CATS - HV

2016 Transmission Study

Impacts of Ten-Year Plan Transmission Projects and Sensitivity to Local Load Growth

For
Central Arizona Transmission System – High Voltage
"CATS HV"
A sub-committee of SWAT

August 13, 2007

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SWAT
Southwest Area Transmission

K. R. Saline & Associates, PLC

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San Carlos Irrigation Project
Santa Cruz Water and Power District Association (Electrical Districts 3, 4, and 5 of Pinal County)
Southwest Transmission Cooperative
Tucson Electric Power Company
Western Area Power Administration

EXECUTIVE SUMMARY

In 2005-2006 the CATS-HV subcommittee completed a saturated load study to identify what the total electric load between Phoenix and Tucson could ultimately be if land development occurs according to county and municipal General Plans in the region. The saturated load study provides the framework for future transmission development based on projected loads at the time the saturation study was conducted. This development plan is likely to change, so while the “satellite” view of the study region is valuable to identify the long-range plan, it is appropriate to follow up such a study with work that identifies the nearer term transmission needs. The addition of transmission and substations ought to be consistent with the long range plan as long as the growth develops similar to the long-range plans.

In 2007, the CATS HV subcommittee studied the CATS HV transmission system for the year 2016 to investigate:

- The performance of the coordinated 2016 Ten-Year Plans for the study area,
- The potential local system impacts of delayed, cancelled, or initially out of service high voltage (HV) and extra high voltage (EHV) planned projects in the state of Arizona, and
- The ability of the planned CATS HV system to accommodate local load growth beyond that forecast for 2016.

The Ten-Year Plan analysis found there were no voltage or thermal issues in the coordinated SWAT base case under pre and post outage conditions.

The second portion of this study investigated the impact of delayed, cancelled or initially out of service HV and EHV planned projects on the Pinal County transmission system. This Planned Project N-1-1 analysis removed the planned project (and in some cases re-instated the original configuration) and then performed a traditional single contingency outage analysis on the modified system. The effect of individual Arizona planned Ten Year Plan projects not being in service by 2016 could adversely impact the performance of the transmission system outside the study region. However, such project outages did not result in any significant thermal loading or voltage violations for the CATS HV area except as noted below:.

- The “Project Outage” analysis generally exhibited the same voltage deviation issues as noted in the Ten-Year Plan analysis,
- Without the TS5-TS1 230 kV line Project (“APS02”) voltage deviations exceeding 5% occur at Browning, SEV, Santa Rosa, and Pinal West 500 kV substations for subsequent outage conditions,
- Without the Raceway-Pinnacle Peak 500 kV line Project (“APS06”) the Coolidge-Sundance 230 kV circuit reaches 99% of its emergency rating for loss of its parallel circuit, and
- Without the Pinal South-Southeast Valley 500 kV line Project (“SRP06”) the Coolidge-Sundance 230 kV line could reach its 415MVA emergency rating for an outage of its parallel circuit.

The third component of this study increased the load in the study area in 100 MW increments above the level modeled in the 2016 base case. Two equally sized equivalent generators were also modeled external to the CATS HV system at Palo Verde and Tortolita 500 kV substations to support the increased load. These two resources are not indicative of any generation expansion planned at either location. Voltage deviations of greater than 5% occurred for local single contingency outages with as little as 100 MW of additional load at 115 kV and 230 kV busses in the CATS HV study area. The first thermal violation occurred with 200 MW of load added to the study system. The voltage and thermal violations occurred on the Western 115 kV system that has been slated for upgrade to 230 kV in the future. An addendum to the Final Report will be issued that will document the effects of improvements associated with the Western re-conductoring of their study area system. Since the Western system has planned upgrades, the incremental load increases were continued to determine at what load level a non-Western element would experience a thermal or voltage criteria violation. No additional thermal or voltage issues were noted in the study area through 800MW of additional load.

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A map of the CATS HV study area is depicted on the next page.

STUDY ASSUMPTIONS

The following sections identify the assumptions used in performing this study. The 2016 analysis started with a 2016 SWAT case coordinated among Arizona entities. A 2015 Heavy Summer WECC base case was modified by Arizona entities to incorporate 2016 loads and resources and recently planned subregional EHV transmission facilities. The case was further modified to meet the needs of the CATS HV analysis including:

- Addition of existing and planned local high voltage (HV) transmission elements,
- Refinements of load models with actual HV substations, and
- Addition of reactive support as required.

TRANSMISSION AND GENERATION CONFIGURATIONS

The coordinated 2016 base case was reviewed by Arizona entities and included the companies' ten year plan elements that would be in service by 2016. A few note-worthy transmission and generation items include:

Elements of Interest

- Southeast Valley, "SEV", 500kV line (Pinal West to Browning) was included.
- Bowie Power Station was excluded from this study. The only significant generation capacity in Arizona remaining available for dispatch was hydro facilities at Glen Canyon and Hoover.[1]
- The Frontier Project, TransWest Express, SunZia Southwest and other EHV injections (transmission) into the state of Arizona were not included in this transmission configuration.[2]
- Arizona Generation: 30,997 MW
- Arizona Load: 24,819 MW

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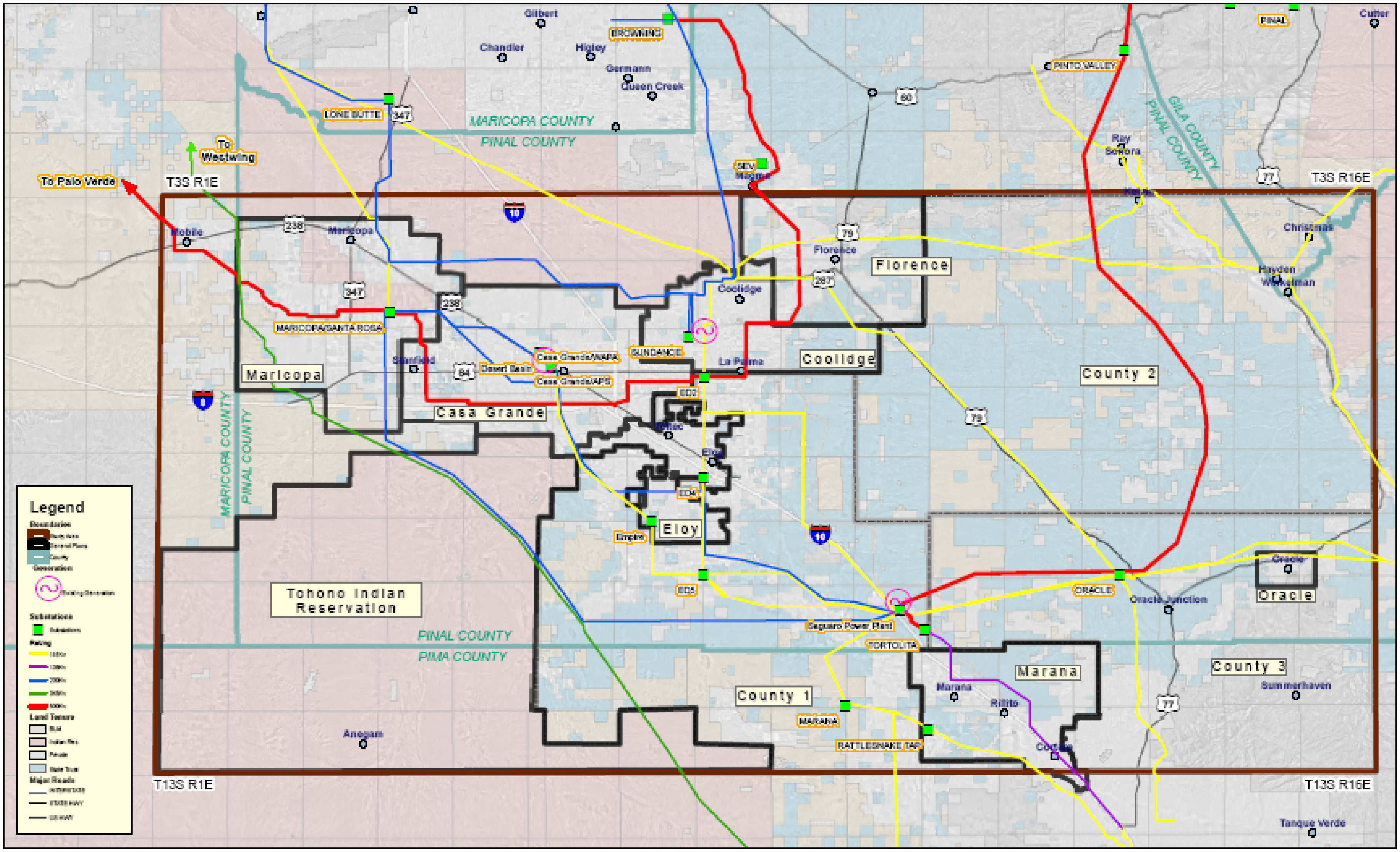
[1] Bowie Power Station was not modeled in the WECC base case and was not available for dispatch. Note that the hydro facilities are fully committed; the fact that there was generation capacity available at these units indicates a low-hydro scenario where units may not be available.

[2] These EHV transmission injections to Arizona, at the time of the study, were not sufficiently defined to be included with this study effort.



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CATS-HV SATURATED LOAD STUDY
PHASE ONE - EXISTING SYSTEM

DISCLAIMER:
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does not warrant the accuracy or location of the facilities shown.
Print Date: 12.30.05

Elements added/changed for CATS HV Analysis:

- Added Sundance-Pinal South 230kV line
- ED3 load increased by approximately 200MW to match 2016 “medium” load forecast
- Moved ED3 loads to the Maricopa 69kV bus and eliminated the 69kV ED3 system (it was an outdated model)
- Added the second Santa Rosa-Maricopa 230/69kV transformer
- Decreased Arizona interchange with LADWP in order to accommodate 200MW of generation at the Palo Verde hub for the increased load in ED3
- Synchronous generator at Adelanto to assist in reactive support for outages
- Corrected a WECC case error for the transmission configuration out of Navajo
- Added reactive support at Buckeye substation.
- Added a 25MVAR shunt at the Thornton 115kV buss to assist with voltage issues in the base case

New Arizona Generation:

The following table highlights generation proposed in Arizona, some that were in the power flow case, and others that were not. Additional generation was added for this study at Palo Verde and Tortolita (not representing any particular project) for the load growth cases since existing or future resources modeled for this timeframe were already fully committed.

Project	Interconnection	Modeled?	Dispatched?
Bowie Power Station	Winchester	No	No
Desert Rock Power Plant	Four Corners	Yes	Yes, 1400MW
Springerville Unit 4	Springerville	Yes	Yes, 430MW
San Luis	North Gila	No	No
New gen @ Palo Verde	Palo Verde	Yes	Yes, for load growth scenarios only
New gen @ Tortolita	Tortolita/Winchester	Yes	Yes, for load growth scenarios only

Arizona Ten Year Planned Projects in the case:

The following table lists the Ten Year Planned Facilities provided to the Arizona Corporation Commission and indicates what transmission is planned in the next ten years. Note that while some transmission projects are included in the ten year plan they have an in-service date listed as “to be determined” and may not be modeled in the power flow case. A project that is modeled in the base case would have a “yes” in the “modeled in base case” column. The status column indicates whether the project was in service (active) or not in service (inactive) for the study.

Owner / Line	Modeled in base case	Status
WAPA		
Casa Grande/Empire/Coolidge 230 kV	No	N/A
Gold Mine Tap/Blythe/Buck 230 kV	No	N/A
Blythe/Parker 230 kV	No	N/A

TEP		
Westwing/Pinal West 345kV	Yes	Active
Pinal West/South 345kV	Yes	Active
Pinal South/Tortolita 500kV	Yes	Active
Saguaro/Tortolita #2	Yes	Active
Tortolita/East Loop 345kV	Yes	Active

SWTC		
Naviska/Saguaro 115kV	Yes	Active
Apache-Hayden/San Manuel 115 kV	Yes	Active
Valencia/CAP Black Mountain 115 kV	Yes	Active
Valenica/San Joaquin 115 kV	Yes	Active
Sandario/San Joaquin 115 kV	Yes	Active
Naviska/Thornydale 115kV	Yes	Active
Thornydale/Picture Rocks 115kV	Yes	Active
Picture Rocks/CAP Twin Peaks 115 kV	Yes	Active
Sandario/CAP Brawley 115kV	Yes	Active
Marana/Avra Valley 115 kV	Yes	Active
Avra Valley-Three Points/Sandario 115 kV	Yes	Active
Pantano/ San Rafael 230kV	Yes	Active

APS		
Rudd-TS4/Palm Valley 230 kV	Yes	Active
Coronado-Cholla/2nd Knoll 500 kV	Yes	Active
WAPA Flagstaff 345 to Flagstaff 69 kV	Yes	Active
Navajo-Westwing/VV1 500 kV	Yes	Active
Harquahala Junction/TS5 500 kV	Yes	Active
TS5/TS1 230 kV	Yes	Active
Raceway/Avery 230 kV	Yes	Active
Pinnacle Peak/TS6/Avery 230 kV	Yes	Active
Palm Valley/TS2/TS1 230 kV	Yes	Active
VV1-Westwing/Raceway 500kV	Yes	Active
Raceway 500/Raceway 230 kV	Yes	Active
TS4-Panda/Jojoba 230 kV	Yes	Active
Cholla-Pinnacle Peak/Mazatzal 345 kV	Yes	Active
North Gila/TS8 230 kV	Yes	Active
TS5/Raceway 500 kV	Yes	Active
Hassayampa/North Gila #2 500 kV	Yes	Active
Sundance/Pinal South 230kV	Yes	Active
Yucca/TS8 230 kV	Yes	Inactive
Westwing/El Sol 230 kV	Yes	Inactive
Westwing/Raceway #2 230 kV	Yes	Inactive
Santa Rosa/Pinal South 230 kV	No	N/A
Palo Verde/Saguaro 500 kV	No	N/A

SRP		
Anderson/Orme 230 kV	Yes	Active
Orme/Rudd 230 kV	Yes	Active
Hassayampa/Pinal West 500 kV	Yes	Active
Pinal West/ Santa Rosa 500 kV	Yes	Active
Santa Rosa/Pinal South 500kV	Yes	Active
Pinal South/SES 500kV	Yes	Active
SES/Browning 500kV	Yes	Acitve
Browning/Dinosaur 230kv	Yes	Active
Desert Basin/Pinal South 230kV	Yes	Acitve
Dinosaur/RS21 230 kV	Yes	Active

Rogers/Browning 230 kV	No	N/A
Silver King/Browning 230 kV	No	N/A
Pinnacle Peak/Brandow 230 kV	No	N/A
Rogers/Corbell 230 kV	No	N/A
Knoll/New Hayden 230 kV	No	N/A
Kearny-Hayden/New Hayden 115 kV	No	N/A
Silver King-Browning/Superior 230 kV	No	N/A

OUTAGE LIST OF PLANNED PROJECTS

The goal of the "Project Outage" analysis was to determine the possible effect on the transmission system if one of the planned projects either does not get built as planned, or is delayed beyond the study timeframe. The designated projects were assumed to not be in service and single contingency outages were simulated. This analysis is more strenuous than normal NERC required N-1-1 analysis. The Project Outages listed below consist of a family of transmission elements planned primarily by Arizona entities as a transmission project. The list of Project Outages was developed from Ten Year Plans filed with the Arizona Corporation Commission.

Case Code	Outage (date anticipated in service)
APS01	Harquahala Junction (Palo Verde)-TS5 500kV line (2009)
APS02	TS5-TS1 230kV line (2009)
APS03	Raceway-Avery 230kV line (2009)
APS04	Pinnacle Peak-TS6-Avery 230kV line (2010)
APS05	Palm Valley-TS2-TS1 230kV line (2010)
APS06	Raceway-Pinnacle Peak 500kV line (2010)
APS07	Raceway 500kV to 230kV transformer (2010)
APS08	TS5-Raceway 500kV line (2012)
APS09	Hassayampa-North Gila 500kV ckt 2 (2012)
APS10	Desert Basin-Pinal South 230kV line (2011)[3]
APS11	Pinal South – Sundance 230kV line (2011)
SRP01	Anderson - Orme 230kV line (2007)
SRP02	Orme-Rudd & Rudd-Liberty,(aka Rudd loop-in Liberty-Orme) 230kV line (2007)
SRP03b	Pinal West - Southeast Valley-Browning 500kV line (2011) and Desert Basin-Pinal South230kV, Pinal South-Sundance 230kV, and Pinal South-Tortolita 500kV,
SRP04	Hassayampa - Pinal West 500kV line (2008)
SRP05	Second Knoll-Cholla, Second Knoll-Coronado 500kV line (2009)
SRP06	Pinal South - Southeast Valley 500kV line (2011)
SRP07	Dinosaur-Browning 230kV line (2007)
TEP01	Pinal West 500/345kV transformer (2008)
TEP02	Pinal South-Tortolita 500kV line (2011)

INCREMENTAL INCREASES IN LOCAL LOAD

In the third component of this study the CATS HV study area load was increased in increments of 100 MW. The incremental load increase studied ranged between 100 MW and 800 MW. The load that was added was assumed to have a unity power factor, or no reactive (var) load. The incremental 100 MW

[3] The APS Ten Year Plan lists Desert Basin-Pinal South 230kV line, however the line is an SRP-managed project. To avoid duplication, the project was only listed as an APS project.

blocks of increased load were assigned study-wide proportionate to each participant's load in the base model. Each of the participants provided a load allocation factor for their existing load serving substations. The load allocation factor was a percentage of 100 MW that should be assigned to each of their substations in the study region. As an example, if 100 MW was added to the study system and a participant had 30% of the study area load, then 30 MW would be distributed across that participant's loads based on the substation allocation factor provided by the participant. The load allocation factors for incrementally increasing the local load are documented in Appendix D.

POWER FLOW RESULTS

The following sections highlight the findings of the power flow modeling of the base case. The results discussed identify voltage issues greater than 5% voltage deviation and element loadings exceeding 100% of the element's continuous rating for normal operation (rating 1) and emergency rating (rating 2) for contingency simulations.

TEN YEAR PLAN ANALYSIS

The base case used for this analysis displayed overloads external to the CATS HV study area prior to and following an element outage. These external system overloads, while important to note for this analysis, will be addressed by the respective transmission owner(s) during their detailed planning processes and/or through other coordinated study efforts.

Similarly, under outage conditions, substations external to the study region violated the 5% voltage deviation criteria. The substations external to the study region with voltage deviation violations, will be addressed by the respective transmission owner(s) during other detailed planning/study processes. A 25MVAR shunt at Thornton 115kV substation mitigated the local voltage deviations noted in an initial analysis of the base case and was therefore modeled in the updated Base Case and all subsequent Incremental Load Analysis cases.

PLANNED PROJECT OUTAGE (N-1-1) ANALYSIS

In general, the planned project outage cases indicated that delay or elimination of the various projects would have minimal impact on the CATS HV study region. While the delay of many of the Projects do not result in local thermal loading or voltage violations, their delay could impact the reliability of the CATS HV study area. These findings do not imply the projects are not needed as many of these projects are for load serving capability and reliability needs external to the CATS HV study area. There were a couple of project outage scenarios, when combined with a standard contingency run, that resulted in voltage deviations and thermal loadings that should be noted.

APS TS5-TS1 230 kV project (APS02)

A delay of the APS TS5-TS1 230 kV project (APS02) and outages could result in voltage deviations slightly greater than 5% at the Southeast Valley (SEV), Santa Rosa, and Pinal West 500 kV stations for loss of Jojoba-Kyrene line. Similarly, loss of the Santa Rosa 500/230 kV transformer without the APS TS5-TS1 230 kV project (APS02) could result in a 5% voltage deviation at the Santa Rosa 500 kV substation.

Raceway-Pinnacle Peak 500 kV (APS06) and Pinal South - SEV 500 kV line (SRP06)

Both of these projects, showed during the project outage analysis that a delay of the project (ie the project not in service) combined with an outage of one Coolidge-Sundance 230kV line, caused a 99-100% loading of the remaining parallel circuit.

SRP Pinal West-Southeast Valley-Browning 500kV project without Pinal South (SRP03B)

A delay in the SRP Pinal West-Southeast Valley-Browning 500kV project (SRP03) would likely result in the delay of three other projects associated with Pinal South which is part of the SEV project. The three other projects that would also likely be delayed without the SEV project include: Pinal South – Desert Basin 230 kV, Pinal South – Sundance 230 kV, and the Pinal South – Tortolita 500 kV projects. Without these projects voltage issues, both limit and deviations, occur in the local study area primarily on Westerns 115kV system. In addition, load serving issues are likely to exist in the Browning 230kV area

Unsolved Project Outages under Contingencies

Several of the project outage cases indicate a divergence problem without the project and an outage of the Jojoba-Kyrene 500kV, Palo Verde-Rudd 500kV, or Cholla-Saguaro 500kV lines. The outage of these elements is a known issue under current system operations and is being addressed by the utilities in their own planning forums. The result of studies by the utilities has resulted in the development of these Ten Year Projects, so the result of divergence without the planned projects to fix current operating limitations is no surprise. Consequently, the delay or cancellation of these planned projects will result in a system similar to what is operated in 2007 resulting in known system limitations. The divergence problems with the outages is mainly attributable to the lack of reactive support. The diverged cases were tested with the addition of 400 to 600 MVAR of reactive support and all outages solved.

INCREMENTAL LOAD ANALYSIS

The increased load cases tested the addition of load in 100 MW increments (with a unity power factor) in the study region until 800MW of load was added. The generation used to offset the increased load was dispatched equally from simulated generation modeled at Palo Verde and Tortolita substations.

The additional load, from 100 MW to 800 MW, did not have an impact on voltage or thermal loadings under normal operating conditions. Under contingency conditions, however, the first violation occurred with only 100 MW of additional load. The violation was a voltage deviation of greater than 5% at the Casa Grande 115 kV, Casa Grande 230 kV bus, and the Thornton 115 kV bus (despite the addition of a 25 MVAR shunt capacitor at the Thornton substation that mitigated voltage deviation in the Ten Year Plan Analysis). Assuming the voltage violations can be mitigated with capacitor banks, the next violation occurred on ED5-Empire 115 kV (101%) line at 200 MW of incremental load and an outage of the Test Track-Casa Grande 230 kV line or Casa Grande 230/115 kV transformer.

Western has plans to upgrade the 115 kV system to 230 kV in the future. Such line improvements should mitigate the thermal and voltage issues found in this incremental load growth simulation. These upgrades will be modeled and tested prior to the next CATSHV study cycle. An addendum to this report will be issued covering these results.

The following tables highlight the results of the incremental load analysis.

No Outage (N-0) Thermal Results

There were no base case or incremental load growth base case overloads in the study area. However, the table below shows some EHV line loadings approaching their continuous rating limit. The table indicates the incremental load increases in the CATS HV study area had little to no effect on these EHV lines.

FR-Name	KV	TO-Name	KV	CK	Rtg 1	Contingency Description	CASE 16Base	LG100	LG200	LG300	LG400	LG500	LG600	LG700	LG800
VAIL2	345	VAIL	138	1	672	Base system (n-0)	97%	97%	97%	97%	97%	97%	97%	97%	97%
CHOLLA	500	SAGUARO	500	1	889	Base system (n-0)	98%	97%	97%	97%	97%	96%	96%	96%	96%
SPRINGR	345	VAIL2	345	1	717	Base system (n-0)	100%	100%	100%	100%	100%	100%	100%	100%	100%
GREEN-SW	345	GREEN-SW	230	1	150	Base system (n-0)	97%	97%	97%	97%	98%	98%	98%	98%	98%

Single Contingency (N-1) Thermal Results

The thermal overloads significant to the study area are presented in the table below. There were no overloads for the Base or Load Growth 100 MW (LG100) cases. When the study area load is increased by more than 100 MW several local 115 kV lines begin experiencing a loading in excessive of their rated capacity for an assortment of single contingency outages. The ED5B-Empire 115 kV line first experienced a thermal violation with 200 MW of load added to the study system. The Thornton-Empire 115 kV line first experienced an overload with 500 MW of load added to the area. The Casa Grande – Thornton 115 kV line experienced an overload with 700 MW added to the system. These thermal violations occurred on the Western 115 kV system that has been slated for upgrade to 230 kV in the future.

FR-Name	KV	TO-Name	KV	CK	Rtg 2	Contingency Description	CASE 16Base	LG100	LG200	LG300	LG400	LG500	LG600	LG700	LG800
ED-5B	115	EMPIRE	115	1	110	Line TESTTRAK 230.0 to CASAGRND 230.0 Circuit 1	84%	93%	102%	111%	120%	130%	141%	152%	165%
						Tran CASAGRND 230.00 to CASAGRND 115.00 Circuit 1	84%	93%	102%	111%	120%	130%	140%	152%	165%
						Line CASAGRND 115.0 to THORNTON 115.0 Circuit 1	50%	58%					96%	104%	113%
THORNTON	115	EMPIRE	115	1	110	Line TESTTRAK 230.0 to CASAGRND 230.0 Circuit 1	69%	78%			97%	104%	111%	119%	129%
						Tran CASAGRND 230.00 to CASAGRND 115.00 Circuit 1	69%	78%			97%	104%	111%	119%	129%
CASAGRND	115	THORNTON	115	1	110	Line SAG.WEST 115.0 to ED-5B 115.0 Circuit 1	50%	58%						102%	109%
						Line ED-5B 115.0 to EMPIRE 115.0 Circuit 1	50%	58%						102%	109%
SAG.WEST	115	ED-5B	115	1	188	Line TESTTRAK 230.0 to CASAGRND 230.0 Circuit 1	50%	54%							96%
						Tran CASAGRND 230.00 to CASAGRND 115.00 Circuit 1	50%	54%							96%

Single Contingency (N1) Voltage Results

The table below shows the voltage deviation violations for each of the load growth simulation cases. Clearly, the studied system is more voltage limited than thermal limited as evidenced by voltage problems occurring at only 100 MW of additional load. Both the voltage deviation (Delta V) and voltage (in per unit) following the contingency (Vcont) are shown.

					CASE		
Name	**kV**	**Outage**	**Contingency Description**	**Data**	**16Base**	**LG100**	**LG200**
CASAGRND	115	line_21	Line TESTTRAK 230.0 to CASAGRND 230.0 Circuit 1	_DeltaV		-0.052	-0.063
				_Vcont		0.961	0.949
		tran_560	Tran CASAGRND 230.00 to CASAGRND 115.00 Circuit 1	_DeltaV		-0.052	-0.063
				_Vcont		0.961	0.949
	230	line_21	Line TESTTRAK 230.0 to CASAGRND 230.0 Circuit 1	_DeltaV			-0.06
				_Vcont			0.949
EMPIRE	115	line_21	Line TESTTRAK 230.0 to CASAGRND 230.0 Circuit 1	_DeltaV			
				_Vcont			
		tran_560	Tran CASAGRND 230.00 to CASAGRND 115.00 Circuit 1	_DeltaV			
				_Vcont			
THORNTON	115	line_21	Line TESTTRAK 230.0 to CASAGRND 230.0 Circuit 1	_DeltaV		-0.051	-0.062
				_Vcont		0.964	0.951
		tran_560	Tran CASAGRND 230.00 to CASAGRND 115.00 Circuit 1	_DeltaV		-0.05	-0.062
				_Vcont		0.964	0.951
ED-5B	115	line_21	Line TESTTRAK 230.0 to CASAGRND 230.0 Circuit 1	_DeltaV			
				_Vcont			
		tran_560	Tran CASAGRND 230.00 to CASAGRND 115.00 Circuit 1	_DeltaV			
				_Vcont			

Even with the inclusion of a 25 MVAR capacitor at the Thornton 115 kV bus there were voltage deviations greater than 5% due to outages and post outage voltages below 0.95 pu. Outage analysis showed that Thornton and Casa Grande 115 kV busses experience voltage violations with the addition of only 100 MW of load (with a unity power factor).

NEXT STEPS

The next steps following the completion of this study include determination of local transmission planning requirements through 2018 and an evaluation of the CATS HV system with the potential development of generation resources locally. The additional load growth and limitations found on the existing system (thermal or voltage violations)in the 2016 study may also be mitigated by the addition of local resources. The study plan for 2009 will include studies related to FERC 890 requirements (including additional N-1-1 and extreme contingency analysis). This will assure the most current transmission analysis is available for the next ACC Biennial Transmission Analysis.