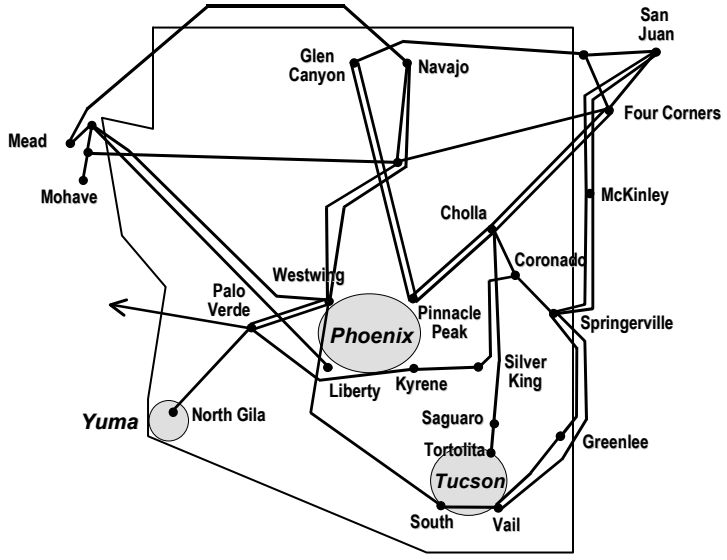
Central Arizona Transmission System (CATS)
Phase I

I. Introduction

Historically, Arizona's EHV transmission system has been developed to interconnect large generating resources to major load centers primarily located in the Phoenix and Tucson metropolitan areas. With the exception of Palo Verde, the resultant transmission development within Arizona was located in the northeastern and northwestern portions of the state (Figure 1). And, while the resultant transmission development interconnected these generation facilities with their consumers located in the Phoenix and Tucson areas, they also provided stronger ties to neighboring states such as California, New Mexico, Colorado, and Utah. In the early stages of developing the transmission system for the Palo Verde generation facility, consideration was given to building a 500kV line from Palo Verde to the Tucson area. However, the final Palo Verde transmission system design moved towards strengthening EHV transmission interconnection in the Phoenix area, resulting in the construction of the second Palo Verde-Westwing 500kV line. This left development of future EHV transmission ties between the Phoenix and Tucson areas for future consideration.

Figure 1
Arizona EHV Transmission



Over the last ten years Arizona has experienced significant increases in business and residential growth in the Phoenix and Tucson areas. As Arizona's electric utility industry continues a breakneck pace to keep up the increasing growth and demand, resource developers vie for opportunities to site and build new generation to access market opportunities in the Arizona and California areas. Under these newer growth scenarios, Arizona's EHV system capability continues to experience higher flows and denser utilization. As projected growth continues to outstrip the ability of the Phoenix and Tucson transmission system's ability to deliver needed energy to their respective areas, new generation proposals are seeking to tap all existing transmission capability to achieve access to as many markets possible. Due to the attractiveness of the Palo Verde switchyard as a market hub, existing gas pipeline capability, and the existing Phoenix and Tucson growth markets, much of the proposed generation, in excess of 10,000 MW, is being sited in the CATS study area, within the central Arizona region between Palo Verde, Phoenix, and Tucson.

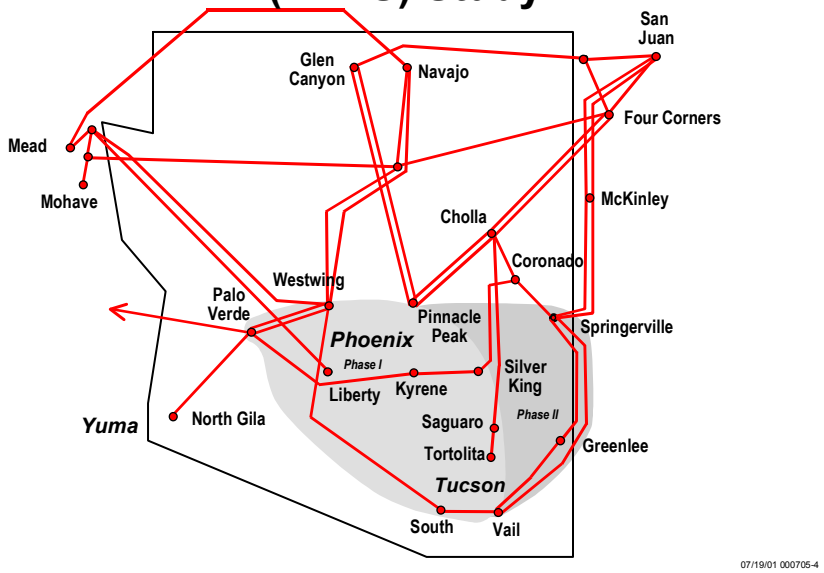
Unfortunately, EHV transmission is limited in this area and local utilities are struggling to keep pace with their near term transmission infrastructure requirements to accommodate the expected growth in customer load while posturing themselves to tap the pool of proposed resource additions that are being proposed.. Others are looking at opportunities to use proposed CATS transmission alternatives to facilitate siting of their generation in a manner that would stimulate economical and reliable transmission service from their facility to existing and future energy markets. Early discussion of these transmission needs occurred between Salt River Project (SRP), Arizona Public Service (APS), and Tucson Electric Power (TEP). In principle, the utilities agreed that a regional transmission planning effort was needed to assess EHV transmission needs and opportunities in the central Arizona area.

From this discussion, the Central Arizona Transmission System (CATS) study effort was proposed. The primary participants were to include all of Arizona's transmission utilities including Arizona Public Service, Salt River Project, Tucson Electric Company, Arizona Electric Power Cooperative, Citizens Communications Company, Western Area Power Administration, and the Arizona Corporation Commission Staff. Recognizing the need to involve all stakeholders in the process, an invitation letter was sent to SWRTA (Southwest Regional Transmission Association) members and other interested parties. Consequently several other utilities, independent power producers, and other interested parties are actively participating in the CATS effort.

The central Arizona region for the (CATS) study encompasses an area

bounded by the Phoenix Metropolitan area to the north, the Tucson Metropolitan area to the south, the Palo Verde Generating Station and environs to the west and to the east the Arizona/New Mexico border. This area includes Coolidge, Casa Grande, Eloy, Marana, Florence, Maricopa as well as the major metropolitan areas of Phoenix and Tucson. A map of the study area is shown in the highlighted areas on Figure 2.

Figure 2
Central Arizona Transmission System (CATS) Study



The study participants held an initial meeting in March 2000 to evaluate the conceptual aspects of a proposed regional study for the central Arizona area. A kick-off meeting was held in June 2000 to formalize the study, develop study objectives and criteria, create organizational structure, and allocate resources to meet the scope of work and schedule. This report documents the results of the Phase I CATS study effort.

II. Conclusions

Based on the results of this study, the following is concluded.

1. Building new transmission in the CATS area will increase transfers between Phoenix and Tucson.
2. While single alternates can provide benefits to individual participants, more synergies are derived to achieve more regional benefits by combining alternates.
3. SRP will derive more benefits from a new transmission alternative between Palo Verde and the Southeast Valley (Southeast Station).
    a. Phoenix load serving capability
    b. Interfacing with the “Build out of Browning”

4. Tucson will derive more benefits from a transmission alternative between Palo Verde – Saguaro – South and Palo Verde – Saguaro - Winchester.
5. AEPCO will derive more benefits from a transmission alternative between Palo Verde – Saguaro – Winchester.
6. The system performance of the Palo Verde – Saguaro and the Gila Bend – Saguaro alternatives is nearly the same. However, the recent establishment of new National Monuments in southeastern Arizona creates uncertainty about being able to build the Gila Bend – Saguaro alternative.
7. The availability of gas in the Saguaro/Southeast Valley area coupled with the proposed CATS transmission alternatives to these areas should enhance the siting of new generation in the Saguaro/Southeast Valley area.
8. Developing new generation in the Saguaro/Southeast Valley area will improve the efficiency of all the transmission alternatives studied and increase the load serving capability to Phoenix and Tucson.
9. Strengthening the interconnection between the Cholla/Saguaro and/or the Coronado/Silverking transmission system to the east of the Phoenix system will enhances exports from Palo Verde to Phoenix.
10. Developing new interconnections to the transmission system east of Tucson enhances exports from Palo Verde to Tucson.
11. Opportunities to tie Winchester to the Southeast Valley may improve the capability of the Springerville south system
12. The Alternatives chosen to advance to Phase II will have to be analyzed in regards to Tucson's Two-County flow requirements.

III. Recommendations

Based on the conclusions of this study, the following is recommended.

1. Continue the CATS study work.
2. Perform phase II of CATS study to assess and quantify the components of CATS that the participants want to initially build.
3. Phase II studies should quantify the regional benefits of the following transmission alternatives:
   a. Jojoba – Southeast Station 500kV line
   b. Jojoba – Saguaro 500kV line
   c. Southeast Station or Saguaro – Winchester 500kV line
4. Individual CATS participants evaluate and develop underlying system requirements needed to integrate the proposed 500kV alternatives into their respective systems.
5. Quantify the regional benefits of strengthening the interconnection between the Cholla/Saguaro and/or the Coronado/Silverking transmission system to the east of the Phoenix system.
6. Facilitate discussions among CATS participants to develop the preferred transmission alternatives.

7. Initiate joint discussions among the CATS participants to begin developing principles for jointly developing a preferred CATS transmission alternative.

IV. Study Objectives and Scope

The objectives of the CATS study are listed below

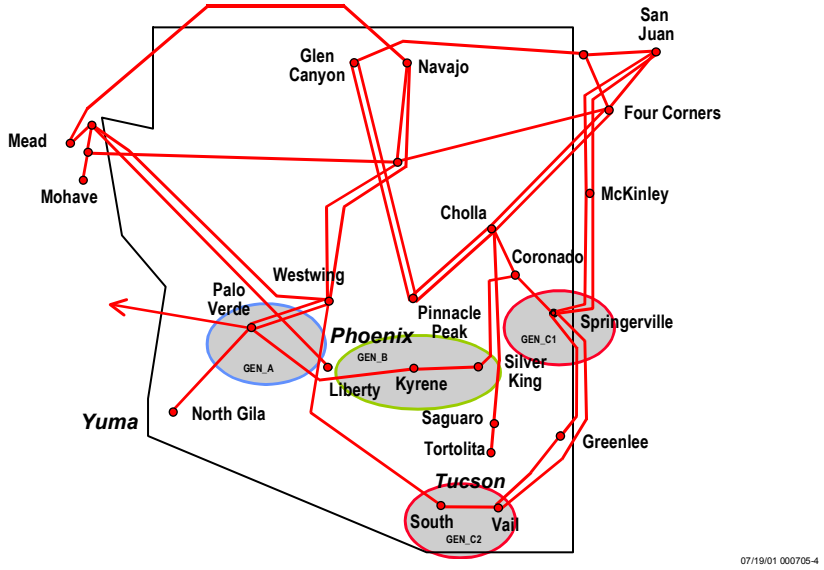
- Improve the use of the existing transmission system for future load growth in Phoenix and southern Arizona.
- Increase the power transfer import level into the Phoenix area.
- Increase the power transfer import level into the Tucson area.
- Increase the power transfer capability between the Phoenix and Tucson areas.
- Encourage future generation additions south of Phoenix and north of Tucson.
- Provide additional transmission capacity to and from the Palo Verde hub

The scope of the study work was limited to a power flow analysis of all transmission alternatives and generations dispatch scenarios for N-0 and N-1 disturbances. Transient stability and post-transient analysis will be performed in the next phase of the study.

V. Study Assumptions

One of the early objectives of the study was to develop transmission alternatives that would meet the needs of the study participants. Due to the regional planning nature of the study, it was recognized that several transmission alternatives would be required to address the needs of all the participants. In addition, the development of new generation resources on the CATS study area also suggested that different dispatch scenarios would also be required to fully assess the system performance of the transmission alternatives. For example, generation sited in the Palo Verde area would most likely benefit the Phoenix area system more than the Tucson area system. Conversely, generation sited in the Saguaro area would most likely benefit the Tucson area system more than the Phoenix area system. For this reason, the assessment of the transmission alternatives was split based on three different generation areas. These areas are shown on Figure 3.

Figure 3
Central Arizona Transmission System (CATS) Generation Study Areas



As can be seen from Figure 3, there are four generation areas that were considered in the study. Due to its geographical distance apart from the Palo Verde, Phoenix, and Tucson areas, analysis was not performed using the Springerville generation area (GEN C1).
Based on input received from the CATS study members, six transmission paths were determined to be of significant interest to the study members. These paths are listed below.

- Palo Verde to Saguaro 500kV Line (4 different variations).
- Palo Verde to Southwest Phoenix Valley 500kV Line (2 different variations)
- Use of Westwing to South 345kV Line (2 different variations)
- 500kV Line to the Southeast Phoenix Valley (1 variations)
- Loop-In of the Cholla to Saguaro 500kV Line into Silverking (2 different variations)
- Saguaro to Tucson Area at 500kV, 345kV or 230kV (4 different variations)

As can be seen from the above list, numerous transmission variations were developed and considered for study. As a result of discussion and evaluation, the CATS study group reduced the number of study alternatives to the seven listed below. Salt River Project studied the first four alternatives, situated in central Arizona, while the last three alternatives, situated in southern Arizona, were studied by Tucson Electric Company. General one-lines of the study alternatives are included the Appendix section of this report.

Central Arizona Alternatives

Alternative 1: Palo Verde to Gila Bend 500kV Line
Gila Bend to Saguaro 500kV Line
Loop-In of the Cholla to Saguaro 500kV Line into Silverking
Alternative 2: Palo Verde to Saguaro 500kV Line
Loop-in of the Cholla to Saguaro 500kV Line into Silverking
Alternative 4:Palo Verde to Jojoba 500kV Line
Jojoba to Mobile 500kV Line
Mobile to Saguaro 500kV Line
Mobile to Southwest Valley 500kV Line
Westwing to Southwest Valley 345kV Line
Mobile to South 345kV Line
Mobile to Santa Rosa 230kV Line
Loop-in of the Cholla to Saguaro 500kV Line into Silverking
Alternative 5:Palo Verde to Mobile 500kV Line
Mobile to Saguaro 500kV Line
Mobile to Southeast Valley 500kV Line
Loop-in of the Cholla to Saguaro 500kV Line into Silverking
Loop-in of the Cholla to Saguaro 500kV Line into Hayden

Southern Arizona Alternatives

Alternative 6: Westwing to South #2 345kV Line
Alternative 7: Palo Verde to Saguaro 500kV Line
Tortolita 500kV/345kV Transformer
Tortolita to South 345kV Line
Alternative 8: Palo Verde to Saguaro 500kV Line
Winchester 500kV/345kV/230kV Station
Saguaro to Winchester 500kV Line
Tie-in of existing Greenlee to Vail 345kV line at Winchester
Winchester to Apache 230kV Line

It should also be noted that the scope of this study was to focus on the high voltage transmission system. No attempt was made to address local area transmission problems or issues.

VI. Methodology

The intent of the (CATS) study was to provide a framework for the participating entities to plan and coordinate transmission lines and bulk power stations located within the study area boundaries. Phase 1 of the study was a screening effort that evaluated a group of transmission alternatives under a broad range of generation patterns to determine how the resultant system performance could meet the objectives of the study. The strengths and weaknesses of the transmission alternatives were evaluated and observed. This work was used to narrow down the transmission options that merit further study in the second phase of the study effort.

Power flow studies were performed to assess the system performance of each of the proposed transmission alternatives for each of the generation dispatch patterns studied. The assessment was performed by raising generation in the generation area being studied and increasing load in the load area being studied until a facility limit is reached. For example, increasing generation in the Palo Verde area and increasing load in the Phoenix area assessed the system performance of the Central Arizona Alternatives.

There were three major load centers identified for this study. These load centers consisted of the Phoenix area load, Tucson area load, and Southern Arizona area load. The Phoenix area load consisted of (55%) SRP Valley Load and (45%)APS Valley Load while the Southern Arizona area load consisted of (80%) TEP Load and (20%) AEPCO Load.
In addition, the study areas were broken down into four separate study areas. The following is a breakdown of the four areas and the responsible participant.

- Schedule new Generation from the Palo Verde area (Group A. Generation) into the Phoenix area (SRP).
- Schedule new Generation from the Coolidge area (Group B. Generation) into the Phoenix area (WAPA).
- Schedule new Generation from Tucson (Group C. Generation), Springer Ville (Group C. Generation) and Palo Verde (Group A. Generation) into the Tucson area (TEP).
- Schedule new Generation from the Palo Verde area (Group A. Generation) to the Colorado/New Mexico area. (APS).

Power flow studies were performed using the General Electric Positive Sequence Load Flow (GE PSLF) program. The Western Systems Coordinating Council (WSCC) 2002 LS1 case was selected for use in this study. All CATS base cases were developed from this case. Study participants added all planned facilities from 2002 to 2005 for Arizona to the CATS base cases. Load was modeled at 90% of the forecasted 2005 summer peak load. All Transmission Alternatives were identified and modeled by study participants in the CATS base case with an out-of-service status.

Study performance standards were based on WSCC Reliability Criteria for Transmission System Planning and individual utility ratings for facilities. All study simulations were evaluated with all facilities in service (N-0) and under single contingency conditions (N-1).

VII. Summary of Technical Results

Arizona Public Service

Arizona Public Service reviewed the effects of delivering new generation from the Palo Verde area into the New Mexico-Colorado area. This review included studying the effects of Transmission Alternatives 1 and 5.

Load

The load in the New Mexico – Colorado area was split in a 45%/55% ratio, Colorado having the greater load. APS maintained the load ratio throughout the study. APS grew the load evenly throughout the affected zones. In addition, generation in the subject area was reduced to arrive at the final results.

Benchmark

Two benchmarks were defined, one at which a system component reached overload for N-0 condition, and one for which an N-1 condition resulted in overload. The benchmarks were determined by simultaneously increasing load and/or decreasing generation in the New Mexico-Colorado area while increasing generation in the Palo Verde area. Area interchange schedules were correspondingly adjusted. Although the Palo Verde area provided the increased generation to fulfill the interchange schedule requirements, the Four Corners, Cholla, Springerville, and Coronado stations actually supplied the growing demand in the Colorado-New Mexico areas.

In either case, the Four Corners 500/345 transformer was the limiting equipment. Overload of the transformer for N-0 occurred at 4260MW transfer from Arizona into Colorado-New Mexico area. At an N-1 condition, overload of the transformer occurred at 3890 MW. The Kyrene-Jojoba line outage resulted in the highest overload of the transformer.

Study Results

Of the various transmission alternatives, APS studied Alternatives 1 and 5, based on input from SRP, and
the fact that the alternatives were not intended to promote transfer capability east into Colorado and New Mexico. From the base case, at 4260MW transfer, the Four Corners 500/345 transformer overloaded at 101%. With a Kyrene-Jojoba outage, the overload increased to 112.6% of rating.

With the addition of Alternative 1, the Four Corners transformer loading

reduced to 94.7% of rating for N-0 condition. The loading also dropped to 102.4% of rating, at a transfer of 4260MW with the Kyrene-Jojoba outage. It should be noted for one of the Cholla 500/345 transformers out of service, the remaining Cholla 500/345 overloads to 109.8% of rating.

Alternative 5 slightly improved the loading of the Four Corners transformer to 93.6% of rating for N-0 condition at 4260MW transfer. For N-1, with the Kyrene-Jojoba line out of service, the loading is only 100.6%. Alternative 5 provides approximately 370MW additional transfer capability into the Colorado-New Mexico area for the worst case N-1 condition. Again, as with Alternative 1, a Cholla 500/345 outage causes the associated Cholla transformer to overload significantly more, at 113.5%.

Conclusions

Alternative 5 allows slightly greater transfer capability from Arizona into New Mexico and Colorado by relieving the loading on the Four Corners 500/345 transformer. This slight improvement is probably negligible considering that it is unforeseeable that such a large amount of generation would be redirected East into New Mexico and Colorado. Therefore, this portion of the analysis of the CATS study does not provide much weight in selecting an Alternative.

Salt River Project

The Salt River Project (SRP) studied the Transmission Alternatives associated with delivering new Palo Verde Generation into the Phoenix area.

Load

There were three major load centers studied. These load centers consisted of the following areas:

- Phoenix area load.
- Tucson area load.
- Southern Arizona area.

SRP was assigned to study the load in the Phoenix area. The Phoenix area load was defined as being 45% APS Valley Load and 55% SRP Valley Load. The load in Phoenix was adjusted base on this APS/SRP 45%/55% break down.

Voltage Devices

System voltages could not be maintained during the load-growing process with existing voltage control facilities. This resulted in bus voltages below the scheduled voltage and in some cases the power flow would not converge. To mitigate the problem, several fictitious static var compensator devices (SVD) were added to the SRP/APS system. The SVDs were added to the Kyrene 230kV, Estrella 230kV, Pinnical Peak 230kV, Agua Fria 230kV and the Santan 230kV buses. These SVDs were sized to provide sufficient vars to support the scheduled bus voltages in the base case for pre contingency conditions. The SVDs were locked down for post-contingency runs.

Benchmark

In order to measure what was gained by adding a transmission alternative to the base case, a benchmark was established. This benchmark was defined as being the amount of load and generation, which can be added to the base case system, without over-loading the Central Arizona 500kV system, for a (N-1) condition.

The load in the Phoenix area and the (Group A) generation were simultaneously raised until an (N -1) over-load condition was reached. The

load was increased by approximately (5000MW). An outage of the Palo Verde to Estrella 500kV Line caused the Kyrene to Jojoba 500kV Line to load to approximately (110%) of its emergency rating. Extrapolating this value back to (100%) yield approximately (4342MW) load increase.

Transmission Alternatives

There were various transmission options reviewed by the CATS study participants. These transmission options were grouped and studied as follows:

Alternative 1: Palo Verde to Gila Bend 500kV Line
Gila Bend to Saguaro 500kV Line
Loop-In of the Cholla to Saguaro 500kV Line into Silver King

Alternative 2: Palo Verde to Saguaro 500kV Line
Loop-in of the Cholla to Saguaro 500kV Line into Silver King

Alternative 4: Palo Verde to Jojoba 500kV Line
Jojoba to Mobile 500kV Line
Mobile to Saguaro 500kV Line
Mobile to Southwest Valley 500kV Line
Westwing to Southwest Valley 345kV Line
Mobile to South 345kV Line
Mobile to Santa Rosa 230kV Line
Loop-in of the Cholla to Saguaro 500kV Line into Silver King

Alternative 5: Palo Verde to Mobile 500kV Line
Mobile to Saguaro 500kV Line
Mobile to Southeast Valley 500kV Line
Loop-in of the Cholla to Saguaro 500kV Line into Silver King
Loop-in of the Cholla to Saguaro 500kV Line into Hayden

Each one of these four transmission alternatives was studied to determine how much more load and generation could be grown above the benchmark case.

Study Results

1. Alternative 1

The immediate result of applying Alternative 1, showed a decrease in the percent loading of the Kyrene to Jojoba 500kV Line from 110% to 89% for a Palo Verde to Estrella 500kV Line outage. The additions of the Palo Verde to Gila Bend 500kV Line, Gila Bend to Saguaro 500kV Line and the Loop-In of the Cholla to Saguaro 500kV Line into Silver

King, reduced the flows on the Kyrene to Jojoba 500kV Line and the Palo Verde to Estrella 500kV Line. The Loop-in of the Cholla to Saguaro 500kV Line into Silver King increased the flows from Silver King to Browning 500kV Line and from Browning to Kyrene 500kV Line.

With the added transmission of Alternative 1, the load and generation could be increased to approximately (5500MW) before the first (N-1) overload occurred. With the increased flows on the Browning to Silver King 500kV Line, this Line now has become the critical path. An outage of the Browning to Silver King 500kV Line causes the Kyrene to Jojoba 500kV Line to load to 100% of its emergency rating.

The increase in load from the (4342MW) benchmark case to the (5500MW) level with Alternative 1 was an increase of (1158MW).

2. Alternative 2

The immediate result of applying Alternative 2 showed a decrease in the percent loading of the Kyrene to Jojoba 500kV Line from 110% to 93% for a Palo Verde to Estrella 500kV Line outage. The additions of the Palo Verde to Saguaro 500kV Line and the Loop-in of the Cholla to Saguaro 500kV Line into Silver King, reduced the flows on the Kyrene to Jojoba 500kV Line and the Palo Verde to Estrella 500kV Line. The Loop-in of the Cholla to Saguaro 500kV Line into Silver King increased the flows on the Silver King to Browning 500kV Line and on the Browning to Kyrene 500kV Line.

With the added transmission of Alternative 2 the load and generation was increased to approximately (5500MW) before the first (n-1) overload occurred. With increased flows on the Browning to Silver King 500kV Line, this Line now has become the critical path. An outage of the Browning to Silver King 500kV Line causes the Kyrene to Jojoba 500kV Line to load to 102% of its emergency rating.

The increase in load from the (4342MW) benchmark case to the (5500MW) level with Alternative 2 was an increase of (1158MW). Extrapolating the (102%) value back to (100%) yield approximately (5375MW) an increase of approximately (1033MW).

3. Alternative 4

Applying Alternative 4 to the benchmark case showed a very small change in line flows. The Loop-in of the Cholla to Saguaro 500kV Line into Silver King caused an increase in flows on the Silver King to Browning 500kV Line and on the Browning to Kyrene 500kV Line. With

this increase in flow the Browning to Silver King 500kV Line becomes the critical path. At the 5000MW increase the loss of the Browning to Silver King 500kV Line causes the Kyrene to Jojoba 500kV Line to load to 99% of it's emergency rating.

With the added transmission of Alternative 4 the load and generation could not be increased beyond the (5000MW) level. The increase in load from the (4342MW) benchmark case to the (5000MW) level with Alternative 4 was an increase of (638MW).

4. Alternative 5

The immediate result of applying Alternative 5 showed a decrease in the percent loading of the Kyrene to Jojoba 500kV Line from 110% to 89% for a Palo Verde to Estrella 500kV Line outage. The additions of the Palo Verde to Mobile 500kV Line, Mobile to Saguaro 500kV Line, Mobile to Southeast Valley 500kV Line and the Loop-in of the Cholla to Saguaro 500kV Line into Silver King, reduces the flows on the Kyrene to Jojoba 500kV Line and the Palo Verde to Estrella 500kV Line. The Loop-in of the Cholla to Saguaro 500kV Line into Silver King increases the flows from Silver King to Browning 500kV Line and from Browning to Kyrene 500kV Line.

With the added transmission of Alternative 5, the load and generation was increased to approximately (5500MW) before the first (N-1) overload occurred. With increased flows on the Browning to Silver King 500kV Line, this Line now has become the critical path. An outage of the Browning to Silver King 500kV Line causes the Kyrene to Jojoba 500kV Line to load to 99% of its emergency rating.

The increase in load from the (4342MW) benchmark case to the (5500MW) level with Alternative 5 was an increase of (1158MW).

Sensitivities

In comparing the results of the four Alternatives, Alternative 1 and Alternative 5 out performed the other two Alternatives. The power flow results of Alternative 1 and Alternative 5 were very similar. The major difference between Alternative 1 and Alternative 5 is a 500kV Line from the Palo Verde area into the Southeast Valley (Mobile to Hayden 500kV Line).

In reviewing the power flow results for Alternative 5 the flow on the Mobile to Hayden 500kV Line was very small. In order to utilize this line, additional 230kV lines out of Hayden to Browning and Hayden to Silver

King would be required.

A sensitivity was run to determine how Alternative 1 and Alternative 5 would perform with 230kV Lines between Hayden, Silver King and Browning. A portion of the Santan load was also moved over to Browning to represent the build out of the Browning station.

1. Alternative 1

   With the addition 230kV Lines added to Alternative 1 the load and generation was increased to approximately (5685MW) before the first (N-1) overload occurred.

   The increase in load from the (4342MW) benchmark case to the (5685MW) level with Alternative 1 was an increase of (1343MW).

2. Alternative 5

   With the addition 230kV Lines added to Alternative 5 the load and generation was increased to approximately (6100MW) before the first (N-1) overload occurred.

   The increase in load from the (4342MW) benchmark case to the (6100MW) level with Alternative 1 was an increase of (1758MW).

A second sensitivity was run to determine how well Transmission Alternative 5 would perform with additional generation added in the Southeast Valley. 2000MW of generation was moved from the Palo Verde (Group A) generation to the Southeast Valley (Hayden/Coolidge/Florence).

Relocating 2000MW of generation to the Southeast Valley reduced the flows on the Palo Verde to Estrella 500kV Line and on the Kyrene to Jojoba 500kV Line. The percent loading of the Kyrene to Jojoba 500kV Line decreased from (100%) to (88%) for a Palo Verde to Estrella 500kV Line outage.

With the addition of generation in the Southeast Valley and the addition of 230kV Lines in the Southeast Valley to Alternative 5 the load and generation was increased to approximately (7500MW) before the first (N-1) overload occurred. The increase in load from the (4342MW) benchmark case to the (7500MW) level was an increase of (3158MW).

Conclusions

1. In analyzing the power flow results and comparing each transmission alternative to the benchmark case, Alternative 1,2 and 5 perform the best in delivering the Palo Verde area generation to the Phoenix Load center.

2. Looping-in the Cholla to Saguaro 500kV Line into Silver King with the adding a 500kV Line from the Palo Verde Hub to Saguaro reduces the loading on the critical Paths (Kyrene to Jojoba 500kV and Palo Verde to Estrella 500kV) into the Phoenix area.

3. Looping in the Cholla to Saguaro 500kV Line into Silver King increased the flows on the Silver King to Browning 500kV Line and the Browining to Kyrene 500kV Line. This increase in flow overloads the underlying 230kV system for certain (N-1) outages. The 230kV Lines out of Silver King and the Kyrene 500/230kV transformers were loaded beyond their emergency limits, for certain (N-1) outages. The underlying system problems can be addressed by adding an additional 500kV transformer at Kyrene and upgrading or building new 230kV Lines out of Silver King and building out the Browining Station.

4. Alternative 5 with generation in the Southeast Valley and additional 230kV in the Southeast Valley performs the best of all Alternatives when serving the Phoenix Valley load.

5. All four of the Transmission Alternatives will require some kind of 230kV system upgrades.

Tucson Electric Power

Tucson Electric Power (TEP) studied the Transmission Alternatives and associated with delivering additional generation from the Palo Verde area into the Tucson/AEPCO area, with input from AEPCO.

Load

Load was initially established in the CATS base case as 90% of forecasted 2005 summer peak. This results in a load split of approximately 80% for TEP and 20% for AEPCO. Load was then increased maintaining these proportions to evaluate the different alternatives. The original load power factors were retained throughout. As part of the base case assumptions, a 500 MW transfer to CFE from the TEP system was also modeled.

Voltage Devices

System voltages could not be maintained during the load-growing process with existing voltage control facilities. This resulted in power flow non-convergence in several instances. To mitigate the problem, several fictitious static var compensator devices (SVD) were added to the TEP/AEPCO system. For TEP, the SVDs were added at Northeast Loop, Rillito, East Loop, South Loop, and Vail 138kV stations and on the Vail 2 345kV bus. For AEPCO, a SVD was added at Morenci 230kV and in some instances at Butterfield 230kV. These SVDs were amply sized to provide sufficient var support and they were modeled with continuous, automatic control – both pre- and post-contingency.

Underlying Systems

Many 138/115 kV load-serving transformers and some 138/115 kV lines were overloaded as a result of the load increases implemented in evaluating the transfer capabilities of the Alternatives. These overloads imply that the 138/115 kV infrastructure must be improved on the respective Tucson and AEPCO systems in order to fully utilize the potential benefits of the Alternatives. This is outside the scope of CATS and will be addressed separately.

Benchmark

In order to measure what was gained by adding a transmission alternative to the base case, a benchmark was established. This benchmark was defined as being the amount of load and generation, which can be added to the base case system, without over-loading the Southern Arizona system, for an N -1 condition.

The load in the Southern Arizona area and the (Group A) generation were simultaneously raised until an N -1 overload condition was reached. A branch was considered overloaded if its flow exceeded its emergency rating. This occurred at a load of approximately 900 MW above the base case level. The limiting element was the Springerville to Vail 345 kV line. Loss of Springerville to Greenlee 345 kV line caused the Springerville to Vail 345 kV line to load to 100% of its emergency rating.

Transmission Alternatives

There were various transmission options reviewed by the CATS study participants for the Southern Arizona Area. These transmission options were grouped and studied as follows:

Alternative 6: Westwing to South #2 345kV Line

Alternative 7: Palo Verde to Saguaro 500kV Line
Tortolita 500kV/345kV Transformer
Tortolita to South 345kV Line

Alternative 7a: Palo Verde to Saguaro 500kV Line
Saguaro to Tortolita 500kV Line (3rd circuit)
Tortolita 500kV/345kV Transformer
Tortolita to South 345kV Line

Alternative 8: Palo Verde to Saguaro 500kV Line
Winchester 500kV/345kV/230kV Station
Saguaro to Winchester 500kV Line
Tie-in of existing Greenlee to Vail 345kV Line at Winchester
Winchester to Apache 230kV Line

Alternative 8a: Palo Verde to Saguaro 500kV Line
Winchester 500kV/345kV/230kV Station
Saguaro to Winchester 500kV Line
Tie-in of existing Greenlee to Vail 345kV Line at Winchester
Additional 345kV circuit from Winchester to Vail
Winchester to Apache 230kV Line

Each one of these transmission alternatives was studied to determine how much more load and generation could be grown above the benchmark case.

Study Results:

1. Alternative 6

   With the added transmission of Alternative 6, the load and generation could be increased approximately (1400MW) above the base case loading before the first (N-1) overload occurred. The limiting element was the Springerville to Vail 345kV line with the corresponding outage being the Springerville to Greenlee 345kV line.

   The delta increase, (1400MW) – (900MW), resulted in a net increase of (500 MW) with Alternative_6 in service.

2. Alternative 7

   With the added transmission of Alternative 7, the load and generation could be increased approximately (1250MW) above the base case loading before the first (N-1) overload occurred. The limiting element was a Saguaro to Tortolita 500kV line with the corresponding outage

being the other Saguaro to Tortolita 500kV line.

The delta increase, (1250MW) – (900MW), resulted in a net increase of (350MW) with Alternative 7 in service.

3. Alternative 7a

   The apparent worth of Alternative 7 seems minimal due to the restrictive capacity of the two Saguaro to Tortolita 500kV lines. Therefore, Alternative 7 was modified so that the South to Tortolita line ultimately terminated at Saguaro instead of Tortolita. This modification consisted of a third circuit from Saguaro to Tortolita instead of a direct connection bypassing Tortolita. The former is more reliable and is certainly feasible since Saguaro and Tortolita are only 1 mile apart.

   With the inclusion of Alternative 7a, the load and generation could be increased approximately (1700MW) above the base case loading before the first (N-1) overload occurred. The limiting element was the Springerville to Vail 345kV line with the corresponding outage being the Springerville to Greenlee 345kV line.

   The delta increase, (1700MW) – (900MW), resulted in a net increase of (800MW) with Alternative 7a in service.

4. Alternative 8

   With the added transmission of Alternative 8, the load and generation could be increased approximately (1100MW) above the base case loading before the first (N-1) overload occurred. The limiting element was the Apache to Butterfield 230kV line with the corresponding outage being the Winchester to Vail 345kV line.

   The delta increase, (1100MW) – (900MW), resulted in a net increase of (200MW) with Alternative 8 in service.

5. Alternative 8a

   The apparent worth of Alternative 8 seems minimal even though significant EHV transmission was added. This has to do with the fact that Alternative 8 is not a completely separate alternative. It is tied into the existing Greenlee – Vail 345 kV via the Winchester station.

   First, with all lines in service, the Winchester – Vail 345kV line overloads with its series comp element in service. This is due to the fact that additional 500kV and 230kV sources are tied into Winchester as well as the existing 345kV source from Greenlee. Therefore, the

series comp was removed from service for studies with Alternative 8 in service.

Second, loss of the Winchester to Vail 345kV line not only eliminates contributions from the new line segments associated with Alternative 8, but it also eliminates contributions from the previously existing Greenlee – Vail 345kV line. This severely limits the effectiveness of Alternative 8.

Consequently, Alternative 8 was modified by adding an additional Winchester to Vail 345kV line segment. With the addition of Alternative 8a, the load and generation could be increased approximately (1800MW) above the base case loading before the first (N-1) overload occurred. The limiting element was the Springerville to Vail 345kV line with the corresponding outage being the Springerville to Greenlee 345kV line.

The delta increase, (1800MW) – (900MW), resulted in a net increase of (900MW) with Alternative 8 in service.

Sensitivities

TEP plans to expand its Springerville generation station to four units from two – effectively doubling the capacity. It is still uncertain, however, exactly how the additional generation will be dispatched. There is the potential for this additional generation to have an impact on the existing transmission system as well as the alternatives.

TEP is still analyzing what additional transmission may be needed to accommodate the additional Springerville generation. For purposes of this sensitivity, the following additional transmission is assumed:

1) Springerville – Greenlee #2
2) Springerville – Coronado #2
3) Additional 500/345 kV transformer at Coronado
4) 35% series comp in the Coronado-Silver King 500kV line
5) Cholla – Saguaro 500kV line tied in to the Silver King 500 kV station.

Alternatives 6, 7a, and 8a, were examined with the Springerville transmission and assuming the extra Springerville generation was dispatched (67%) to the Phoenix area and (33%) to AEPCO at Morenci. Again, this particular dispatch scenario is only an estimate for study purposes. The actual dispatch could be different. The transfer capabilities of the alternatives, as previously measured, were decreased as follows:

1) Alternative 6 200 MW decrease
2) Alternative 7a 200 MW decrease
3) Alternative 8a 50 MW decrease

Note these values are decreases in the transfer capability of additional generation from the Palo Verde area. Approximately 250 MW is being transferred from Springerville to the Morenci (AEPCO) area in the sensitivites. Therefore, even though a reduction in the transfer capacity from the Palo Verde area occurred, there was an overall increase into the Tucson/AEPCO systems.

More investigation needs to be performed in this area once dispatch scenarios and generation related transmission facilities are finalized.

Conclusions

Power flow analysis, using an (N-1), emergency overload criteria, indicates that Options 7a and 8a are the most beneficial projects to bring in power from the Palo Verde area to the Tucson/AEPCO area.

The underlying 138/115 kV systems for Tucson and AEPCO will have to be improved in order to fully utilize the capacity import improvements the Alternatives provide.

Note: The Alternatives chosen to advance to Phase II will have to be analyzed in regards to Tucson's Two-County flow requirements.