AMERICAN TRANSMISSION COMPANY

THE ENERGY ACCESS COMPANY

PRELIMINARY MADISON AREA TRANSMISSION STUDIES

POWER FLOW AND VOLTAGE STABILITY ANALYSES

Jamal Khudai

American Transmission Company
February 9, 2004

Madison Area Transmission System Studies

Background

Higher than average load growth is projected for the Madison area, particularly to the west and south of the city, that has created the need for transmission system reinforcements in the area. The City of Madison is located in ATC planning Zone 3 and the load growth in this zone is projected to be the highest among the five-zone ATC territory, at roughly 2.61% annually from 2004 through 2012. To ensure secure operation of the transmission system as it serves this growing load, several reinforcement projects will need to be completed by the year 2009 or earlier.

The addition of the West Campus generating units, with approximately 150 MW of capacity, will improve voltages in the Madison area and delay the need for transmission system reinforcements. However, there is not enough local generation to serve the entire load in the Madison area. Generation in the Madison area, projected to be approximately 500 MW at maximum output, would only be able to serve about 55% of the projected load in 2012. Unless measures are taken to significantly lower or eliminate load growth, transmission system reinforcements will become essential for the system to be able to import power and maintain transmission system voltages under normal and contingency conditions. The local generation is not only short of peak demand, but may also not be economical to operate most of the year because, except for the Blount Street plant, all other units are fired with natural gas and diesel fuel and tend to have operating higher operating costs than other available generators outside of Madison area. Further, while these most recent studies conducted by ATC have kept all Blount units in service, there is some uncertainty associated with some/all of the Blount units in the future due to several factors, with age of the units being a primary concern.

ATC is planning or constructing various transmission system reinforcement from now through 2008. Key projects include:

- Conversion of the Columbia-North Madison 138 kV circuit to 345 kV
- Rebuild of the North Madison substation (345 kV and 138 kV ring busses)
- North Madison 345/138 KV Transformer replacement
- Rebuild of the Kegonsa-McFarland-Femrite 69 kV line and conversion to 138 kV
- Conversion of the Sycamore-Sprecher 69 kV line to 138 kV
- Construction of a new Femrite-Sprecher 138 kV line
- Fitchburg 138/69 kV Transformer replacement
- Sycamore 138/69 kV Transformer addition
- Reiner 138/69 kV Transformer addition

These projects were included in the models used by ATC to evaluate the system in 2009 and 2012 and the proposed base configuration for Madison area is provided in Figure 1.

Purpose of Studies

Studies conducted previously by ATC indicate that there is potential for voltage collapse in the Madison area for loss of key 138 kV circuits and certainly for several double contingency scenarios under peak load conditions by 2012. The purpose of the studies described in this document is to:

- ❑ Update the power flow studies previously performed, this time modeling various generation and import scenarios.
- ❑ Provide information on voltage and thermal criteria violations, voltage collapse limits and asses the risks associated with depending on local generation, for various generation scenarios, and

- ❑ Provide information on potential transmission system reinforcement alternatives under consideration.

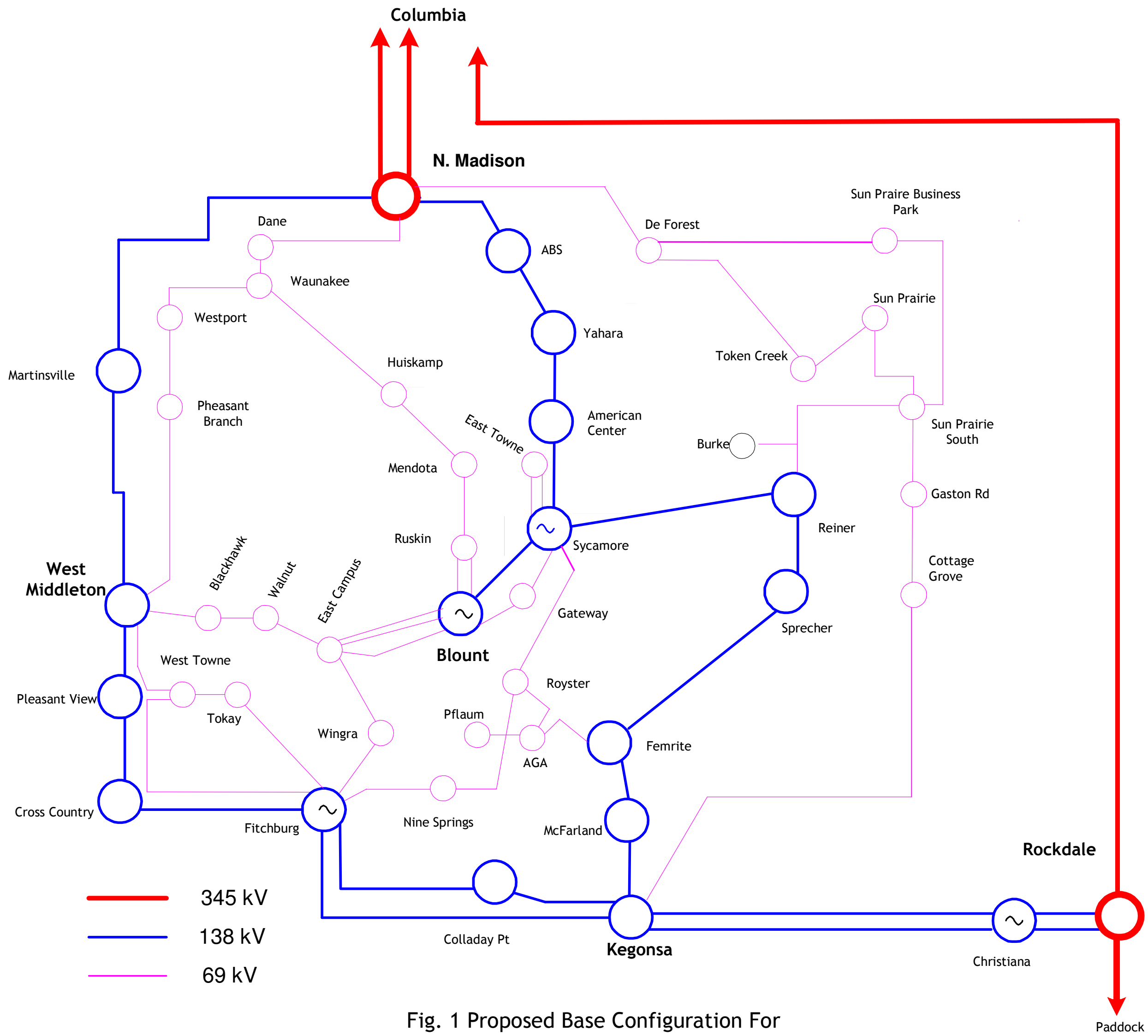


Fig. 1 Proposed Base Configuration For Madison Area in Year 2012

Primary Assumptions and Results of Analyses

ATC conducted system normal and single contingency (n-1) analyses for several generation and import scenarios. The primary study year was 2012, with all projects planned or proposed by ATC in Dane County and scheduled to be in-service by 2009. The study results from these analyses are provided in this document. Similar analyses were also conducted for 2009, and the results of those analyses are provided in Table 11 and Appendix A. Load data used in these models was provided by Alliant, MG&E and WPPI (Lodi, Stoughton, Sun Prairie, Waunakee).

As noted above, all system reinforcements planned by ATC to be in-service by 2009 were included in the system models. The following four base case were developed for year 2012 to study the a range of generation and import scenarios:

- **Scenario 0-12**: Base model with the West Campus units turned OFF
- **Scenario 10-12**: Base model with West Campus Unit turned ON but equivalent amount of generators is turned OFF in the Madison area (West Campus displaces higher cost local generation)
- **Scenario 20-12**: Base model with West Campus Units turned ON but net imports are reduced by 150 MW
- **Scenario 40-12**: Base model with West Campus Units turned ON but output of the existing units is reduced by 50 MWs and net imports are reduced by 100 MW

Table 1a and 1b summarize the results of the power flow analysis for the year 2012.
In addition, several supporting tables are provided that may be useful to visualize data within the models. Table 2 provides the generation dispatch modeled for each of the base case, Table 3 lists unit data for generation in the Madison area and Table 4 lists the 48 buses that were monitored for each contingency to calculate average voltages.

The results of the analyses of the existing system are described in the following sections.

<u>Low Voltages</u>

- Average voltages (for the 48 bus sample) under the base scenarios and no contingencies are in the range of 93% to 97%. This is much lower than the desirable average, which is in the upper 90% under normal in tact system conditions. ATC's criteria for bus voltages under normal in tact system conditions is a minimum of 95%. Having a few isolated busses in the 95-97% range may be acceptable, but having area-wide average this low is an indication of a heavily loaded system with inadequate reactive support.
- The low voltages would be widespread in Scenario 0-12 and Scenario 10-12 for a single contingency even with 100% utilization of local generators' reactive capability at the time of contingencies. This condition would most likely result in voltage collapse.
- Scenario 20-12 may not result in voltage collapse but the voltages are marginal, even with most of the area generation on-line. The power flow solution relies heavily on reactive output from the local generators during contingencies. The voltage stability analysis also indicates small margins to collapse.
- Scenario 40-12 may not result in voltage collapse under contingency conditions but the voltages are depressed and the solution relies heavily on local generators' reactive output during contingencies.

- The voltages stability analysis indicates in general, small margins to collapse.

Thermal Overloads

- North Madison substation is one of the major sources of supply for Madison. In general, loss of the any one of the 138 kV outlets would be a critical contingency that would result in low voltages and thermal overloads. Overloads are projected on the North Madison 138/69kV autotransformer for single contingencies under all base scenarios and in most cases, the 69kV North Madison-Dane line would also load to its limit.

- Overloads on the Femrite 138/69kV autotransformer and Royster-Sycamore 69 kV circuit are related to each other and could be resolved by adding 2nd autotransformer at Femrite substation.

Common Mode Failures

The 345kV corridor between Columbia and North Madison and 138kV corridor between Christiana and Kegonsa are the two major supply routes of power to Madison. Both routes carry two circuits on a single structure. By 2009, the loss of both circuits on either corridor due to a common mode failure would result in significant thermal overloads and very low voltages and most likely would result in voltage collapse. The current studies are focused on resolving impending voltage collapse issues for only loss of a single circuit and may not address all the issues related to common mode failures of two circuits that occupy a common structure or common corridor. Discussion of common mode failure provides another perspective and results would be factored into final alternative selection process.

Energy Access

The primary focus of current studies is to resolve potentially severe reliability issues in a timely manner. However, most infrastructures built for reliability improvements would inherently increase import capability to the Madison area. Increasing import capability would result in the potential for lower energy costs for customers in the area. ATC is in the process of conducting separate analyses to improve import capability, though not specifically to the Madison area, but to the ATC service territory as a whole.

Potential Solutions

To address reliability issues in the Madison area, ATC has evaluated numerous alternatives, including:

- A new Rockdale-West Middleton 345 kV line
- A new North Madison-West Middleton 345 kV line
- A new Salem-Nelson Dewey-Spring Green-West Middleton 345 kV line (under study)
- 138 kV alternatives evaluated
    - North Madison-Waunakee-Blount 138 kV circuit (new construction along with 138 to 69 kV conversion)
    - West Middleton-Walnut-Blount 138 kV circuit (new construction along with 138 to 69 kV conversion)
    - 2nd circuit from Kegonsa-McFarland-Femrite-Sprecher-Reiner
    - 2nd circuit between Sycamore and Blount
- 345 kV and 138 kV components combined
    - A new Rockdale-West Middleton 345 kV line and North Madison-Waunakee-Blount 138 kV circuit (new construction along with 138 to 69 kV conversion)
    - A new North Madison-West Middleton 345 kV line and North Madison-Waunakee-Blount 138 kV circuit (new construction along with 138 to 69 kV conversion)

Preliminary Findings

- West Middleton substation appears to be the preferred terminus for a new 345 kV line from electrical perspective. The substation property is sized to accommodate 345kV bus and equipment and is located to the west of the area that is growing rapidly.
- A new 345 kV line from North Madison, Rockdale or Iowa, initially terminating at West Middleton would need to be supplemented with either a new 138 kV line or conversion of existing 69 kV lines to 138 kV, likely from North Madison. The circuits from Rockdale and Iowa would perform better for common mode failure of two 345 kV circuits from Columbia to North Madison or two 138 kV circuits form Christian to Kegonsa.
- Alternatives involving only 138 kV reinforcements do not appear to provide anywhere near the same benefits as a 345 kV line to the west side of Madison. At least 4 or more new 138 kV lines appear to be needed to equate to the performance of a single 345 kV line. The solution based entirely on 138kV circuits from North Madison, West Middleton and Kegonsa would perform poorly for the common mode failure of two 345 circuits from Columbia to North Madison or two 138 kV circuits from Christian to Kegonsa.
- A new 345 kV line from North Madison, Rockdale or Iowa, initially terminating at West Middleton plus 138 kV line from North Madison to Blount is expected to avert unacceptably low voltages for about 5-6 years. At that point, one of the potential solutions would be another 345 kV line from West Middleton to some other 345 kV locations in the system.

Single 345 kV or 138 kV Circuit

- Addition of new 345 kV or 138 kV circuit by itself would not provide sufficient performance under all scenarios studied but may work if most of the generation is assumed on-line as shown in Table 7.
- A 345 kV circuit would provide greater reduction in losses and would have greater potential for future imports and load serving expansion compared to 138 kV.
- Results for a new 345 kV or 138 kV single circuit solutions are provided for scenarios 0-12, 10-12 and 40-12 in Table 5a and b, Table 6a and b and Table 7 respectively.
- Results for Scenario 20a-12 are not included due to time constraints but in general results are predicable because it is a superset of Scenario 40-12 and would only improve Table 7 results.
- A new 345 kV or 138 kV circuit under Scenario 0-12 and 10-12 would not provide sufficient voltage margins. On-going analyses indicate lower voltages, heavy reliance on generators' reactive power output and potential for voltage collapse under contingency conditions. However under Scenario 40-12 system performance would have acceptable margins if most of the local generation were available to dispatch.

345kV Combined with 138 KV or multiple 138kV Circuits

- Results for a plan consisting of a 345 kV circuit from North Madison to West Middleton or Rockdale to West Middleton along with 138 kV circuit from North Madison-Waunakee-Blount appears to provide acceptable performance under all base scenarios as shown in Tables 8a and b, 9a and 9b, and 10. However there is one contrast worth pointing out that 345 kV circuit from Rockdale to West Middleton would performance much better in terms of performance under common mode failure of two 345 kV circuits from Columbia to North Madison or 138 kV circuits from Christiana to Kegonsa.

- New 138 kV circuits originating from North Madison would be most effective due to stronger source (345 kV) at North Madison. For example a new Madison-Waunakee-Blount 138 kV line performs better compared to other 138 kV circuits evaluated from West Middleton or Kegonsa. Results for a combination of three 138 kV circuits are provided in Tables 8a and 8b. The overloads on the Sycamore-Blount circuit would require a 2nd circuit between Sycamore and Blount and that would make it a total of four 138 kV circuits. The overall performance would be inferior to the combination of 345 kV and 138 kV circuits in terms of average voltages, system losses and common mode failures and on-going studies might indicate need for more 138 kV circuits to be equivalent to a 345/138 kV combination plan.

Next Steps

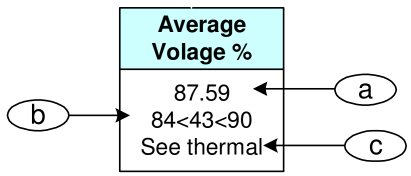
Results for alternative reinforcement plans being studied are under internal feasibility review. The outcome of these reviews and study results for each of the alternatives will be shared in the next phase. Deliverables will include constructability assessments for substations that would need to be expanded for each alternative along with screening level cost estimates.

Table 1a Performance of Base Scenarios
(Voltages and System Data)

Scenario	Sub. Scenario	System Losses MW	Voltage					Load MW	Gen MW	Import MW	Voltage Stability Limit MW
			Normal		Worst Contingency						
			Average Voltage %	Gen VAR's Utilized %	Contingency	Average Voltage %	Gen VAR's Utilized %				
Scenario 0-12 • Base • West campus Unit OFF	Case does not solve for the some contingencies	411	93.47	95	American Center -Sycamore (No Solution for N. Madison-ABS)	87.36	100	900	361	561	<900
Scenario 10-12 • Base • West Campus Units ON • Reduce existing units by 150 MW	Impact of generation location	409	94.43	91.49	N Madison-ABS	87.59 84<43<90 See thermal	100	900	359	561	910
Scenario 20-12 • Base • West Campus Units ON • 150 MW Export to CE	This would be the best scenario	394	96.82	77.82	N Madison-ABS	94.40 92<6<93 See thermal	93.61	900	506	411	980
Scenario 40-12 • Base • West Campus Units ON • 100 MW Export to CE • Reduce existing units by 50 MW		399	96.31	83.67	N. Madison-ABS	92.69 90<16<92 See thermal	96.22	900	458	460	960

Explanation for data in Table 1

Scenario	Sub Scenario	System Losses MW	Voltage					Load MW	Gen MW	Import MW	Voltage Stability Limits
			Normal		Worst Contingency						
			Average Voltage %	Gen Var's Utilized %	Contigency	Average Voltage %	Gen Var's Utilized %				
1	2	3	4	5	6	7	8	9	10	11	12



1. Base Scenario
2. Sub. Scenario to add minor updates (if any)
3. System losses
4. Average voltage; average of 48-bus sample provided in Table 6 under system intact conditions
5. Ratio of MVAR output vs. maximum Mvar capability of the on-line generating units under system intact conditions
6. Worst contingency
7. Average voltage; average of 48-bus sample provided in Table 6 under worst contingency
8. Ratio of Mvar output vs. maximum Mvar capability of the on-line generating units for the worst contingency
9. Total load in MW for the study area
10. Total output of the generators in the study area
11. Total import into the study area
12. Voltage stability limits

a. Average voltage of 48-bus sample under normal or contingency conditions
b. Number of buses in certain voltage band, the first number is the lowest voltage on any of the 48-bus sample
c. Indication whether there are thermal violation for a given base under any contingency

Table 1b Performance of Base Scenarios
(Thermal Violations)

Contingency	Critical Element	Rating SE	% Load				Comments
			Scenario 0a-12	Scenario 10a-12	Scenario 20a-12	Scenario 40a-12	
N. Madison-ABS	North Madison 138/69 kV transformer (38179-39819*)	187	No Solution	**107**	98	**101**	
	North Madison-Dane (8179-38150)	103		**104**	92	96	Rating reduction to 95 MVA
	North Madison-Martinsville (39819-33652)	233		**101**	85	90	
	Kegonsa-McFarland (39122-38146)	287		**101**	85	89	Rating change to 454 MVA
Royster-Sycamore	Femrite 138/69 kV transformer (39854-39853)	100	**111**	**119**	**106**	**114**	Rating change to 125 MVA
Femrite 138/69 kV transformer	Royster-Sycamore (38676-39851)	81	90	**105**	94	**105**	
Kegonsa-Colladay	Femrite 138/69 kV transformer (39854-39853)	100	**116**	**117**	**101**	**107**	Rating change to 125 MVA

Table 2 Generators' Dispatch Order for Each Scenario

BUS#	NAME	BSKV	CD	ID	Scenario 0a-12	Scenario 10a-12	Scenario 20a-12	Scenario 40a-12
39860	BLT 14	13.8	-2	1	6		6	
39860	BLT 14	13.8	-2	3	39	39	39	39
39860	BLT 14	13.8	-2	4	22	22	22	22
39860	BLT 14	13.8	-2	5	28	28	28	28
39969	BLT G6	13.8	2	6	49	49	49	49
39968	BLT G7	13.8	-2	7	42.4	37	36.9	38.5
33598	ETN14-1	13.8	-2	X				
39822	FCH 14-1	13.8	-2	1	21		21	
39823	FCH 14-2	13.8	-2	2	21		21	21
39991	FEMGN	13.8	-2	3				
39825	HKP 14	13.8	-2	X				
39180	IC29 CT1	13.8	-2	1		50	50	50
39181	IC29 CT2	13.8	-2	1		50	50	50
39182	IC29 ST	13.8	-2	1		50	50	50
33660	MGEWIND	138	-2	W	11		11	
39852	NSP 14-1	13.8	-2	1	12		12	
33608	NSP 14-2	13.8	-2	X				
33612	RYS 14	13.8	-2	X				
39835	SYC 14-1	13.8	-2	1	14		14	14
39836	SYC 14-2	13.8	-2	2	21		21	21
39824	WEM 34	13.8	-2	1	75	35	75	75
39826	WMD14-7	13.8	-2	X				
					361.4	360	506	458

Table 3 Madison Area Generator Capabilities

BUS#	NAME	BSKV	CD	ID	QMAX	QMIN	PMAX	PMIN	OWN
39860	BLT 14	13.8	-2	1	0	0	6.8	1	383
39860	BLT 14	13.8	-2	3	15	0	39.2	4	383
39860	BLT 14	13.8	-2	4	10	0	22.4	2	383
39860	BLT 14	13.8	-2	5	15	0	28.5	4	383
39969	BLT G6	13.8	2	6	25	0	49.3	15	383
39968	BLT G7	13.8	-2	7	25	0	49.8	15	383
33598	ETN14-1	13.8	-2	X	0	0	10	1	383
39822	FCH 14-1	13.8	-2	1	12	0	21.1	10	383
39823	FCH 14-2	13.8	-2	2	21.5	12.5	21.5	10	383
39825	HKP 14	13.8	-2	X	0	0	10	1	383
39180	IC29 CT1	13.8	-2	1	30.2	-20	50.5	0	383
39181	IC29 CT2	13.8	-2	1	30.2	-20	50.5	0	383
39182	IC29 ST	13.8	-2	1	30.5	-23	51.4	0	383
33660	MGEWIND*	138	-2	W	0	0	11	1	384
39852	NSP 14-1	13.8	-2	1	5	0	12.3	10	383
33608	NSP 14-2	13.8	-2	X	0	0	5	1	383
33612	RYS 14	13.8	-2	X	0	0	10	1	383
39835	SYC 14-1	13.8	-2	1	10	0	14.7	8	383
39836	SYC 14-2	13.8	-2	2	10	0	21.8	10	383
39824	WEM 34*	13.8	-2	1	30	0	79.5	35	384
39826	WMD14-7	13.8	-2	X	0	0	10	1	383

* Units are not physically located in Madison and are not taken into for area's total Mvar capability calculations.

Table 4 Sample Of 48 Buses Used For Average Voltage Calculations

BUS#	NAME	BSKV	AREA	OWN	BUS#	NAME	BSKV	AREA	OWN
38680	WGA 69	69	367	383	39821	FCH 138	138	367	383
38672	WLT 69	69	367	383	39815	PLVM138	138	367	383
38671	ECA 69	69	367	383	38676	RYS 69	69	367	383
38684	BLKM69	69	367	383	39168	RNR_138	138	367	383
38678	MEN 69	69	367	383	38138	CCS 69	69	367	383
39165	MEN TAP	69	367	383	38164	WE1 69	69	364	383
39967	RKN 69-2	69	367	383	38146	MCF_138	138	364	383
39164	RKN 69-1	69	367	383	39864	BLT 138	138	367	383
39874	BLTM69	69	367	383	38668	WMD 69	69	367	383
38673	PHB 69	69	367	383	38166	WPK 69	69	364	383
38677	ETN 69	69	367	383	39831	FCH 69	69	367	383
38674	WTNM 69	69	367	383	39816	WE2M 69	69	367	383
38167	WTN 69	69	364	383	39841	SYC 138	138	367	383
38679	GWY 69	69	367	383	39820	WMD 138	138	367	383
38675	WPT 69	69	367	383	39853	FEM 69	69	367	383
39817	TOK 69	69	367	383	39123	COD 138	138	364	383
39216	CCS 138	138	364	383	39122	KEG 138	138	364	383
38681	LCI 69	69	367	383	33992	AMERCNTR	138	364	383
38669	HKP 69	69	367	383	39217	YAR 138	138	364	383
38683	PFL 69	69	367	383	38160	DAN 69	69	364	383
39854	FEM_138	138	367	383	38145	KEG 69	69	364	383
39851	SYC 69	69	367	383	33991	ABS	138	367	383
38670	NSP 69	69	367	383	38150	RNR 69	69	364	383
38667	SPR_138	138	367	383	38179	NMA 69	69	364	383

Table 5a: Impact of Reinforcements on Scenario 0-12
Single Circuits
(Voltages and System Data)

Reinforcement	Sub. Scenario	System Losses MW	Voltage					Load MW	Gen MW	Import MW	Voltage Stability Limit MW
			Normal		Worst Contingency						
			Average Voltage %	Gen VAR's Utilized %	Contingency	Average Voltage %	Gen VAR's Utilized %				
Rockdale-West Middleton 34 5kV circuit	1a-12	392	96.21	79.8	N. Madison-ABS	91.93 88<9<90 See thermal	99.46	900	356	561	945 N. Madison-ABS
North Madison-West Middleton 345 kV Circuit	2a-12	396	96.32	78.25	N. Madison-ABS	93.14 90<7<91 See thermal	96.22	900	356	562	960 N. Madison-ABS
North Madison-Waunakee-Blount 138 kV Circuit	3a-12	401	96.06	86.40	N. Madison-Waunakee	93.35 91<7<92 See thermal	95.56	900	359	561	967 N. Madison-Waunakee

Table 5b Performances of Reinforcements for Scenarios 0-12
Single Circuits
(Thermal Violations)

Contingency	Critical Element	Rating	% Load			Comments
			Scenario 1a-12	Scenario 2a-12	Scenario 3a-12	
N. Madison-ABS	N. Madison 138/69 kV transformer (38179-39189)	186.7	**102**		**105**	
	W. Middleton-Blackhawk (38668-38684)	111	**116**	**112**		Possible cable cooling or review 24 hr emergency rating of the cable
N. Madison 138/69kV Auto	W. Middleton-Pheasant Branch (38668-38673)	72	106.9	106		Rating change to 82 MVA
Royster-Sycamore	Femrite 138/69 kV transformer	100	100	101	109	Rating change to 125 MVA
Columbia-North Madison 345kV KT 2	Columbia-North Madison 345 kV	597		103		Terminal upgrades will be done before 2012
North Madison ABS	North Madison-Waunakee (33914-39819)	290			108	Install larger conductor or operate it at higher temperature
N. Madison-Martinsville	Waunakee-Waunakee Muni (38162-39816)	72			119	Terminal upgrades
	Pheasant Branch-Westport (38673-38675	49			135	
North Madison-Waunakee	Sycamore-Blount (39841-39864)	185			97	Use 24 hour emergency of 254 MVA
East Campus-Blount CKT 1	East Campus Blount (38671-39874)	95			**106**	

In addition to voltages problems in Table 7a, thermal overload under all scenarios that would require major upgrades

Table 6a: Impact of Reinforcements on Scenario 10-12
Single Circuits
(Voltages and System Data)

Reinforcement	Sub. Scenario	System Losses MW	Voltage					Load MW	Gen MW	Import MW	Voltage Stability Limit MW
			Normal		Worst Contingency						
			Average Voltage %	Gen VAR's Utilized %	Contingency	Average Voltage %	Gen VAR's Utilized %				
Rockdale-West Middleton 34 5kV circuit	12a-12	392	96.65	78.22	N. Madison-ABS	93.38 90<4<91 See thermal	94.47	900	360	557	975 N. Madison-ABS
North Madison-West Middleton 345 kV Circuit	13a-12	396	96.79	77.66	N. Madison-W. Middleton	94.50 92<6<93 Thermal ok	91.21	900	357	561	985 N. Madison-ABS
North Madison-Waunakee-Blount 138 kV Circuit	11b-12 • East Campus to Wingra circuit with 5 ohm series inductor • 2nd Femrite auto	401	96.62	76.28	N. Madison-Waunakee	94.25 92<7<93 Thermal ok	89.49	900	363	557	1000 Kegonsa-McFarland

Table 6b Impact of Reinforcements on Scenario 10-12
Single Circuits
(Thermal Violations)

Contingency	Critical Element	Rating	Scenario 12a_12	Comments
N. Madison-ABS	N. Madison 138/69 kV transformer (38179-39189)	186.7	97	May be issue later on
Royster-Sycamore	Femrite 138/69 kV transformer	100	109	Change rating to 125 MVA
Femrite 69kV Auto	Royster-Sycamore (38676-398510)	81	97	Operate at higher temperature or install 2nd autotransformer at Femrite
West Middleton-Pleasant View	East Campus-Wingra (38671-38680)	68	99	Install series inductor or obtain 24hr emergency rating

Table 7: Impact of Reinforcements on Scenario 40-12
Single Circuits
(Voltages and System Data)

Reinforcement	Sub. Scenario	System Losses MW	Voltage					Load MW	Gen MW	Import MW	Voltage Stability Limit MW
			Normal		Worst Contingency						
			Average Voltage %	Gen VAR's Utilized %	Contingency	Average Voltage %	Gen VAR's Utilized %				
Rockdale-West Middleton 34 5kV circuit	42a-12	385	97.57	68.25	N. Madison-ABS	95.85 93<3<94 Thermal ok	87.54	900	454	461	1015 N. Madison-ABS
North Madison-West Middleton 345 kV Circuit	43a-12	389	97.65	67.26	N. Madison-W. Middleton	96.29 94<7<95 Thermal ok	83.58	900	455	461	1035 N. Madison-ABS
North Madison-Waunakee-Blount 138 kV Circuit	41b-12 • East Campus to Wingra circuit with 5 ohm series inductor • 2nd Femrite auto	393	97.56	68.88	N. Madison-Waunakee	96.24 94<13<95 Thermal ok	82.73	900	456	461	1045 Kegonsa-McFarland

Table 8a: Impact of Reinforcements on Scenario 0-12
Multiple Circuits
(Voltages and System Data)

Reinforcement	Sub. Scenario	System Losses MW	Voltage					Load MW	Gen MW	Import MW	Voltage Stability Limit MW
			Normal		Worst Contingency						
			Average Voltage %	Gen VAR's Utilized %	Contingency	Average Voltage %	Gen VAR's Utilized %				
1. Rockdale-West Middleton 34 5kV circuit 2. N. Madison-Waunakee-Blount 138kV circuit via Waunakee	1b-12	386	97.67	68.55	Rockdale-West Middleton	95.97 94<17<95 Thermal ok	86.8	900	356	559	1010 Rockdale-West Middleton
1. North Madison-West Middleton 345 kV Circuit 2. N. Madison-Waunakee-Blount 138kV circuit via Waunakee	2b-12	391	97.53	69.83	N. Madison-West Middleton	95.59 94<17<95 Thermal ok	86.68	900	356	561	1010 N. Madison-West Middleton 345 kV
1. North Madison-Waunakee-Blount 138 kV Circuit 2. N. Madison-Walnut-Blount 138kV circuit	3b-12	399	96.64	76.56	N. Madison-Waunakee	94.49 92<7<94 See Thermal	91	900	357	561	995 N. Madison-Waunakee
1. North Madison-Waunakee-Blount 138 kV Circuit 2. N. Madison-Walnut-Blount 138kV circuit 3. 2nd Kegonsa-McFarland-Sprecher-Reiner 138kv circuit	3d-12	398	96.82	74.28	N. Madison-Waunakee	94.85 92<15<94 See Thermal	89.76	900	359	560	1002 N. Madison-Waunakee

Table 8b: Impact of Reinforcements on Scenario 0-12
Multiple Circuits
(Thermal Violation)

Contingency	Critical Element	Rating	% Load		Comments
			Scenario 3b-12	Scenario 3d-12	
North Madison 345/138kV Transformer	North Madison 345/138 kV transformer	500	109.1	105	Change rating to 625 NMVA
North Madison ABS	North Madison-Waunakee (33914-39819)	290	108.8	104	Install larger conductor or operate at higher temperature
Waunakee-West Port	Waunakee-Waunakee Muni (38162-39816)	72	102.4	102	Terminal Upgrade
	Pheasant Branch-Westport (38673-38675	49	110.6	111	
North Madison-Waunakee	Sycamore-Blount (39841-39864)	185	103	118	Change rating to 254 MVA
Royster-Sycamore	Femrite 138/69 kV transformer	100	105	107	Change rating to 125 MVA
Kegonsa-Christiana CKT 1	Kegonsa-Christian (39122-39218)	455	96.2		Change rating to 478 MVA
Columbia-North Madison 345kV KT 2	Columbia-North Madison 345 kV	597	96.5	99	Terminal upgrades will be completed before 2012

Table 9a: Impact of Reinforcements on Scenario 10-12
Multiple Circuits
(Voltages and System Data)

Reinforcement	Sub. Scenario	System Losses MW	Voltage					Load MW	Gen MW	Import MW	Voltage Stability Limit MW
			Normal		Worst Contingency						
			Average Voltage %	Gen VAR's Utilized %	Contingency	Average Voltage %	Gen VAR's Utilized %				
1. Rockdale-West Middleton 34 5kV circuit 2. N. Madison-Waunakee-Blount 138kV circuit via Waunakee	12c-12 • East Campus to Wingra circuit with 5 ohm series inductor • 2nd Femrite Auto	388	97.81	61.91	N. Madison-Waunakee	96.55 94<5<95 Thermal ok	78.05	900	354	561	1040 Rockdale-W Middleton
1. North Madison-West Middleton 345 kV Circuit 2. N. Madison-Waunakee-Blount 138kV circuit via Waunakee	13b-12	392	97.70	65.39	N. Madison-W. Middleton 345kV	96.44 93<11<95 Thermal ok	80.98	900	356	561	1035 N. Madison-W. Middleton 345kV
1. North Madison-Waunakee-Blount 138 kV Circuit 2. N. Madison-Walnut-Blount 138kV circuit	11c-12 • East Campus to Wingra circuit with 5 ohm series inductor	400	96.54	67.60	N. Madison-Waunakee	95.10 92<15<94 See Thermal	83.80	900	359	561	1015 N. Madison-Waunakee

Table 9b: Impact of Reinforcements on Scenario 10-12
Multiple Circuits
(Thermal Violations)

Contingency	Critical Element	Rating	% Load Scenario 11c-12	Comments
N. Madison 345/138 kV Transformer CKT1	N. Madison 345/138 kV Transformer CKT2	500	102.9	Change rating to 625 MVA
North Madison-ABS	North Madison-Waunakee (33914-39189)	290	**99.3**	Operate conductor at higher temperature or install larger conductor
	Pheasant Branch-Westport (38673-38675)	49	**99.1**	Terminal Upgrades
East Campus-Walnut CKT2	East Campus-Walnut CKT1	103.5	98.4	May require another circuit
Royster-Sycamore	Femrite 138/69 KV Transformer	100	116.2	Change rating to 125 MVA
Femrite 138/69 kV Transformer	Royster-Sycamore (38676-39851)	81	111.6	Line rebuild or 2nd Auto at Femrite
	Gateway-Sycamore (38679-39851)	81	113.6	

Table 10: Impact of Reinforcements on Scenario 40-12
Multiple Circuits
(Voltages and System Data)

Reinforcement	Sub. Scenario	System Losses MW	Voltage					Load MW	Gen MW	Import MW	Voltage Stability Limit MW
			Normal		Worst Contingency						
			Average Voltage %	Gen VAR's Utilized %	Contingency	Average Voltage %	Gen VAR's Utilized %				
1. Rockdale-West Middleton 34 5kV circuit 2. N. Madison-Waunakee-Blount 138kV circuit via Waunakee	42c-12 • 2nd Femrite Auto • East Campus to Wingra circuit with 5 ohm series inductor	381	98.66	54.40	Rockdale-W. Middleton	97.54 95<10<96 Thermal ok	70.18	900	452	461	1090 Rockdale-West Middleton
1. North Madison-West Middleton 345 kV Circuit 2. N. Madison-Waunakee-Blount 138kV circuit via Waunakee	43b-12 • 2nd Femrite Auto • East Campus to Wingra circuit with 5 ohm series inductor	385	98.46	56.87	N. Madison-W. Middleton	97.43 95<10<96 Thermal Ok	71.85	900	454	461	1085 N. Madison-W. Middleton
1. North Madison-Waunakee-Blount 138 kV Circuit 2. N. Madison-Walnut-Blount 138kV circuit	41c-12 • 2nd Femrite Auto • East Campus to Wingra circuit with 5 ohm series inductor	392	97.63	60.65	N. Madison-Waunakee	96.33 94<7<95 Thermal ok	76.25	900	456	461	1067 Madison-Waunakee

APPENDIX A

Table 11 Performances of Base Scenarios

(Voltages And System Data)

Scenario	Sub. Scenario	Voltage						Load MW	Gen MW	Import MW	Voltage Stability Limit MW
		Normal			Worst Contingency						
		Losses MW	Average Voltage %	Gen VARs Utilized %	Contingency	Average Voltage %	Gen VARs Utilized %				
Scenario 0-09 • Base • West campus Unit OFF		360	97.41	65.05	N. Madison-ABS	94.60 92<23<94 Thermal ok	87.87	840	327	530	920
Scenario 30-09 • Base • West campus Unit OFF • Decrease generation and Increase import by 50 MW	This is would be the worse scenario	365	96.72	76.96	N. Madison-ABS	93.29 91<14<92 Thermal ok	94.98	840	277	581	895
Scenario10-09 • Base • West Campus Units ON • Reduce existing units by 150 MW	The impact of generator location	362	97.68	62.63	N. Madison-ABS	95.75 93<16<95 Thermal ok	87.45	840	322	535	945
Scenario 20-09 • Base • West Campus Units ON • Reduce imports by 150 MW	This would be the best but may not be realistic	351	98.71	49.91	N. Madison-ABS	97.74 96<12<97 Thermal ok	63.74	840	469	384	1010
Scenario 40-09 • Base • West Campus Units ON • Reduce imports by 100 MW • Reduce existing units by 50 MW		355	98.33	56	N. Madison-ABS	97.23 96<4<97 Thermal ok	71.76	840	420	435	985

APPENDIX A (continue):

The following five base case were developed for year 2009 to study a range of generation and import scenarios:

Scenario 0-09: Base model with West Campus units turned OFF

Scenario 10-09: Base model with West Campus Units turned ON but equivalent amount of generation is turned OFF in the Madison area.

Scenario 20-09: Base model with West Campus Units turned ON but net imports reduced by 150 MW.

Scenario 30-09: Base model with west campus units turned OFF and 50 MW increase in imports to further stress the base case.

Scenario 40-09: Base model with West Campus Units turned ON but output of the existing units is reduced by 50 MWs and net imports reduced by 100 MW.