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Smart Solutions, Real Results

Navajo Generating Station Southwest Regional Reliability Study Report

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TABLE OF CONTENTS

Figure Index

Table Index

QUANTA TECHNOLOGY
Smart Solutions, Real Results

EXECUTIVE SUMMARY

The Navajo Generating Station (NGS) is the centerpiece of Arizona's power and water system. The plant was sanctioned by the U.S. Congress and built to provide electricity for the Central Arizona Project (CAP), which pumps water through a 335-mile canal system to Phoenix, Tucson and other communities. NGS provides power to nearly 3 million customers in the U.S. Southwest and over 90 percent of the power for the CAP. The plant is located on Navajo lands near Page, Arizona, and was built to operate 70 years through 2044.

NGS has been a reliable and stable power supply resource in Western U.S. power markets, providing 2,250 MW of low-cost energy production and contributing to stability and resiliency of the electric grid. With relatively low and stable fuel costs due to the close proximity of the coal mine providing its fuel, NGS historically has operated at a high capacity factor and has been a competitive baseload power plant with low variable operating costs.

Quanta Technology, LLC ("Quanta") was retained by Peabody to complete an independent study looking at the impacts of the potential retirement of NGS on reliability in the Southwest region of the United States, and more specifically the state of Arizona. The objective of this study was to determine whether premature retirement of NGS in 2019 could result in grid operational issues or instigate potential vulnerabilities in the regional power supply.

The power flow model used in this study for the thermal and voltage analysis was based on the FERC 715 WECC 2020 model year. Quanta used data obtained from Western Electricity Coordinating Council (WECC), WestConnect, and Peabody in completing the study. Additionally, Quanta obtained the 2020 WECC stability model to perform the transient stability analysis, which simulates disturbances to the electric grid.

Quanta performed a reliability assessment, assuming that NGS is retired after 2019, investigating the thermal, voltage, and transient stability implications. The study considered standard transmission planning criteria, as commonly used throughout the North American Electric Reliability Corporation (NERC) critical infrastructure protection analysis, and certain unique Arizona scenarios as follows:

- Single Outage in the System (N-1 Analysis)
- Two Simultaneous Outages in the System (N-1-1 Analysis)
- Substation Outage Analysis (Impact on the NERC CIP-014 Physical Security Standard)
- Loss of Palo Verde Nuclear Station (Loss of ~4,100 MW of Generation)
- Loss of the El Paso Natural Gas Pipeline (Loss of ~6,825 MW of Generation)
- Loss of the Trans-Western Gas Pipeline (Loss of ~6,180 MW of Generation)

Key Study Findings

All three of the unique Arizona scenarios analyzed as separate events including loss of the Palo Verde Nuclear Station, the El Paso Natural Gas Pipeline and the Trans-Western Gas Pipeline were found to stress the Arizona electric grid with unacceptable overloads. Unacceptable overloads are indicative of potential violations to operating criteria that serve as guidelines for reliable grid operation.

These material impacts could potentially include damage to equipment, extended hours of power outage in the region and obstacles to daily activities. The most severe disruptions were in Phoenix, Flagstaff, Scottsdale, Vail (Pima county), Tucson and Raso, while materially impacting the neighboring state of California, in particular the cities of Lugo (Los Angeles county) and Shandon (San Luis Obispo county).

Without NGS in operation, these conditions led to power deficiencies which could evolve into potential voltage collapse and outages, load shedding triggers, potential rotating brownouts, failing transformers or transmission lines and equipment damage.

Conversely, with NGS in service, reliability of the electric grid was maintained under all of the unique scenarios. System overloads and potential outages were no longer observed.

Quanta further found that Arizona system performance under select contingencies without NGS is more reliant on generation in neighboring state of California, including generation in Los Angeles Department of Water and Power (LADWP) and Southern California Edison (SCE). This behavior was observed as a change in inter-regional power transfer.

Potential mitigation measures to address thermal and voltage issues include constructing new transmission lines and new generation systems. However, these options require new capital, long lead times, and potential permitting challenges. None of these are ideal near-term solutions.

Quanta's findings from its NGS retirement analysis showed there are potential reliability concerns that should be considered as the generation resource mix changes in Arizona and the Desert Southwest. As the region contemplates retiring baseload coal-fueled generating units, these decisions could limit options for the future. Consideration must be given to the potential reliability risks associated with the loss of inertia and dynamic reactive capability that has been traditionally supplied by these power plants.

Further, Quanta's assessment and findings are aligned with the Southwest Area Transmission (SWAT) Coal Reduction Assessment performed in August 2014. SWAT performed an assessment to evaluate the impact of a reduction in area coal capacity of approximately 25% (~2,500 MW) by 2019. The study was performed to identify potential reliability issues due to the loss of inertia and/or dynamic reactive capability associated with anticipated coal plant shutdowns and the potential limit to shutdowns that can be accepted by the grid before losing stability. Additionally, the investigation looks at the WECC path rating issues associated with the changing generation mix due to coal plant shutdowns.

It was observed that with higher coal reductions and renewables making up most of the generation mix within Arizona in future years, the bus voltages were unstable while significantly reducing system inertia and reactive power support in the region. Additionally, rotor angle oscillations were prominent resulting in generator trips and cascading failures in the system[1].

[1] https://www.wecc.biz/Administrative/140813_SWAT_CoalStudy_Presentation_R1.pdf

1 ABOUT QUANTA TECHNOLOGY

Quanta Technology is an expertise-based, independent technical consulting firm that helps electric utilities and other power industry companies by providing objective and practical solutions to their most complex transmission and distribution challenges. The company draws from a vast network of experienced power system experts from around the world, ensuring efficient, objective and credible outcomes for our clients. Our mission is to earn our clients' trust by enabling their success and providing value with the best technical and business consulting expertise in the industry.

As an independent consulting arm of Quanta Services, we are able to deliver end-to-end solutions that span the spectrum from business consulting, all the way through to engineering, procurement and construction. Quanta Technology, LLC is headquartered in Raleigh, NC with offices in Boston, MA; Chicago, IL; Oakland, CA; Escondido, CA; Toronto, Canada and Ecuador in South America.

We offer a full spectrum of services in the following areas:

- Transmission & Distribution
- Protection & Control
- Asset Operations
- Asset Management
- Enterprise Integration & Smart Grid Strategies
- Renewables Energy Integration, Storage & Microgrids
- Regulatory Compliance
- Optical Sensors
- Automation & Testing
- Synchrophasors & WAMPAC
- Applied Research & Development
- Workforce Training & Augmentation

Quanta Technology's client base is well established in North America and in numerous international markets. Our clients include energy delivery utility companies, large industrial companies, energy suppliers, Regional Transmission Operators (RTOs), Independent System Operators (ISOs), and energy industry research and support organizations.

Quanta Technology is a wholly owned subsidiary of Quanta Services, Inc. (NYSE: PWR). Quanta Services safely provides engineering, procurement and construction (EPC) services for comprehensive infrastructure needs in the electric power and oil and natural gas industries. With a workforce greater than 30,000 strong and offices throughout North America, Quanta Services is the premier provider in the industries it serves. As part of the Quanta Services family of companies, Quanta Technology has the manpower, resources, and expertise to complete projects that are local, regional, national, and/or international in scope.

About Quanta Services:

- The largest electric transmission and distribution specialty contractor in North America.
- Largest employer of certified electric power linemen in North America.
- The largest pipeline specialty contractor in North America.
- The owner of the largest specialized equipment fleet in the industry.
- Fortune 400 company with a strong balance and the financial resources for capital-intensive projects.
- Full service engineering, procurement and construction (EPC) service provider.
- An innovator of technologies and proprietary methodologies.

2 NAVAJO GENERATING STATION

NGS began operations in 1974, and is the largest coal-fired generating station operating in the WECC, with 2,250 megawatts (MW) of operating capacity.

The plant was initiated by the U.S. Department of the Interior in the late 1960s. The U.S. Department of the Interior, through the Bureau of Reclamation, holds a 24.3% ownership interest in NGS, and that capacity is used as an electricity source for operating the pumps of the Central Arizona Project, which delivers most of Arizona's share of water from the Colorado River to the central and southern parts of the state, including the Phoenix and Tucson areas.

Today, the participant make-up of NGS includes the following:

- U.S. Bureau of Reclamation – 24.3%
- Salt River Project (SRP) – 42.9%
- Arizona Public Service Company (APS) – 14.0%
- NV Energy – 11.3%
- Tucson Electric Power (TEP) – 7.5%

NGS is located on land that is leased from the Navajo Nation near Page, Arizona. An extension to the current lease agreement, structured to allow NGS to continue operation through 2019, with plant decommissioning after that date was executed in July 2017. In addition, several rights of way were issued by federal agencies for both the plant and additional facilities, including railroads, transmission lines, ash disposal areas, water from Lake Powell and more.

Because NGS is sited on tribal land, approvals for extended operation beyond 2019 must be obtained from the Bureau of Reclamation, the Bureau of Indian Affairs and other federal agencies.

3 RELIABILITY REVIEW OF NGS RETIREMENT – METHODOLOGY

3.1 Thermal and Voltage Analysis of NGS Retirement

Quanta used the WECC 2020 High Summer Peak FERC 715 model as the base case for the thermal and voltage review of the NGS retirement. The base case was updated to reflect approximately 4,000 MW of generation retirements, approximately 1,400 MW of new generation additions, transmission expansion plans of the major utilities in the southwest region of the United States, and the redispatch of generation from LADWP, SCE and AZ. The sources of data that Quanta used for the base case updates included WECC, Arizona Public Service Company, Public Service Company of New Mexico (PNM), Salt River Project (SRP), Tucson Electric Power (TEP), Ten West Link, and Peabody.

Quanta built two scenarios to study the system steady state performance (1) all three NGS units (2,250 MW) out of service, and (2) all three NGS units (750 MW each) generating at individual maximum capacity. Quanta then performed the following steady state contingency analyses to identify thermal and voltage violations created by the removal of NGS from the system as well as import capability:

- Single Outage in the System (N-1 Analysis)
- Two Simultaneous Outages in the System (N-1-1 Analysis)
- Substation Outage Analysis (Impact on the NERC CIP-014 Physical Security Standard)[2]
- Loss of Palo Verde Nuclear Station (Loss of ~4,100 MW of Generation)
- Loss of the El Paso Natural Gas Pipeline (Loss of ~6,825 MW of Generation)
- Loss of the Trans-Western Gas Pipeline (Loss of ~6,180 MW of Generation)

The study scope was performed with the starting assumption that NGS is retired after 2019 and considered standard transmission planning criteria, NERC critical infrastructure analysis and looked at the performance of the grid under certain unique Arizona scenarios with and without NGS.

3.2 Key Model Assumptions

3.2.1 Generator Retirements and Additions

Quanta relied on WECC documentation and market information provided by Peabody to develop the list below of generation retirements. The list of the generators exceeding 200 MW are included in the table below. This list does not include generation retirements already accounted for by the planning cases.

[2] The study did not comprise a CIP study. Potential impact of substation failure on BES security was reviewed.

Table 1 – 2020 Generation retirement (in addition to the ones already in base case)

Name	Sub Type	State	Area	Region	Category	Capacity (MW)	Retirement Year
Ormond_Beach_2	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	775	2020
MossLanding7	ST-NatGas	CA	CIPV	CA_CISO	Steam - Other	756	2020
MossLanding6	ST-NatGas	CA	CIPV	CA_CISO	Steam - Other	754	2020
Navajo_NAV1	ST-Coal	AZ	SRP	SW_SRP	Steam - Coal	750	2019
Ormond_Beach_1	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	741	2020
Centralia1	ST-Coal	WA	BPAT	NW_BPAT	Steam - Coal	688	2020
Boardman	ST-Coal	OR	PGE	NW_PGE	Steam - Coal	610	2020
RedondoBeach7	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	506	2020
Alamitos5	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	498	2020
RedondoBeach8	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	496	2020
Alamitos6	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	495	2020
Alamitos4	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	336	2020
Alamitos3	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	332	2020
SundanceAB1	ST-Coal	AB	AESO	AB_AESO	Steam - Coal	288	2019
SundanceAB2	ST-Coal	AB	AESO	AB_AESO	Steam - Coal	288	2019
HuntingtonBeach2	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	226	2020
HuntingtonBeach1	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	226	2020
Mandalay_2	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	215	2020
Mandalay_1	ST-NatGas	CA	CISC	CA_CISO	Steam - Other	215	2020

Retired generation was redispatched from the closest area sharing intertie with Desert Southwest (i.e., LADWP, SCE, and El Paso Electric). To compensate for retired capacity, Quanta included new generation projects that were under construction or had signed interconnection agreements with a projected in-service date within the study timeframe of 2020.

Below a listing of the generation additions included in the analysis.

Table 2 – 2020 Generation addition (in addition to the ones already in the base case)

Area	County	Type	Interconnection Location	Capacity (MW)
Desert South-west, WAPA	Riverside County, CA	Gas	Blythe Sub 161kV	539
Desert South-west, WAPA	San Bernardino County, CA	PV	Topock Substation 69 kV	120
SRP	Pinal, AZ	PV	Dinosaur - Hunt 69kV linE	48
APS	Maricopa County, AZ	PV	Komatke 69 kV Switchyard	20
APS	Maricopa County, AZ	Gas	Ocotillo 230kV Switchyard	595
APS	Navajo County, AZ	Solar PV	Conley Sub 69 kV	30
PNM	Cibola County, NM	Solar	BW 115 kV line near San Fidel	49.5
PNM	San Juan Cty, NM	Gas	San Juan Unit 5	175

3.2.2 Transmission Additions

Quanta reviewed the January 2017 10-year transmission plans submitted to the Arizona Corporation Commission by Arizona Public Service Company, PNM, Salt River Project, Tucson Electric Power, and Ten West Link. It was verified that the transmission projects proposed with an in-service date of 2020 were consistently modeled in the base case.

We also found that several of the plans included some conceptual transmission projects that were still under study and determined not to include those conceptual projects in the model. Below is a listing of the projects that were not included in the 2020 High Summer Peak FERC 715 model, but we determined should be included in the base case for the evaluation.

Table 3 – APS, SRP and Tucson Electric 10-year study plan

Project	Point of Origin	Point of Termination	Length	In Service Year
Golden Valley 230 kV Transmission Line	Harris Substation	Mineral Park Substation	17 miles	2020
Avery230/69kV Substation	Pinnacle Peak-Raceway230kV line, Sec. 8, T4N, ICE	Avery Substation, Sec. 15, T5N, R2E		2020
North Gila - Orchard 230kV Project Name Line Circuit #I	North Gila Substation	Orchard 230kV Substation	13 miles	2020
Coolidge to Hayden 115kV Re-route/Re-conductor	Coolidge 115kV Substation	Hayden 115kV Substation	1.5 miles	2019
Price Road Corridor	Knox 230kV Substation	Schrader 230kV Substation		2019

4 RELIABILITY REVIEW OF NGS RETIREMENT – STUDY RESULTS

4.1 Standard Criteria – Single Contingency Analysis

Single Outage in the System (N-1 Analysis)

Quanta performed an N-1 analysis, running steady state power flow models and simulating nearly 3,500 single contingency outages of various transmission elements.

For each outage, a comparative study (with and without NGS) was conducted to determine if any additional thermal violations (overloading of a transmission element) or voltage deviations are introduced by NGS retirement.

Single Contingency Analysis Findings

No thermal or voltage violations in the Arizona area were observed associated with the single contingency analysis. However, several low level thermal and voltage violations were observed outside of the Arizona area due to regional redispatch caused by the NGS retirement.

4.2 Standard Criteria – Double Contingency Analysis

Two Simultaneous Outages in the System (N-1-1 Analysis)

Quanta then performed an N-1-1 analysis, running steady state power flow models and simulating nearly 700,000 double contingency outage pairs of transmission elements.

For each outage a comparative study (with and without NGS) was conducted to determine if any additional thermal violations (overloading of a transmission element) or voltage deviations are introduced by NGS retirement.

Double Contingency Analysis Findings

For the N-1-1 analysis, Quanta did observe numerous thermal violations (10 at EHV[3] level) in the Arizona area and throughout the surrounding regions as well. The magnitude of the impacts were minimal (small overloads) and most could be practically mitigated.

Quanta did not observe any additional voltage violations in Arizona or outside of the state.

Finally, Quanta found that the Arizona system performance under select contingencies is more reliant on generation in neighboring states without NGS in service. This behavior was observed as change in Interregional power transfer between Arizona and neighboring states.

[3] Extra High Voltage, typically 345 kV and above.

4.3 NERC Critical Infrastructure Protection Analysis

Substation Outage Analysis (Impact on NERC CIP-014 Physical Security Standard)

To supplement the N-1 and N-1-1 analyses, Quanta performed a substation outage event analysis for several substations in the Arizona area. The substation outage study included the loss of a substation with all associated transmission lines, similar to how Quanta[4] approaches NERC CIP-014 Physical Security assessments. The conducted study is considered partial, and does not comprise a full vulnerability evaluation. These results should be considered as indicative only.

Critical Infrastructure Analysis Findings

Substation outage event analysis demonstrated that the retirement of NGS increases the number of substations classified as critical (note – the loss of critical substations may result in instability, uncontrolled separation, cascading outages or large load shedding). Through partial evaluation, Quanta observed that the NGS retirement elevates the criticality of the Pinnacle Peak substation, which can require additional physical security measures to meet NERC CIP-014 compliance. Further, any new security measures needed to achieve NERC CIP-014 compliance would likely be significant and will be borne by the utility.

4.4 Unique Arizona Scenario Analysis

In another supplement to the N-1 and N-1-1 analyses, Quanta performed steady state thermal and voltage sensitivity analyses for three Unique Arizona Scenarios as separate events with a base assumption of NGS out of service.

The three unique Arizona scenarios considered included[5]:

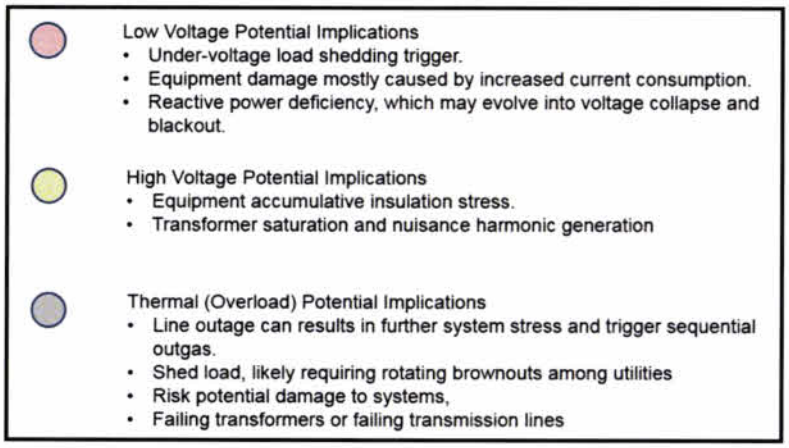
(1) Loss of Palo Verde Nuclear Station – Simultaneous loss of all three units or a total of 4,100 MW of generation (WECC, WestConnect and CAISO all contemplate the loss of Palo Verde units to some extent in their transmission planning studies).
(2) Single contingency loss of the El Paso Natural Gas Pipeline that results in the loss of approximately 6,825 MW of Arizona generation.
(3) Single contingency loss of the Trans-Western Gas Pipeline that results in the loss of approximately 6,180 MW of Arizona generation.

[4] As stipulated by the standard, CIP-014-2 study conducted for utilities, methodology and results are confidential.

[5] Information used to calculate generation loss including gas pipelines outage is collected from publicly available resources. Information pertinent to generators and their pipeline service have been obtained from FERC Form2Viewer (www.ferc.gov/docs-filing/forms/form-2/view-inst.asp) and publically available FERC filed dockets (Sample www.ferc.gov/whats-new/comm-meet/2013/101713/G-2.pdf). Generators served by Laterals or Distribution Companies branching out of the key pipelines have been considered a part of the parent pipeline system.

For each of the three unique scenarios, the impact of NGS retirement throughout the system are graphically demonstrated on the following pages. The color code and legend for Figures 2 to 4 are presented below.

Figure 1 – Thermal and Voltage Legend



All three of these unique Arizona scenarios with NGS out of service were found to stress the Arizona electric grid with unacceptable overloads. The most severe disruptions were in Phoenix, Flagstaff, Scottsdale, Vail (Pima county), Tucson and Raso, while materially impacting the neighboring state of California, in particular the cities of Lugo (Los Angeles county) and Shandon (San Luis Obispo county).

4.4.1 Unique Arizona Scenario Analysis – Loss of Palo Verde Nuclear Plant

Loss of Palo Verde Findings

Under this scenario, approximately 4,100 MW of nuclear generation is removed from the system.

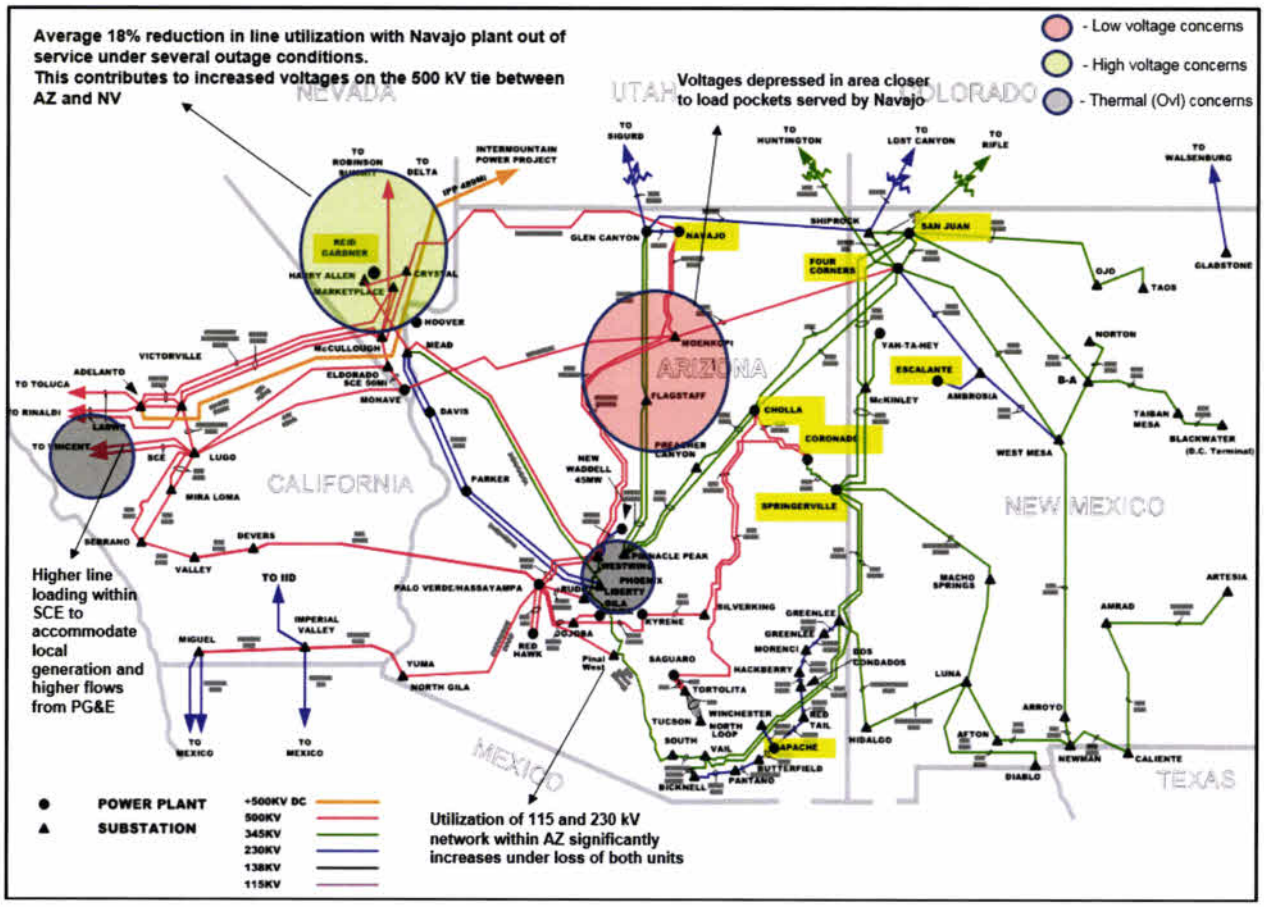
Thermal Results

The study results for the loss of Palo Verde Nuclear Plant and NGS indicated the Arizona system becomes thermally stressed by the nuclear outage, with reduced capability of firm export. Further, the reliability of the adjacent states/utilities is impacted. For example, the California/Oregon interface becomes stressed as North to South flows on the Western Interconnect increase to accommodate the generation shortfall near the Arizona/California border. Loss of NGS aggravates this condition. Under the N-1 single contingency analysis without Palo Verde and NGS, the system is not secure and the overload of several transmission elements was observed. The overloads are mainly observed in the Pinnacle Peak area. However, with NGS in service, these overloads are mitigated and were no longer observed.

Voltage Results (with NGS Out of Service)

Quanta investigated voltage impacts on the Arizona electric system with the loss of the Palo Verde Nuclear Plant and NGS. Voltage deviations (both under and over) were observed in different parts of the system, as exhibited in Figure 2. Over voltage was observed at the Nevada-Arizona interface and under voltage occurs in areas closer to load pockets formerly served by NGS. As observed with the thermal analysis, with NGS in service, the above concerns are not present in the system.

Figure 2 – Loss of Palo Verde Nuclear Plant Voltage and Thermal Concerns



4.4.2 Unique Arizona Scenario Analysis – Loss of El Paso Natural Gas Pipeline

Loss of El Paso Natural Gas Pipeline Findings

Under this scenario, Arizona dropped approximately 6,825 MW of generation served by the El Paso Pipeline. This scenario does not influence California downstream generation served from the same pipeline.

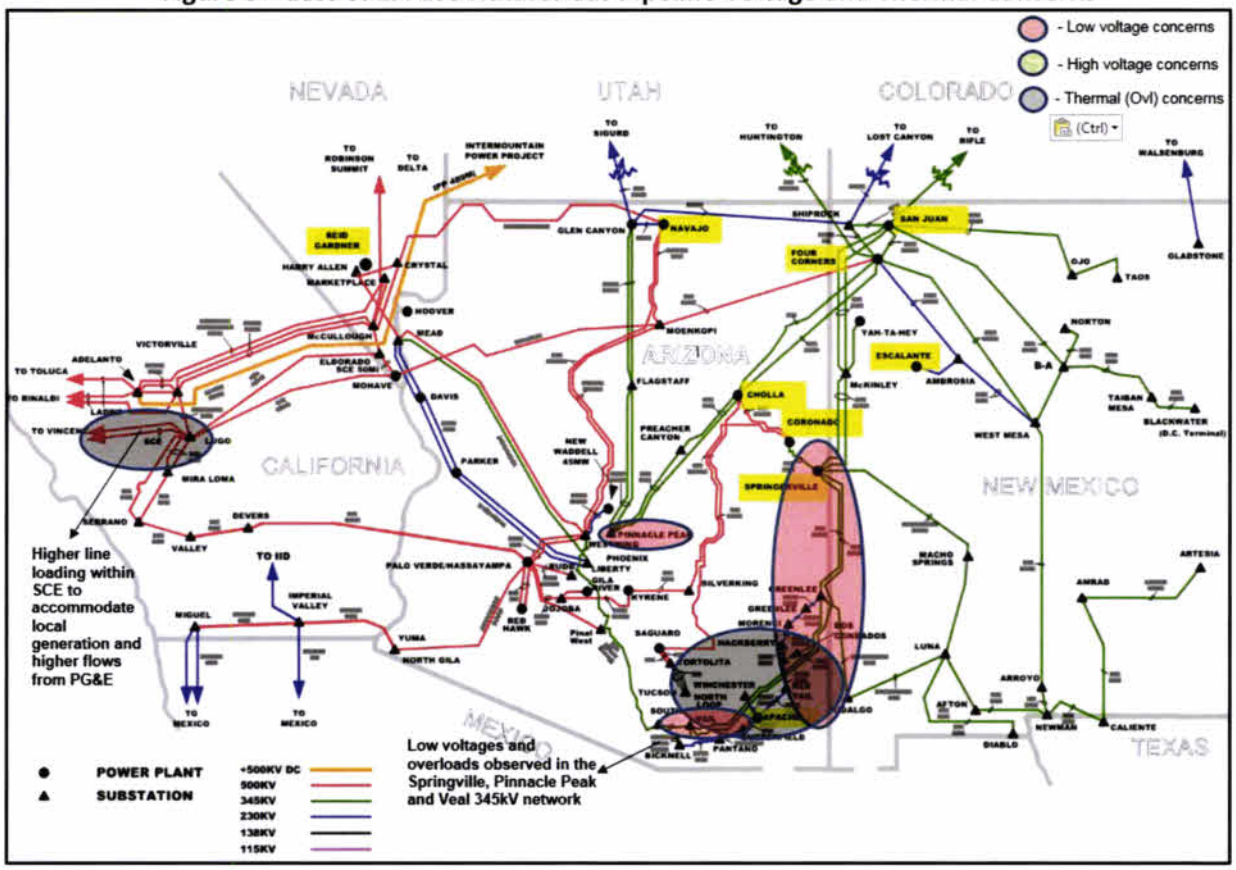
Thermal Results

The study results for loss of the El Paso Pipeline indicated that under single contingency analysis, the system is not secure. Several transmission elements were observed to be overloaded in the Pinnacle Peak and Springerville area. Further, the reliability of adjacent states/utilities is impacted. For example, the California/Oregon interface and the Northern California to Southern California path become stressed as the North to South flows on the Western Interconnect increase to accommodate the generation shortfall in Arizona. Loss of NGS aggravates this condition. Consequently, with NGS is in service, the reliability concerns are fully mitigated and no longer observed.

Voltage Results (with NGS Out of Service)

Quanta also looked at the voltage impacts on the Arizona system with the loss of the El Paso Pipeline. Quanta found that voltage deviations (low voltage only) were observed in different parts of the system as exhibited in Figure 3. More specifically, under-voltage concerns were observed within the Pinnacle Peak, Springerville, and Vail 345 kV network. Additionally, as was the case with the thermal analysis, with NGS in service, all of the voltage concerns are mitigated.

Figure 3 – Loss of El Paso Natural Gas Pipeline Voltage and Thermal Concerns



4.4.3 Unique Arizona Scenario Analysis – Loss of the Trans-Western Natural Gas Pipeline

Loss of the Trans-Western Natural Gas Pipeline Findings

Under the Trans-Western Natural Gas Pipeline scenario, approximately 6,180 MW of generation is dropped. This scenario does not influence California downstream generation served from the same pipeline.

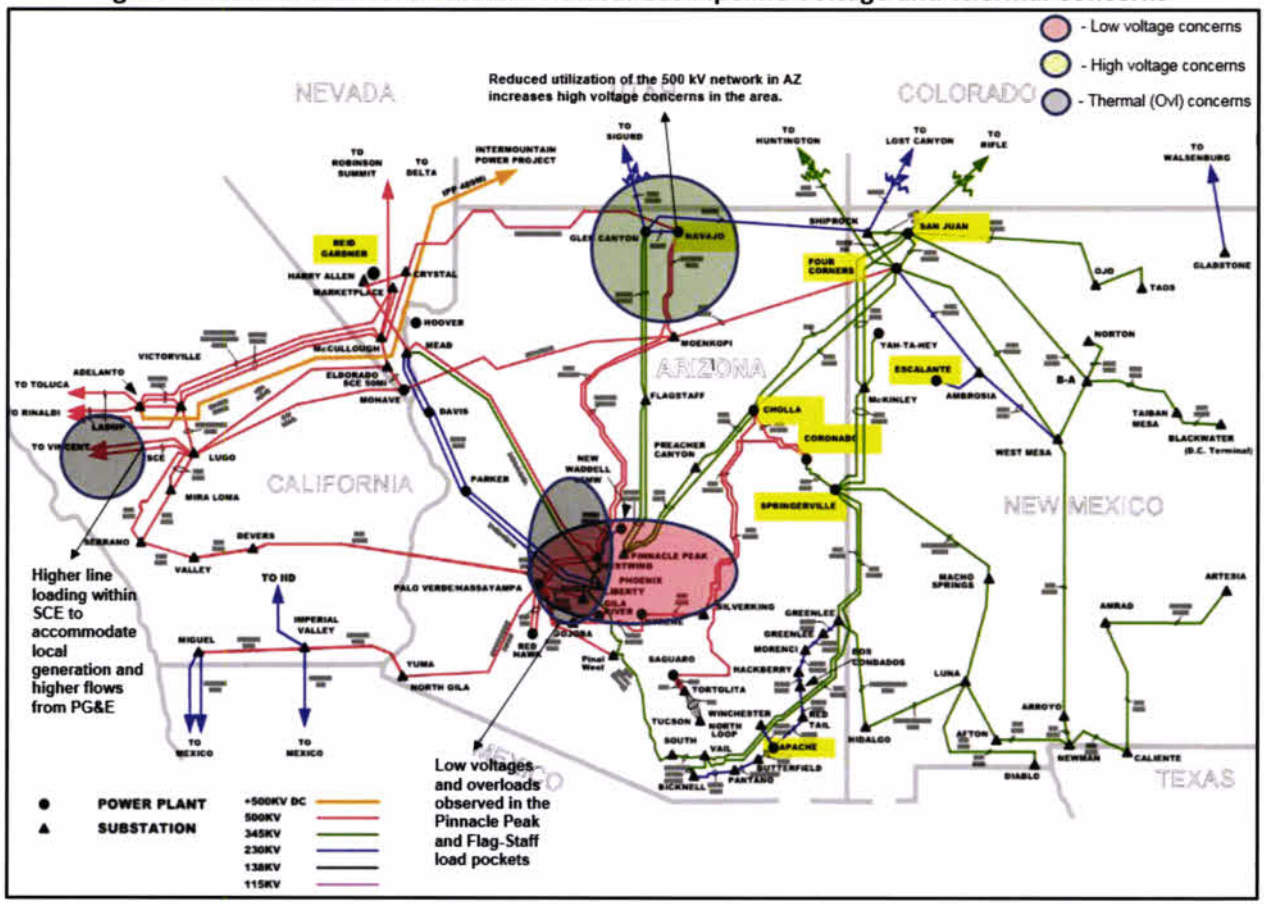
Thermal Results

When Quanta looked at the impact of the loss of the Trans-Western Natural Gas Pipeline, it was observed that under single contingency analysis, the system is not secure. Several transmission elements overloaded and are in violation. Further, the reliability of adjacent states/utilities is impacted. For example, the California/Oregon interface and the Northern California to Southern California path become stressed as the North to South flows on the Western Interconnect increase to accommodate the generation shortfall in Arizona. The loss of NGS aggravates this condition. However, when NGS is added back into service, the reliability concerns are fully mitigated and no longer observed.

Voltage Results (with NGS Out of Service)

Quanta also looked at the voltage impacts on the Arizona system with the loss of the Trans-Western Natural Gas Pipeline. Quanta found that voltage deviations (under and over) were observed in different parts of the system (see "Figure 4 – Loss of the Trans-Western Natural Gas Pipeline Voltage and Thermal Concerns" below). More specifically, over voltage concerns were observed around the NGS area and under voltage concerns were observed in the Pinnacle Peak and Flagstaff areas. As was the case with the thermal analysis, all of the voltage concerns are mitigated when NGS is in service.

Figure 4 – Loss of the Trans-Western Natural Gas Pipeline Voltage and Thermal Concerns



4.5 Transient Stability

System transient performance following three-phase fault and clearing was simulated to evaluate system performance including voltage recovery and generator rotor angle oscillations. For the sake of this study, three-phase fault on a number of transmission lines, including ones connected to critical substations were considered. The fault was cleared and the faulted lines were subsequently disconnected at two terminals. The study was conducted on cases with and without NGS. Generator's angle and impacted load pockets voltage recovery were evaluated against transmission planning criteria. No violations were observed.

While Quanta did not necessarily observe any transient stability violations in its stability assessment, the simulation results demonstrated patterns consistent with the August 2014 SWAT Coal Reduction Assessment. There is likely a limit to the amount of coal plants that can be shut down while still maintaining reliable system operation. Further, the Desert Southwest region should consider the potential reliability risks associated with the loss of inertia and/or dynamic reactive capability that has traditionally supplied by the local fleet of coal fired power plants.

5 CONCLUSION

A summary of study results pertaining to proposed NGS retirement and its impact on electric grid performance and reliability is provided. In order to assess the potential reliability impacts associated with the retirement of NGS, Quanta performed a reliability assessment (assuming that NGS is retired after 2019) looking at the thermal, voltage, and transient stability implications. The power flow model used in this study for the thermal and voltage analysis was based on the FERC 715 WECC 2020 model year. Quanta used data obtained from WECC, WestConnect, and Peabody in completing the study. Additionally, Quanta obtained the 2020 WECC stability model to perform the transient stability analysis. The study considered consensus transmission planning criteria, NERC critical infrastructure protection analysis, and certain unique Arizona scenarios as follows:

1. ***Standard Transmission Planning Criteria***
   - Single Outage in the System (N-1 Analysis)
   - Two Simultaneous Outage in the System (N-1-1 Analysis)

   Findings: Study observed some minor violations and the absence of NGS appears to have a detrimental impact under some contingencies. However, NGS retirement does not contribute to unacceptable system performance, including voltage and branch loading violation, based on consensus criteria proposed by Transmission planning standards.

2. ***NERC Critical Infrastructure Protection Analysis***
   - Substation Outage Analysis (Impact on Physical Security NERC CIP-014)

   Findings: NGS retirement can potentially affect the consequences associated with substation outage event as studied under a partial critical Infrastructure protection analysis. It was observed that the NGS retirement elevates the criticality of the Pinnacle Peak substation, which may require additional physical security measures to be compliant with NERC CIP-014, with compliance costs to be borne by the local utility.

3. ***Unique Arizona Scenario Analysis***
   - Loss of Palo Verde Nuclear Station (Loss of ~4,100 MW of Generation)
   - Single contingency loss of the El Paso Natural Gas Pipeline (Loss of ~6,825 MW of Generation)
   - Single contingency loss of the Trans-Western Gas Pipeline (Loss of ~6,180 MW of Generation)

   Findings: NGS retirement contributes to questionable system performance, including voltage and branch loading violations. These material impacts could potentially include damage to equipment, extended hours of power outage in the region and obstacles to daily activities. These conditions can lead to power deficiencies which could evolve into potential voltage collapse and outages, load shedding triggers, potential rotating brownouts, failing transformers or transmission lines and equipment damage.

The findings of this analysis did show some minor violations under the standard transmission planning criteria (N-1 and N-1-1). Additionally, there were reliability concerns that were observed for the critical infrastructure protection analysis and the unique Arizona scenarios. All three of the unique Arizona

scenarios with NGS out of service were found to stress the Arizona electric grid with unacceptable overloads, materially impacting neighboring state areas.

Finally, it was observed that continued operation of NGS can partially or fully mitigate the reliability concerns addressed in this study. Other mitigation measures that could potentially address the thermal and voltage issues of the unique Arizona scenarios include new transmission and generation solutions. However, neither of these options are considered to be ideal or near term solution as both new transmission and generation can face long lead times and potential permitting challenges.

The conclusions presented herein are based on the work performed as described in this report. Quanta Technology reserves the right to revise these conclusions and recommendations if and when additional information becomes available.

Quanta Technology investigated the specific issues relevant to the objectives of this project. Therefore, the scope of services performed during this study may not adequately address the needs of other users, and any reuse of this report or its findings or conclusions presented herein is at the sole risk of the user.