53.00			43.35					
108	Jamaica	138	1	45	LLG	46.47	38.92	LLG	48.12	41.50	1	45	LLG	48.99	41.59
			3	45			41.32			42.41	3	45			41.72
			4	45			39.11			41.64	4	45			41.52
			6	45			41.42			42.54	6	45			41.88
			7	45			36.99			38.31	7	45			39.00
			8	40			33.66			34.86	8	40			35.49
			13	40			29.51			30.56	13	40			31.11
			14	40			27.45			28.43	14	40			28.94
129	Queenbridge	138	1E	45	LLG	40.35	40.35	LLG	45.82	45.82					
			2E	45			$			45.82					
			3E	45			$			45.82					
			4E	45			$			45.82					
			5E	45			$			45.82					
			6E	45			$			45.82					
			7E	45			$			45.82					
			8E	45			$			45.82					
			9E	45			$			45.82					
			11E	45			$			45.82					
			12E	40			40.35			45.82					
			14E	45			$			45.82					

$ Breaker rating greater than bus duty, IBD not calculated

Table App-1(f): Detailed results of individual breaker duty analysis

No	BUS	Bus kV.	Base Line					Year 2001 Nonmitigation			Year 2001 Mitigation				
			Bkr	Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Fault Type	Bus Sym kA	Bkr Sym kA	Bkr	Sym. kA Rating	Fault Type	Sym kA	Bkr Sym kA
134	Sherman Crk	138	3W	40	LLG	42.74	40.00	LLG	48.12	45.29	?	50			
151	East River	69	12#	42	L-G	50.62	49.95	L-G	51.13	50.01	12	50	L-G	50.66	49.95
			22	42			47.79			47.78	22	50			47.78
			53	50			47.79			47.78	53	50			47.78
			63	50			47.79			47.78	63	50			47.78
			73	50			47.79			47.78	73	50			47.78
			83	50			47.79			47.78	83	50			47.78
			TR17	40			37.94			38.10	TR17	50			37.94
			GEN 5#	50			49.95			50.01	GEN 5	50			49.95
			GEN 6	50			44.55			47.43	GEN 6	50			47.36
			BT7-8	42			47.79			47.78	BT7-8	50			47.78
			BT-81-82	42			47.79			47.78	BT-81-82	50			47.78

? Sherman Crk breaker with 40-kA rating included in ATBA but not in breaker list from Con Ed dated 9/20/01.
Cannot locate on Dwg 900 (Jun 19, 2000), Greatest duty listed