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January 29, 2014

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Arizona Corporation Commission
1200 West Washington
Phoenix, AZ 85007

RE: Southwest Transmission Cooperative, Inc. Ten Year Transmission Plan
Docket No. E-00000D-13-002

In compliance with A.R.S. § 40-360.02, enclosed please find Southwest Transmission Cooperative, Inc. ("SWTC") Ten Year Plan for the period 2014 – 2023. It includes the Ten Year Plan Report and the Technical Study Report.

An original copy plus thirteen copies pursuant to A.R.S. Section 40-360-02, has been included for each Report.

Sincerely,

Boris Tumarin
Manager of Transmission Planning

Arizona Corporation Commission
DOCKETED
JAN 31 2014
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Enc.

c/Corporate Records

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TEN-YEAR TRANSMISSION PLAN

2014 – 2023

Docket No. E00000D-13-0002

JANUARY 29, 2014

SOUTHWEST TRANSMISSION COOPERATIVE, INC.

TEN-YEAR TRANSMISSION PLAN

2014 – 2023

Prepared for the

ARIZONA CORPORATION COMMISSION

Docket No. E-00000D-13-0002

TRANSMISSION PLANNING

JANUARY 29, 2014

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SOUTHWEST TRANSMISSION COOPERATIVE, INC.

TEN-YEAR TRANSMISSION PLAN

GENERAL INFORMATION

This Ten-Year Plan is submitted to the Arizona Corporation Commission ("Commission") to satisfy the requirements of section 40-360.02 of the Arizona Revised Statutes ("A.R.S."), relating to power plant and transmission line siting requirements. It outlines the plans of Southwest Transmission Cooperative, Inc. ("SWTC") to install electric facilities required to meet anticipated system load growth of its Distribution Cooperative Members ("Members") and other network and point to point customers.

This report contains transmission projects that SWTC anticipates may be constructed over the next ten-year period. As noted in A.R.S. section 40-360.02.F, the plans contained in this report are tentative information only and are subject to change at any time at the discretion of SWTC. SWTC anticipates that any changes to this plan will likely to be due to changes in load forecasts, environmental constraints, economic considerations, other utilities' plans, regulatory and legal developments, as well as future regional and federal mandates. All projects are subject to a peer-review by SWTC's Class A Operating Committee ("CAOC") prior to submittal to the SWTC Board for approval. Meetings of the CAOC are held quarterly, or as needed, and changes to these projects are reviewed as necessary to meet the Member needs. One of the responsibilities of the CAOC is to review the preparation of a Construction Work Plan ("CWP") that is then submitted to the SWTC Board for approval. Once the CWP is approved, the projects are considered by SWTC as "planned" projects. Conceptual projects, or those that have not been vetted by the CAOC for placement into a CWP, may be included in ten year plan filings but will be listed as conceptual projects with tentative or "to-be-determined" ("TBD") in-service dates. TBD as used in this document means that in addition to the project not being yet vetted by the CAOC, it can also mean that the project is still in negotiations with other entities. Changes of

any significance that occur prior to the next Ten-Year Plan filing, will be discussed with Commission Staff.

This specific report is divided into two sections, as outlined in the Table of Contents on page 2. Section I describes planned transmission lines and projects SWTC may construct over the ten-year plan period, whose nominal rating is equal to or greater than one hundred fifteen thousand volts ("115 kV").

Section II contains SWTC's internal planning criteria and facility ratings, pursuant to Commission Decision #63876, dated July 25, 2001.

A technical study report, to satisfy the requirements of paragraph C.7 of A.R.S. Section 40-360.02, has been prepared as a stand-alone document and will be filed jointly with this document to the Commission.

The planned transmission lines that are listed in Section I are needed to maintain system reliability, meet reliability standards, and to serve load of SWTC Members and other customers. Due to the proximity of the new lines to the Member load being served, studies conducted show little impact to the overall interconnected transmission system.

REGIONAL PLANNING

SWTC has been an active participant in regional and sub-regional transmission planning efforts within the Western Interconnection for many years. This participation has been through the Southwest Area Transmission ("SWAT"), membership in the Western Electricity Coordinating Council ("WECC") and WestConnect. SWTC is involved in the following subcommittees of SWAT, either through active participation or copy interest:

- Arizona Subcommittee ("SWAT-AZ")
- Short-circuit Work Group ("SCWG")

SWTC is an active participant within the following committees of WECC:

- Operating Committee ("OC")
- Planning Coordination Committee ("PCC")
- Technical Studies Subcommittee ("TSS")
- System Review Work Group ("SRWG").

In addition, SWTC continues to monitor the efforts of the WECC Transmission Expansion Planning Policy Committee ("TEPPC") which has been tasked with the development of 10- and 20-year transmission plans for the Western Interconnection.

SWTC continues its involvement in the regional transmission planning activities of WestConnect. WestConnect coordinates its efforts with other regional planning entities within the Western Interconnection and its most recent efforts have focused on compliance with the provisions of the Federal Energy Regulatory Commission ("FERC") Order No. 1000 "Transmission Planning and Cost Allocation by Transmission Owning and Operating Public Utilities" that was issued July 21, 2011. A Planning Management Committee ("PMC"), made up of one representative from each of the WestConnect participants, has been tasked with implementation of the regional and interregional planning processes outlined in Order No. 1000, and is working to establish a new Planning Participation Agreement ("PPA") to replace the May 23, 2007 WestConnect Project Agreement for Subregional Transmission Planning ("STP Agreement"), as amended on January 14, 2009. The responsibilities of the PMC going forward under this new PPA will include approving a Regional Transmission Plan that includes cost allocation processes, developing and approving budgets for the planning processes, and creating ad hoc workgroups and/or subcommittees. The structure of the PMC will initially include two subcommittees, the Planning Subcommittee and the Cost Allocation Subcommittee.

At the WestConnect Annual Planning Workshop, held November 19, 2013, SWTC presented its 2014-2023 Ten-Year Transmission Plan for inclusion into the 2014 WestConnect Transmission

Plan. The WestConnect plan is scheduled for approval at the February 20, 2014 WestConnect Annual Planning Meeting. The projects that are included in this ten year plan filing to the Commission contain some minor changes to those originally presented at the WestConnect Annual Planning Workshop. These changes relate to conceptual projects that SWTC has not included in this filing, with tentative or TBD in-service dates.

PRIOR BTA ORDER REQUIREMENTS

In previous filings, information regarding specific recommendations from prior BTA requirements that apply to SWTC have been included. SWTC remains committed to adhering to the recommendations from the 7th and 6th BTA's as noted in the previous filings. The following items have been included as they apply to this 2014-2023 filing:

7th BTA Recommendation #7C: This recommendation requires the jurisdictional utilities *"to report relevant findings in future BTAs regarding compliance with transmission planning standards (TPL-001 through TPL-004) from NERC/WECC reliability audits that have been finalized and filed with FERC."* SWTC does not have any relevant findings to report from NERC/WECC reliability audits, as it is not scheduled for an audit until January 2015.

7th BTA Recommendation #7D: This recommendation is for *"the CCSG participants and UNS Electric to continue to monitor the reliability in Cochise and Santa Cruz Counties, respectively, and propose any modifications the each deem to be appropriate in future ten year plans."* On January 14th of this year, SWTC met with representatives from Sulphur Springs Valley Electric Cooperative, Inc. ("SSVEC") and Arizona Public Service Company ("APS"), both CCSG participants, to discuss a project proposal, involving both entities, that is a promising alternative to the plans submitted to the ACC by the CCSG. The proposed project is the Tombstone Junction Project which does not at present carry an in-service date. The Project scope, to be more fully defined as discussions continue with SSVEC and APS, initially involves looping the SWTC Butterfield to San Rafael 230 kV line into a new Tombstone Junction Substation that will lie adjacent to the SSVEC Tombstone

Junction Substation. A 230/69 kV transformation is initially planned to tie the proposed new Tombstone Junction Substation to SSVEC's Tombstone Junction Substation. An additional 230/115 kV transformation is initially planned to tie to a new 115 kV line from Tombstone Junction to the APS Boothill Substation. Both projects as initially proposed will enhance system reliability, increase transfer capability and voltage support for the interconnected transmission system in Southeast Arizona. Both projects will also require a Certificate of Environmental Compatability ("CEC"). Discussions will continue throughout 2014, and if a refined project scope has been established with agreements from project participants, and with approvals from governing boards, these projects may be reflected in next year's ten year plan.

7th BTA Recommendation #7E: The recommendation requires *"the jurisdictional utilities to include planned transmission reconductor projects, transformer capacity upgrade projects and reactive power compensation facility additions at 115 kV and above in future 10-year plan filings."* There are no transmission reconductor projects or transformer capacity upgrade projects in this ten year plan filing.

Reactive power compensation facility additions at 115 kV and above for this ten-year plan filing, as noted in the SWTC 2013-2016 CWP, are planned for addition on the SWTC system as per the following schedule:

Year	Substation	MVAR Quantity
2015	Avra Valley	9.45
2014	Butterfield	14.4
2015	Sahuarita	14.4

Recent studies conducted since last December, have indicated a need to install additional shunt capacitors during the ten year plan horizon. These are noted below, but are conceptual projects that have not yet been vetted by the CAOC. The 50 MVAR capacitor bank at Dos Condados is scheduled to be moved from Morenci substation, where 2-50 MVAR capacitor banks reside.

Year	Substation	MVAR Quantity
2017	Bicknell	19.2
2019	Avra Valley	19.2
2019	Dos Condados	50
2023	Kartchner	9.6
2023	San Rafael	9.45 & 14.4

Additional studies conducted in 2014, due to the recently approved 2013 load forecast or other circumstances that may tend to refine these values and/or suggest the need to adjust locations for reactive support to the SWTC system, will be reported in the next ten-year plan filing.

7th BTA Recommendation #7H: This recommendation directs Arizona utilities *"to advise each interconnection applicant of the need to contact the Commission for appropriate ACC filing requirements at the time the applicant files for interconnection."* SWTC continues to advise each interconnection applicant of the need to contact the Commission for the associated ACC filing requirements by including an advisory notice to this effect on the SWTC OASIS site, as well as in any SWTC initial written correspondence responding to any applicant.

CHANGES FROM 2013 TEN-YEAR PLAN FILING

There are minor changes to the projects considered by SWTC for inclusion in this Ten-Year Plan filing over last year's ("2013-2022") Ten-Year Plan filing. These are noted below:

Saguaro to Tucson 115 kV Line Loop-in To Marana. This conceptual project loops in the Western Area Power Administration ("Western") Saguaro to Tucson 115 kV line into the SWTC Marana Substation, a distance of 0.2 miles. There has been no progress to date on sufficient development of this project to be able to determine an effective in-service date which has now changed from the year 2014 to TBD. The project has not progressed to a point where a definite in-service date can be listed. Any change that occurs prior to the next Ten-Year Plan filing, will be discussed with Commission Staff.

ADDITIONAL PROJECTS UNDER CONSIDERATION

SWTC is studying the feasibility of additional projects to be added in future ten year plans that have been included in previous ten year plans, but have been deferred for various reasons.

A brief description of each of these projects follows, for information purposes only. The projects have not been vetted by the CAOC. SWTC has studied the addition of these projects and found a need to reconsider them to enhance load serving capability, system reliability, increased transfer capability and voltage support to the SWTC and Central Arizona Project ("CAP") systems and to also provide for anticipated Member load growth. Discussions with potential project participants will occur throughout 2014, and if refined project scopes have been established with agreements from project participants, and with approvals from governing boards, these projects may be reflected in next year's ten year plan.

Apache/Hayden to San Manuel 115 kV Line. This project has been presented in previous SWTC ten year plans, but was deferred from 2017 to beyond the ten-year plan horizon in last year's ten year plan filing. It was approved by the ACC Line Siting Committee on May 12, 2009 and by the Commission on July 9, 2009 (Case #142, Decision #71218). A new 115 kV line would be extended from the existing SWTC Apache to Hayden 115 kV line a distance of approximately 4.5 miles to the existing APS San Manuel Substation. Revised interest in this project is due to a potential Trico Electric Cooperative, Inc. ("Trico") customer in the area. SWTC intends to apply to extend the CEC for this project prior to its expiration this summer. This project will require the agreement of APS.

Saguaro to Thornydale 115 kV Line. This line segment is akin to the Saguaro to North Loop 115 kV line that was presented in the SWTC 2010-2019 ten year plan. It was approved by the ACC Line Siting Committee on October 7, 2009 and by the Commission on November 19, 2009 (Case #149, Decision #71420). The new 115 kV line between the existing APS Saguaro Substation and SWTC's existing Thornydale Substation is approximately 15 miles in length. This line project will require the agreement of APS.

The following projects had previously been deferred by mutual agreement with CAP. As stated above, SWTC intends to work with CAP as may be required to accommodate these particular projects.

Thornydale to Twin Peaks 115 kV Line. This line segment is akin to the North Loop to Rattlesnake 115 kV line that was also presented in the SWTC 2010-2019 ten year plan. It was approved by the ACC Line Siting Committee on February 10, 2010 and by the Commission on April 14, 2010 (Case #152, Decision #71649). The new 115 kV line between SWTC's Thornydale Substation and the CAP Twin Peaks Substation is approximately 8 miles in length. This line project will require the agreement of CAP.

CAP 115 kV Line Tap to SWTC Sandario Substation. This line segment is akin to the CAP 115 kV Line Loop-in Project that was presented in the SWTC 2010-2019 ten year plan. It was also approved by the ACC Line Siting Committee on February 10, 2010 and by the Commission on April 14, 2010 (Case #152, Decision #71649) as part of the North Loop to Rattlesnake 115 kV Line Project. A new 115 kV line will be tapped off of the existing CAP Sandario to Brawley 115 kV line to tie to the existing SWTC Sandario Substation, a distance of approximately 0.6 miles. This line project will require the agreement of CAP.

Valencia to CAP Black Mountain 115 kV line. This line segment is akin to the Valencia to CAP Black Mountain 115 kV Line Project that was also presented in the SWTC 2010-2019 ten year plan. It was also approved by the ACC Line Siting Committee on February 10, 2010 and by the Commission on April 14, 2010 (Case #152, Decision #71649) as part of the North Loop to Rattlesnake 115 kV Line Project. A new 115 kV line will extend from the existing SWTC Valencia Substation to the turning structure of the 115 kV CAP line that heads directly north 2 miles to the existing CAP Black Mountain Substation, for a total distance of approximately 2.6 miles. This line project will require the agreement of CAP.

PROJECT MAPS

The following maps are included to show the location of existing and future transmission projects. These maps have historically resided in the Technical Study Report, but will also be included in this document for ease of reference when reviewing the proposed projects that are listed in the next Section. The maps included in this report are:

Figure 1 - SWTC Northern Area

Figure 2 - SWTC Southern Area

Figure 3 - SWTC Western Area

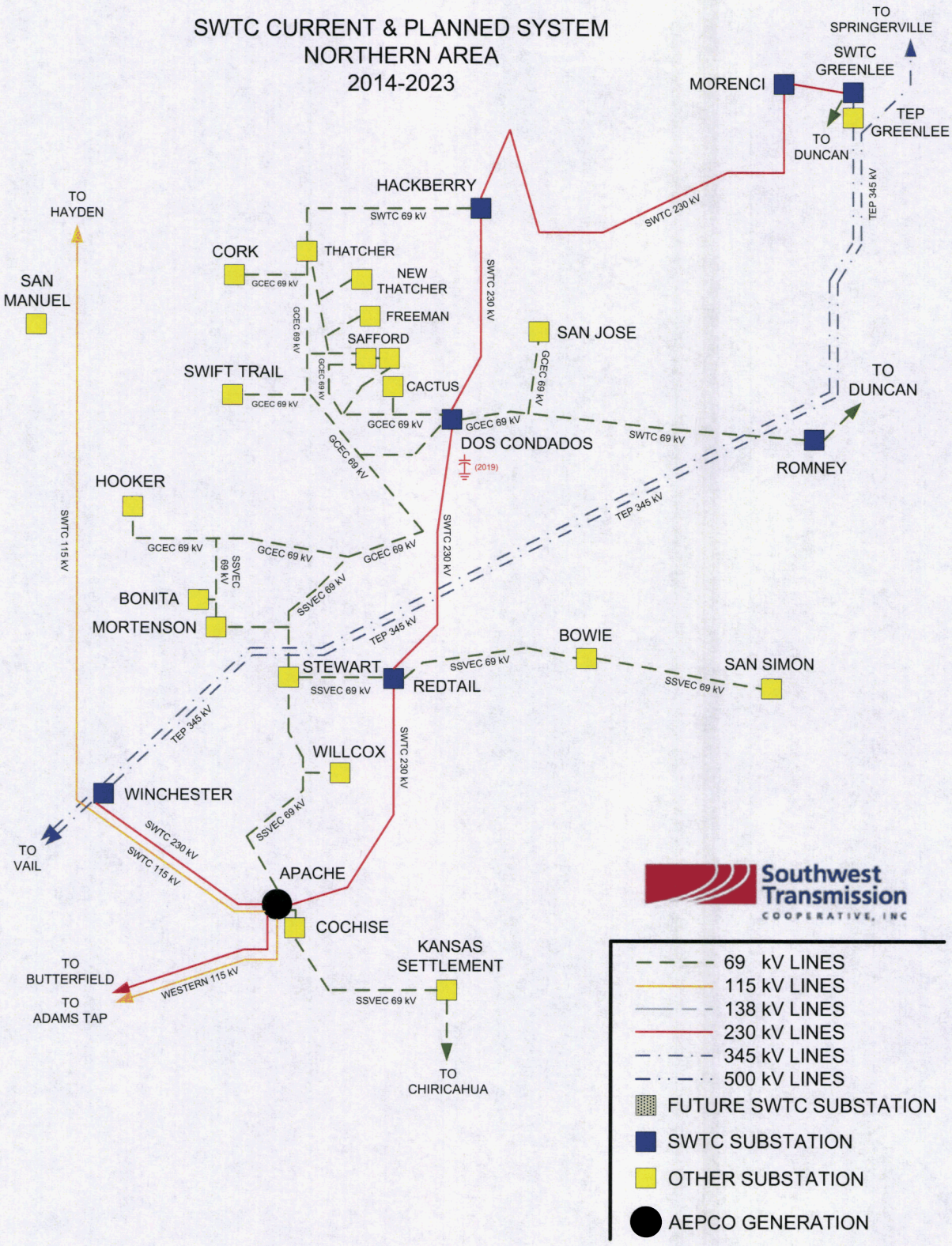

Figure 1 – SWTC Northern Area

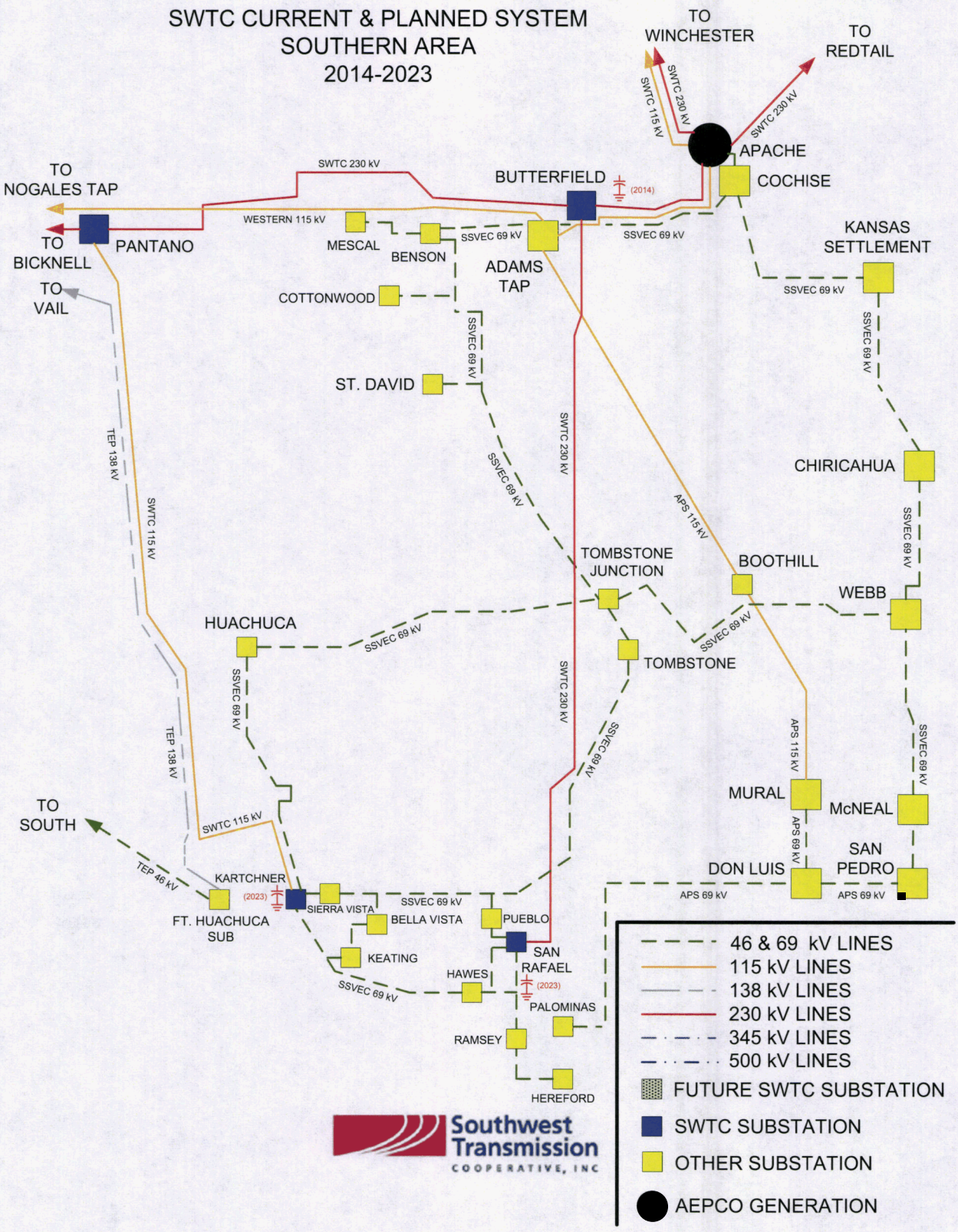

Figure 2 – SWTC Southern Area

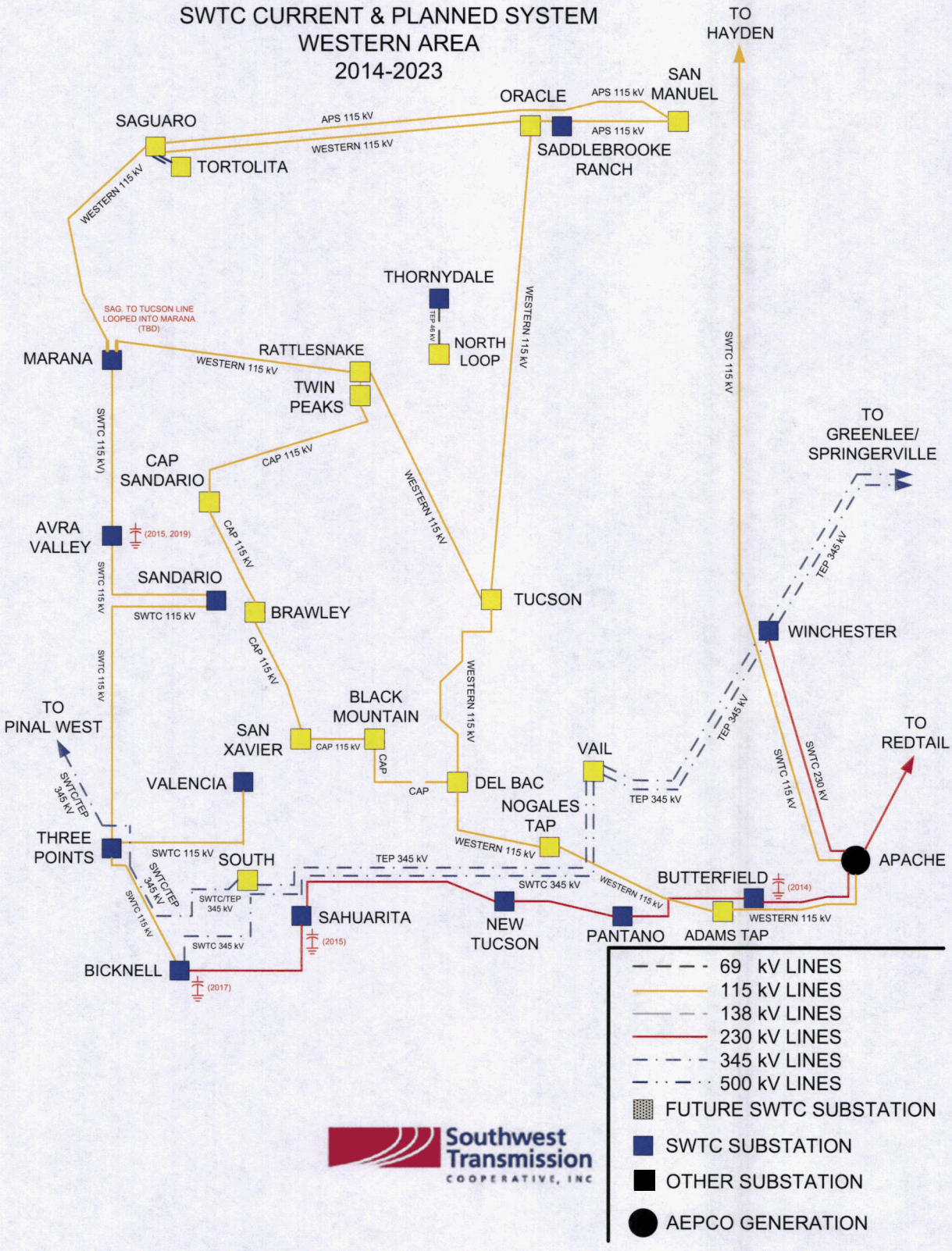

Figure 3 – SWTC Western Area

SECTION I - PLANNED TRANSMISSION LINES

SAGUARO TO TUCSON 115 kV LINE LOOP-IN TO MARANA

Line Designation:		Saguaro to Tucson 115 kV Line Loop-in to Marana (Formerly the Marana Tap to Marana 115 kV Line Upgrade)
Size:		
a)	Voltage	115 kV
b)	Capacity	261 MVA
c)	Point of Origin	Marana Tap Sec. 26 T11S R10E
d)	Point of Termination	Marana Substation Sec. 26 T11S R10E
e)	Length	Approximately 0.2 miles
Routing:		Western's Marana Tap, west to the SWTC Marana Substation.
Purpose:		To enhance system reliability, increased transfer capability and voltage support for the SWTC system and to provide for anticipated Member load growth.
Dates:		
a)	Construction Start	TBD
b)	In-Service Date	TBD

Notes: The Marana Tap to Marana project was approved by the ACC Line Siting Committee on May 3, 2011 and by the Commission (Case #161, Decision #72447) on June 28, 2011. The Saguaro to Tucson 115 kV line loop-in to Marana Project is considered to be a minor modification to this original project approval as it utilizes the same line path. This planned project is currently under study with the Western Area Power Administration.

SECTION II - INTERNAL PLANNING CRITERIA AND FACILITY RATINGS

SWTC's current internal planning criteria and facility ratings have been documented in its "Facility Ratings Methodology and Establish and Communicate Facility Ratings (FAC-008-1 and FAC-009-1)," dated February 11, 2009, and revised June 26, 2013, to meet requirements of the North American Reliability Corporation ("NERC") Planning Standards. Portions of the document are reprinted below, which identify the assumptions and methodologies used by SWTC to determine electrical facility ratings and also describe the electrical load limits for SWTC on the various power system transmission lines, power transformers, and other facility equipment under normal and emergency operating conditions.

1.0 Introduction

In accordance with NERC and Western Electricity Coordinating Council ("WECC") standards, this document sets forth the methodology used by SWTC to rate its facilities. It is the method by which the Rating of SWTC major Bulk Electric System ("BES") equipment is determined.

1.1 The facilities addressed in this document include transmission conductors, transformers, relay protective devices, terminal equipment, and compensation devices.

1.2 This methodology addresses Normal and Emergency ratings for the facilities that comprise SWTC's BES.

1.3 This Facility Ratings Methodology considers the ratings provided by equipment manufacturers, IEEE and ANSI standards, ambient conditions for solar input, temperature and wind speed, design criteria, operating limitations, and other assumptions, as applicable.

1.4 The ratings for all of SWTC BES facilities, including but not limited to lines, transformers, and shunt compensation devices, shall be equal to the most limiting applicable equipment rating of the individual equipment that comprises the facility.

1.5 In cases where a facility is jointly owned, the operator of the facility determines the rating and shares the rating with the other joint owners.

1.6 In cases where a facility is owned in segments (such as a transmission line being owned by one party with the breaker being owned by a different party), each owner will determine the rating for their segment and coordinate with the other owners to determine the most limiting segment. The rating for the most limiting segment would be used for the entire facility.

2.0 Facility Rating Methodologies for Transmission Facilities

The following sections describe the rating method for SWTC facilities.

2.1 Generation Facilities

SWTC does not own generation facilities. However, generation facilities, including step-up transformers, which are owned by Arizona Electric Power Cooperative, Inc. (AEPCO), are modeled in the SWTC power flow base case models according to AEPCO's facility ratings methodology.

2.2 Transmission Lines

SWTC owns transmission facilities. The rating of transmission lines involves comparison of the ratings of all elements which make up the line between the two identified busses, including the terminal equipment. The overall line rating is limited by the rating of the component with the lowest rating element or the stability limit of the line, whichever is lower. The bulk of SWTC's transmission lines are thermally limited. The sag rating of the line is used when appropriate. SWTC calculates its thermal transmission line ratings based upon the parameters outlined in Table 2. The calculations for normal operating conditions use the design criteria of 75°C, and the emergency operating conditions use a conductor design temperature rating of 100°C. SWTC incorporates the calculations used in the IEEE Standard 738 in its analysis of determining the current-temperature relationship of its lines, given the parameters noted in Table 2. The ratings can be found in Table 1 below.

SWTC ensures that its transmission line ratings are aligned with current design tolerances based on the National Electric Safety Code ("NESC") and likewise ensures that actual field conditions do not create conditions that will cause the facilities to be non-compliant with the NESC clearance requirements.

Based on historical, conservative design practices, SWTC has incorporated additional design margin to compensate for minor variations between design conditions and actual field conditions. In addition, SWTC verifies its "as-built" conditions by scheduled field visits. Each line segment part of the BES is monitored on an annual basis. SWTC's current maintenance practices include an annual inspection on concrete and steel structures and a semi-annual inspection on wood structures. The inspection is a visual inspection designed to monitor the integrity, reliability, and compliance with NESC standards checking minimum conductor sag distances at key points throughout the system. Findings are documented, reported, and addressed as issues arise. In addition to on-ground line inspections, SWTC also performs regular aerial bucket or climbing inspections in high risk areas outlined in SWTC's Transmission Vegetation Management Plan ("TVMP").

2.2.1 Transmission Line Conductors

The transmission line conductor ratings are found below in Table 1:

TABLE 1: Conductor Thermal Ratings			
At 75 Deg. Celsius Operating Temperature			
Based on 4 ft. per second Wind Velocity			
and 40 deg. Celsius Air Temperature			
ACSR Conductor		Copper Conductor	
SIZE	AMPS	SIZE	AMPS
	(Normal/Emergency)		(Normal/Emergency)
1/0 – 105.7 MCM	216/281	#2 – 3 Strand	221/287
2/0 – 133.0 MCM	247/321	#2 – 7 Strand	209/272
3/0 – 167.7 MCM	282/367	4/0 – 211.6 MCM	426/554
4/0 – 211.6 MCM	322/419	350 MCM	578/751
266.8 MCM	400/520		
336.4 MCM	461/599		
397.5 MCM	510/663		
477.0 MCM	570/741		
556.0 MCM	626/814		
636.0 MCM	678/881		
795.0 MCM	776/1009		
954.0 MCM	849/1104		
1033.5 MCM	891/1158		
1192.5 MCM	970/1261		
1272.0 MCM	1009/1312		
1351.5 MCM	1047/1361		
1590.0 MCM	1153/1499		
2167.0 MCM	1366/1776		
2 – 954 MCM	1699/2209		

TABLE 2: Conductor Rating Parameters		
Parameters Common to All Locations/Conductors		
Parameter	**Continuous Rating**	**Emergency Rating**
Wind Direction	70° to Line	70° to Line
Emissivity	0.5	0.5
Absorptivity	0.7	0.7
Date	July 1	July 1
Time	12 PM	12 PM
Latitude and Longitude	32.5° North	32.5° North
Elevation	2500 Ft	2500 Ft
Solar Input	Clear	Clear
Allowable Cond. Temp (ACSR)	75°C	100° C or sag limit
Wind Speed	4 ft/s	4 ft/s
Ambient Temperature	40°C	40°C

The following items are pertinent with regard to the conductor rating method:

a. The thermal ratings from Table 1, used by SWTC to rate its transmission lines, are considered to be conservative. If through internal studies it is determined that a line will become stability limited, (at a value lower than the thermal limit) its rating will be based on its particular stability limit.

b. The weather parameters for development of the existing conductor thermal ratings are based on the values for wind direction, absorptivity and wind speed as noted in Table 2 above. The conductor ratings are based on a 75° C operating temperature with a 4 ft. per second wind speed and a 40° C air temperature. Emergency ratings are based on a 100° C operating temperature with a 4 ft. per second wind speed and a 40° C air temperature. SWTC can exceed its emergency ratings for up to 30 minutes. Where a transmission line, or line section, is constructed or upgraded with more than one size conductor, the overall line rating is determined by the rating of the most limiting sized conductor. If other equipment (switches, series capacitors, etc) in series with the transmission conductor is more limiting, the lowest limitation defines the transmission line rating.

c. Rigid Bus and Strain Bus design are determined by the RUS Design Guide for Rural Substations Bulletin 1724E-300 (Bulletin) and National Electric Safety Code as a minimum. The design involves many factors, which are spelled out in the Bulletin. For new 115 kV substations, SWTC uses a standard schedule 40 aluminum pipe conductor size of 3", which is rated at approximately 1900 A. For new 230 kV substations, SWTC uses an aluminum pipe conductor size of 4", which is rated at approximately 2,500A. There is currently no case on the SWTC system where the rigid bus or strain bus is a limiting factor for any of SWTC's transmission line ratings. The ratings of the Aluminum rigid bus or pipe conductor are based on IEEE Standard 738.

2.3 Transformers

SWTC owns the following types of power transformers:

a. Load serving transformers with LTC
   - Conventional
   - Auto

b. Tie Autotransformers

The Normal and Emergency Ratings for transformers are determined as follows:

Equipment	Normal Rating	Emergency Rating
SWTC Transformers	100% of Manufacturer's highest Nameplate Rating @ 55°C or 65°C rise	125% of Manufacturer's highest Nameplate Rating @ 55°C or 65°C rise

During All Lines In Service ("ALIS") operation the loading of the transformer should not exceed its Normal Rating. During system contingencies the loading of the transformer should not exceed its Emergency Rating, which is set at 125% of the normal rating based on ratings developed for each transformer according to IEEE Std. C57.91-1995. SWTC can exceed its normal ratings for up to 30 minutes. In addition, SWTC follows the recommendations of PRC-023 which limits the ability of automatic protection equipment to de-energize transformers. This allows time to permit operator intervention and helps avoid potential system cascading.

Under special circumstances, SWTC may wish to evaluate other sources in regard to manufacturer's specifications, such as the latest applicable versions of IEEE Standards C57.13-2209, 57.91-1995, or C57.119-2001.

2.4 Relay Protective Devices

None of SWTC BES facilities have ratings that are limited by protection or monitoring devices. SWTC's relays will not trip (trip on Zone 3) due to normal or emergency load current (See PRC-023-1 Transmission Relay Loadability). New facilities and protection schemes are reviewed by SWTC to ensure that loadability requirements are met.

2.5 Terminal Equipment (switches, breakers, etc)

The Normal and Emergency Ratings for terminal equipment are determined as follows:

Equipment	Normal Rating	Emergency Rating
Power Circuit breakers	100% of Manufacturer's Nameplate Rating	100% of Manufacturer's Nameplate Rating
Power Circuit switchers	100% of Manufacturer's Nameplate Rating	100% of Manufacturer's Nameplate Rating
Air Disconnect switches	100% of Manufacturer's Nameplate Rating	100% of Manufacturer's Nameplate Rating
Current transformers	100% of Manufacturer's Nameplate Rating	100% of Manufacturer's Nameplate Rating

SWTC shall consult the most current and applicable IEEE standards as deemed necessary regarding the rating of its terminal equipment: IEEE Std. C37.010-1999 (R2005), IEEE Std C37.37-1996, IEEE Std. C57.13-2008, IEEE Std. C93.3-1995, or RUS Bulletin 1724E-300.

2.6 Shunt Compensation Devices

a. Shunt compensation

The normal and emergency ratings for shunt compensation devices are determined as follows:

Equipment	Normal Rating	Emergency Rating
Shunt Capacitors	100% of Manufacturer's Test Report Rating	100% of Manufacturer's Test Report Rating

b. Series compensation

SWTC has no series compensation devices on its system.

3.0 Internal Planning Criteria for Facility Ratings

The factors used to determine equipment ratings were outlined above. They represent criteria that SWTC has used for a number of years, to meet requirements of the NERC, WECC, and the FERC.

The following is SWTC's internal transmission reliability planning criteria as published in the FERC FORM #715 filing:

1) Nominal Operating Limit

- Transmission lines should not be loaded greater than 100% of the thermal rating of the conductors.
- Transformers, circuit breakers, current transformers, and other equipment should not be loaded above their continuous nameplate rating.
- Transmission system voltages should not fall below 0.95 per unit (p.u.) of nominal rating nor rise above 1.05 p.u. of nominal rating.
- For long range planning system studies, an appropriate power factor for the planning period will used.
- For operating system studies, an appropriate power factor for the operating planning period will be used.

2) Emergency Operating Limit

- Transmission lines should not be loaded greater than the specified emergency rating of the conductors.

- Transformers should not be loaded greater than the specified emergency rating of the transformers.

- Circuit breakers, current transformers, and other equipment should not be loaded above their continuous nameplate rating, except as permitted under applicable standards.

- Transmission system voltages should not fall below 0.90 per unit (p.u.) of nominal rating nor rise above 1.10 p.u. of nominal rating.

- For long range planning system studies, an appropriate power factor for the planning period will used.

- For operating system studies, an appropriate power factor for the operating planning period will be used.

4.0 Establishment and Communication of Facility Ratings

SWTC establishes the facility ratings for its BES in accordance with the facility rating methodologies described above. SWTC submits its most up-to-date ratings as part of the WECC base case preparation process on a periodic basis as required by WECC.

SWTC shall communicate its Facility Ratings Methodology for its solely and jointly owned Facilities that are existing Facilities, new Facilities, modifications to existing Facilities and re-ratings of existing Facilities to WECC, its LLRC, its Planning Coordinator, and to other Transmission Owners, Operators, or Planners within 21 calendar days of a receipt of a request. If any of the aforementioned entities provides documented comments on its technical review of the SWTC Facility Ratings Methodology, SWTC shall provide a response to the commenting entity within 45 calendar days of a receipt of those comments, indicating whether a change will be made to the Facility Ratings Methodology and , if no change will be made, the reason why. Within 30 calendar days (or a later date if specified by a requestor) for any requested Facility with a Thermal Rating that limits the use of Facilities under a requestor's authority by causing any of the following: 1) An Interconnection Reliability Operating Limit, 2) A limitation of Total Transfer Capability, 3) An impediment to generator deliverability, or 4) An impediment to service to a major load center, SWTC shall identify the existing next most limiting equipment of the Facility and the Thermal Rating for that most limiting equipment.

When SWTC has determined that updated ratings are applicable, it will communicate those ratings as part of the WECC base case preparation process, by email or by telephone, as appropriate. SWTC shall keep all superseded portions of its Facility Ratings Methodology for 12 months beyond the date of the change in that methodology and shall keep all documented

comments on the Facility Ratings Methodology and associated responses for three years, in accordance with NERC Standard FAC-008-3.

The following table of SWTC Transmission Line Rating Limits is found in Appendix A of SWTC's Facility Rating Methodology:

SWTC Transmission Line Rating Limits							
Station A From	Station B To	Voltage KV	Normal Limit Amps	Emergency Limit Amps	Normal Limit MVA	Emergency Limit MVA	Limiting Equipment
HASSAYAMPA	PINAL WEST	500	3000	3000	2598	2598	Breaker Out for Maintenance
PINAL WEST	HASSAYAMPA	500	3000	3000	2598	2598	
GREEN-SW	GREENLEE	345	1699	2209	1015	1320	Conductor
GREENLEE	GREEN-SW	345	1699	2209	1015	1320	Conductor
BICKNELL	VAIL	345	1600	1600	956	956	Station Motor-Operated Switch
VAIL	BICKNELL	345	1600	1600	956	956	
PINAL WEST	VAIL	345	1548	1858	925	1110	Station Terminal Equipment
VAIL	PINAL WEST	345	1548	1858	925	1110	
PINAL WEST	WESTWING	345	1548	1858	925	1110	Station Terminal Equipment
WESTWING	PINAL WEST	345	1548	1858	925	1110	
DOSCONDO	HACKBERRY	230	1009	1312	402	523	Conductor
HACKBERRY	DOSCONDO	230	1009	1312	402	523	Conductor
HACKBERRY	MORENCI	230	1009	1312	402	523	Conductor
MORENCI	HACKBERRY	230	1009	1312	402	523	Conductor
GREEN-SW	MORENCI	230	1009	1312	402	523	Conductor
MORENCI	GREEN-SW	230	1009	1312	402	523	Conductor
MORENCI	PD-MORNC	230	849	1104	338	440	Conductor
PD-MORNC	MORENCI	230	849	1104	338	440	Conductor
APACHE	BUTERFLD	230	776	1072	309	427	Conductor
BUTERFLD	APACHE	230	776	1072	309	427	Conductor
APACHE	RED TAIL	230	1009	1312	402	523	Conductor
RED TAIL	APACHE	230	1009	1312	402	523	Conductor
APACHE	WINCHESTER	230	1009	1312	402	523	Conductor
WINCHESTER	APACHE	230	1009	1312	402	523	Conductor
BUTERFLD	PANTANO	230	776	1009	309	402	Conductor
PANTANO	BUTERFLD	230	776	1009	309	402	Conductor
BUTERFLD	SAN RAF	230	849	1104	338	440	Conductor
PANTANO	NEWTUCSN	230	776	1009	309	402	Conductor
NEWTUCSN	PANTANO	230	776	1009	309	402	Conductor
NEWTUCSN	SAHUARITA	230	776	1009	309	402	Conductor
SAHUARITA	NEWTUCSN	230	776	1009	309	402	Conductor
SAHUARITA	BICKNELL	230	776	1009	309	402	Conductor
BICKNELL	SAHUARITA	230	776	1009	309	402	Conductor
RED TAIL	DOSCONDO	230	1009	1312	402	523	Conductor
DOSCONDO	RED TAIL	230	1009	1312	402	523	Conductor
DAVIS	RIVIERA	230	600	600	239	239	WAPA Relays wound CT
APACHE	HAYDENAZ	115	570	741	114	148	Conductor
HAYDENAZ	APACHE	115	570	741	114	148	Conductor
MARANA	MARANATP	115	800	800	159	159	Disconnect Switch
MARANATP	MARANA	115	800	800	159	159	
MARANA	AVRA	115	1009	1312	201	261	Conductor
AVRA	MARANA	115	1009	1312	201	261	Conductor
AVRA	SANDARIO	115	776	1009	155	201	Conductor
SANDARIO	AVRA	115	776	1009	155	201	Conductor
SANDARIO	THREEPNT	115	322	419	64	83	Conductor
THREEPNT	SANDARIO	115	322	419	64	83	Conductor
BICKNELL	THREEPNT	115	570	741	114	148	Conductor
THREEPNT	BICKNELL	115	570	741	114	148	Conductor
THREEPNT	VALENCIA	115	570	741	114	148	Conductor
PANTANO	KARTCHNR	115	570	741	114	148	Conductor

Notes:

1) SRP is the operating agent for the Hassayampa to Pinal West 500 kV line and has determined its line ratings. SWTC owns 7.305% of this line.
2) TEP is the operating agent for Pinal West to Vail and Pinal West to Westwing 345 kV lines and have determined their line ratings. SWTC owns 24% of these lines.
3) Emergency rating for Apache to Butterfield 230 kV line based on the calculated emergency rating of the conductor due to a previous re-rating process completed January 28, 2011

TECHNICAL STUDY REPORT

2014 – 2023

Docket No. E-00000D-13-00021

JANUARY 29, 2014

SOUTHWEST TRANSMISSION COOPERATIVE, INC.

TEN-YEAR PLAN

2014 – 2023

TECHNICAL STUDY REPORT

SUBMITTED TO THE ARIZONA CORPORATION COMMISSION IN FULFILLMENT OF A.R.S. §40-360.02 ¶C.7

Docket No. E-00000D-13-0002

TRANSMISSION PLANNING
JANUARY 29, 2014

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SOUTHWEST TRANSMISSION COOPERATIVE, INC.
TEN-YEAR PLAN
2014 – 2023
TECHNICAL STUDY REPORT

INTRODUCTION

This technical report is submitted to the Arizona Corporation Commission ("Commission") pursuant to the Arizona Revised Statutes ("ARS") §40-360.02 ¶C.7, and Decision No. 63876, dated July 25, 2001, regarding the Biennial Transmission Assessment prepared by Commission Utilities Division Staff.

Each year, SWTC performs an annual assessment of its interconnected transmission system in accordance with the TPL Standards. Power flow analyses used for this report were performed in accordance with the NERC criteria for Planning Standards TPL-001-0 through TPL-004-0, and are contained in the SWTC 2013 Transmission Planning Assessment Report that details study results for the years 2014 through 2023. As required by the Standards, the SWTC transmission system was analyzed within the near-term planning horizon (2014-2019) and the long-term planning horizon (2019-2023). Heavy summer and light winter conditions were analyzed for all years of the 2014-2023 planning horizon, but only the years 2014, 2019 and 2023 will be discussed in this report.

The transmission planning assessment performed by SWTC did not consider the Sunzia Southwest Transmission Project and the Southline Transmission Project. These projects are still undergoing study through the Western Electricity Coordinating Council ("WECC") Three-Phase Rating Process. Consideration was made as to whether or not to include these projects in the bases cases for study, as they may potentially have an impact upon the SWTC system, but for the present it was decided not include to them until a degree of certainty is achieved regarding completion of the projects.

The ten year plan document that this report accompanies, contains a discussion of a number of projects that are being considered as future projects. These are not yet ready to put into the ten year plan, but are important because of the ability these projects will have to enhance load serving capability, system reliability, increased transfer capability and voltage support to the SWTC transmission system. These projects were studied as part of SWTC's annual transmission assessment and the initial results are included in this report. Discussions with potential project participants will occur throughout 2014 and if refined project scopes have been established with agreements from project participants, and with approvals from governing boards, these projects may be reflected in next year's ten year plan.

The analyses performed for this study have been done with the latest SWTC load forecast and the results show that under a variety of outage conditions, the system will perform well with no violations of the NERC criteria.

SWTC's current and planned transmission system maps are included in Appendix A, starting on page 23. The contingency list used for the TPL Assessment is included in Appendix B, starting on page 27. Selective power flow one-line diagrams, showing the entire SWTC system under various outage conditions, for the years 2014, 2019 and 2023, are included in Appendix C, starting on page 34. As part of SWTC's TPL Assessment, selective N-2 outages of the SWTC transmission system were evaluated. However, only a few of the High Voltage ("HV") and Extra-High Voltage ("EHV") N-1 and N-2 outage simulations for the years 2014, 2019, and 2023 are included in this report. A few N-n or common corridor outage simulations for each year are also included. N-1 simulations for radial transmission lines have been excluded from this listing.

Post-transient studies for reactive margin were performed for the interconnected SWTC transmission system for heavy summer and light winter conditions for the years 2014, 2019 and 2023. Q-V plots can be found in Appendix D, starting on page 168.

Dynamic stability evaluations were performed on heavy summer conditions for the years 2014, 2019, and 2023. These can be found in Appendix E, starting on page 241.

At this time, there are no planned third-party generation interconnections to the SWTC transmission system.

POWER FLOW ANALYSES

Power flow studies were performed using General Electric's Positive Sequence Load Flow ("PSLF") program. The power flow base cases were created for the 2014-2023 study period, using the latest Arizona seed cases that have been developed from Western Electricity Coordinating Council ("WECC") approved base cases. The cases used for this report are listed below:

- 2014HS Case (Created from coordinated Arizona 2014HS seed case that was originally developed from WECC 2013H2-OP approved base case) – Load Flow and Stability
- 2014LW Case (Created from the WECC 2013-14LW1 approved base case) – Load Flow and Stability
- 2019HS Case (Created from coordinated Arizona 2023HS seed case that was originally developed from WECC 2023HS1 approved base case) – Load Flow and Stability
- 2019LW Case (Created from the WECC 2022LA1S-TEPC approved base case) – Load Flow and Stability
- 2023HS Case (Created from coordinated Arizona 2023HS seed case that was originally developed from WECC 2023HS1A approved base case) – Load Flow and Stability
- 2023LW Case (Created from WECC TEPPC 2022LA1S-TEPC approved base case) – Load Flow and Stability

The Heavy Summer ("HS") base cases represent the non-coincident peak summer load of the Member Cooperatives and the Light Winter ("LW") base cases represent approximately 70% of the SWTC non-coincident peak winter load of the Member Cooperatives.

These base cases were updated with the latest (2012) load projections of SWTC, using the medium economic forecast. Base case and single contingency conditions were evaluated using PSLF to determine system impacts and timing of transmission facilities needed to mitigate those system impacts.

Numerous outage simulations were performed for heavy summer and light winter conditions for the years 2014, 2019 and 2023. The analyses looked at the impact of the most recent projected member system load growth to the interconnected transmission system. The analyses determined where facilities would be placed to most economically serve this projected member system load.

ON-GOING BTA REQUIREMENTS

The Seventh Biennial Transmission Assessment (BTA) was approved in December 2012 by the Commission as Decision #73625. Recommendation #7E of this BTA states the following:

"Continue to require the jurisdictional utilities to include planned transmission reconductor projects, transformer capacity upgrade projects and reactive power compensation facility additions at 115 kV and above in future 10-year plan filings."

There are no transmission reconductor projects or capacity upgrade projects in this ten year plan filing.

Reactive power compensation facility additions at 115 kV and above for this ten year plan filing, are as per the following schedule:

Year	Substation	MVAR Quantity
2015	Avra Valley	9.45
2014	Butterfield	14.4
2015	Sahaurita	14.4
2017	Bicknell	19.2
2019	Avra Valley	19.2
2019	Dos Condados	50 (Moved from Morenci)
2023	Kartchner	9.6
2023	San Rafael	9.45 & 14.4

The capacitor banks at Avra Valley, Butterfield and Sahuarita are planned projects in SWTC's 2013-2016 Construction Work Plan ("CWP") that are scheduled to be constructed according to

this schedule. The other capacitor banks are considered conceptual projects that have not yet been vetted by the Class A Operating Committee ("CAOC") for placement into future CWP's. The 50 MVAR bank at Morenci in 2019 will be a unit that is proposed to be moved from Morenci where 2-50 MVAR units are installed. Additional studies conducted during 2014, due to a potential change in the upcoming 2013 load forecast or other circumstances may tend to refine these values and/or suggest the need to adjust locations for reactive support to the SWTC system. These will be reported in the next ten year plan filing.

NEAR TERM ASSESSMENT (2014-2019)

2014 Heavy Summer Conditions

The 2014HS SWTC base case developed from the WECC approved 2013HS2-OP base case was used as the base model for this projected timeframe. The load levels within the case were adjusted to represent the non-coincidental loads of the Member Systems totaling 679.72 MW served by SWTC transmission (not including system losses).

The system additions represented in this base year are:

- Butterfield 14.4 MVAR Capacitor Bank

The Saguaro to Tucson 115 kV line loop-in to Marana Project that was modeled in last year's Ten Year Plan, with an in-service date of 2015, was not modeled for this year's Ten Year Plan, due to ongoing discussions internally regarding this Project and with discussions with Western. The in-service date for the project has been changed to TBD. Negotiations with Western may result in a change of this designation or result in the project not being considered. SWTC expects to resolve the status of this project in next year's Ten Year Plan filing, to ensure that it provides benefits to both parties.

2014HS Category A (N-0) Analysis:

With all lines and facilities in service, the SWTC system for 2014 heavy summer conditions, meets the requirements and measures of the TPL Standards and does not require any further plans to meet Category A criteria.

2014HS Category B (N-1) Analysis:

The Category B criteria violations are as follows:

Voltage Violations:

- Under four N-1 outages, there are five (5) buses with voltages in excess of 1.05 per unit.

Voltage Deviations:

- Under one N-1 outage, there are three (3) buses with voltage deviations greater than 5%.

Thermal Overloads

- Under three N-1 outages, there is one (1) transmission element that exceeded its emergency rating.

There were no non-solved cases found on the system under the Category B criterion.

Mitigation Plans

Four of the five buses with voltages in excess of 1.05 per unit do not belong to SWTC, nor do the outaged elements that caused the voltages to be in excess of 1.05 per unit belong to SWTC. These will be addressed by the system owners.

Mitigation of the one SWTC bus with a voltage in excess of 1.05 per unit, the Saddlebrooke 115 kV bus, is also caused by an outaged element that does not belong to SWTC and would therefore be addressed by the system owner that provides transmission service to the Saddlebrooke substation.

The three buses that experience voltage deviations are the Avra, Marana and Sandario 115 kV buses for an outage of the Saguaro to Marana Tap 115 kV line. Mitigation to resolve these voltage deviations will be through the use of existing and planned capacitor banks on the SWTC system.

The one element exhibiting thermal overload issues is the SWTC Greenlee 345/230 kV transformer for the loss of the Freeport McMoRan ("FMI") Greenlee to Copper Verde 345 kV line, or loss of the FMI Copper Verde to Frisco 230 kV line or for loss of the FMI PD-Morenci to Frisco 230 kV line. The thermal issues will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

2014HS Category C (N-2) Analysis:

The Category C criteria violations are as follows:

Voltage Violations:

- Under one N-2 outage, there is one (1) bus with a voltage less than 0.90 per unit.

Voltage Deviations:

- Under one N-2 outage, there is one (1) bus with a voltage deviation greater than 10%.

Thermal Overloads:

- Under various N-2 outages, there are six (6) transmission elements that exceeded their emergency ratings.

There was one non-solved cases found on the system under the Category C criterion.

Mitigation Plans

The one bus exhibiting low voltage and voltage deviations is the Hackberry 230 kV bus for the loss of the Dos Condados to Hackberry and Hackberry to Morenci 230 kV lines. The Hackberry bus becomes islanded in this scenario and there is a potential for loss of load. This will be mitigated by implementing the Hackberry to Thatcher Reverse Power Relay operating procedure to resolve the issue and ensure that the SWTC member system loads in the area are not impacted.

The six N-2 elements exhibiting thermal overload issues are the Western Saguaro East to Marana Tap 115 kV line, the SWTC Marana Tap to Marana 115 kV line, the SWTC Three Points to Sandario Tap 115 kV line, one FMI Copper Verde 345/230 kV transformer, the SWTC Bicknell 345/230 kV transformer and the SWTC Greenlee 345/230 kV transformer.

The Saguaro East to Marana Tap and Marana Tap to Marana 115 kV lines are limited by disconnect switches at Marana Tap, which would need to be replaced. Mitigation of these outages and the outage of the Three Points to Sandario 115 kV line will be accomplished by shedding load. Overloads of the Bicknell 345/230 kV transformer will also be accomplished by shedding load.

The overload of one FMI Copper Verde 345/230 kV transformer is an issue that has been studied by affected utilities in the area and will be addressed by FMI.

The thermal issues involving the overload of the Greenlee 345/230 kV transformer will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

In order to mitigate the one non-solved case, it will be necessary for SWTC to either shed load at the appropriate locations or adjust generation dispatch, to bring post contingency voltages and thermal loading within the Category C criterion.

2014HS Category D (N-n) Analysis:

A load flow was conducted to assess Category D conditions and eight (8) common corridor or adjacent transmission circuit outages were selected for study. It should be noted that these outages are considered Category D by NERC, but are considered Category B by WECC. All eight outages solved with no voltage violations or thermal overload issues.

2014 Light Winter Conditions

The 2014LW SWTC base case developed from the WECC approved 2013-14 LW1 base case was used as the base model for this projected timeframe. The load levels within the case were adjusted to represent approximately 70% of the peak non-coincidental winter peak loads of the

Member systems totaling 381.26 MW served by the SWTC transmission system (not including system losses).

The system additions represented in this base year are the same as those shown for the 2014 Heavy Summer case.

2014LW Category A (N-0) Analysis:

With all lines and facilities in service, the SWTC system for 2014 light winter conditions, meets the requirements and measures of the TPL Standards and does not require any further plans to meet Category A criteria.

2014LW Category B (N-1) Analysis:

The Category B criteria violations are as follows:

Voltage Violations:

- Under two N-1 outages, there are two (2) buses with voltages in excess of 1.05 per unit.

Voltage Deviations:

- None

Thermal Overloads:

- None

There were no non-solved cases found on the system under the Category B criterion.

Mitigation Plans

The two buses with voltages in excess of 1.05 per unit do not belong to SWTC, nor do the outaged elements that caused the voltages to be in excess of 1.05 per unit belong to SWTC. These will be mitigated by the system owners.

2014LW Category C (N-2) Analysis:

The Category C criteria violations are as follows:

Voltage Violations:

- Under one N-2 outage, there is one bus (1) bus with a voltage less than 0.90 per unit.

Voltage Deviations:

- Under one N-2 outage, there is one bus (1) with a voltage deviation greater than 10%.

Thermal Overloads:

- Under three N-2 outages, there are five (5) transmission elements that exceeded their emergency ratings.

There were no non-solved cases found on the system under the Category C criterion.

Mitigation Plans

The one bus exhibiting low voltage and voltage deviations is the Hackberry 230 kV bus for the loss of the Dos Condados to Hackberry and Hackberry to Morenci 230 kV lines. The Hackberry bus becomes islanded in this scenario and there is a potential for loss of load. This will be mitigated by implementing the Hackberry to Thatcher Reverse Power Relay operating procedure to resolve the issues and ensure that the SWTC member system loads in the area are not impacted.

The five overloaded transmission elements are the Western Saguaro East to Marana Tap 115 kV line, the SWTC Marana Tap to Marana 115 kV line, the SWTC Three Points to Sandario Tap 115 kV line, one FMI Copper Verde 345/230 kV transformer and the SWTC Greenlee 345/230 kV transformer.

The Saguaro East to Marana Tap and Marana Tap to Marana 115 kV lines are limited by disconnect switches at Marana Tap, which would need to be replaced. Mitigation of these outages and the outage of the Three Points to Sandario 115 kV line will be accomplished by shedding load.

The overload of one FMI Copper Verde 345/230 kV transformer is an issue that has been studied by affected utilities in the area and will be addressed by FMI.

The thermal issues involving the overload of the Greenlee 345/230 kV transformer will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

2014LW Category D (N-n) Analysis:

A load flow was conducted to assess Category D conditions and eight (8) common corridor or adjacent transmission circuit outages were selected for study. All eight outages solved with no voltage violations or thermal overload issues.

2019 Light Winter Conditions

The 2019LW SWTC base case developed from the WECC approved 2022LA1S-TEPC base case was used as the base model for this projected timeframe. The load levels within the case were adjusted to represent approximately 70% of the peak non-coincidental winter peak loads of the

Member systems (excluding AEC) totaling 409.66 MW served by SWTC transmission (not including system losses).

The system additions represented in this base year are:

- Avra Valley 9.45 MVAR Capacitor Bank (2015)
- Sahuarita 14.4 MVAR Capacitor Bank (2015)
- Bicknell 19.2 MVAR Capacitor Bank (2017)

2019LW Category A (N-0) Analysis:

With all lines and facilities in service, the SWTC system for 2019 light winter conditions, meets the requirements and measures of the TPL Standards and does not require any further plans to meet Category A criteria.

2019LW Category B (N-1) Analysis:

The Category B criteria violations are as follows:

Voltage Violations:

- Under one N-1 outage, there is one (1) bus with a voltage in excess of 1.05 per unit.

Voltage Deviations:

- None.

Thermal Overloads:

- Under two N-1 outage, there is (1) transmission element that exceeded its emergency rating.

There were no non-solved cases found on the system under the Category B criterion.

Mitigation Plans

The one bus with a voltage in excess of 1.05 per unit does not belong to SWTC, nor does the outaged elements that caused the voltage to be in excess of 1.05 per unit belong to SWTC. This will be addressed by the system owners.

The one element exhibiting thermal overload issues is the SWTC Greenlee 345/230 kV transformer for the loss of the FMI Greenlee to Copper Verde 345 kV line, or for loss of the FMI Copper Verde to Frisco 230 kV line. The thermal issues will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

2019LW Category C (N-2) Analysis:

The Category C criteria violations are as follows:

Voltage Violations:

- Under one N-2 outage, there is one (1) bus with a voltage that is less than 0.90 per unit.

Voltage Deviations:

- Under one N-2 outage, there is one (1) bus with a voltage deviation greater than 10%.

Thermal Overloads:

- Under several N-2 outages, there is one (1) transmission element that exceeded its emergency rating.

There was one non-solved case found on the system under the Category C criterion.

Mitigation Plans

The one bus exhibiting low voltage and voltage deviations is the Hackberry 230 kV bus for the loss of the Dos Condados to Hackberry and Hackberry to Morenci 230 kV lines. The Hackberry bus becomes islanded in this scenario and there is a potential for loss of load. This will be mitigated by implementing the Hackberry to Thatcher Reverse Power Relay operating procedure to resolve the issue and ensure that the SWTC member system loads in the area are not impacted.

The thermal issues involve the overload of the Greenlee 345/230 kV transformer and will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

In order to mitigate the one non-solved case, it will be necessary for SWTC to either shed load at the appropriate locations or adjust generation dispatch, to bring post contingency voltages and thermal loading within the Category C criterion.

2019LW Category D (N-n) Analysis:

A load flow was conducted to assess Category D conditions and eight (8) common corridor or adjacent transmission circuit outages were selected for study. All eight outages solved with no voltage violations or thermal overload issues.

LONG TERM ASSESSMENT (2019-2023)

2019 Heavy Summer Conditions

The 2019HS SWTC base case developed from the WECC approved 2023HS1 base case was used as the base model for this projected timeframe. The load levels within the case were adjusted to represent the non-coincidental loads of the Member systems totaling 762.93 MW served by SWTC transmission (not including system losses).

The system additions represented in this base year are the same as those shown for the 2019LW case as well as the following:

- Avra Valley 19.2 MVAR Capacitor Bank

2019HS Category A (N-0) Analysis:

With all lines and facilities in service, the SWTC system for 2019 heavy summer conditions, meets the requirements and measures of the TPL Standards and does not require any further plans to meet Category A criteria.

2019HS Category B (N-1) Analysis:

The Category B criteria violations are as follows:

Voltage Violations:

- Under one N-1 outage, there is one (1) bus with a voltage in excess of 1.05 per unit.

Voltage Deviations:

- Under one N-1 outages, there is one (1) bus with a voltage deviation greater than 5%.

Thermal Overloads:

- Under five N-1 outages, there are two (2) transmission elements that exceeded their emergency ratings.

There were no non-solved cases found on the system under the Category B criterion.

Mitigation Plans

The one bus with a voltage in excess of 1.05 per unit does not belong to SWTC, nor does the outaged element that caused the voltage to be in excess of 1.05 per unit belong to SWTC. This will be addressed by the system owners.
The one bus that experiences a voltage deviation is the Pantano 115 kV bus for an outage of the Pantano 230/115 kV transformer. Mitigation to resolve this voltage deviation will be through the use of existing and planned capacitor banks on the SWTC system.

The two overloaded transmission elements are one FMI Copper Verde 345/230 kV transformer and the SWTC Greenlee 345/230 kV transformer.

The thermal issues involving an overload of one Copper Verde 345/230 kV transformer is due to loss of the second Copper Verde 345/230 kV transformer. This is an issue that has been studied by affected utilities in the area and will be addressed by FMI.

The thermal issues involve the overload of the Greenlee 345/230 kV transformer and will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

2019HS Category C (N-2) Analysis:

The Category C criteria violations are as follows:

Voltage Violations:

- None

Voltage Deviations:

- None

Thermal Overloads:

- Under various N-2 outages, there were nine (9) transmission elements that exceeded their emergency ratings.

There were four non-solved cases found on the system under the Category C criterion.

Mitigation Plans

No mitigation plans are needed for category C voltage issues or voltage deviations on the SWTC system.

The eight overloaded transmission elements are the TEP Winchester to Vail 345 kV line, the FMI Copper Verde to Frisco 230 kV line, the FMI PD-Morenci to Frisco 230 kV Line, the SWTC Morenci to Greenlee 230 kV line, the SWTC Three Points to Sandario 115 kV line, one TEP Vail2 345/138 kV transformer, one Copper Verde 345/230 kV transformer, one SWTC Apache 230/115 kV transformer and the SWTC Greenlee 345/230 kV transformer.

The thermal issues involving the overload of the Winchester to Vail 345 kV line and the Vail2 345/138 kV transformer will be addressed by TEP.

The overload of the FMI Copper Verde to Frisco and PD-Morenci to Frisco 230 kV lines will need to be addressed by FMI.

The overload of the SWTC Morenci to Greenlee 230 kV line and the overload of the Three Points to Sandario 115 kV line will mitigated by shedding load. Overloads of the one Apache 230/115 kV transformer will be mitigated by a redispatch of Apache generation.

The overload of one FMI Copper Verde 345/230 kV transformer is an issue that has been studied by affected utilities in the area and will be addressed by FMI.

The thermal issues involve the overload of the Greenlee 345/230 kV transformer and will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

In order to mitigate the non-solved cases, it will be necessary for SWTC to either shed load at the appropriate locations or adjust generation dispatch, to bring post contingency voltages and thermal loading within the Category C criterion.

2019HS Category D (N-n) Analysis:

A load flow was conducted to assess Category D conditions and eight (8) common corridor or adjacent transmission circuit outages were selected for study. Of the eight outages, one did not solve, #1. To mitigate this one outage, it will be necessary for SWTC to either shed load or adjust generation dispatch.

2023 Heavy Summer Conditions

The 2023HS SWTC base case developed from the WECC approved 2023HS1 base case was used as the base model for this projected timeframe. The load levels within the case were adjusted to represent the non-coincidental loads of the Member systems (excluding AEC) totaling 839.5 MW served by SWTC transmission (not including system losses).

The system additions represented in this base year are:

- Kartchner 9.6 MVAR Capacitor Bank
- San Rafael 9.45 MVAR and 14.4 MVAR Capacitor Banks

2023HS Category A (N-0) Analysis:

With all lines and facilities in service, the SWTC system for 2023 summer conditions, meets the requirements and measures of the TPL Standards and does not require any further plans to meet Category A criteria.

2023HS Category B (N-1) Analysis:

The Category B criteria violations are as follows:

Voltage Violations:

- Under one N-1 outages, there is one (1) bus with a voltage in excess of 1.05 per unit.

Voltage Deviations:

- None

Thermal Overloads:

- Under various N-1 outages, there were three (3) transmission elements that exceeded their emergency ratings.

There were no non-solved cases found on the system under the Category B criterion.

Mitigation Plans

The one bus with a voltage in excess of 1.05 per unit does not belong to SWTC, nor does the outaged element that caused the voltage to be in excess of 1.05 per unit belong to SWTC. This will be addressed by the system owners.

The two overloaded transmission elements are one FMI Copper Verde 345/230 kV transformer, the Bicknell to Three Points 115 kV line and the SWTC Greenlee 345/230 kV transformer.

The overload of one FMI Copper Verde 345/230 kV transformer is an issue that has been studied by affected utilities in the area and will be addressed by FMI.

The overload of the Bicknell to Three Points 115 kV line will be mitigated by either by a rebuild of the line or the consideration of an additional project under study.

The thermal issues involve the overload of the Greenlee 345/230 kV transformer and will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

2023HS Category C (N-2) Analysis:

The Category C criteria violations are as follows:

Voltage Violations:

- None

Voltage Deviations:

- None

Thermal Overloads:

- Under various N-2 outages, there are twelve (12) transmission elements that exceeded their emergency ratings.

There were six non-solved cases found on the system under the Category C criterion.

Mitigation Plans

The twelve overloaded transmission elements are the Western Saguaro East to Marana Tap 115 kV line, the TEP Winchester to Vail 345 kV line, the TEP Winchester to Willow 345 kV line, the FMI Copper Verde to Frisco 230 kV line, the FMI PD Morenci to Frisco 230 kV line, the SWTC Apache to Butterfield 230 kV line, the SWTC Bicknell to Three Points 115 kV line, the SWTC Morenci to Greenlee 230 kV line, the SWTC Three Points to Sandario 115 kV line, on TEP Vail2 345/138 kV transformer, one FMI Copper Verde 345/230 kV transformer, one SWTC Apache 230/115 kV transformer, and the SWTC Greenlee 345/230 kV transformer.

The overload of the Saguaro East to Marana Tap 115 kV line would need to be addressed by Western. However, it is anticipated that by this date, the line would either be upgraded or the system elements that are causing the overload, would be upgraded.

Overloads involving the Winchester to Vail and Winchester to Willow 345 kV lines, as well as overloads of the Vail2 345/138 kV transformer, will be addressed by TEP.

The overload of the FMI Copper Verde to Frisco and PD-Morenci to Frisco 230 kV lines will need to be addressed by FMI.

Overloads of the Apache to Butterfield and Morenci to Greenlee 230 kV lines, as well as the Bicknell to Three Points and Three Points to Sandario 115 kV lines, will be mitigated by shedding load. Overloads of the one Apache 230/115 kV transformer will be mitigated by a resdispatch of Apache generation.

The thermal issues involve the overload of the Greenlee 345/230 kV transformer and will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

In order to mitigate the non-solved cases, it will be necessary for SWTC to either shed load at the appropriate locations or for generation to be adjusted to bring post contingency voltages and thermal loading within the Category C criterion.

2023HS Category D (N-n) Analysis:

A load flow was conducted to assess Category D conditions and eight (8) common corridor or adjacent transmission circuit outages were selected for study. Of the eight outages, five did not solve, #1. To mitigate this one outage, it will be necessary for SWTC to either shed load at the appropriate locations or for generation to be adjusted.

2023 Light Winter Conditions

The 2018LW base case developed from the WECC approved 2022LA1S-TEPC base case was used as the base model for this projected timeframe. The load levels within the case were adjusted to represent approximately 70% of the peak non-coincidental winter peak loads of the Member systems (excluding AEC) totaling 454.7 MW served by SWTC transmission (not including system losses).

The system additions represented in this base year have been noted previously.

2023LW Category A (N-0) Analysis:

With all lines and facilities in service, the SWTC system for 2023 light winter conditions, meets the requirements and measures of the TPL Standards and does not require any further plans to meet Category A criteria.

2023LW Category B (N-1) Analysis:

The Category B criteria violations are as follows:

Voltage Violations:

- Under one N-1 outage, there is one (1) bus with a voltage in excess of 1.05 per unit.

Voltage Deviations:

- None

Thermal Overloads:

- Under two N-1 outage, there is one (1) transmission element that exceeded its emergency rating.

There were no non-solved cases found on the system under the Category B criterion.

Mitigation Plans

The one bus with a voltage in excess of 1.05 per unit does not belong to SWTC, nor does the outaged element that caused the voltage to be in excess of 1.05 per unit belong to SWTC. This will be addressed by the system owners.

The one overloaded transmission element is the SWTC Greenlee 345/230 kV transformer, which is due to loss of the Greenlee to Copper Verde 345 kV line or loss of the Copper Verde to Frisco 230 kV line. The thermal issues involve the overload of the Greenlee 345/230 kV transformer and will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

2023LW Category C (N-2) Analysis:

The Category C criteria violations are as follows:

Voltage Violations:

- Under one N-2 outage, there is one (1) bus with a voltage below 0.90 per unit.

Voltage Deviations:

- Under one N-2 outage, there is one (1) bus with a voltage deviations greater than 10%.

Thermal Overloads:

- Under several N-2 outages, there is one (1) transmission element that exceeded its emergency rating.

There was one non-solved case found on the system under the Category C criterion.

Mitigation Plans

The one bus exhibiting low voltage and voltage deviations is the Hackberry 230 kV bus for the loss of the Dos Condados to Hackberry and Hackberry to Morenci 230 kV lines. The Hackberry bus becomes islanded in this scenario and there is a potential for loss of load. This will be mitigated by implementing the Hackberry to Thatcher Reverse Power Relay operating procedure to resolve the issue and ensure that the SWTC member system loads in the area are not impacted.

The one overloaded transmission element is the SWTC Greenlee 345/230 kV transformer which will be mitigated by a long standing operating procedure that is in place to ease the overload of this transformer. There will be no loss of firm load under this procedure.

In order to mitigate the one non-solved case, it will be necessary for SWTC to either shed load at the appropriate locations or for generation to be adjusted to bring post contingency voltages and thermal loading within the Category C criterion.

2023LW Category D (N-n) Analysis:

A load flow was conducted to assess Category D conditions and eight (8) common corridor or adjacent transmission circuit outages were selected for study. All eight outages solved with no voltage or thermal overload issues.

REACTIVE MARGIN ANALYSIS

Q-V Analyses for reactive margin were performed for the interconnected SWTC transmission system for heavy summer and light winter conditions for the years 2014, 2019, and 2023. These can be found in Appendix D.

STABILITY ANALYSIS

Transient stability analyses were performed for the interconnected SWTC transmission system for heavy summer conditions for the years 2014, 2019, and 2023, using the cases listed in the Power Flow Analyses Section above.

Only a representative sample of the N-1 and N-2 outage conditions under heavy summer conditions for the study years 2014, 2019 and 2023 are included in this report.
The outages considered in this report are as follows:

N-1 Outage conditions:

- Apache to Butterfield 230 kV Line
- Apache to Redtail 230 kV Line
- Bicknell to Vail 345 kV Line
- Saguaro East to Marana 115 kV Line

N-2 Outage Conditions:

- Apache to Butterfield 230 kV & Saguaro East to Marana Tap 115 kV
- Apache to Butterfield 230 kV & Bicknell to Vail 345 kV

For double-contingency outages of the above lines, operating procedures are in place to curtail load.

These selective stability plots can be found in Appendix E.

SOUTHWEST TRANSMISSION COOPERATIVE, INC.

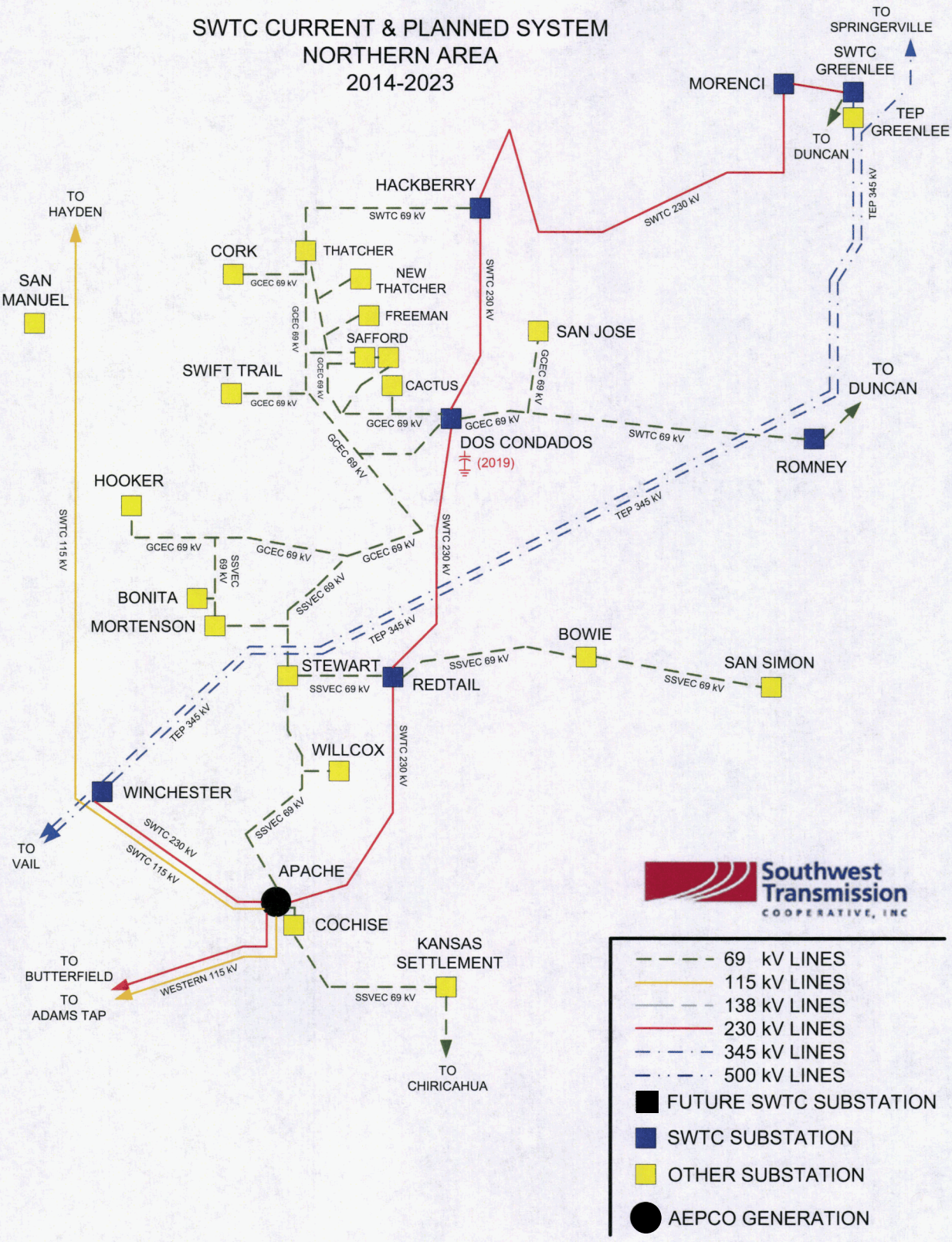
TEN-YEAR PLAN

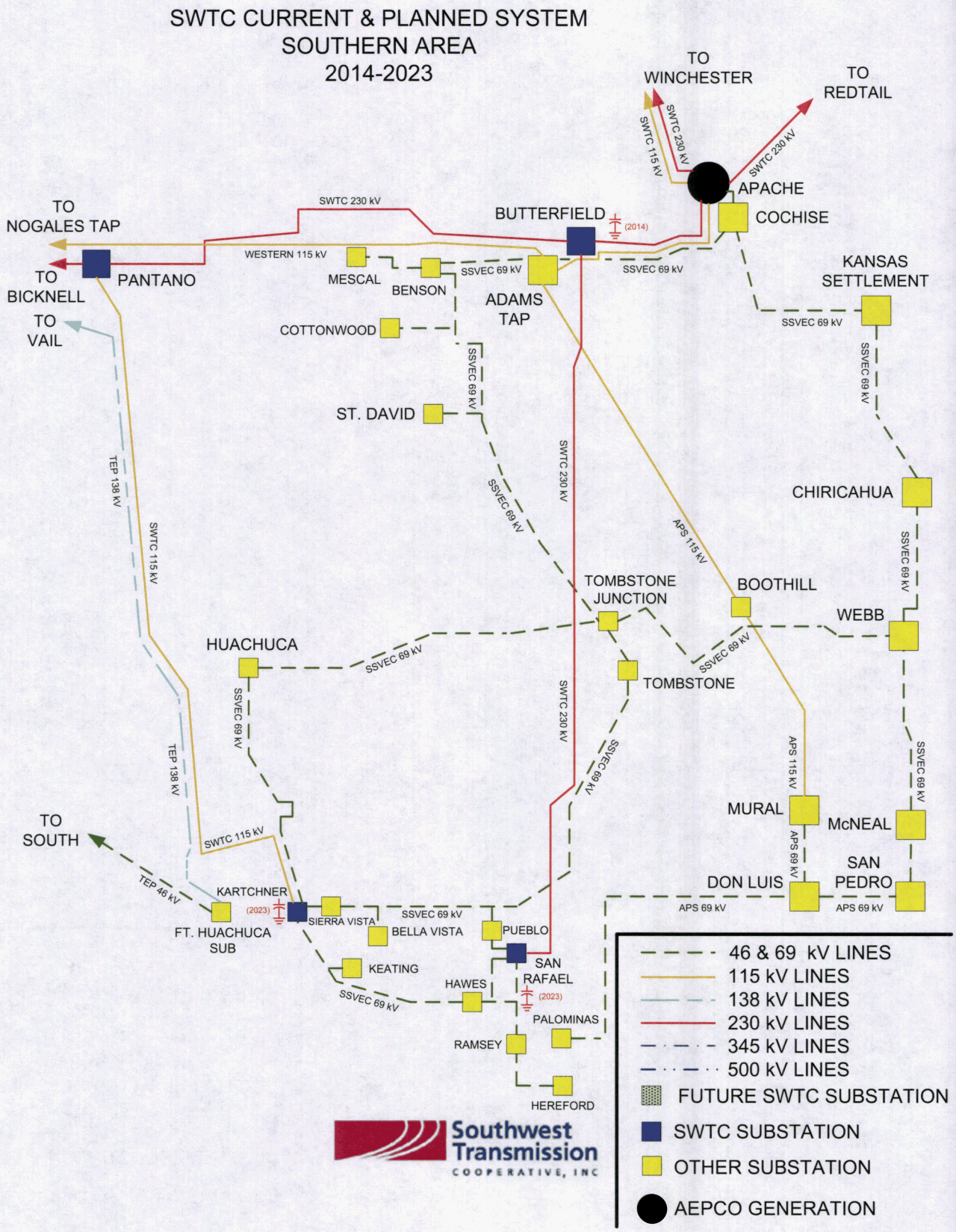
2011 - 2020

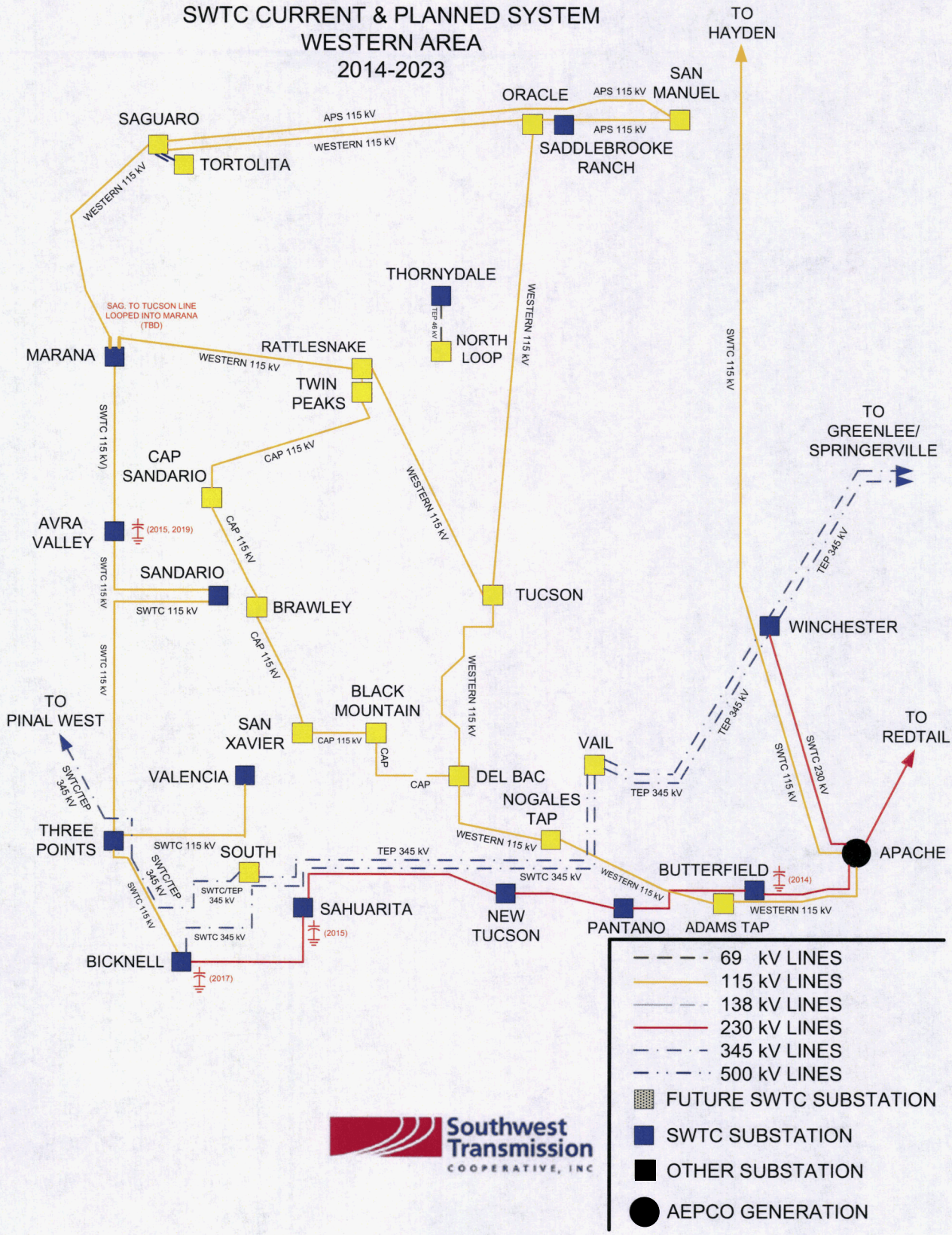
TECHNICAL STUDY REPORT APPENDICES

APPENDIX A

CURRENT AND PLANNED TRANSMISSION SYSTEM MAPS


SWTC CURRENT & PLANNED SYSTEM
NORTHERN AREA
2014-2023
TO SPRINGERVILLE
SWTC GREENLEE
MORENCI
TEP GREENLEE
TO DUNCAN
TEP 345 kV
SWTC 230 kV
HACKBERRY
SWTC 69 kV
TO HAYDEN
CORK
THATCHER
NEW THATCHER
FREEMAN
SAFFORD
SWIFT TRAIL
CACTUS
SAN JOSE
GCEC 69 kV
SAN MANUEL
SWTC 230 kV
DOS CONDADOS
(2019)
SWTC 69 kV
ROMNEY
TO DUNCAN
HOOKER
SWTC 115 kV
GCEC 69 kV
SSVEC 69 kV
BONITA
MORTENSON
TEP 345 kV
BOWIE
SAN SIMON
STEWART
REDTAIL
WILLCOX
WINCHESTER
TO VAIL
SWTC 230 kV
SWTC 115 kV
APACHE
COCHISE
KANSAS SETTLEMENT
TO BUTTERFIELD
TO ADAMS TAP
WESTERN 115 kV
TO CHIRICAHUA
Southwest Transmission COOPERATIVE, INC
69 kV LINES
115 kV LINES
138 kV LINES
230 kV LINES
345 kV LINES
500 kV LINES
FUTURE SWTC SUBSTATION
SWTC SUBSTATION
OTHER SUBSTATION
AEPCO GENERATION


SWTC CURRENT & PLANNED SYSTEM
SOUTHERN AREA
2014-2023
TO WINCHESTER
TO REDTAIL
SWTC 115 kV
SWTC 230 kV
SWTC 230 kV
APACHE
COCHISE
TO NOGALES TAP
SWTC 230 kV
BUTTERFIELD
(2014)
WESTERN 115 kV
MESCAL
BENSON
SSVEC 69 kV
SSVEC 69 kV
ADAMS TAP
KANSAS SETTLEMENT
SSVEC 69 kV
TO BICKNELL
PANTANO
TO VAIL
COTTONWOOD
SSVEC 69 kV
SSVEC 69 kV
ST. DAVID
SWTC 230 kV
TEP 138 kV
SSVEC 69 kV
CHIRICAHUA
APS 115 kV
SSVEC 69 kV
SWTC 115 kV
TOMBSTONE JUNCTION
BOOTHILL
WEBB
HUACHUCA
SSVEC 69 kV
SSVEC 69 kV
TOMBSTONE
SSVEC 69 kV
SWTC 230 kV
SSVEC 69 kV
TEP 138 kV
APS 115 kV
SSVEC 69 kV
MURAL
McNEAL
TO SOUTH
SWTC 115 kV
APS 69 kV
SAN PEDRO
TEP 46 kV
KARTCHNER
(2023)
SIERRA VISTA
SSVEC 69 kV
DON LUIS
APS 69 kV
APS 69 kV
FT. HUACHUCA SUB
BELLA VISTA
PUEBLO
KEATING
SAN RAFAEL
(2023)
HAWES
SSVEC 69 kV
PALOMINAS
RAMSEY
HEREFORD
Southwest Transmission
COOPERATIVE, INC
46 & 69 kV LINES
115 kV LINES
138 kV LINES
230 kV LINES
345 kV LINES
500 kV LINES
FUTURE SWTC SUBSTATION
SWTC SUBSTATION
OTHER SUBSTATION
AEPCO GENERATION


SWTC CURRENT & PLANNED SYSTEM
WESTERN AREA
2014-2023
TO HAYDEN
SAN MANUEL
ORACLE
APS 115 kV
APS 115 kV
SAGUARO
APS 115 kV
WESTERN 115 kV
SADDLEBROOKE RANCH
TORTOLITA
WESTERN 115 kV
THORNYDALE
TEP 46 kV
NORTH LOOP
WESTERN 115 kV
SWTC 115 kV
SAG. TO TUCSON LINE LOOPED INTO MARANA (TBD)
MARANA
RATTLESNAKE
WESTERN 115 kV
TWIN PEAKS
TO GREENLEE/ SPRINGERVILLE
SWTC 115 kV
CAP SANDARIO
CAP 115 kV
WESTERN 115 kV
TEP 345 kV
AVRA VALLEY
(2015, 2019)
CAP 115 kV
SWTC 115 kV
SANDARIO
SWTC 115 kV
BRAWLEY
TUCSON
WINCHESTER
SWTC 115 kV
CAP 115 kV
WESTERN 115 kV
TO PINAL WEST
BLACK MOUNTAIN
SAN XAVIER
CAP 115 kV
CAP
TEP 345 kV
SWTC 115 kV
SWTC 230 kV
TO REDTAIL
SWTC/TEP 345 kV
VALENCIA
CAP
DEL BAC
VAIL
NOGALES TAP
TEP 345 kV
THREE POINTS
SWTC 115 kV
SOUTH
WESTERN 115 kV
SWTC 345 kV
WESTERN 115 kV
BUTTERFIELD
(2014)
APACHE
SWTC/TEP 345 kV
TEP 345 kV
SWTC/TEP 345 kV
SWTC 115 kV
SAHUARITA
(2015)
NEW TUCSON
PANTANO
ADAMS TAP
WESTERN 115 kV
SWTC 345 kV
BICKNELL
(2017)
69 kV LINES
115 kV LINES
138 kV LINES
230 kV LINES
345 kV LINES
500 kV LINES
FUTURE SWTC SUBSTATION
SWTC SUBSTATION
OTHER SUBSTATION
AEPCO GENERATION
Southwest Transmission
COOPERATIVE, INC

APPENDIX B

2013-2023 POWER FLOW CONTINGENCY LIST

The following contingency list was used for all cases of this Assessment.

Contingency 1 represents loss of the Saguaro to Tucson 115 kV line, with associated taps (N-1)

Contingencies 2-7 represent various breaker failure scenarios (N-2).

Contingencies 8-15 represent common corridor or adjacent transmission circuit outages as defined by NERC for Category D (N-n) conditions

Contingencies 16 – 76 represent N-1 outage scenarios.

Contingencies 77-253 represent N-2 outage scenarios.

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1 Group_MARA115: | RATTLSNK 115 TUCSON 115 | RATTLSNK 115 TWINPEAK 115 | TWINPEAK 115
SANDARIO 115 | TWINPEAK 115 TWINPKAZ 115 | SAG.EAST 115 MARANATP 115 | MARANATP 115
MARANA 115 | MARANATP 115 RATTLSNK 115
2 Breaker_BICK230_1: | BICKNELL 345 VAIL 345 | BICKNELL 345 BICKNELL 230 | BICKNELL
230 BICKNELL 115 | BICKNELL 230 BICKNELL 115
3 Breaker_BICK230_2: | SAHUARIT 230 BICKNELL 230 | BICKNELL 345 VAIL 345 | BICKNELL
345 BICKNELL 230
4 Breaker_BUTE230: | APACHE 230 BUTERFLD 230 | BUTERFLD 230 PANTANO 230 | BUTERFLD 230
SAN RAF 230
5 Breaker_PANT230: | BUTERFLD 230 PANTANO 230 | PANTANO 230 NEWTUCSN 230 | PANTANO 230
PANTANO 115
6 Breaker_RED 230: | APACHE 230 RED TAIL 230 | RED TAIL 230 DOSCONDO 230
7 Breaker_WINC230: | WINCHSTR 345 WINCHSTR 230 | WINCHSTR 345 VAIL 345 | WINCHSTR 345
WILLOW 345
8 CommonCorr_1: | GREENLEE 345 COPPERVR 345 | MORENCI 230 GREEN-SW 230
9 CommonCorr_2: | BUTERFLD 230 PANTANO 230 | ADAMSTAP 115 APACHE 115
10 CommonCorr_3: | APACHE 230 BUTERFLD 230 | ADAMSTAP 115 APACHE 115
11 CommonCorr_4: | APACHE 230 BUTERFLD 230 | APACHE 115 HAYDENAZ 115
12 CommonCorr_5: | VAIL 345 SOUTH 345 | NEWTUCSN 230 SAHUARIT 230
13 CommonCorr_6: | PINALWES 345 SOUTH 345 | BICKNELL 115 THREEPNT 115
14 CommonCorr_7: | PINALWES 345 SOUTH 345 | THREEPNT 115 SNDARIO 115
15 CommonCorr_9: | APACHE 230 BUTERFLD 230 | APACHE 230 WINCHSTR 230
16 APAC115HAYD115: | APACHE 115 HAYDENAZ 115
17 APAC230APAC115: | APACHE 230 APACHE 115
18 APAC230APAC115: | APACHE 230 APACHE 115
19 APAC230BUTE230: | APACHE 230 BUTERFLD 230
20 APAC230RED 230: | APACHE 230 RED TAIL 230
21 APAC230WINC230: | APACHE 230 WINCHSTR 230
22 WINC345WINC230: | WINCHSTR 345 WINCHSTR 230
23 WINC345VAIL345: | WINCHSTR 345 VAIL 345
24 GREE345COPP345: | GREENLEE 345 COPPERVR 345
25 GREE345GREE345: | GREEN-SW 345 GREENLEE 345
26 SPRI345GREE345: | SPRINGR 345 GREENLEE 345
27 BUTE230PANT230: | BUTERFLD 230 PANTANO 230
28 RED 230DOSC230: | RED TAIL 230 DOSCONDO 230
29 DOSC230HACK230: | DOSCONDO 230 HACKBERY 230
30 HACK230MORE230: | HACKBERY 230 MORENCI 230
31 MORE230GREE230: | MORENCI 230 GREEN-SW 230
32 GREE345GREE230: | GREEN-SW 345 GREEN-SW 230
33 PANT230NEWT230: | PANTANO 230 NEWTUCSN 230
34 PANT230PANT115: | PANTANO 230 PANTANO 115
35 NEWT230SAHU230: | NEWTUCSN 230 SAHUARIT 230
36 SAHU230BICK230: | SAHUARIT 230 BICKNELL 230
37 PANT115KART115: | PANTANO 115 KARTCHNR 115
38 VAIL345SOUT345: | VAIL 345 SOUTH 345
39 BICK345VAIL345: | BICKNELL 345 VAIL 345
40 BICK345BICK230: | BICKNELL 345 BICKNELL 230
41 PINA345SOUT345: | PINALWES 345 SOUTH 345
42 PINA500PINA345: | PINAL_W 500 PINALWES 345
43 WEST345PINA345: | WESTWING 345 PINALWES 345
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44 WEST500WEST345:  | WESTWING 500 WESTWING 345
45 BICK230BICK115:  | BICKNELL 230 BICKNELL 115
46 BICK230BICK115:  | BICKNELL 230 BICKNELL 115
47 BICK115THRE115:  | BICKNELL 115 THREEPNT 115
48 THRE115SNDA115:  | THREEPNT 115 SNDARIO 115
49 THRE115VALE115:  | THREEPNT 115 VALEN-SW 115
50 AVRA115SNDA115:  | AVRA 115 SNDARIO 115
51 MARA115AVRA115:  | MARANA 115 AVRA 115
52 SPRI345VAIL345:  | SPRINGR 345 VAIL2 345
53 SAG.115SAG.115:  | SAG.EAST 115 SAG.WEST 115
54 SAG.115ORAC115:  | SAG.EAST 115 ORACLE 115
55 SAGU500SAG.115:  | SAGUARO 500 SAG.EAST 115
56 SAGU500SAG.115:  | SAGUARO 500 SAG.WEST 115
57 SAGU230SAG.115:  | SAGUARO 230 SAG.EAST 115
58 SAGU230SAG.115:  | SAGUARO 230 SAG.WEST 115
59 ORAC115ORAC115:  | ORACLE 115 ORACLEAZ 115
60 ORAC115S.BR115:  | ORACLE 115 S.BRKRCH 115
61 TUCS115ORAC115:  | TUCSON 115 ORACLE 115
62 SAG.115SNMA115:  | SAG.WEST 115 SNMANUEL 115
63 S.BR115SNMA115:  | S.BRKRCH 115 SNMANUEL 115
64 SAGU500TORT500:  | SAGUARO 500 TORTOLIT 500
65 SAGU500TORT500:  | SAGUARO 500 TORTOLIT 500
66 VAIL345VAIL138:  | VAIL 345 VAIL 138
67 VAIL345VAIL138:  | VAIL2 345 VAIL 138
68 BUTE230SAN 230:  | BUTERFLD 230 SAN RAF 230
69 COPP345COPP230:  | COPPERVR 345 COPPERVR 230
70 COPP345COPP230:  | COPPERVR 345 COPPERVR 230
71 COPP230FRIS230:  | COPPERVR 230 FRISCO 230
72 PD-M230FRIS230:  | PD-MORNC 230 FRISCO 230
73 PINA500DUKE500:  | PINAL_C 500 DUKE 500
74 PINA500DUKE500:  | PINAL_W 500 DUKE 500
75 GREE345WILL345:  | GREENLEE 345 WILLOW 345
76 WINC345WILL345:  | WINCHSTR 345 WILLOW 345
77 APAC230BUTE230 | APAC230RED 230:  | APACHE 230 BUTERFLD 230 | APACHE 230 RED TAIL
230
78 APAC230BUTE230 | WINC345WINC230:  | APACHE 230 BUTERFLD 230 | WINCHSTR 345 WINCHSTR
230
79 APAC230BUTE230 | WINC345WILL345:  | APACHE 230 BUTERFLD 230 | WINCHSTR 345 WILLOW
345
80 APAC230BUTE230 | WINC345VAIL345:  | APACHE 230 BUTERFLD 230 | WINCHSTR 345 VAIL 345
81 APAC230BUTE230 | GREE345COPP345:  | APACHE 230 BUTERFLD 230 | GREENLEE 345 COPPERVR
345
82 APAC230BUTE230 | SPRI345GREE345:  | APACHE 230 BUTERFLD 230 | SPRINGR 345 GREENLEE
345
83 APAC230BUTE230 | HACK230MORE230:  | APACHE 230 BUTERFLD 230 | HACKBERY 230 MORENCI
230
84 APAC230BUTE230 | GREE345GREE230:  | APACHE 230 BUTERFLD 230 | GREEN-SW 345 GREEN-SW
230
85 APAC230BUTE230 | SAHU230BICK230:  | APACHE 230 BUTERFLD 230 | SAHUARIT 230 BICKNELL
230
86 APAC230BUTE230 | VAIL345SOUT345:  | APACHE 230 BUTERFLD 230 | VAIL 345 SOUTH 345
87 APAC230BUTE230 | BICK345BICK230:  | APACHE 230 BUTERFLD 230 | BICKNELL 345 BICKNELL
230
88 APAC230BUTE230 | BICK230BICK115:  | APACHE 230 BUTERFLD 230 | BICKNELL 230 BICKNELL
115
89 APAC230BUTE230 | BICK115THRE115:  | APACHE 230 BUTERFLD 230 | BICKNELL 115 THREEPNT
115
90 APAC230BUTE230 | THRE115SNDA115:  | APACHE 230 BUTERFLD 230 | THREEPNT 115 SNDARIO
115
91 APAC230BUTE230 | AVRA115SNDA115:  | APACHE 230 BUTERFLD 230 | AVRA 115 SNDARIO 115
92 APAC230BUTE230 | MARA115AVRA115:  | APACHE 230 BUTERFLD 230 | MARANA 115 AVRA 115
93 APAC230BUTE230 | SPRI345VAIL345:  | APACHE 230 BUTERFLD 230 | SPRINGR 345 VAIL2 345
94 APAC230BUTE230 | SAG.115MARA115:  | APACHE 230 BUTERFLD 230 | RATTLSNK 115 TUCSON
115 | SAG.EAST 115 MARANATP 115 | MARANATP 115 MARANA 115
95 APAC230RED 230 | APAC230WINC230:  | APACHE 230 RED TAIL 230 | APACHE 230 WINCHSTR
230
96 APAC230RED 230 | WINC345WINC230:  | APACHE 230 RED TAIL 230 | WINCHSTR 345 WINCHSTR
230
97 APAC230RED 230 | WINC345WILL345:  | APACHE 230 RED TAIL 230 | WINCHSTR 345 WILLOW
345
98 APAC230RED 230 | WINC345VAIL345:  | APACHE 230 RED TAIL 230 | WINCHSTR 345 VAIL 345
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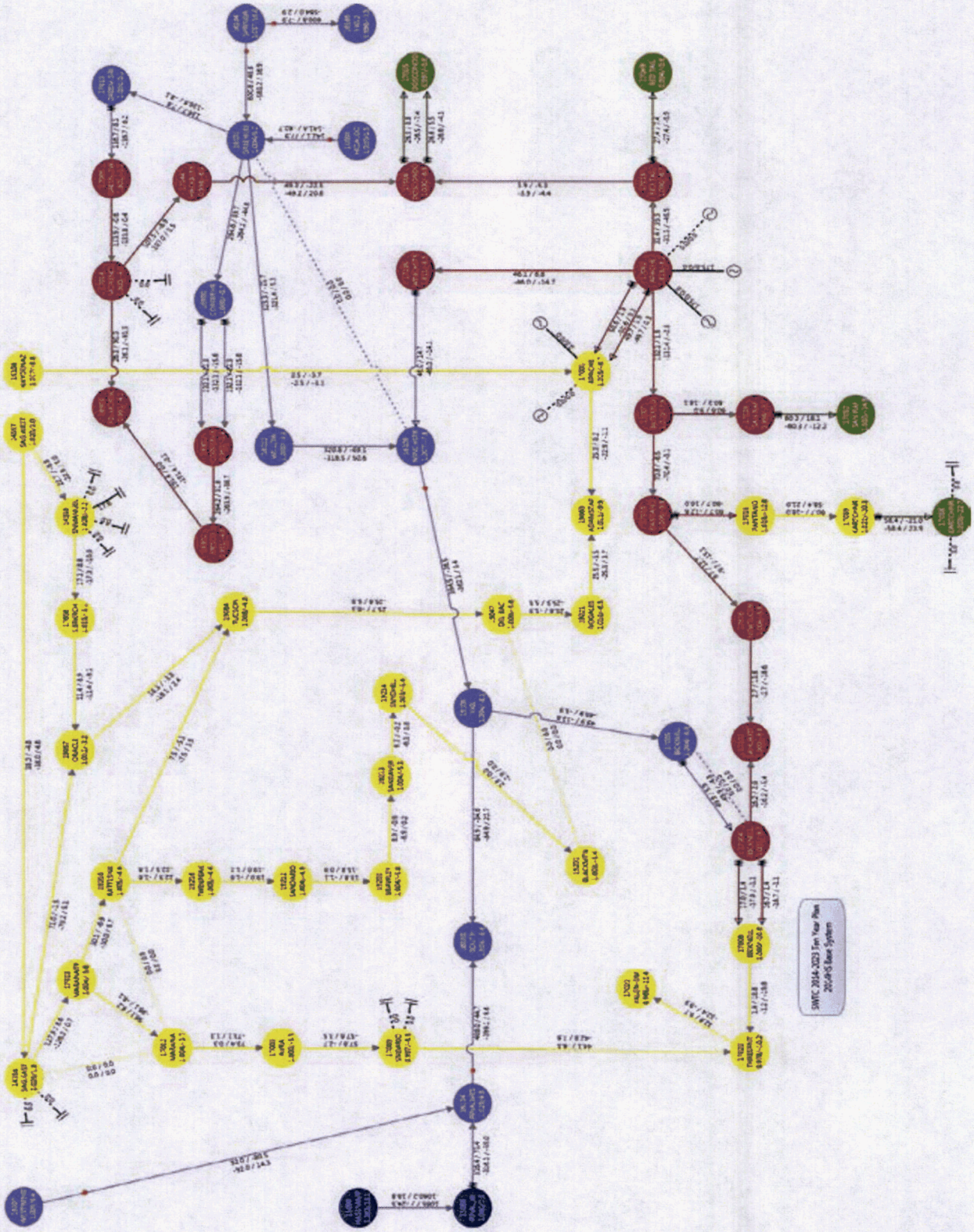
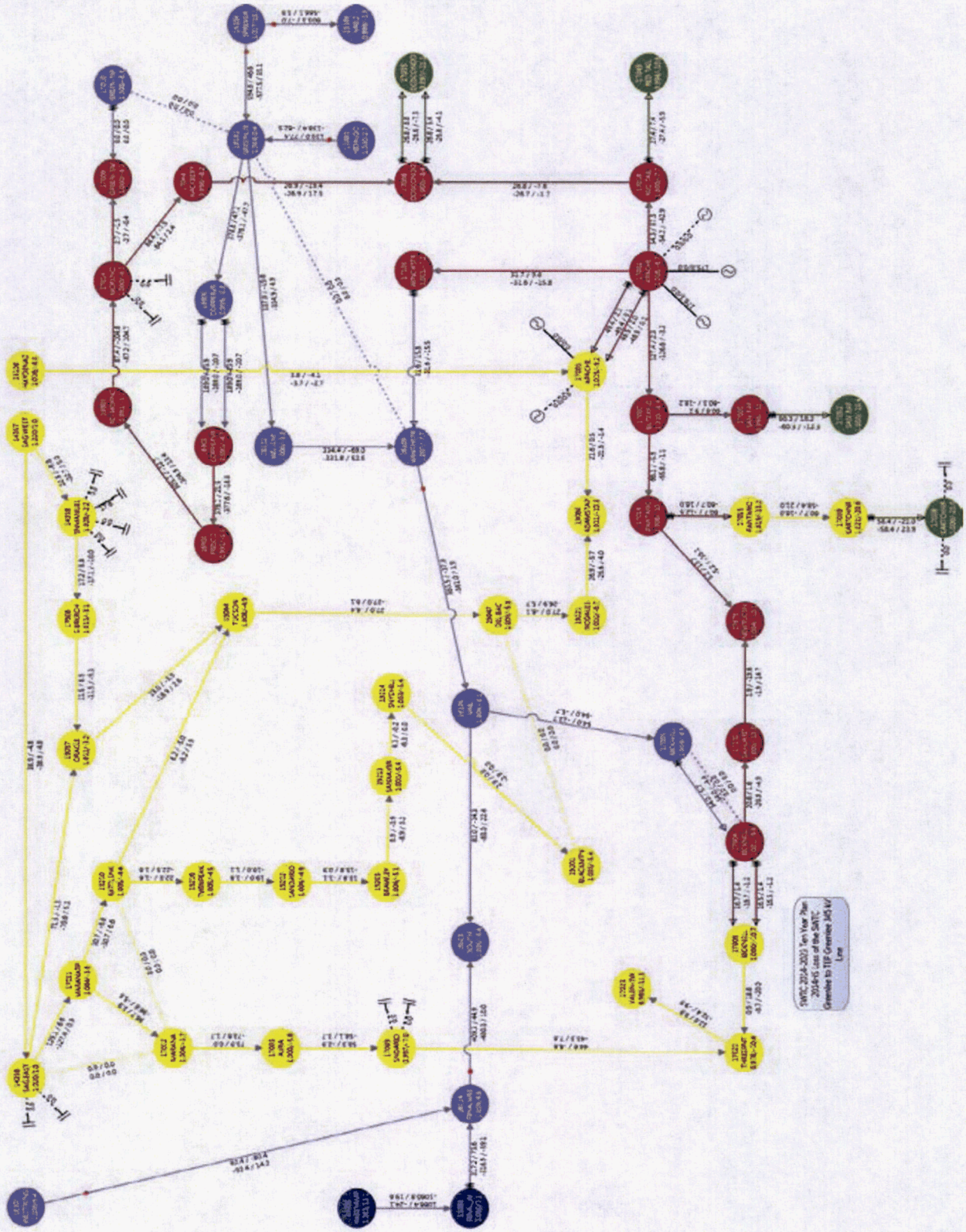
APPENDIX C

POWER FLOW ONE LINE DIAGRAMS

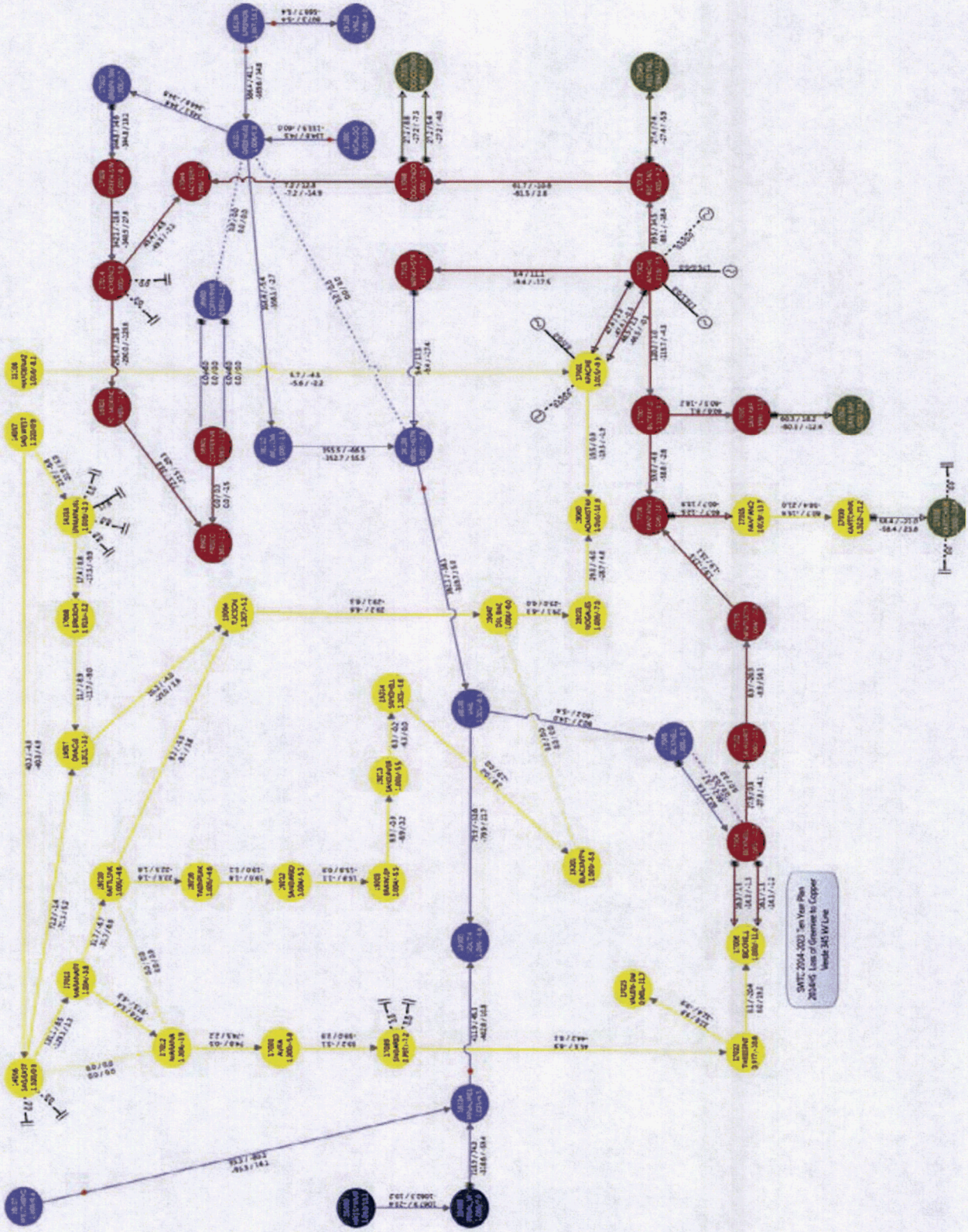
2014HS Southwest Transmission Cooperative Base System



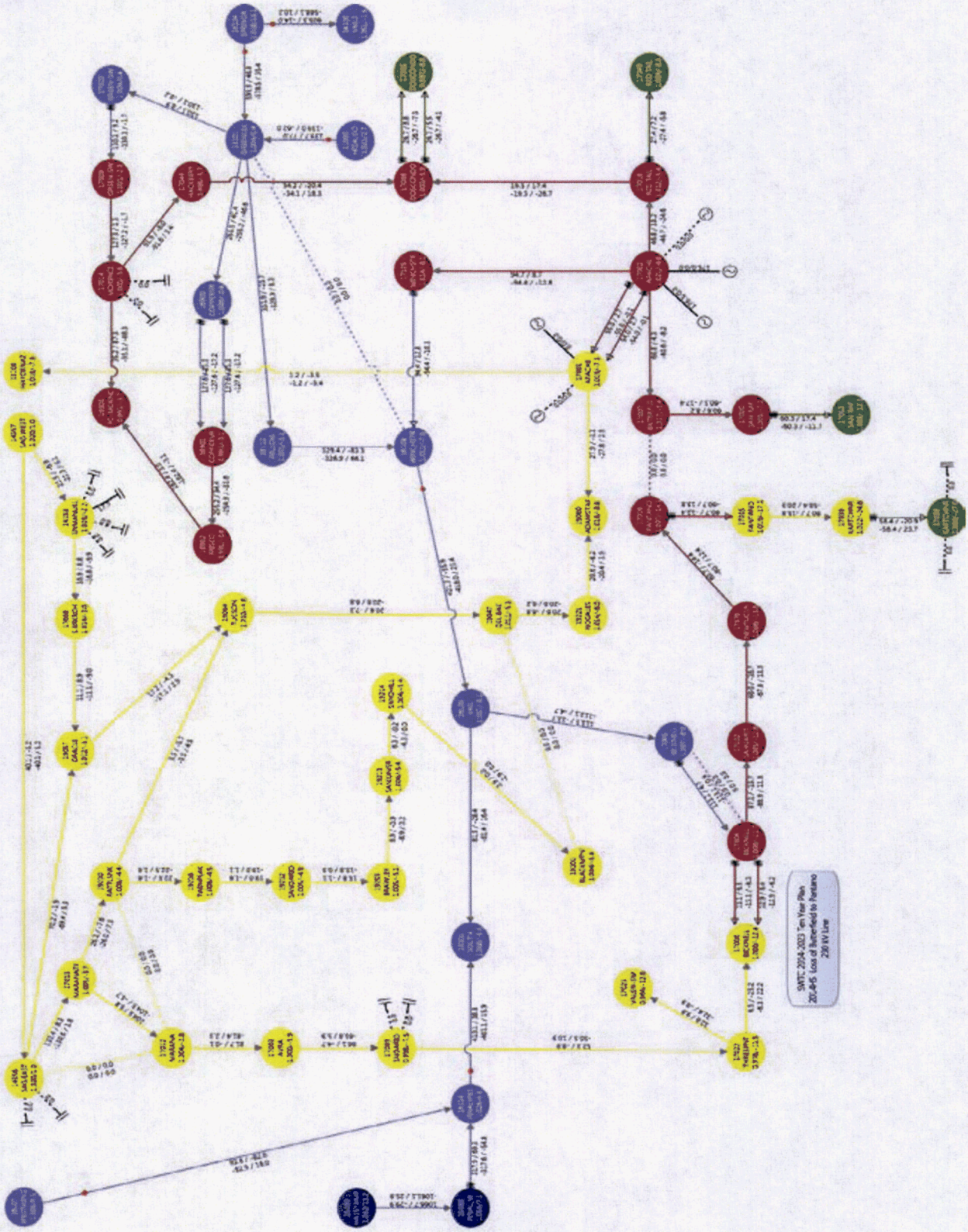
2014HS Southwest Transmission Cooperative Base System with Green-SW to Greenlee 345 kV Line out of service



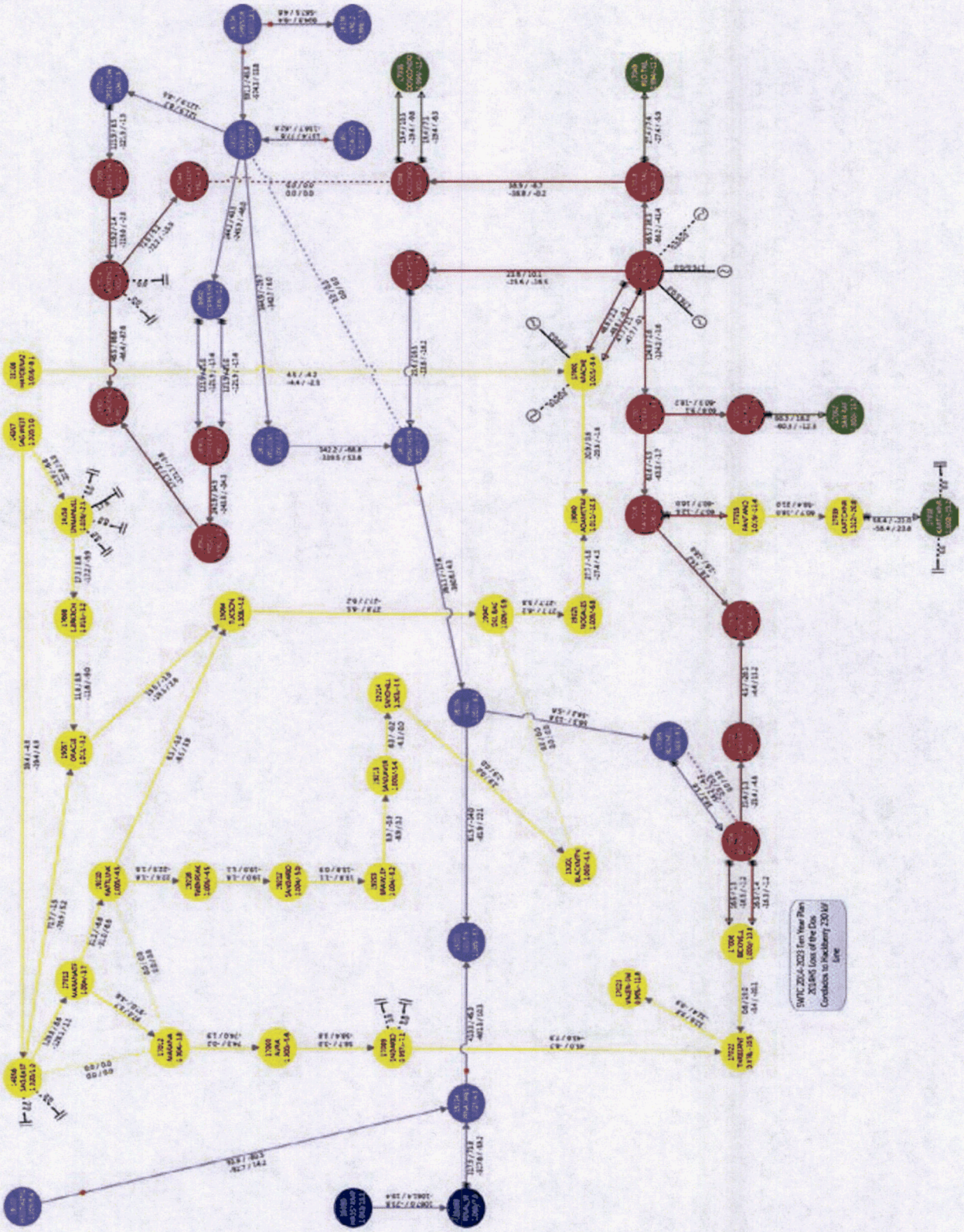
2014HS Southwest Transmission Cooperative Base System with Greenlee to Copper Verde 345 kV Line out of service



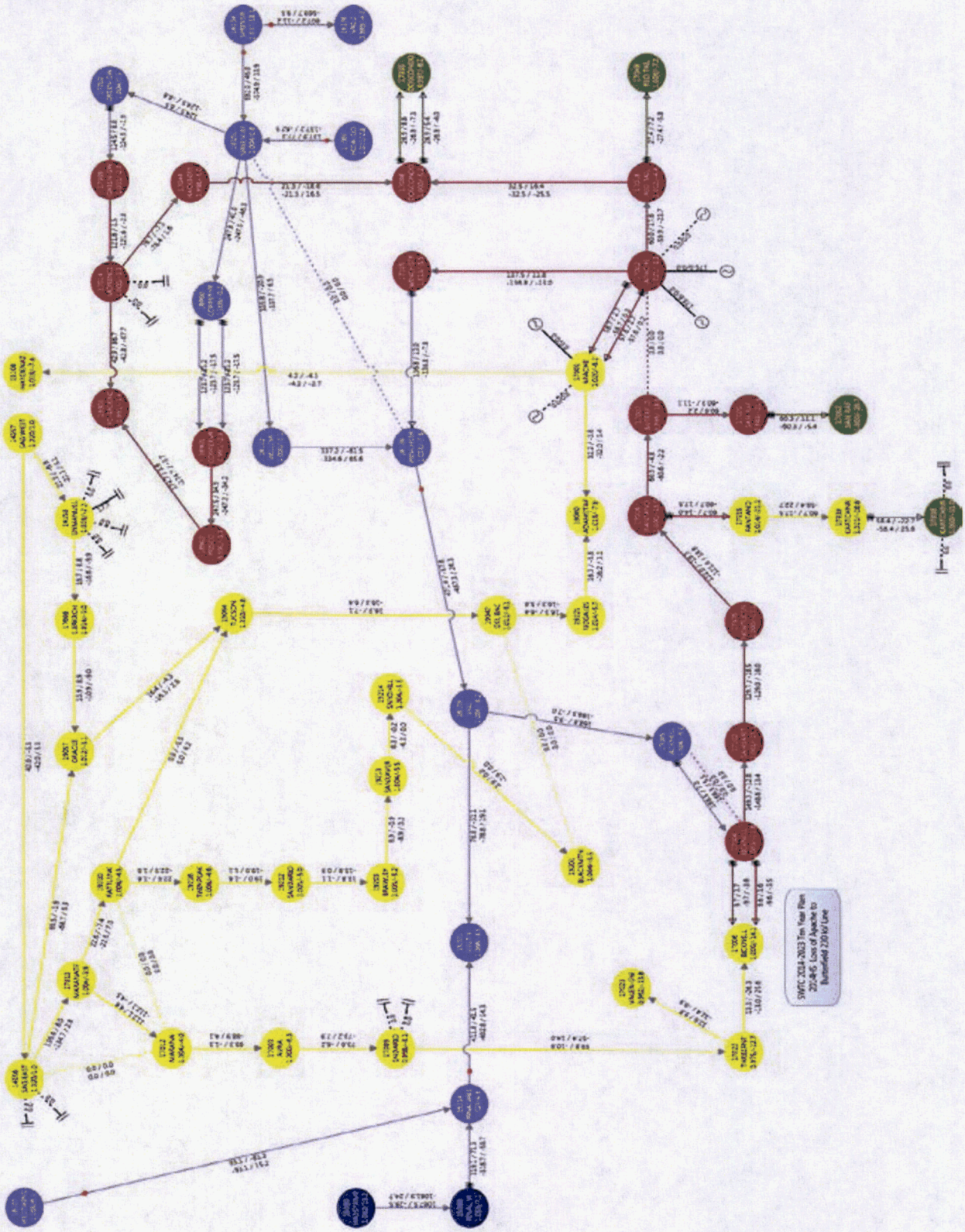
2014HS Southwest Transmission Cooperative Base System with Butterfield to Pantano 230 kV Line out of service



2014HS Southwest Transmission Cooperative Base System with Dos Condados to Hackberry 230 kV Line out of service



2014HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out of service



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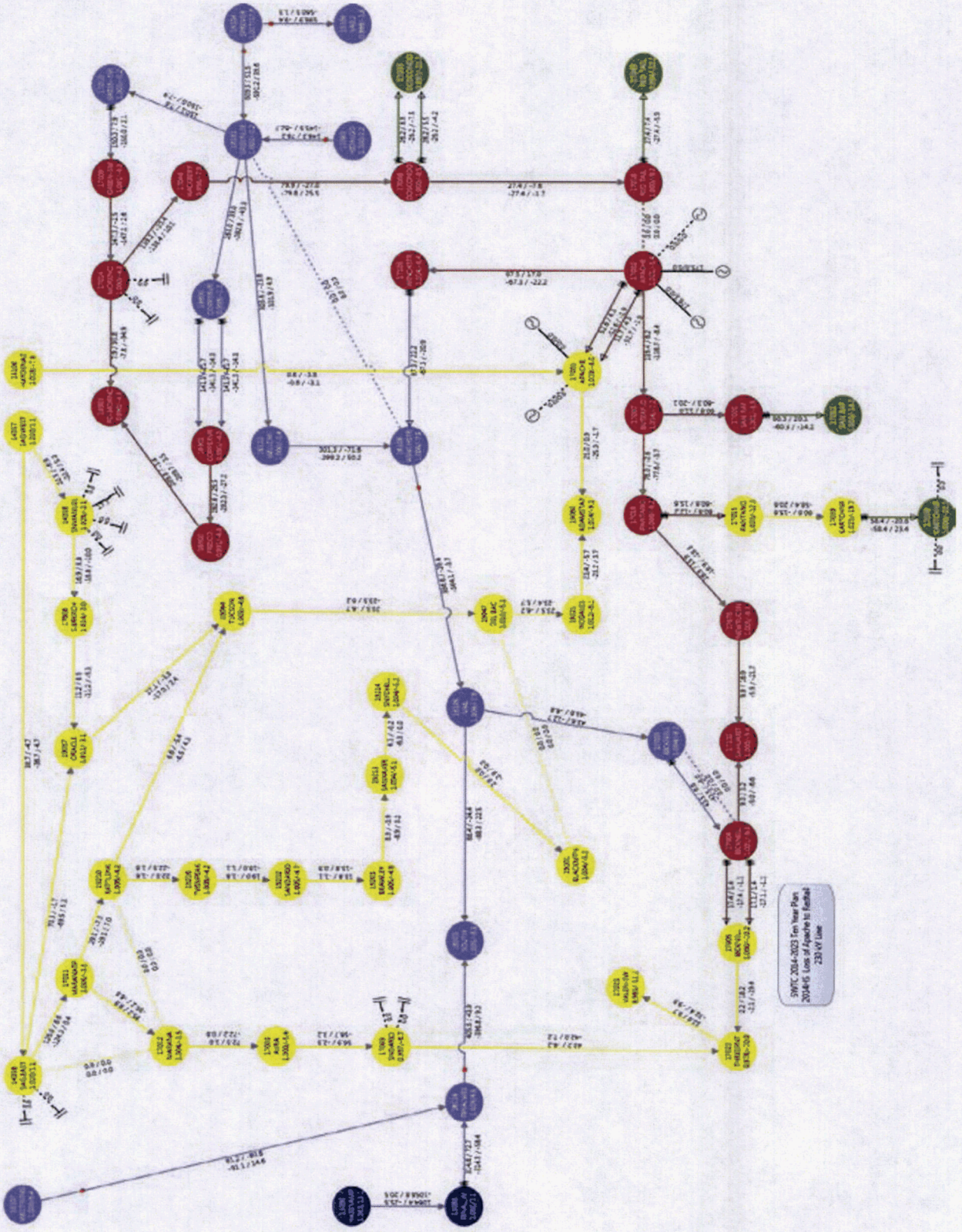
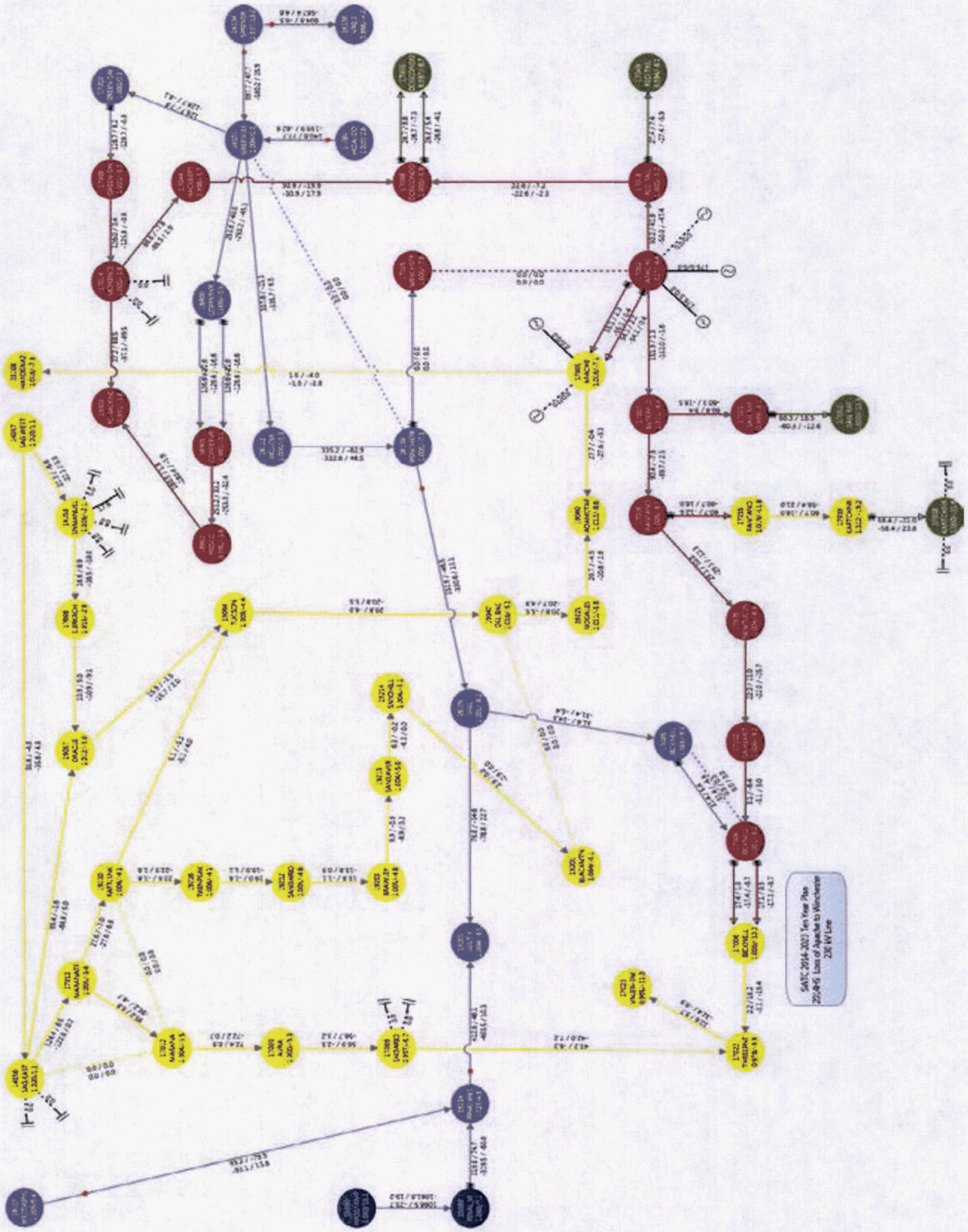
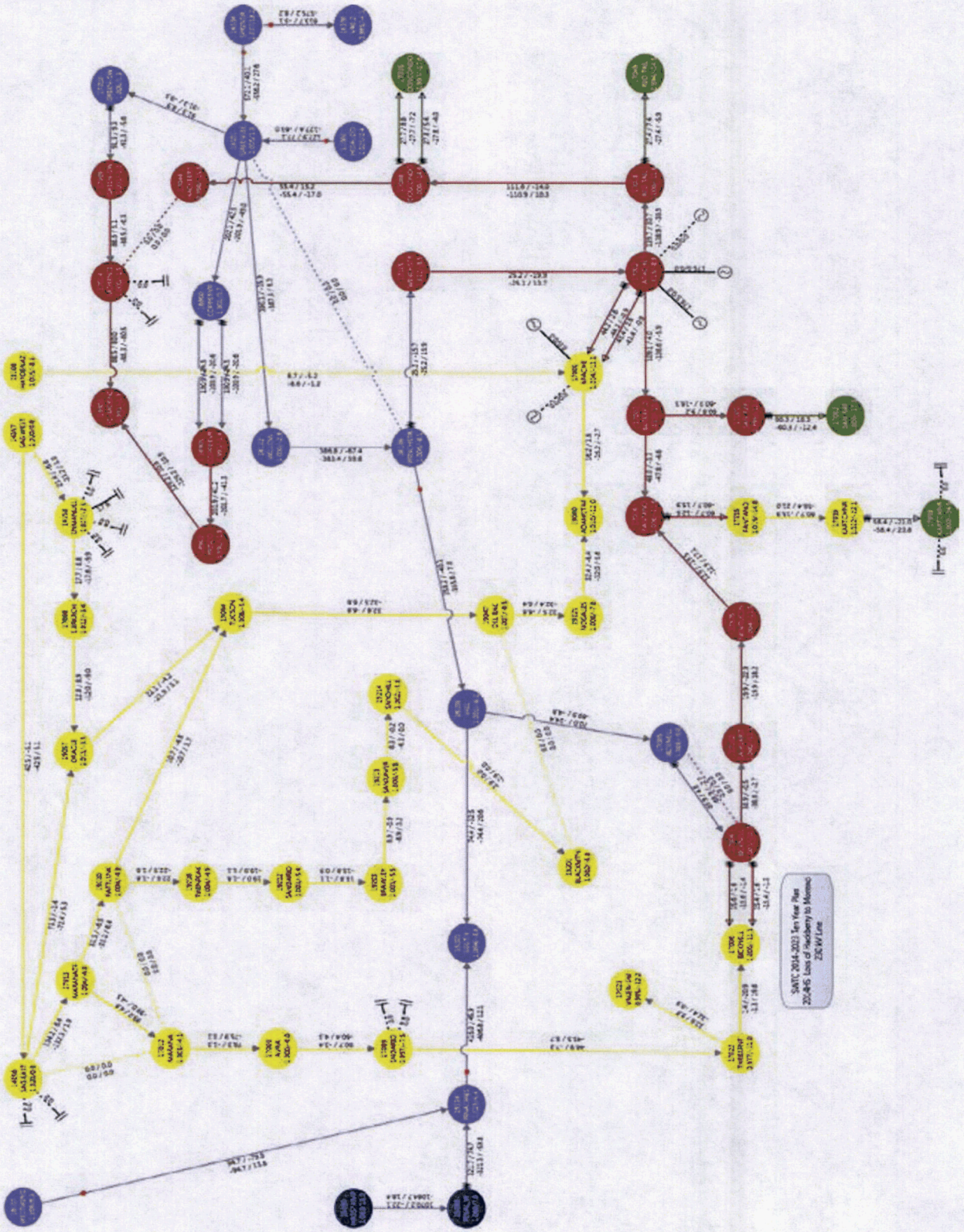


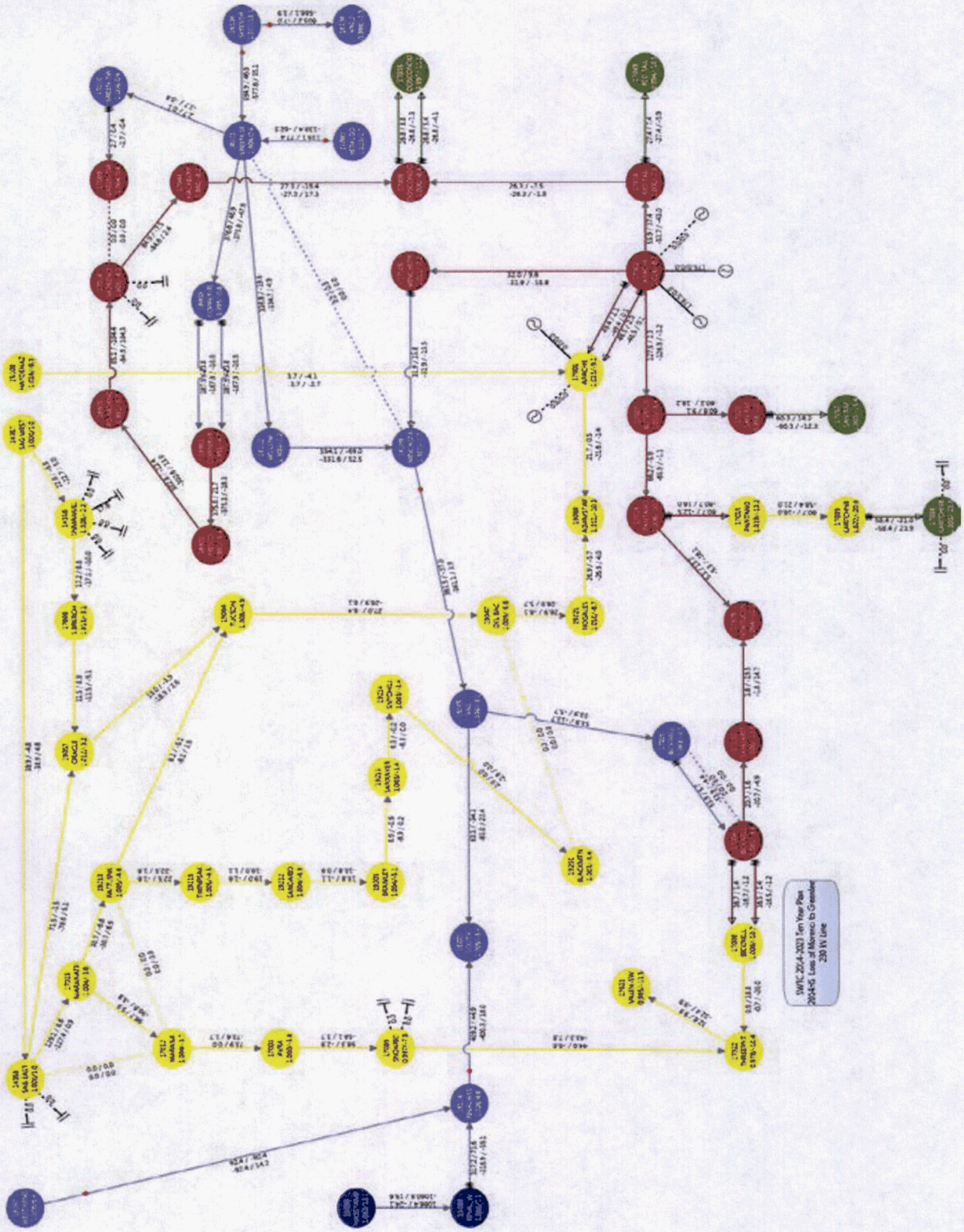
2014HS Southwest Transmission Cooperative Base System with Apache to Winchester 230 kV Line out of service



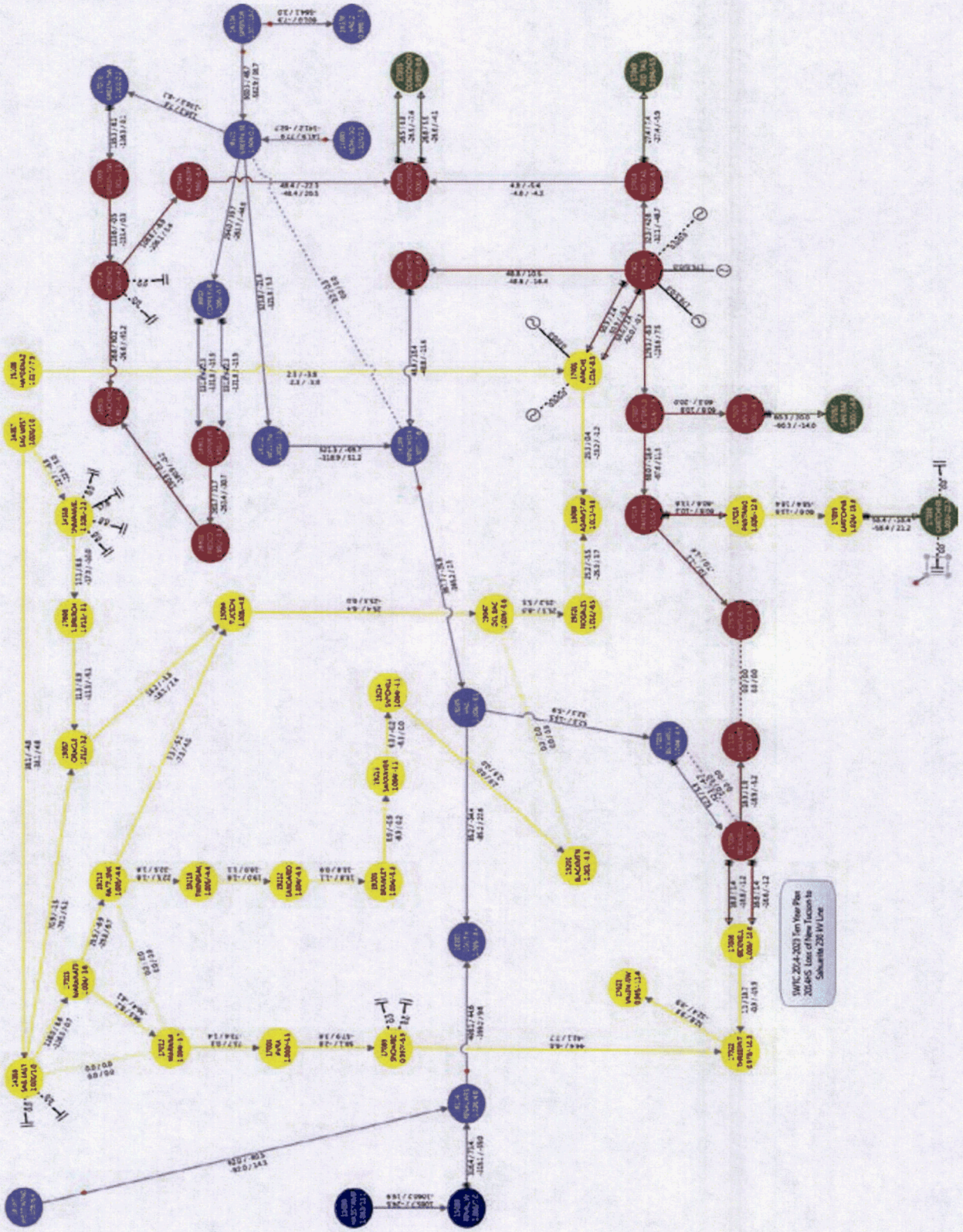
2014HS Southwest Transmission Cooperative Base System with Hackberry to Morenci 230 kV Line out of service



2014HS Southwest Transmission Cooperative Base System with Morenci to Greenlee-SW 230 kV Line out of service



2014HS Southwest Transmission Cooperative Base System with New Tucson to Sahuarita 230 kV Line out of service



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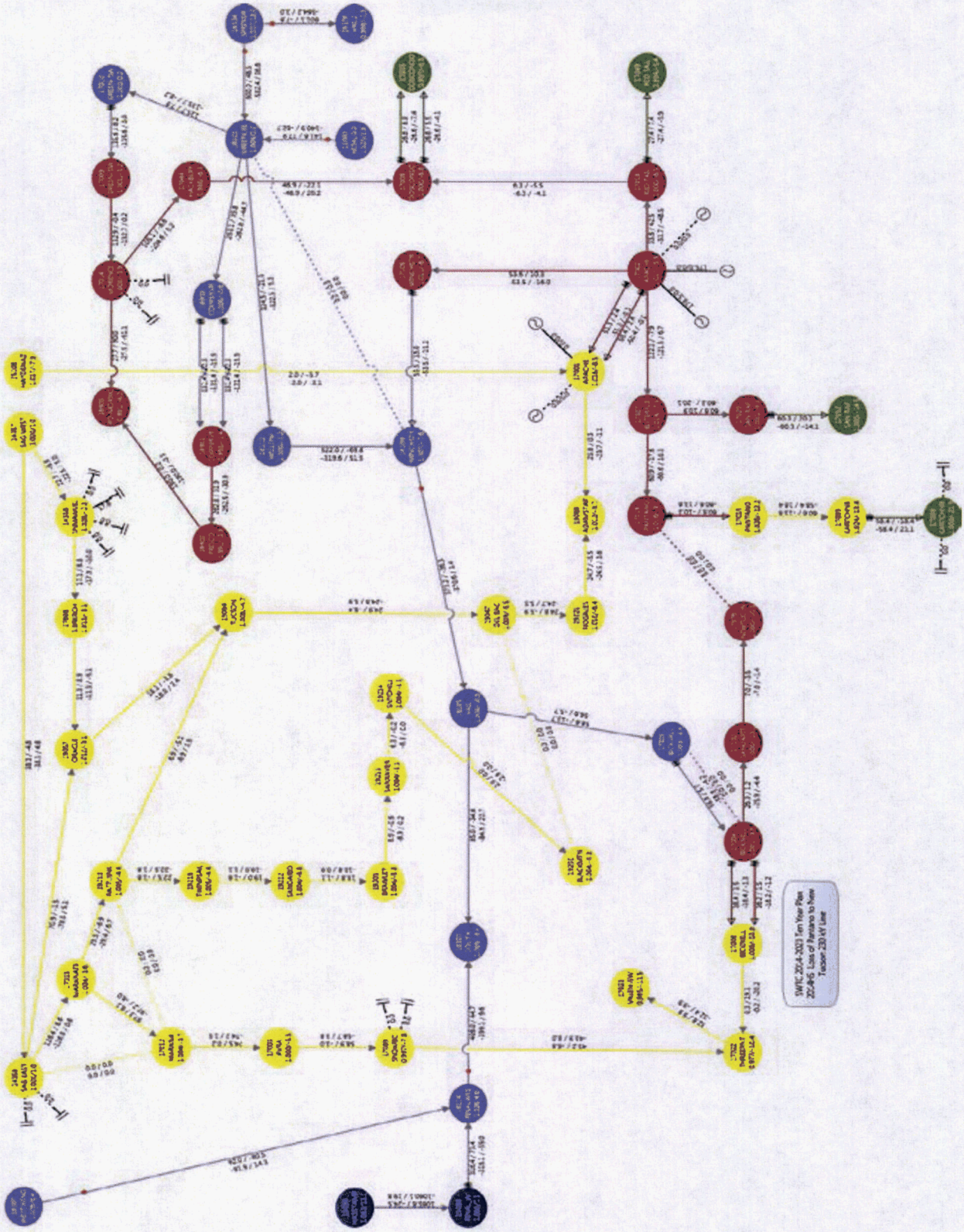

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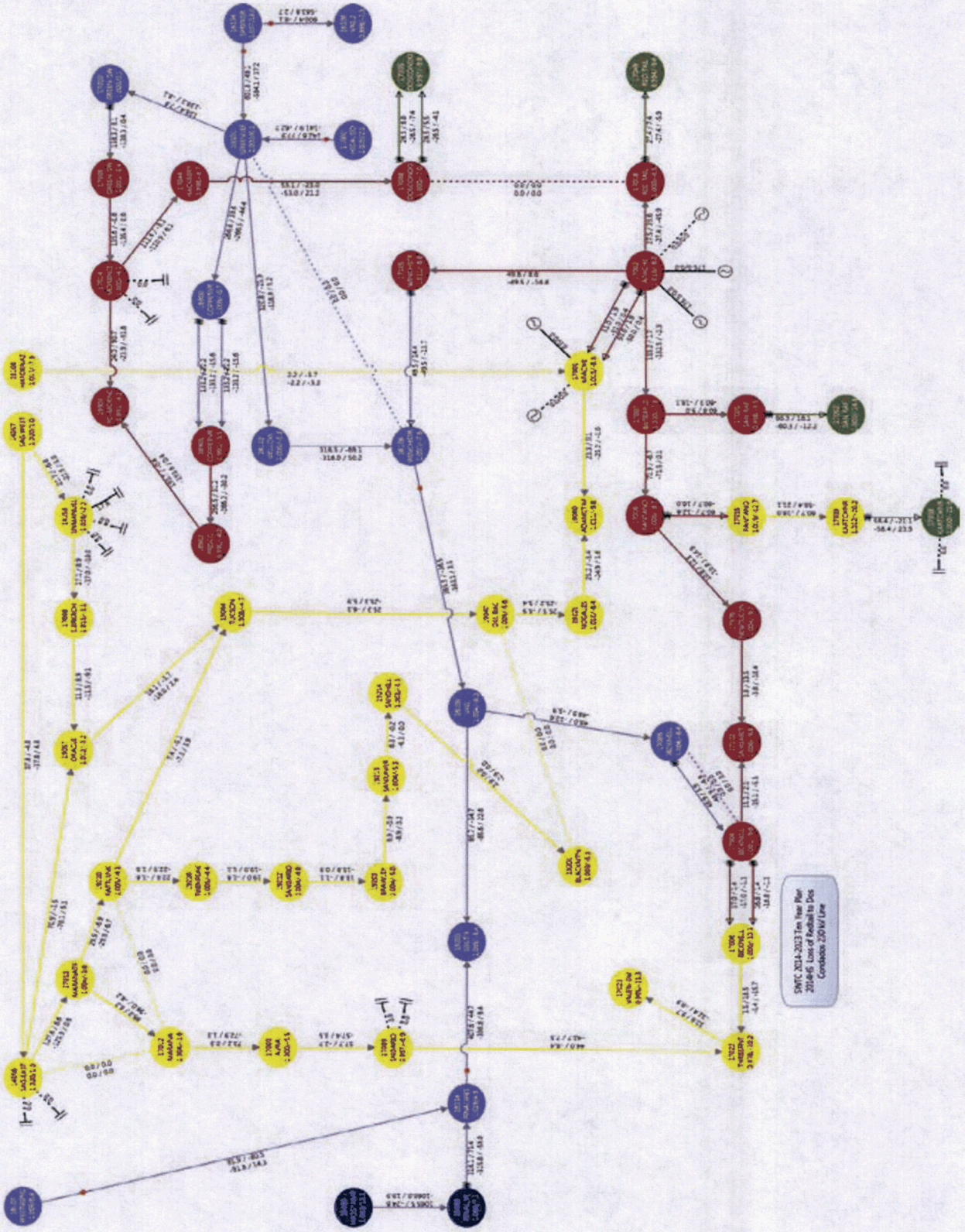
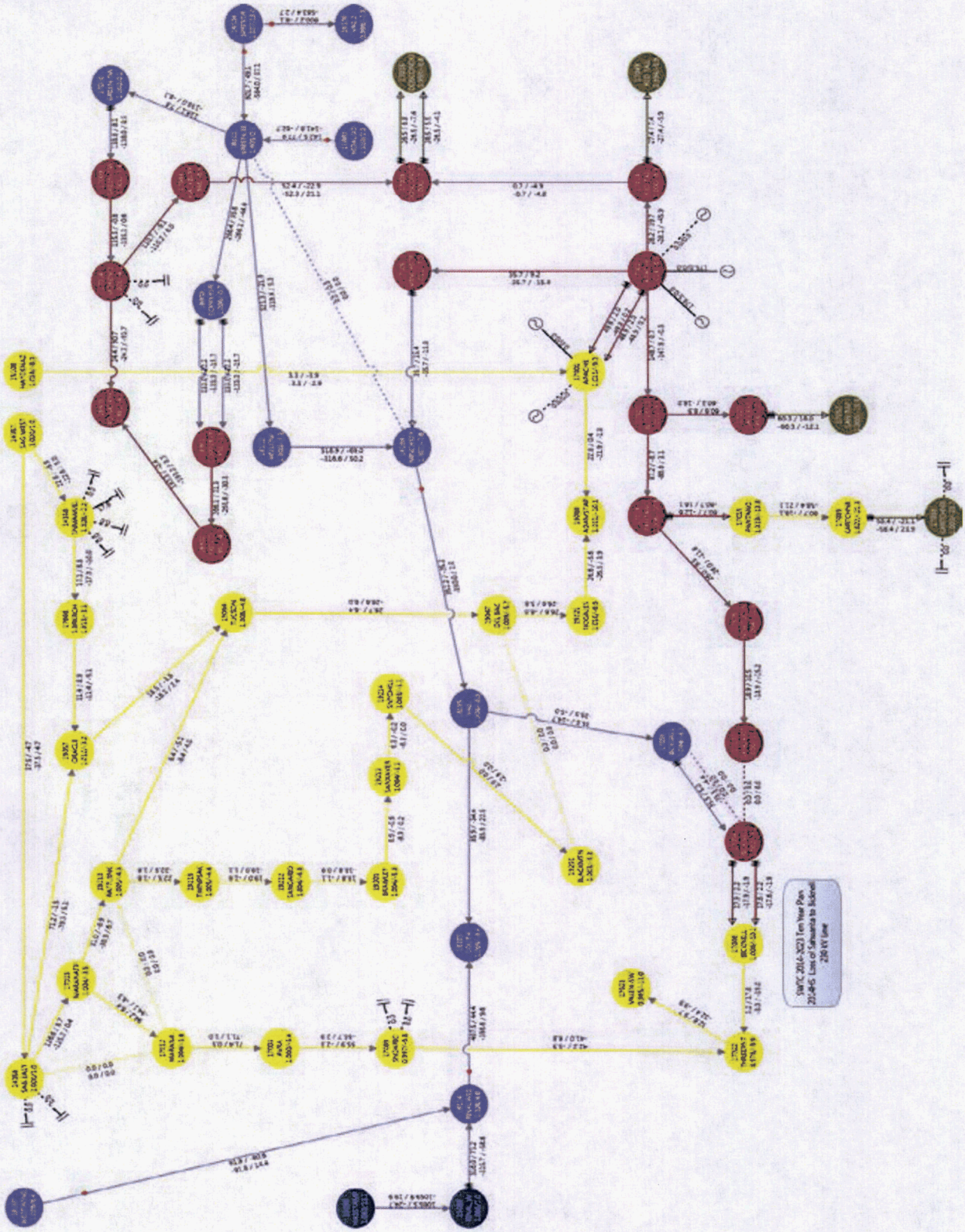
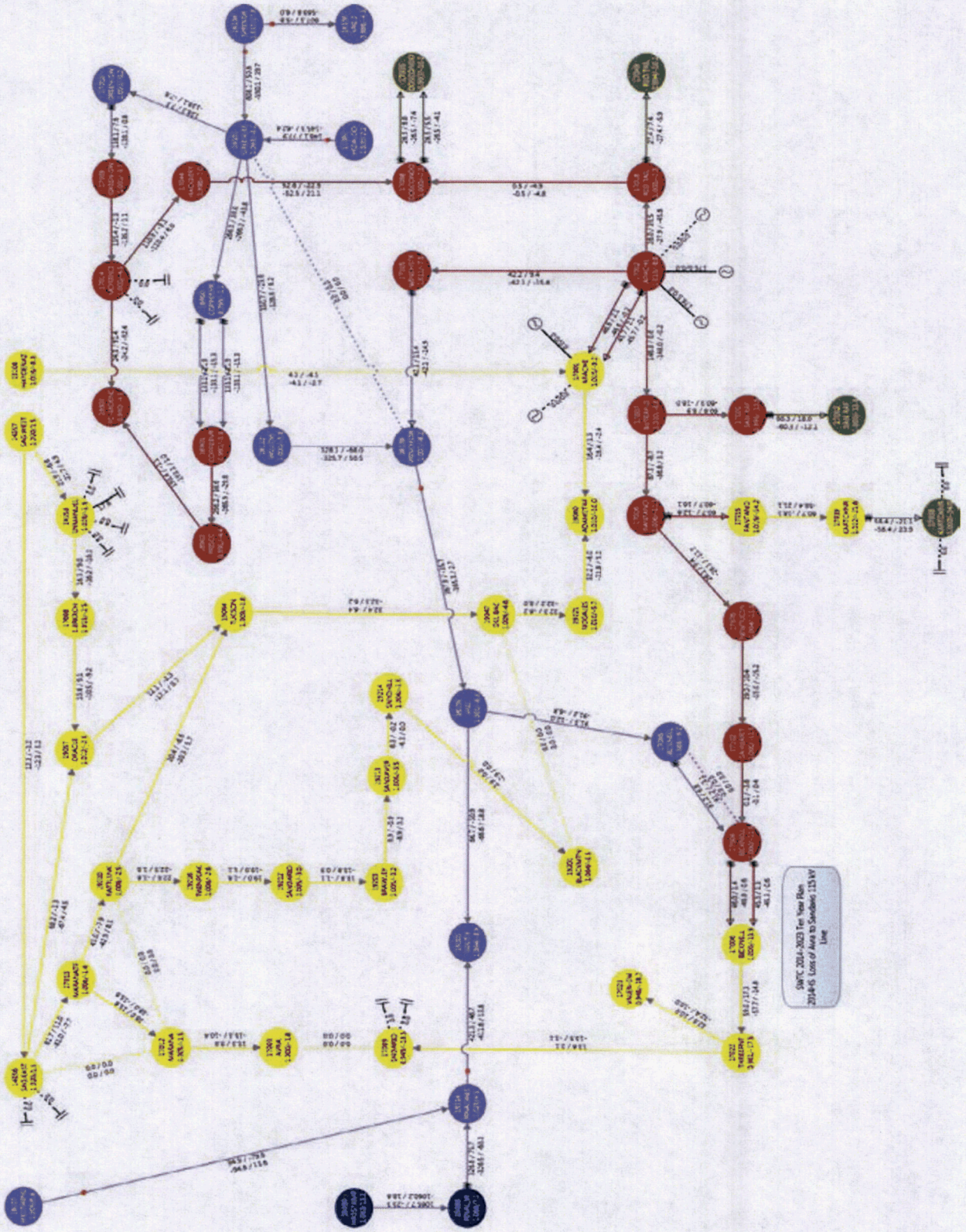


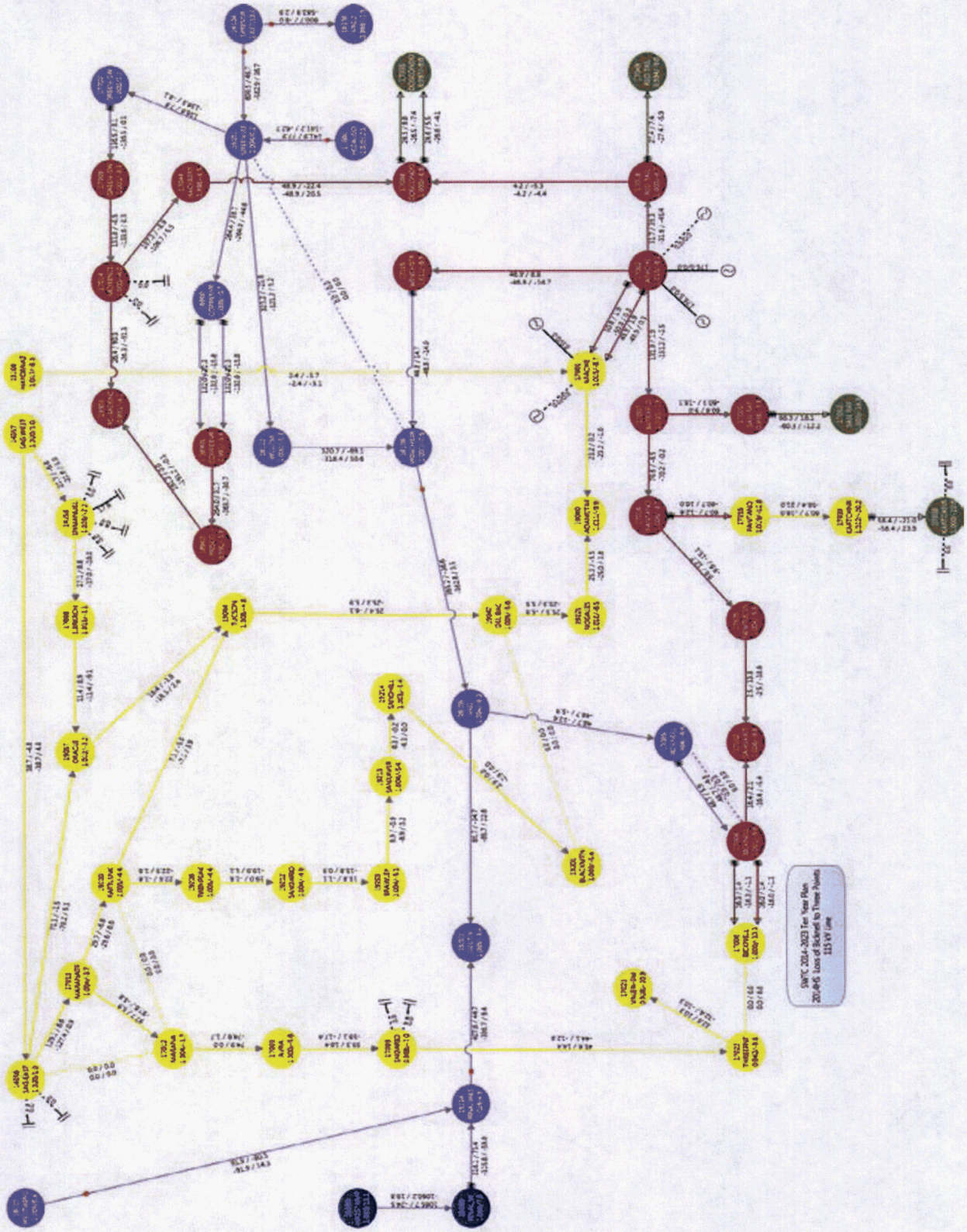
2014HS Southwest Transmission Cooperative Base System with Sahuarita to Bicknell 230 kV Line out of service



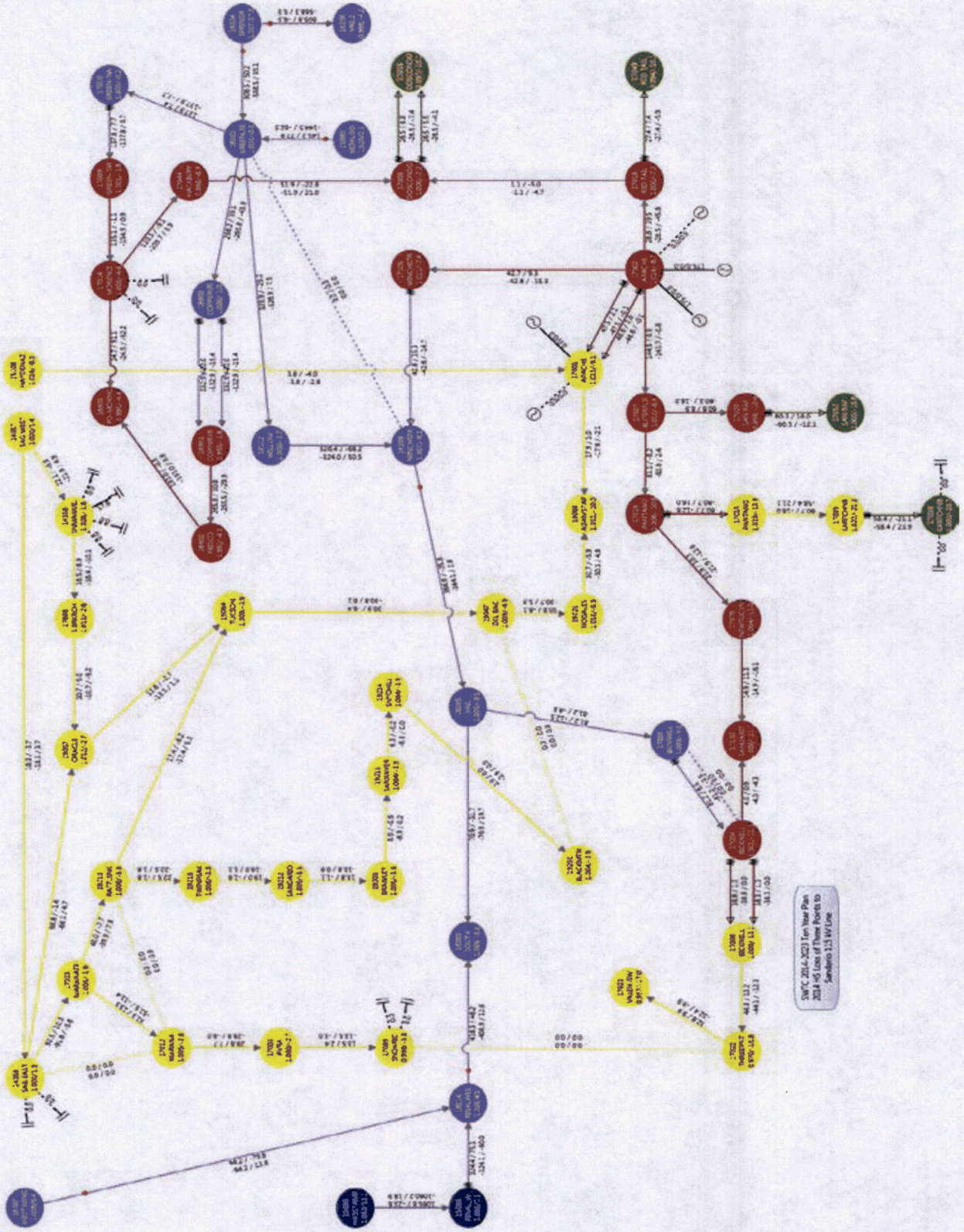
2014HS Southwest Transmission Cooperative Base System with Avra to Sandario 115 kV Line out of service



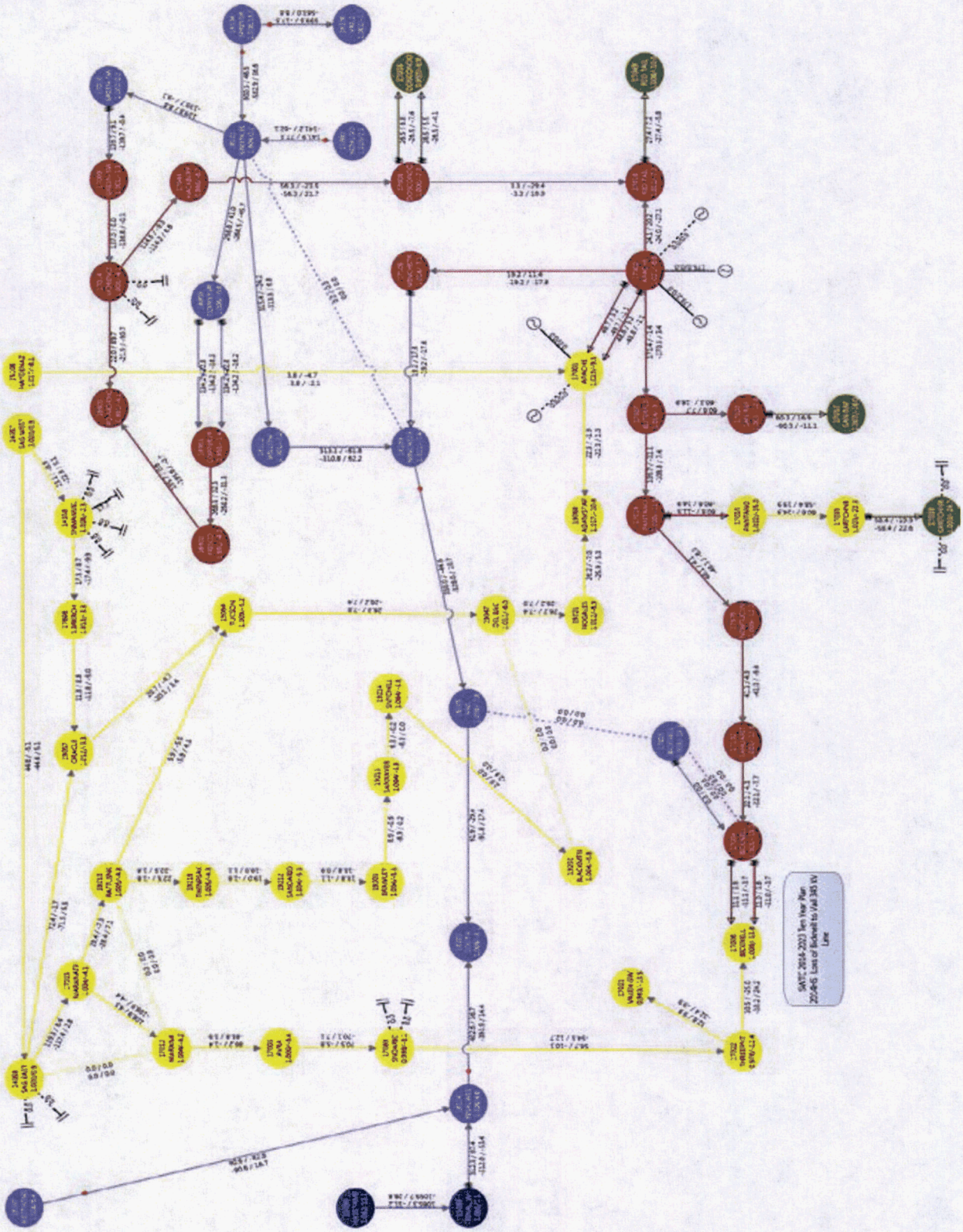
2014HS Southwest Transmission Cooperative Base System with Bicknell to Three Points 115 kV Line out of service



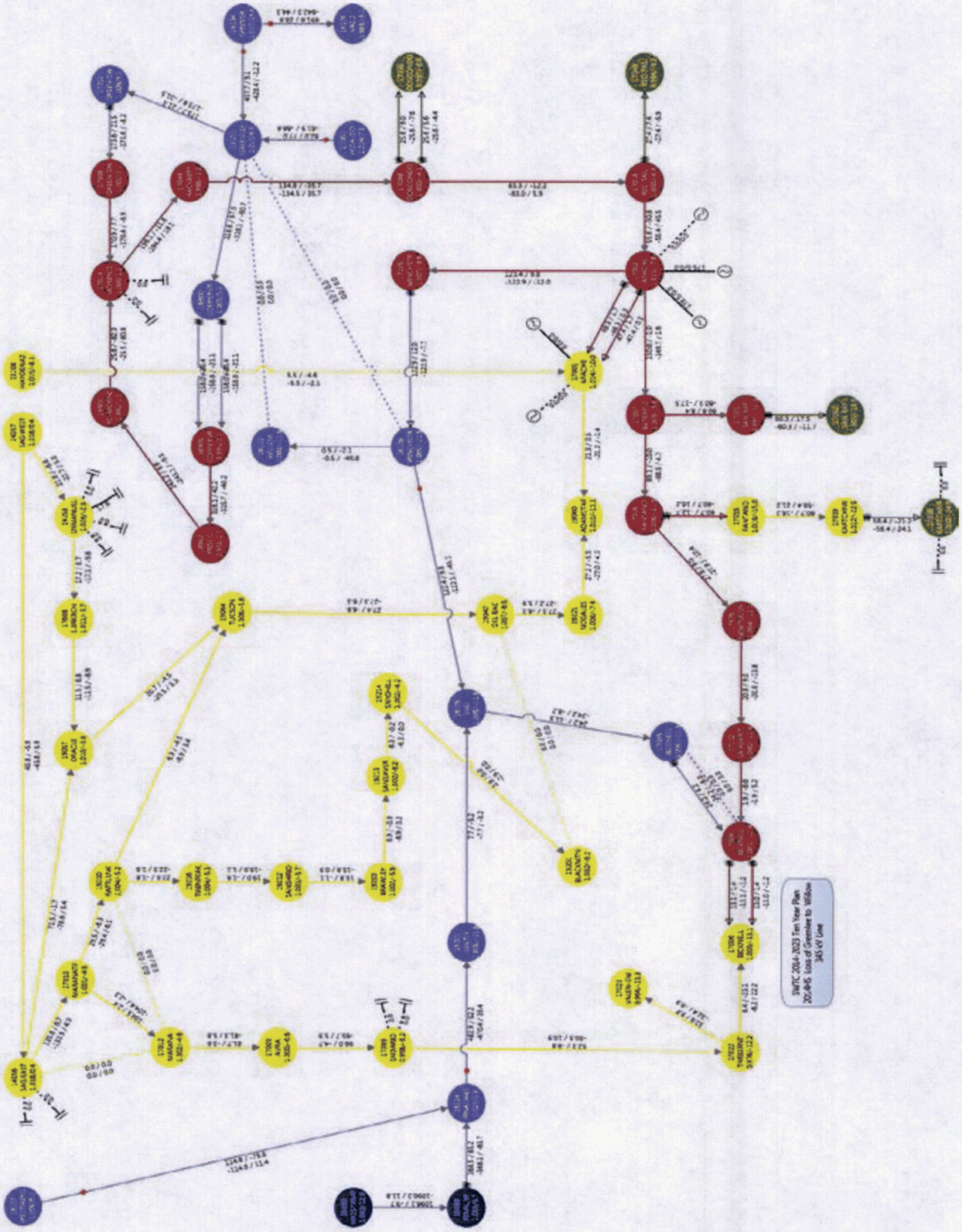
2014HS Southwest Transmission Cooperative Base System with Three Points to Sandario 115 kV Line out of service



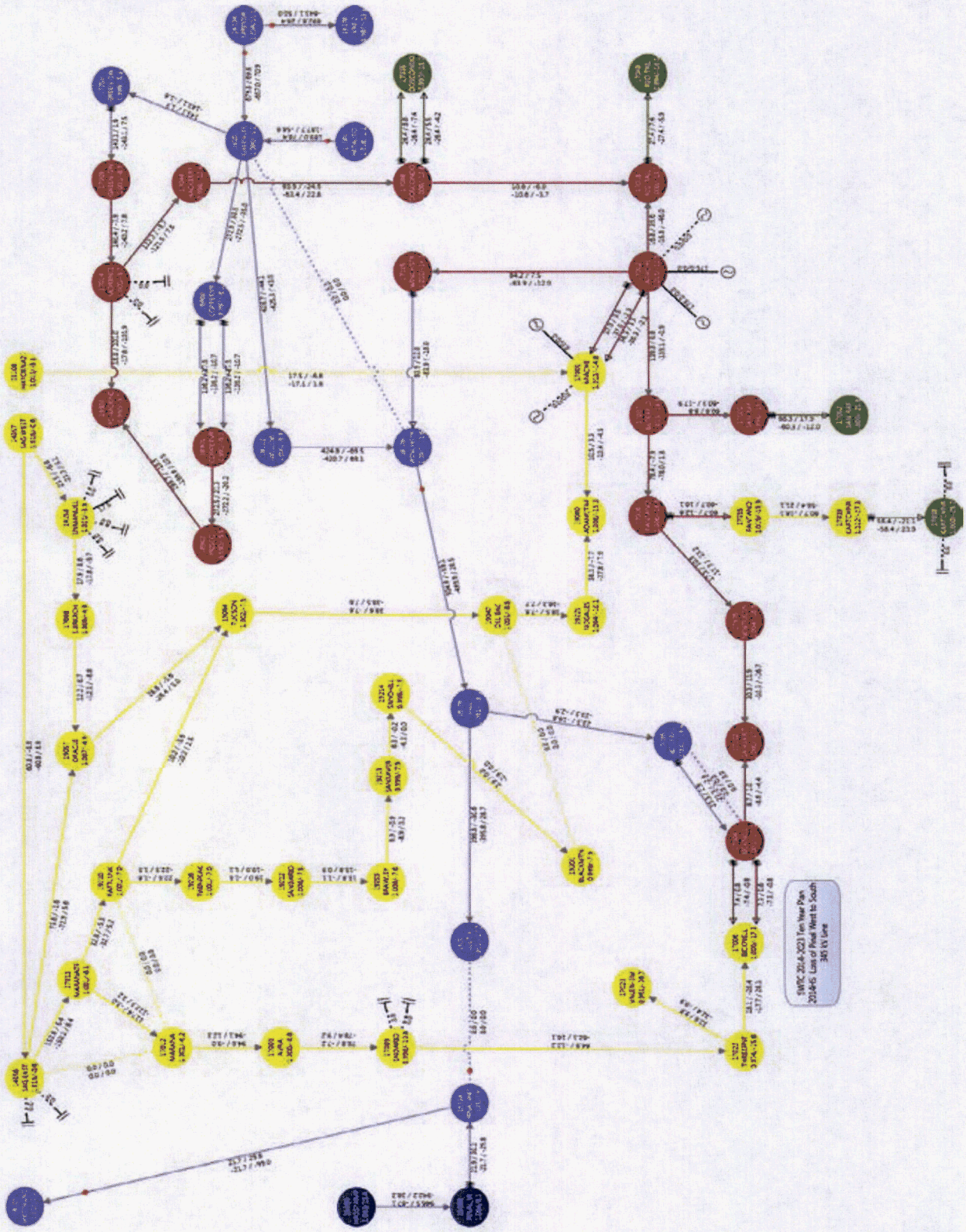
2014HS Southwest Transmission Cooperative Base System with Bicknell to Vail 345 kV Line out of service



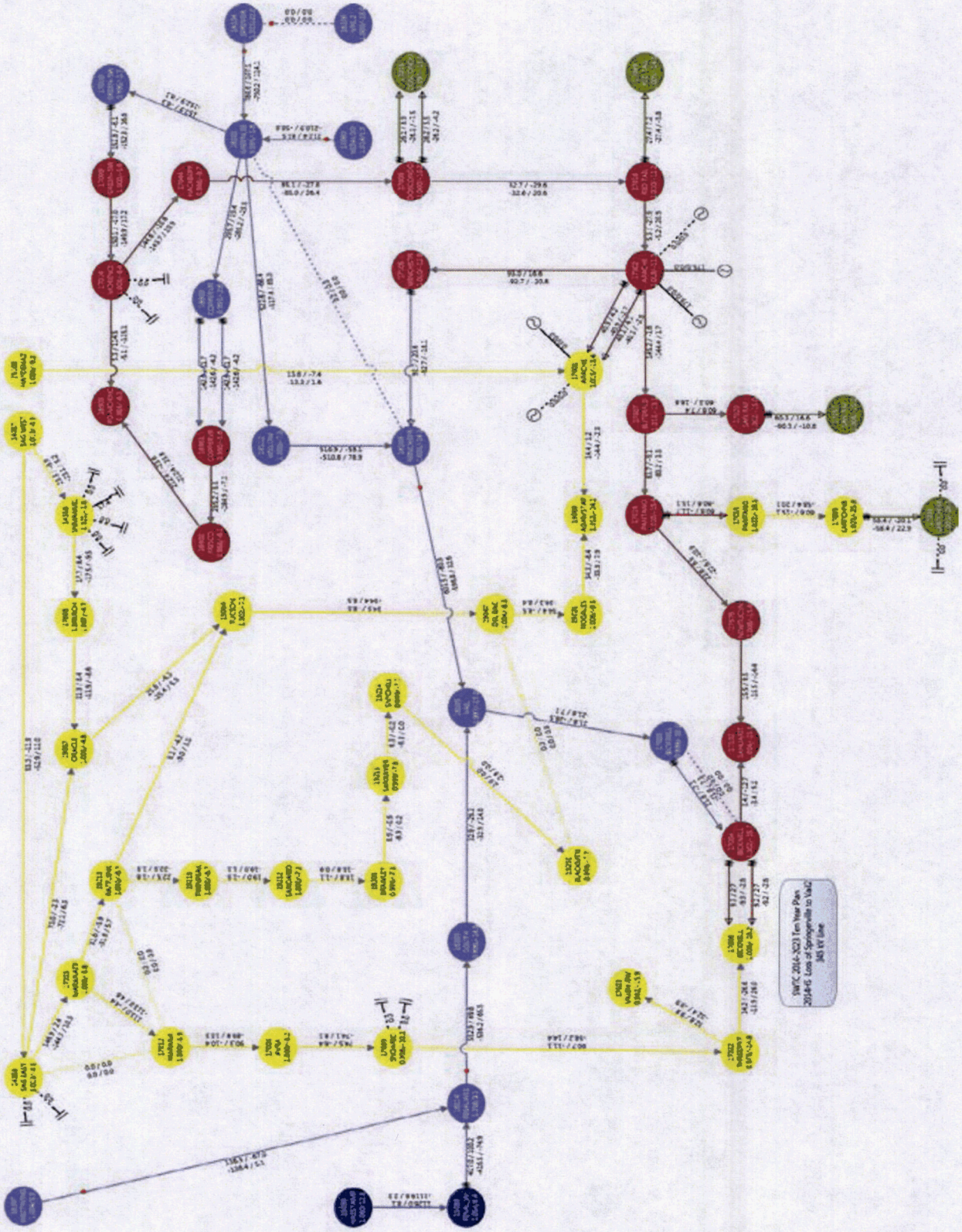
2014HS Southwest Transmission Cooperative Base System with Greenlee to Winchester 345 kV Line out of service



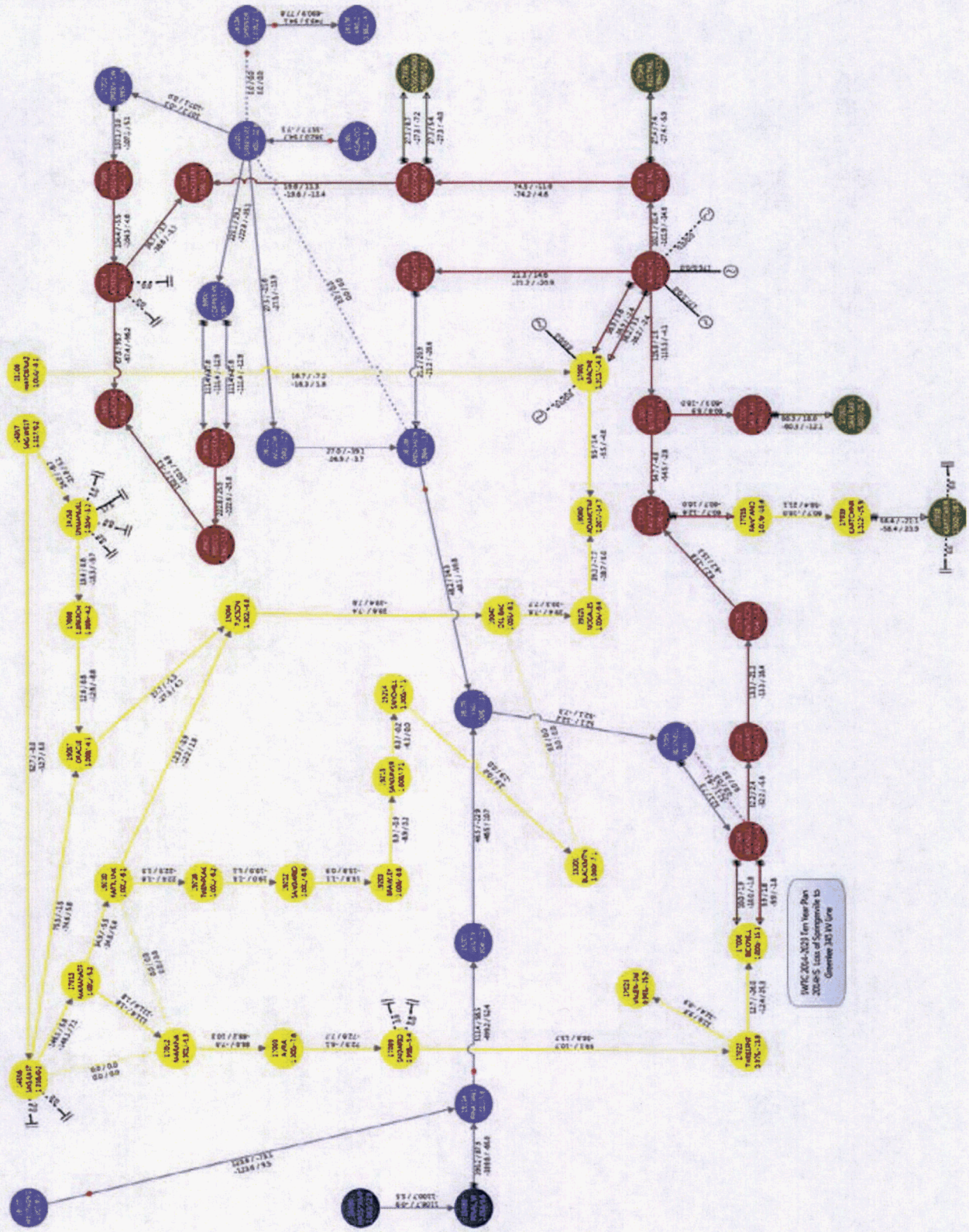
2014HS Southwest Transmission Cooperative Base System with Pinal West to South 345 kV Line out of service



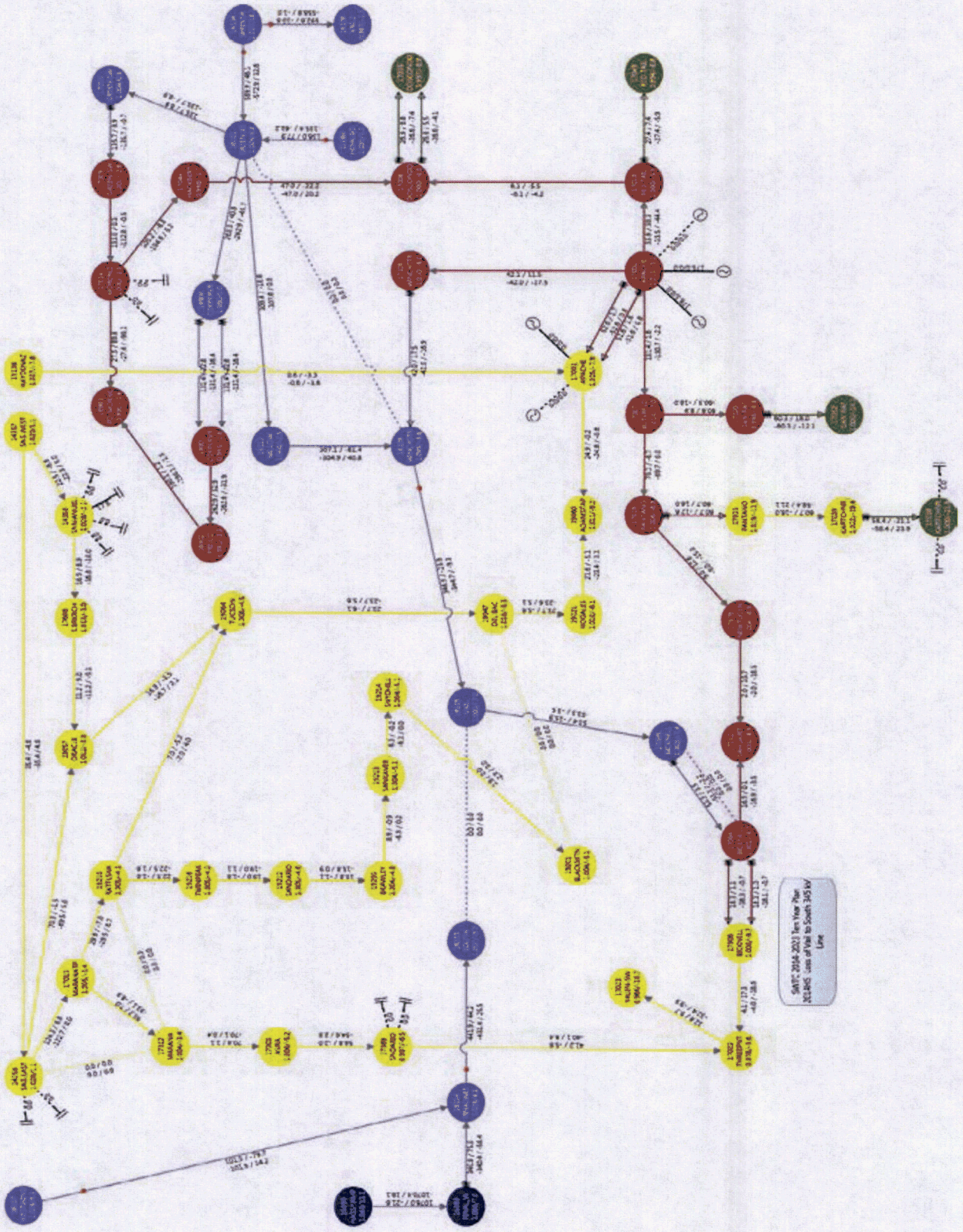
2014HS Southwest Transmission Cooperative Base System with Springerville to Vail2 345 kV Line out of service



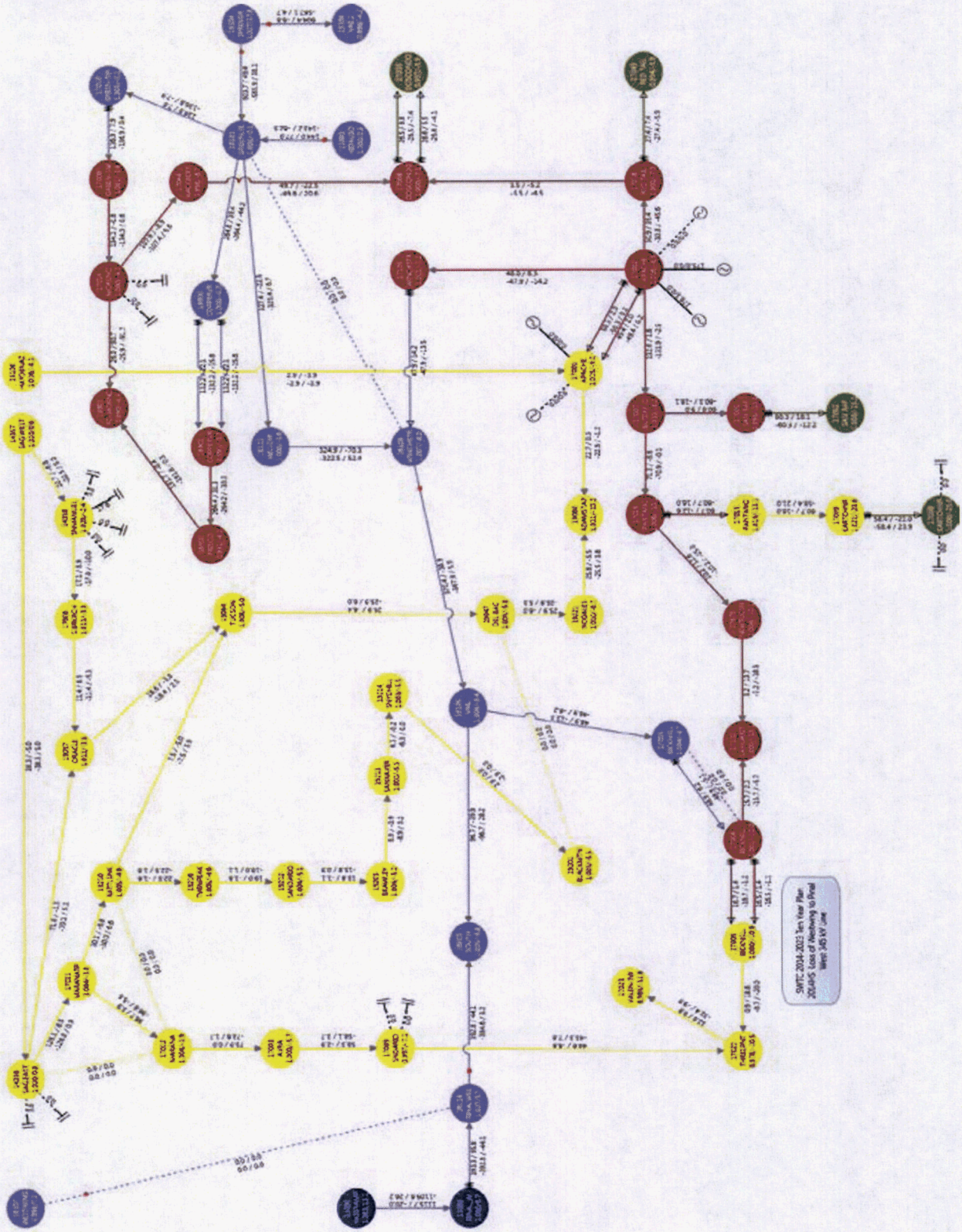
2014HS Southwest Transmission Cooperative Base System with Springerville to Greenlee 345 kV Line out of service



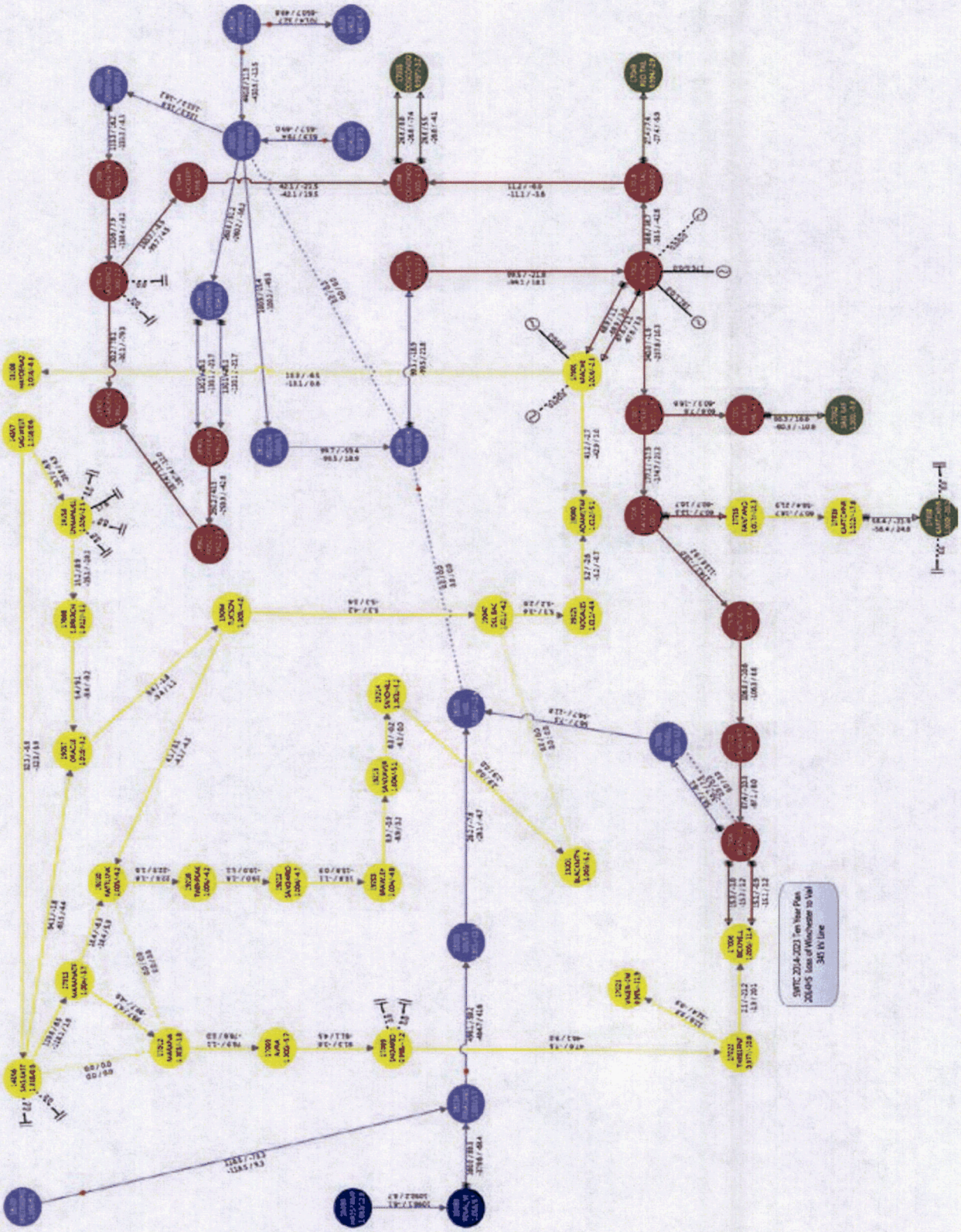
2014HS Southwest Transmission Cooperative Base System with Vail to South 345 kV Line out of service



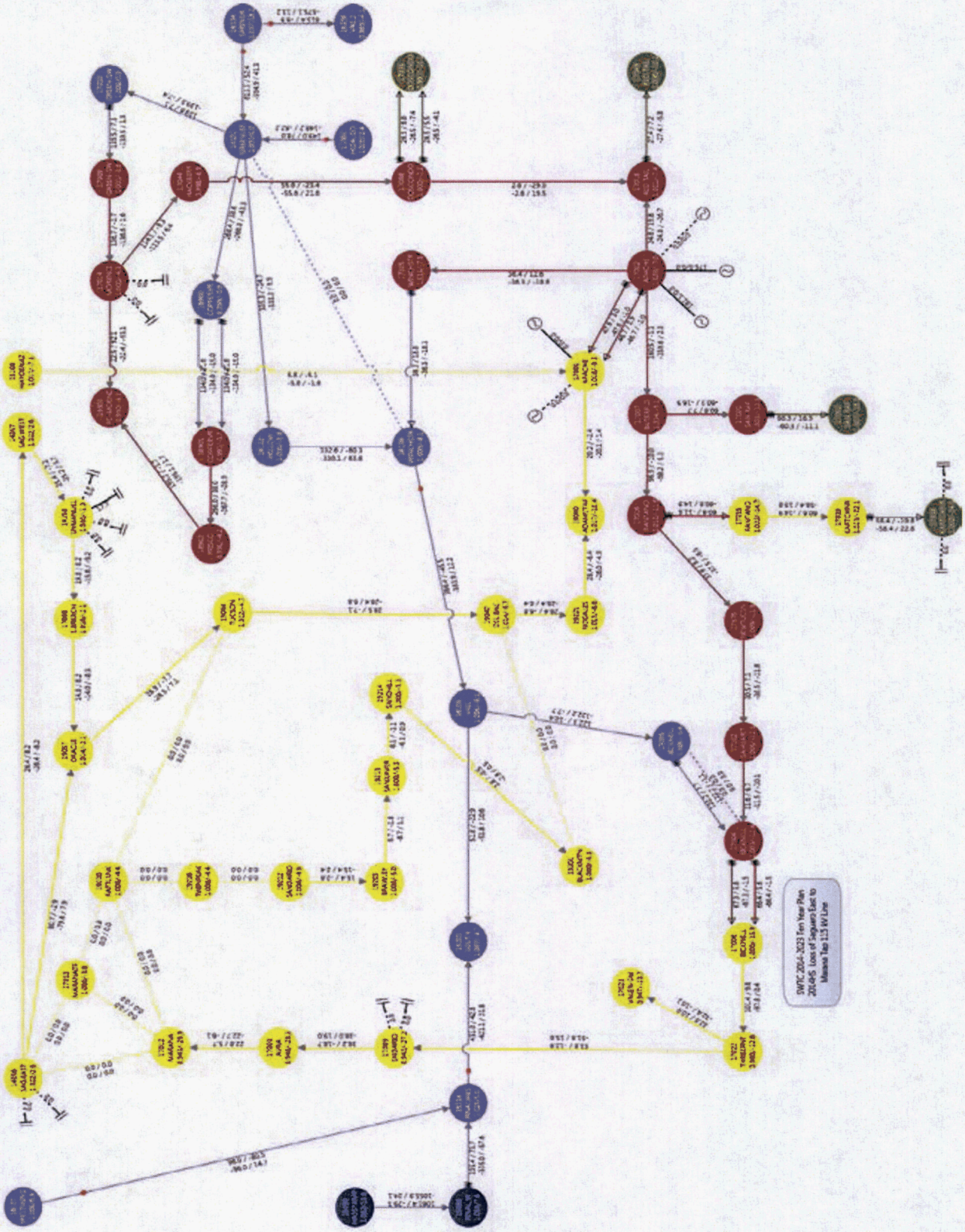
2014HS Southwest Transmission Cooperative Base System with Westwing to Pinal West 345 kV Line out of service



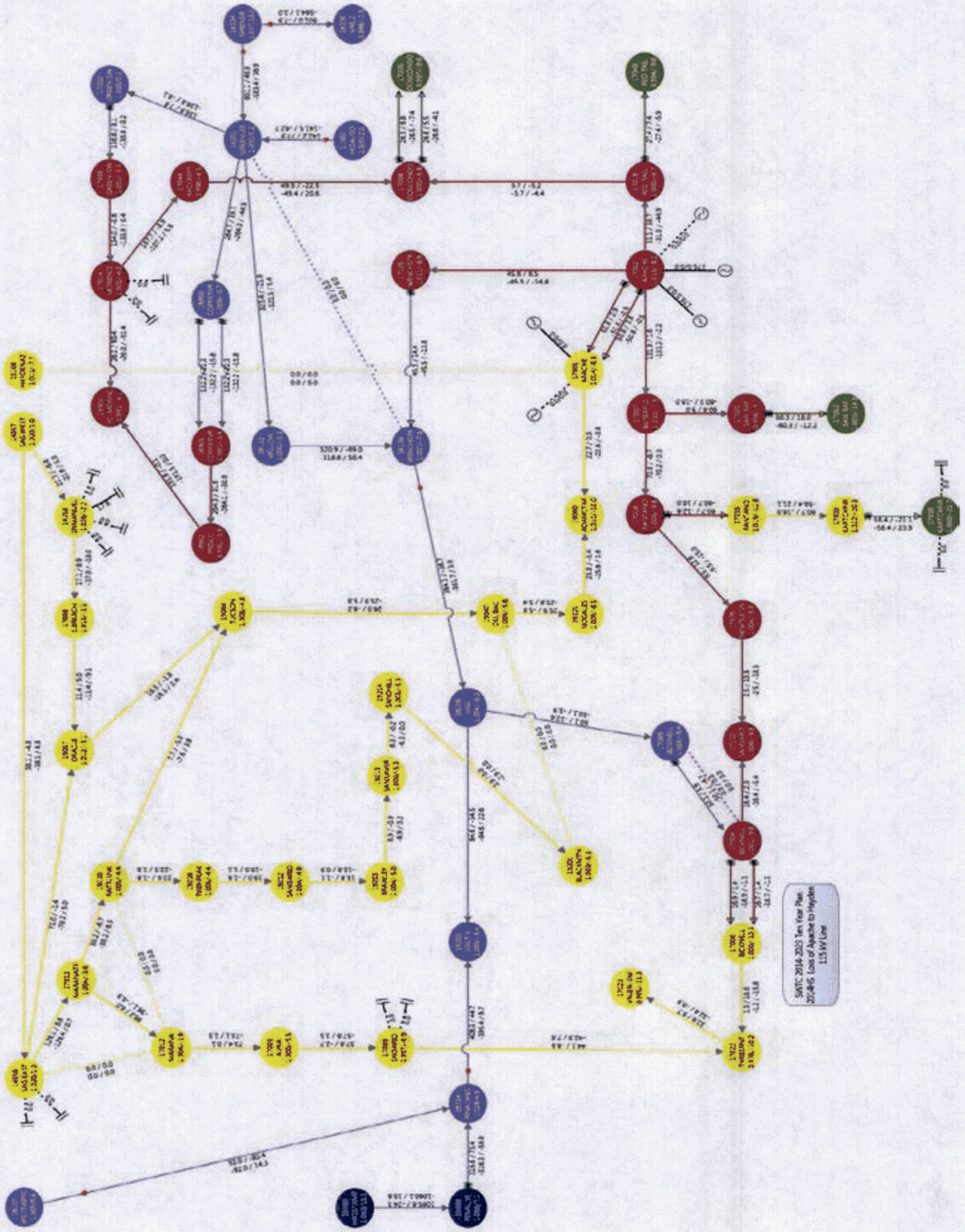
2014HS Southwest Transmission Cooperative Base System with Winchester to Vail 345 kV Line out of service



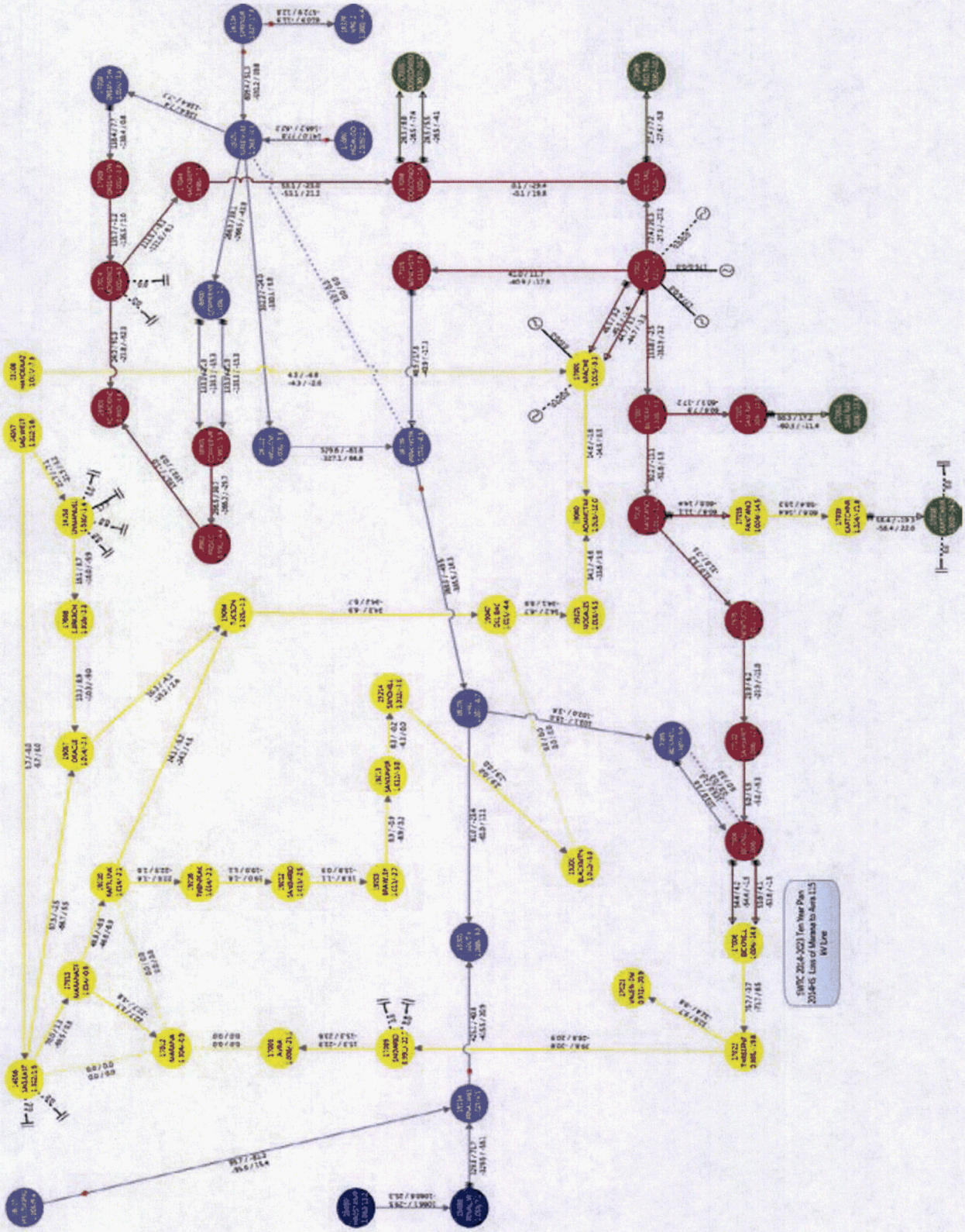
2014HS Southwest Transmission Cooperative Base System with Saguaro East to Marana Tap 115 kV Line out of service



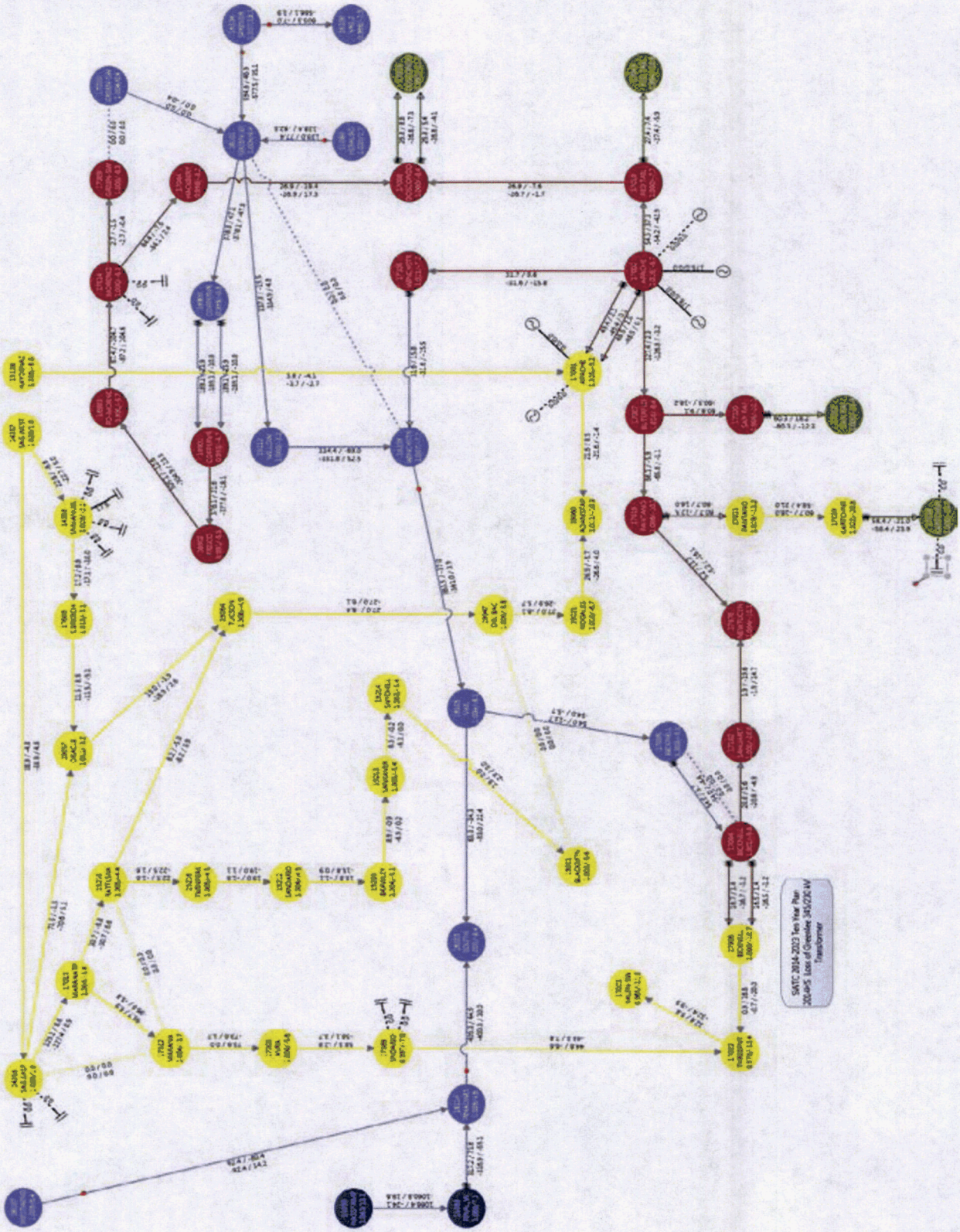
2014HS Southwest Transmission Cooperative Base System with Apache to Hayden 115 kV Line out of service



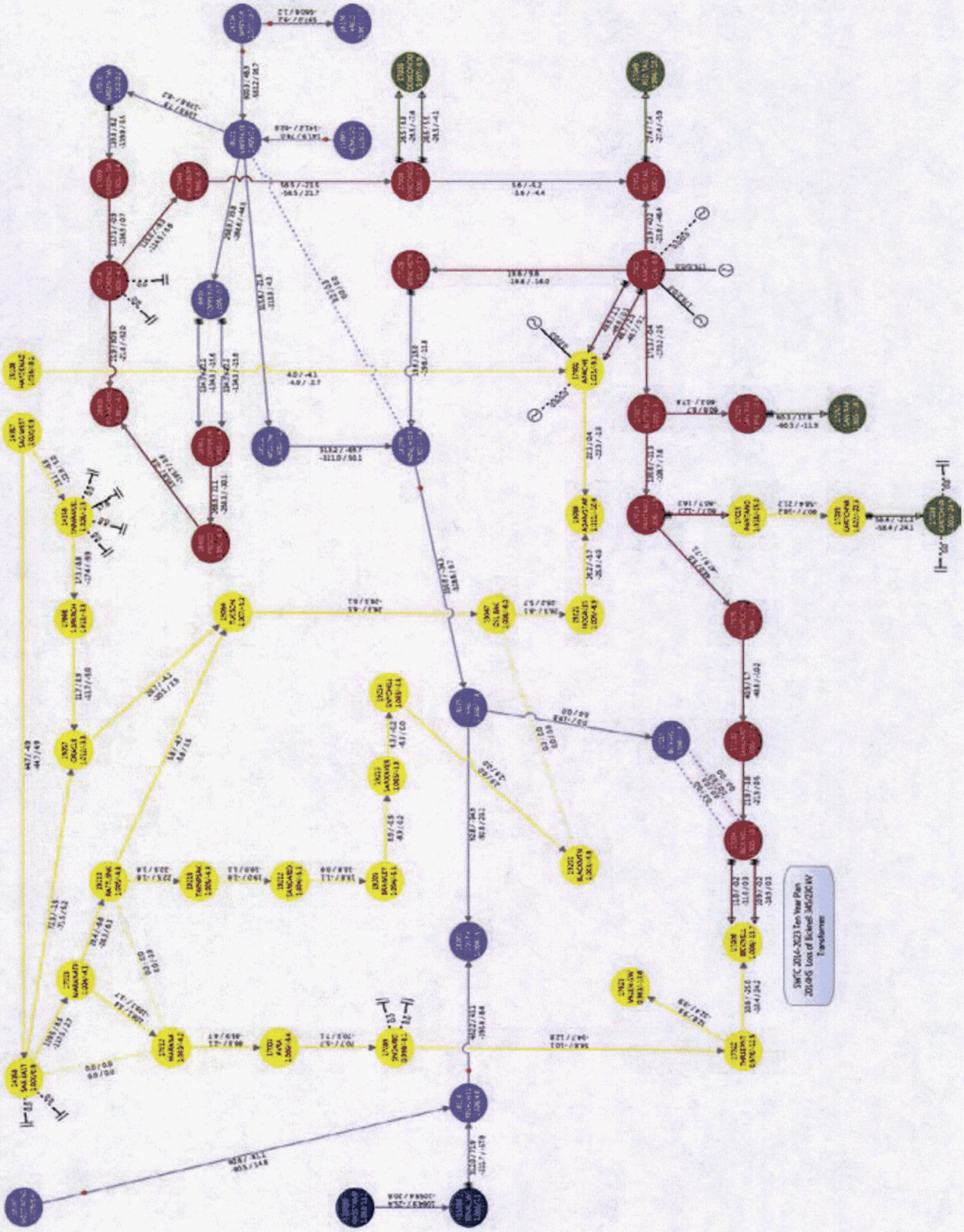
2014HS Southwest Transmission Cooperative Base System with Marana to Avra 115 kV Line out of service



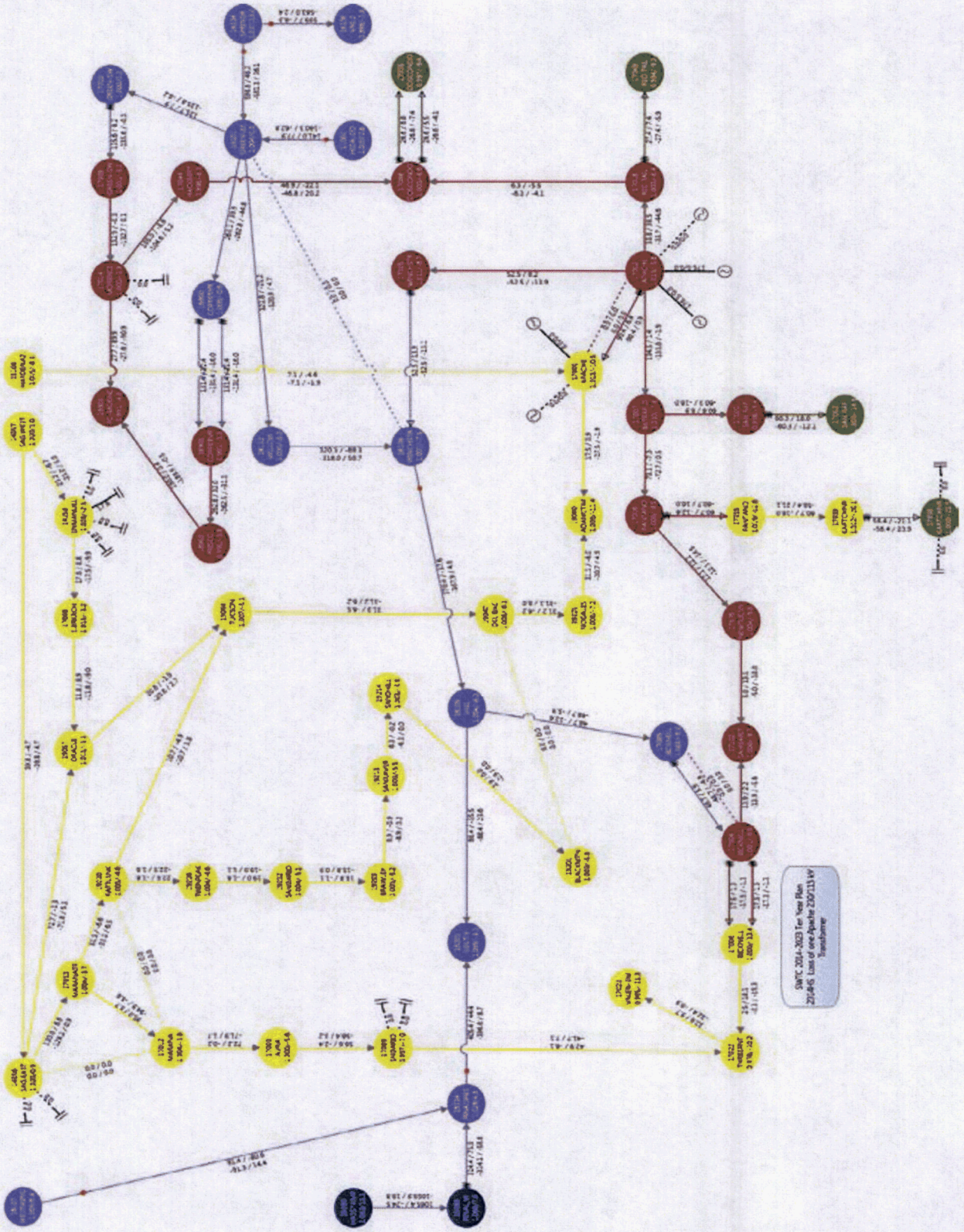
2014HS Southwest Transmission Cooperative Base System with Green-SW 345/230 kV Transformer out of service



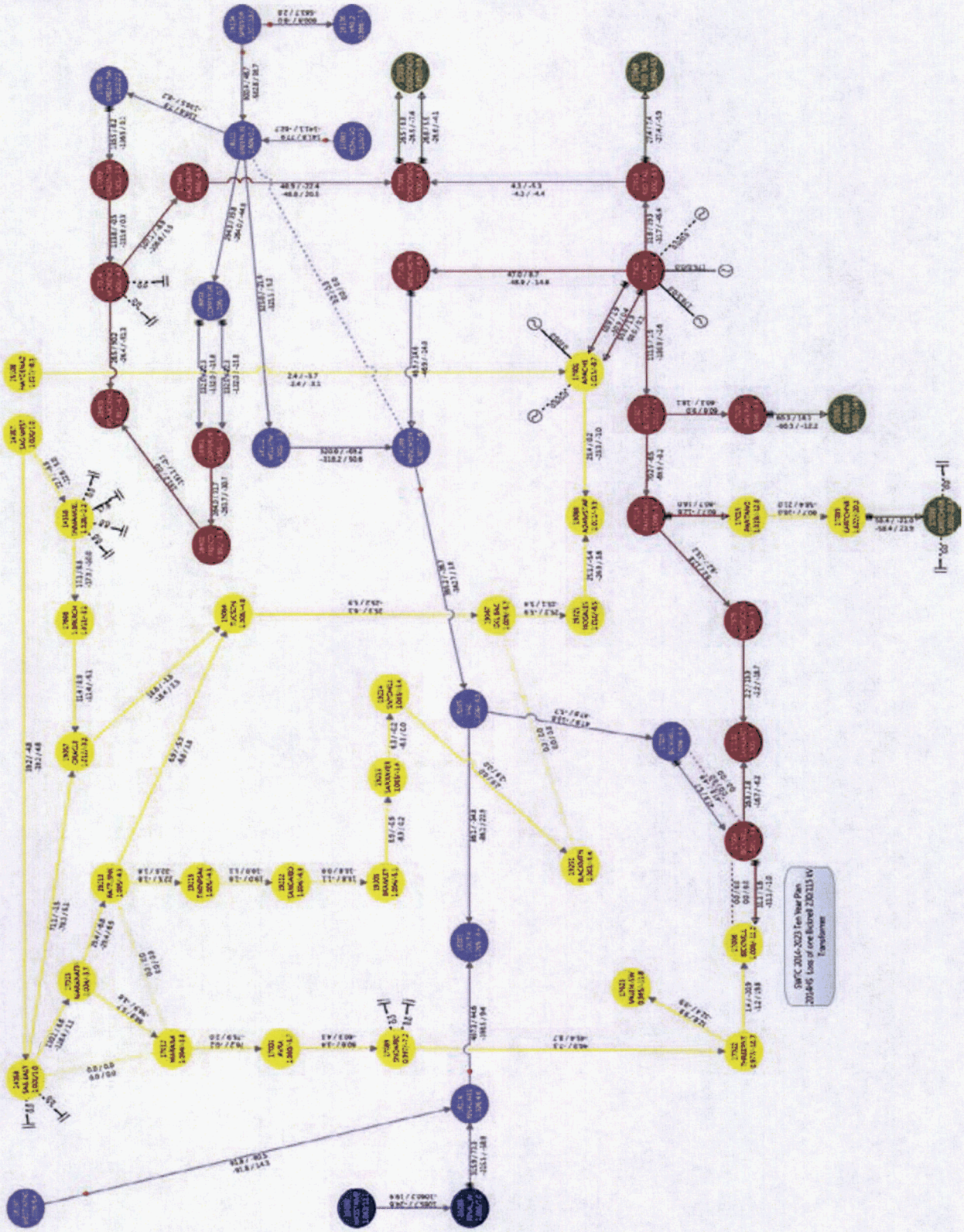
2014HS Southwest Transmission Cooperative Base System with Bicknell 345/230 kV Transformer out of service



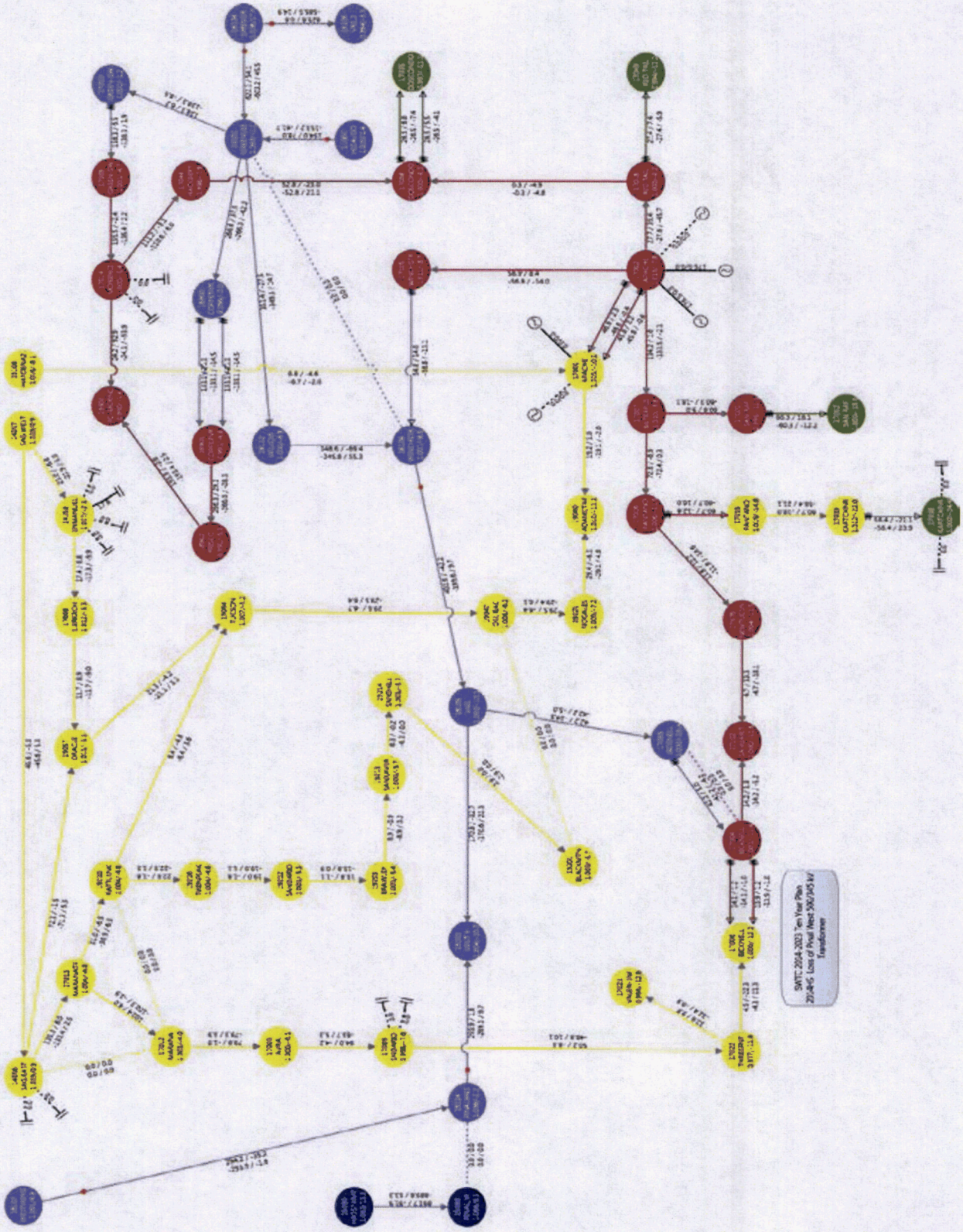
2014HS Southwest Transmission Cooperative Base System with one Apache 230/115 kV Transformer out of service



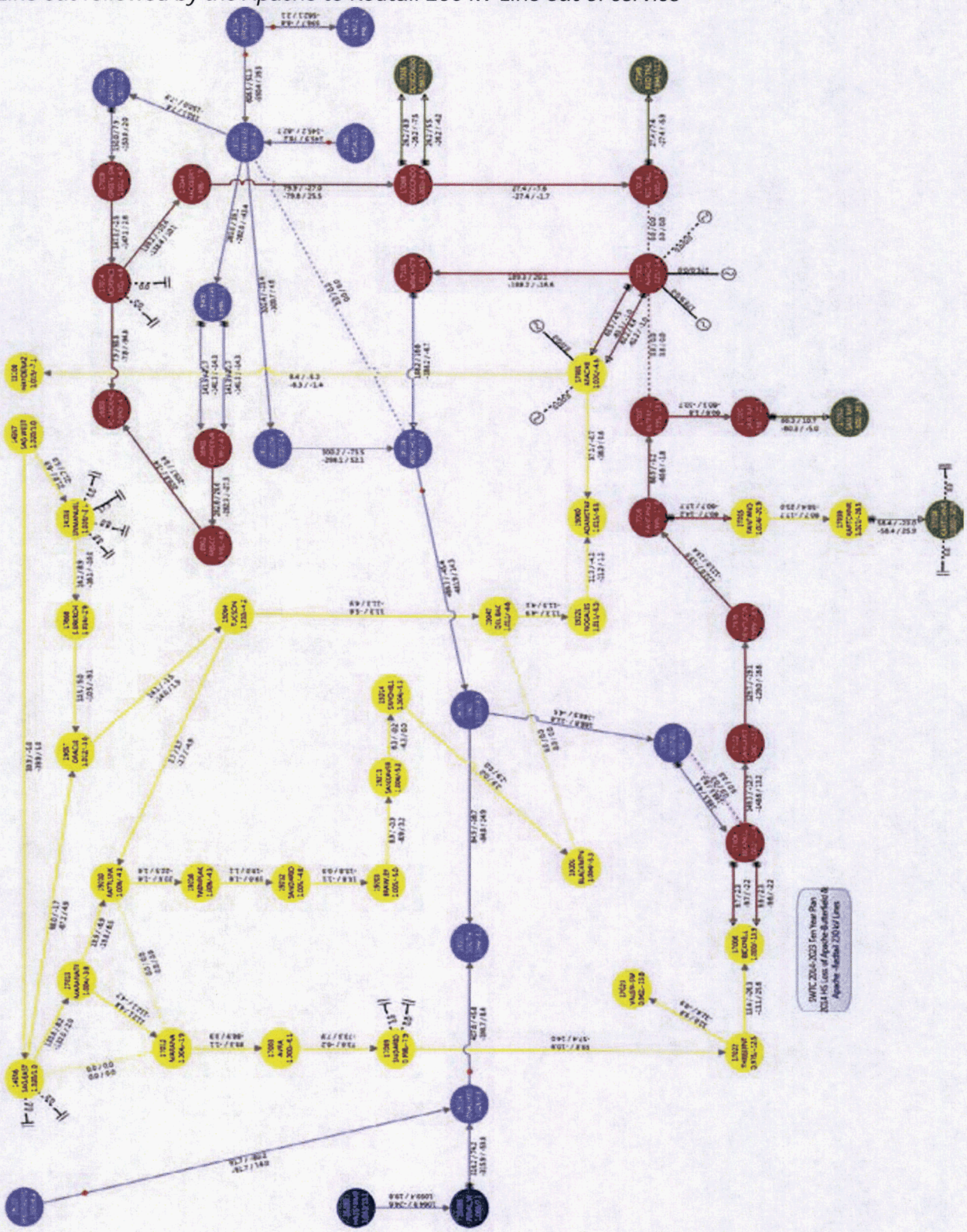
2014HS Southwest Transmission Cooperative Base System with one Bicknell 230/115 kV Transformer out of service



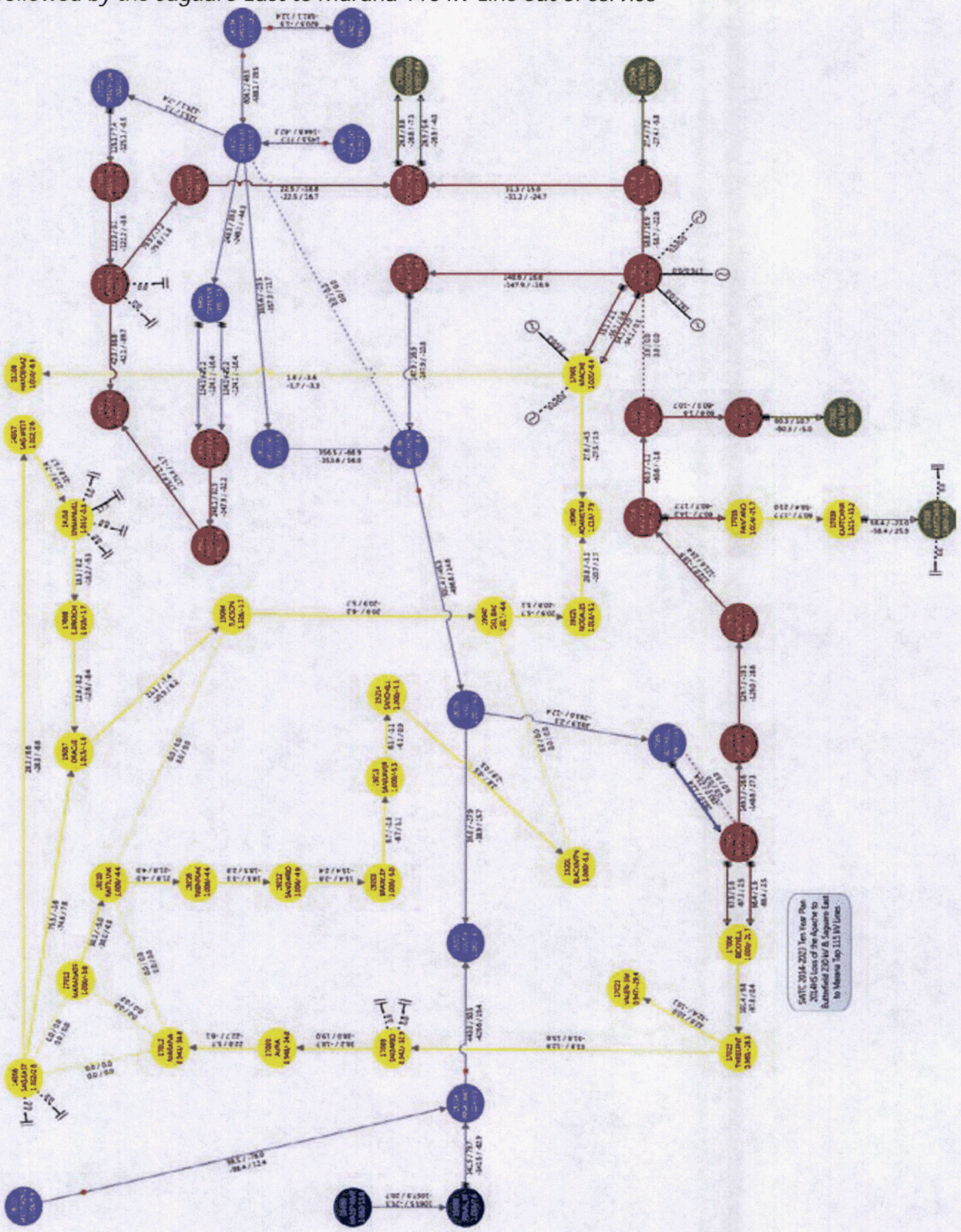
2013HS Southwest Transmission Cooperative Base System with Pinal West 500/345 kV Transformer out of service



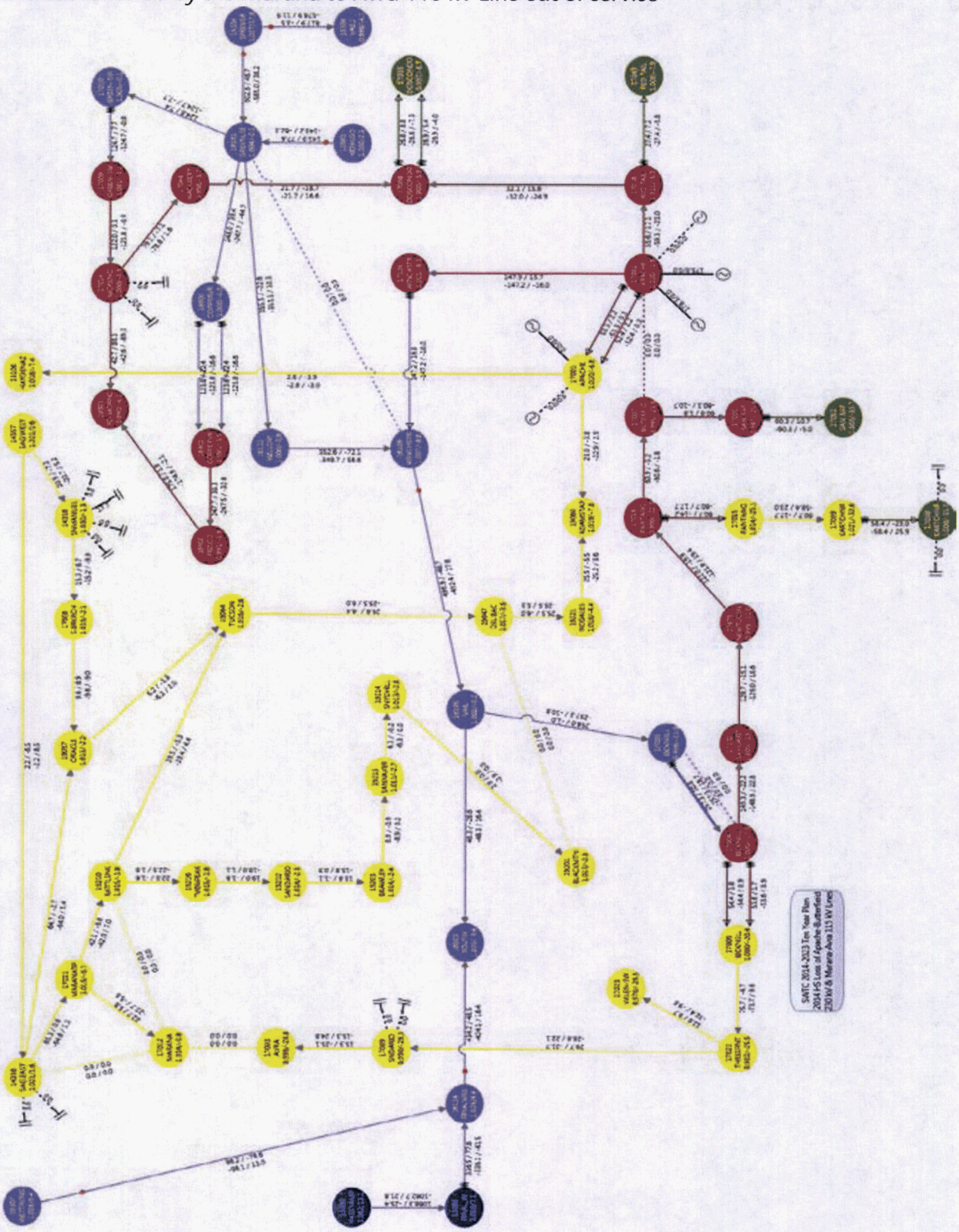
2014HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Apache to Redtail 230 kV Line out of service



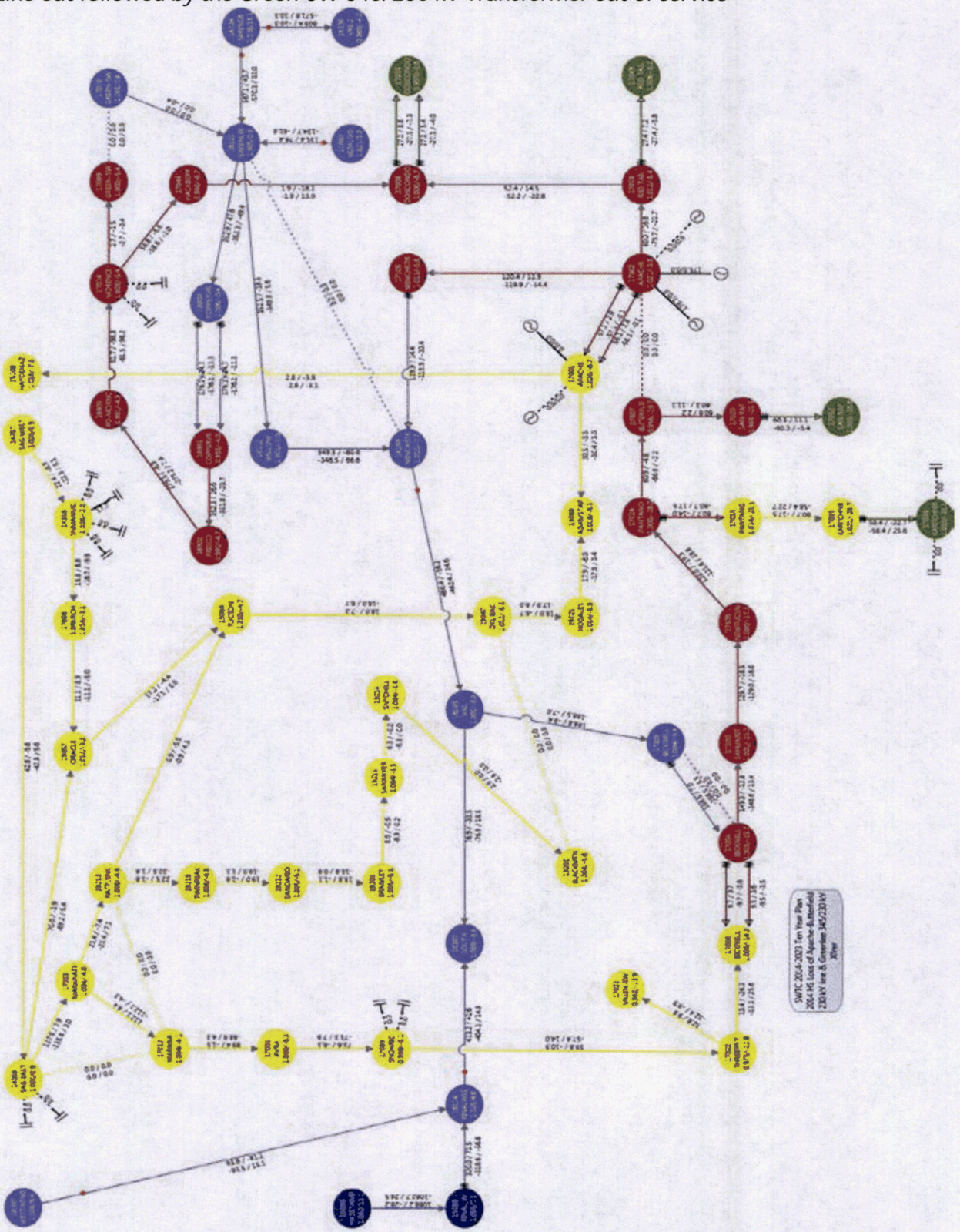
2014HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV out followed by the Saguaro East to Marana 115 kV Line out of service



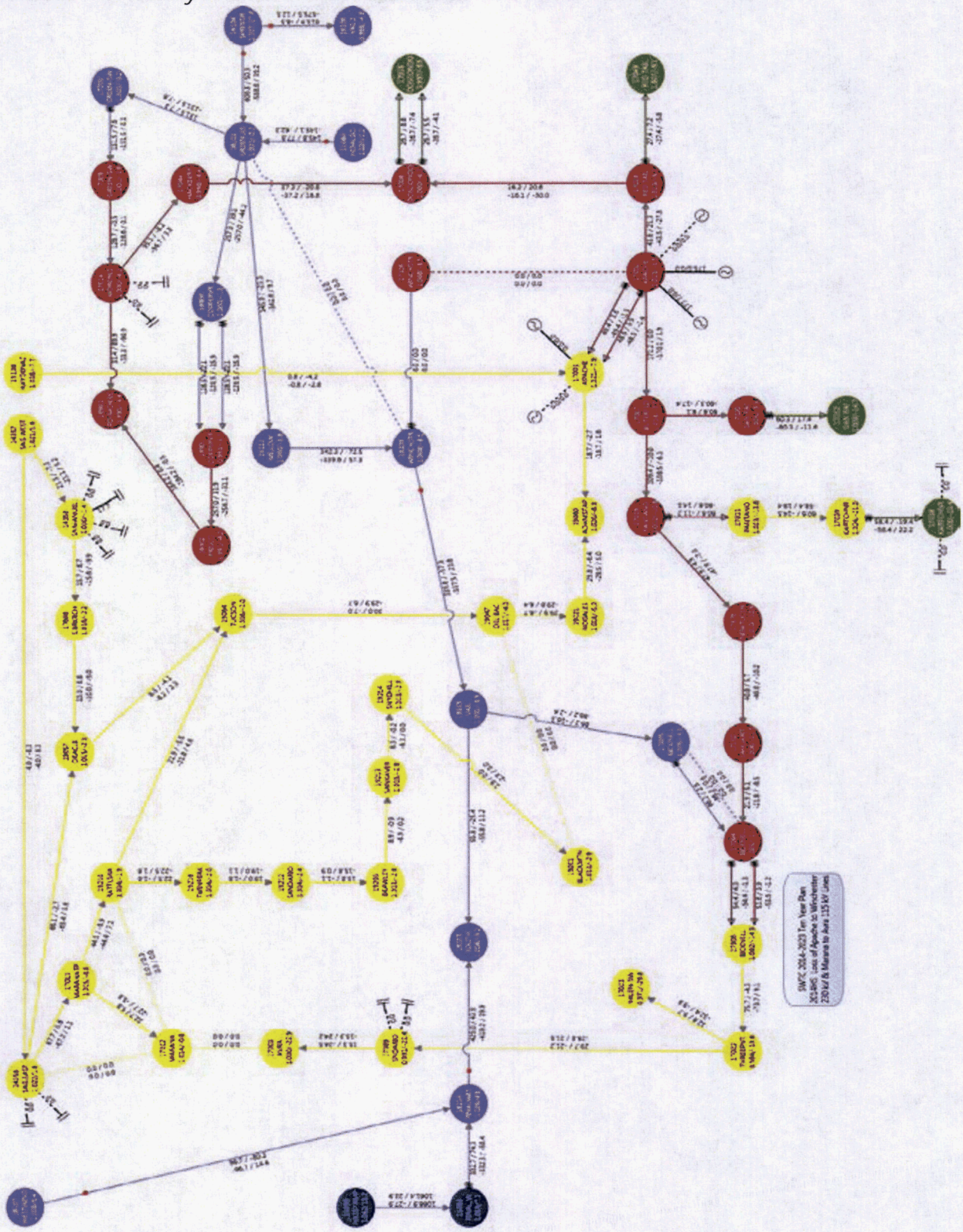
2014HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Marana to Avra 115 kV Line out of service



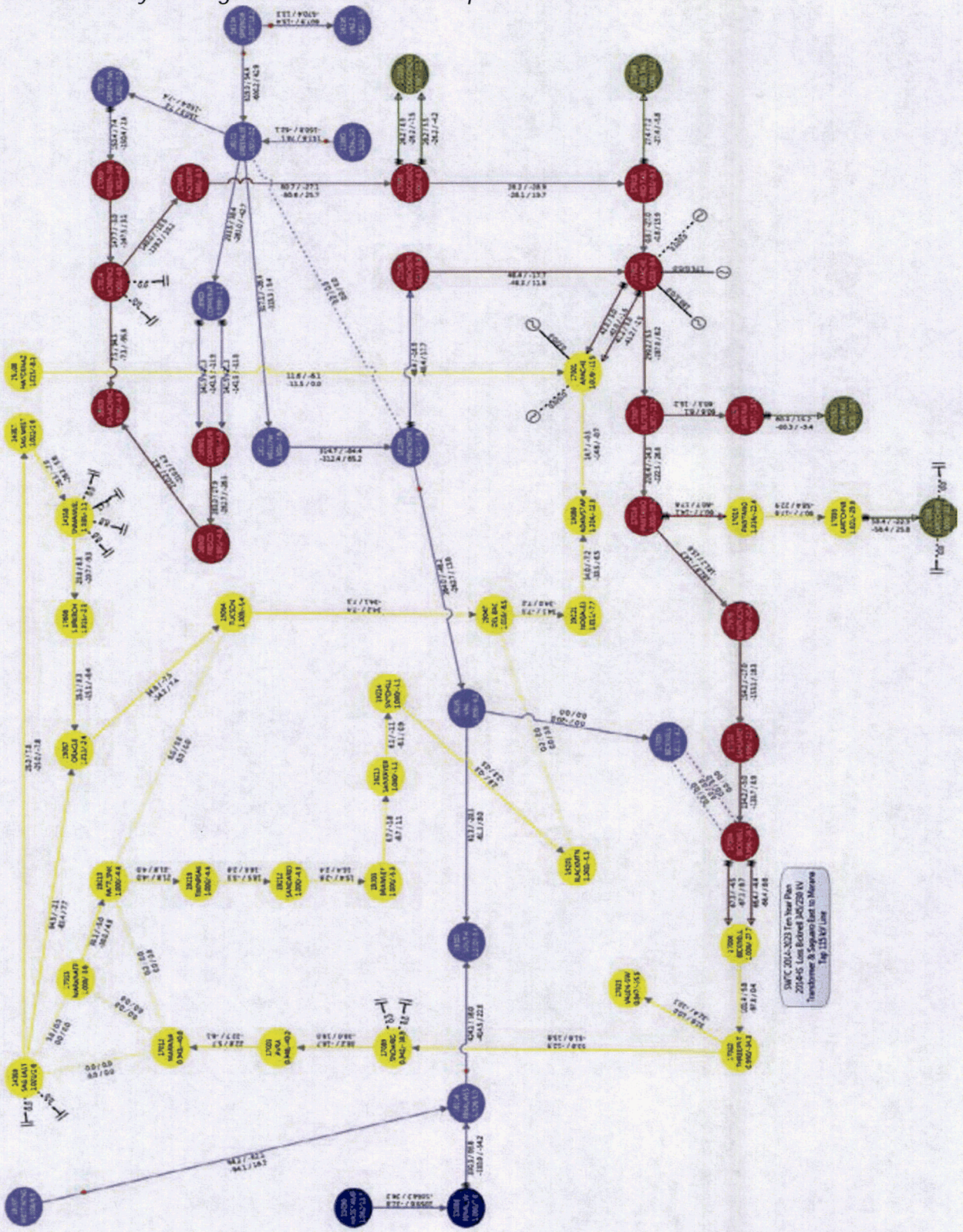
2014HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Green-SW 345/230 kV Transformer out of service



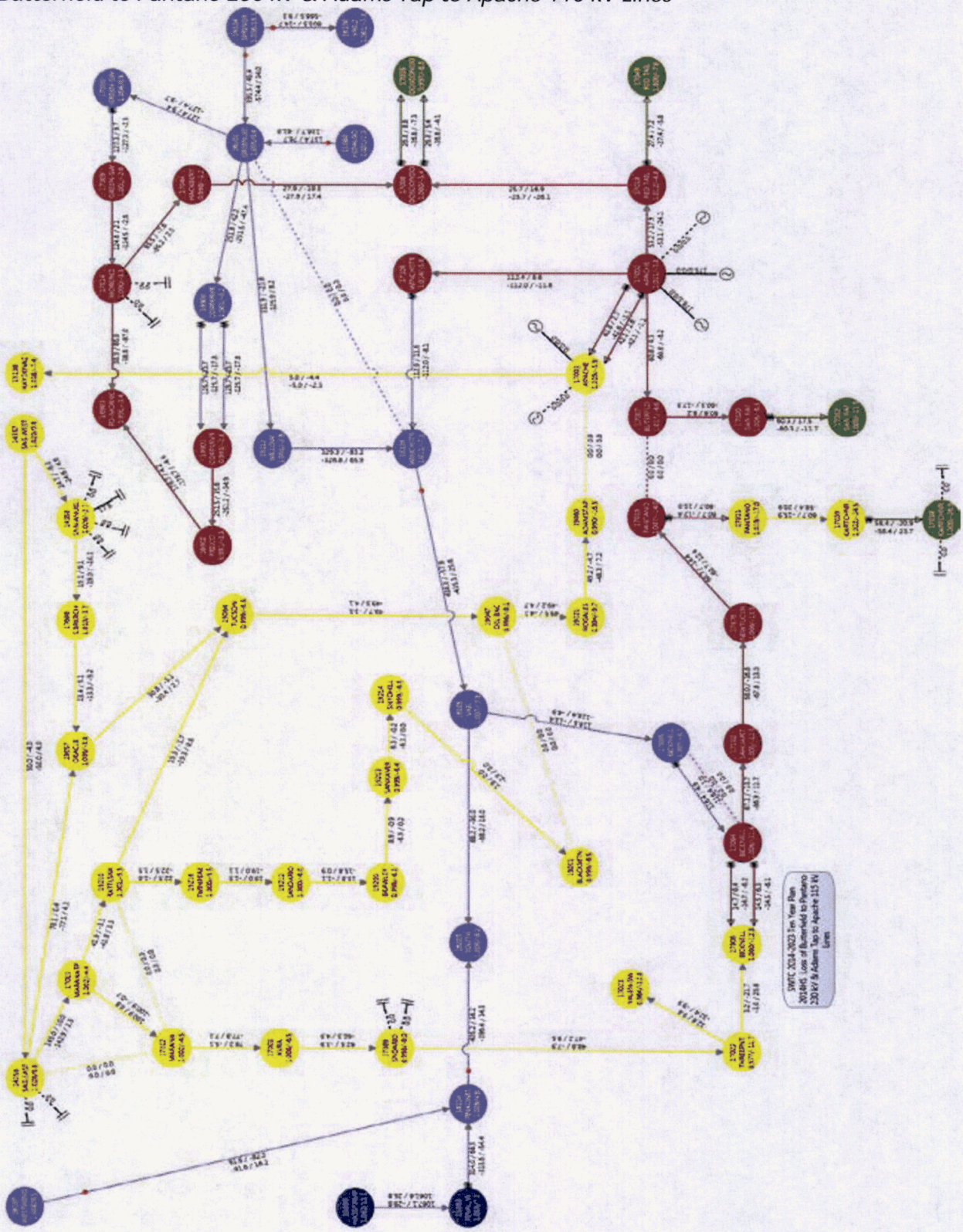
2014HS Southwest Transmission Cooperative Base System with Apache to Winchester 230 kV Line out followed by the Marana to Avra 115 kV Line out of service



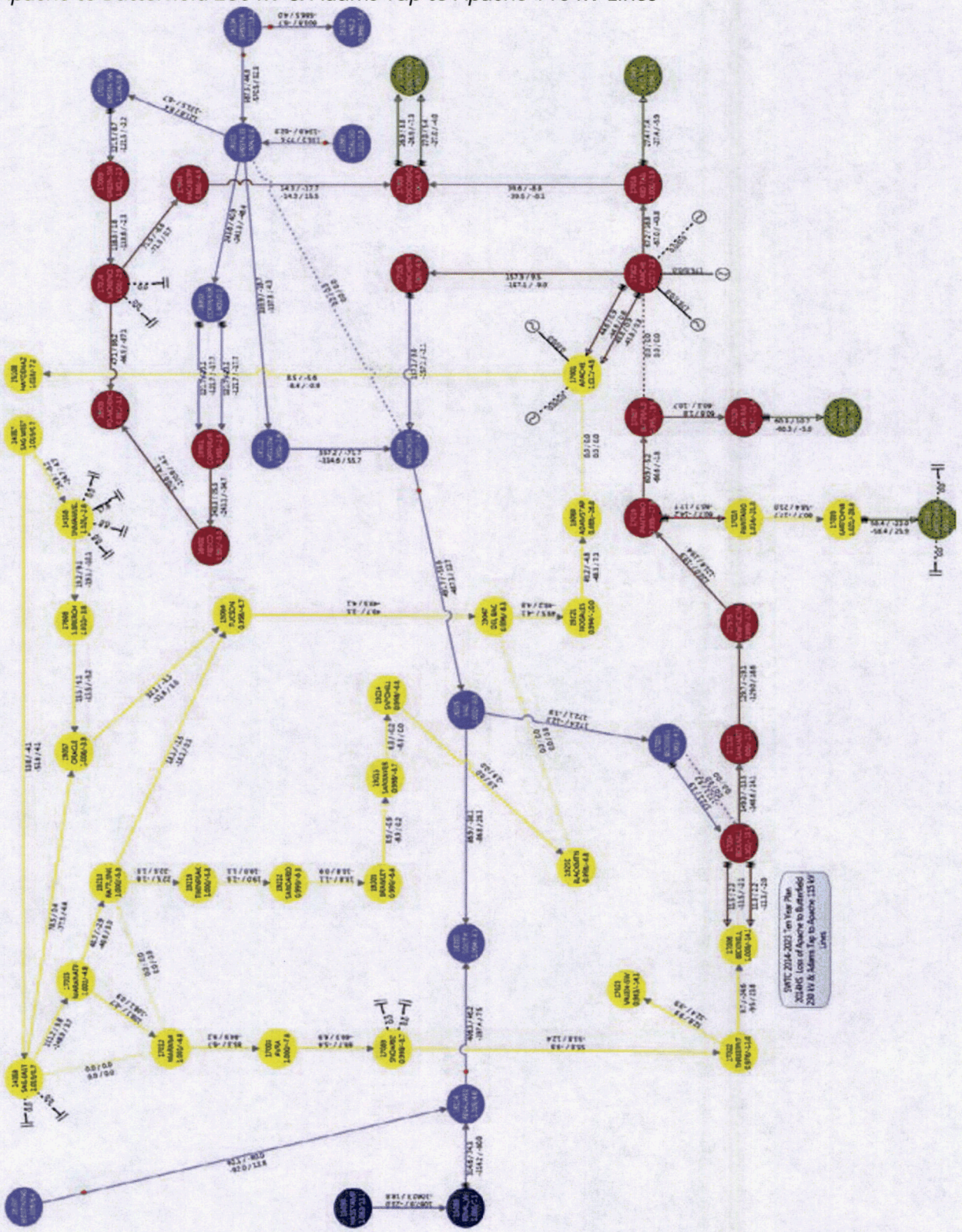
2014HS Southwest Transmission Cooperative Base System with Bicknell 345/230 kV Transformer out followed by the Saguaro East to Marana Tap 115 kV Line out of service



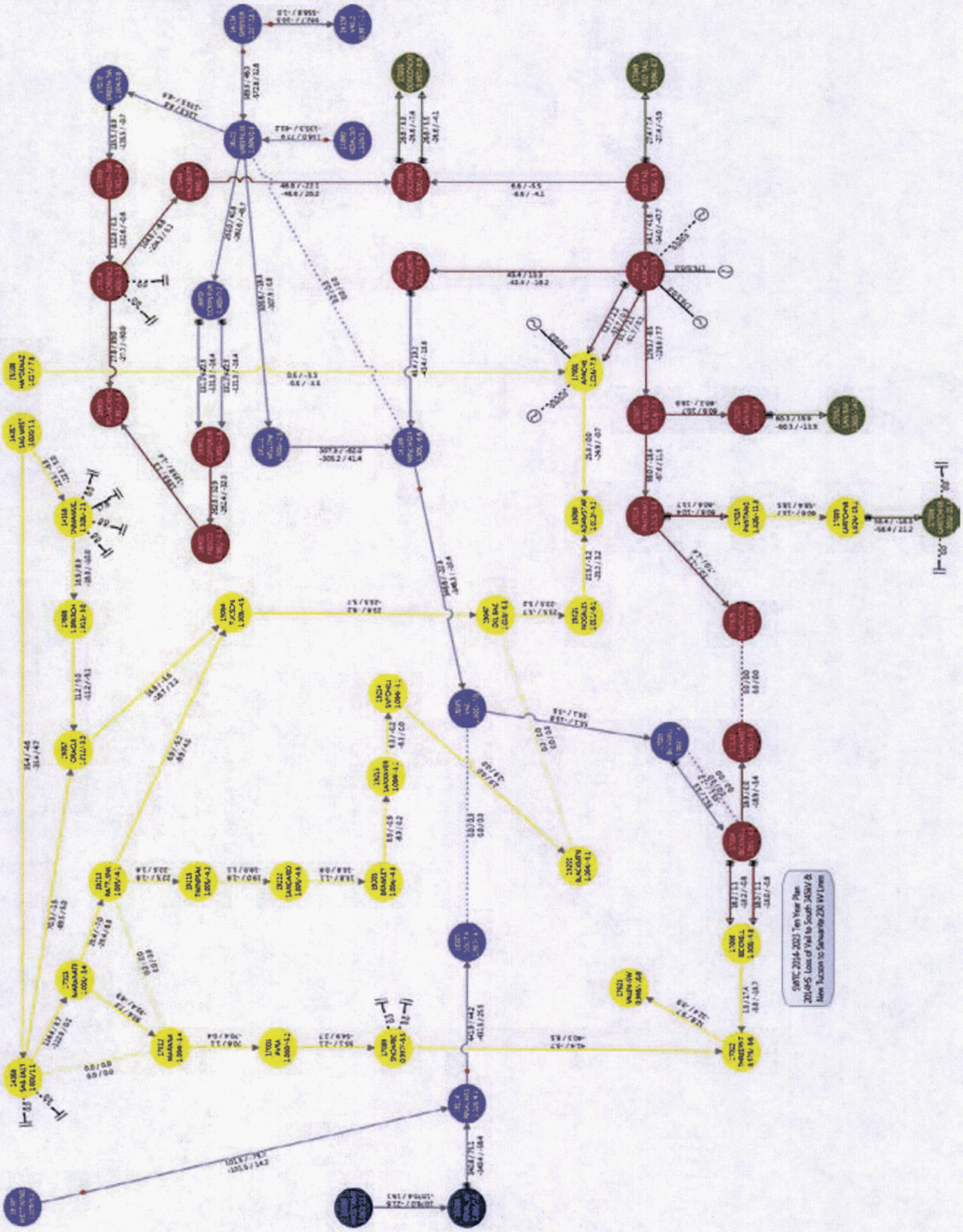
2014HS Southwest Transmission Cooperative Base System with Common Corridor outage of the Butterfield to Pantano 230 kV & Adams Tap to Apache 115 kV Lines



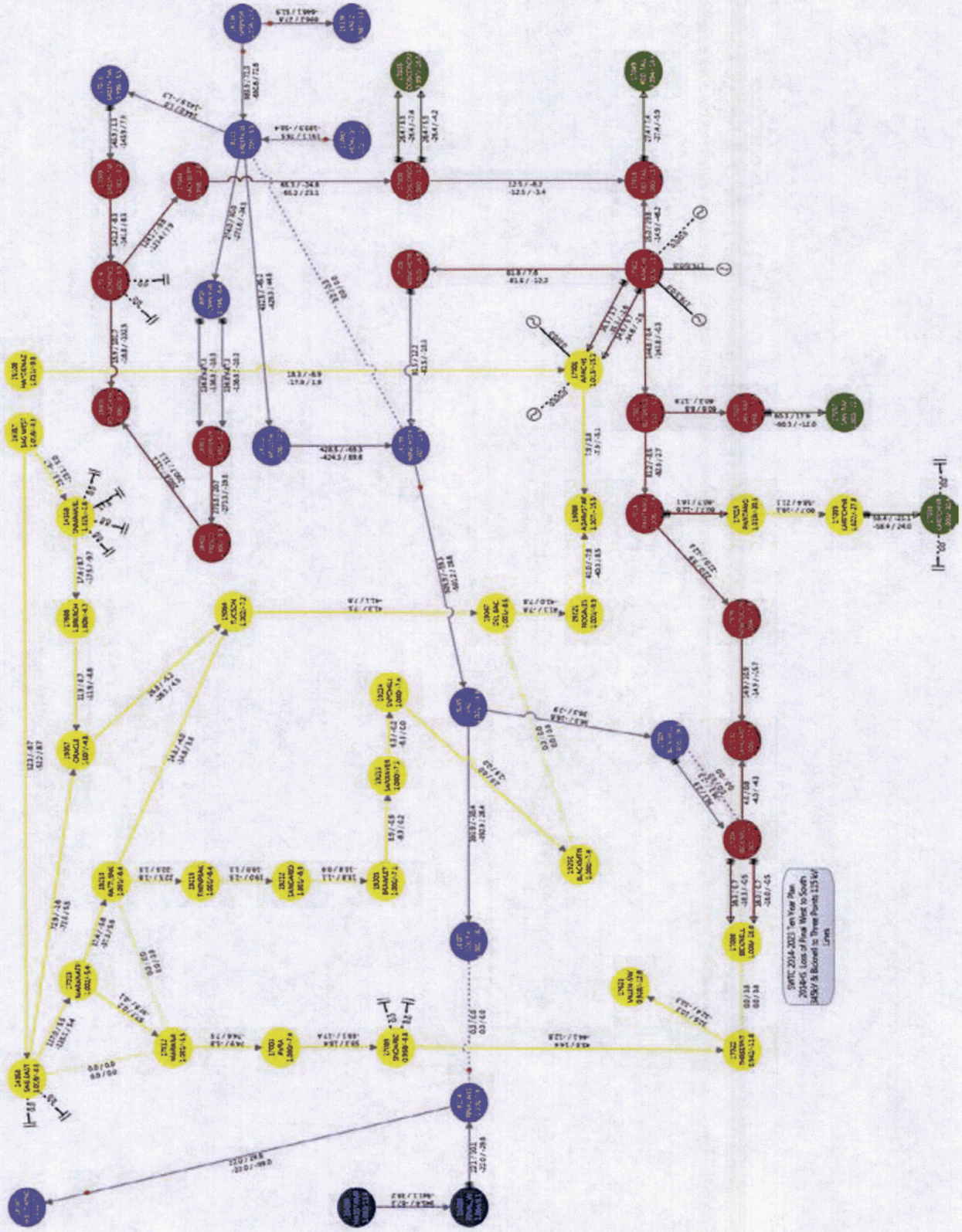
2014HS Southwest Transmission Cooperative Base System with Common Corridor outage of the Apache to Butterfield 230 kV & Adams Tap to Apache 115 kV Lines



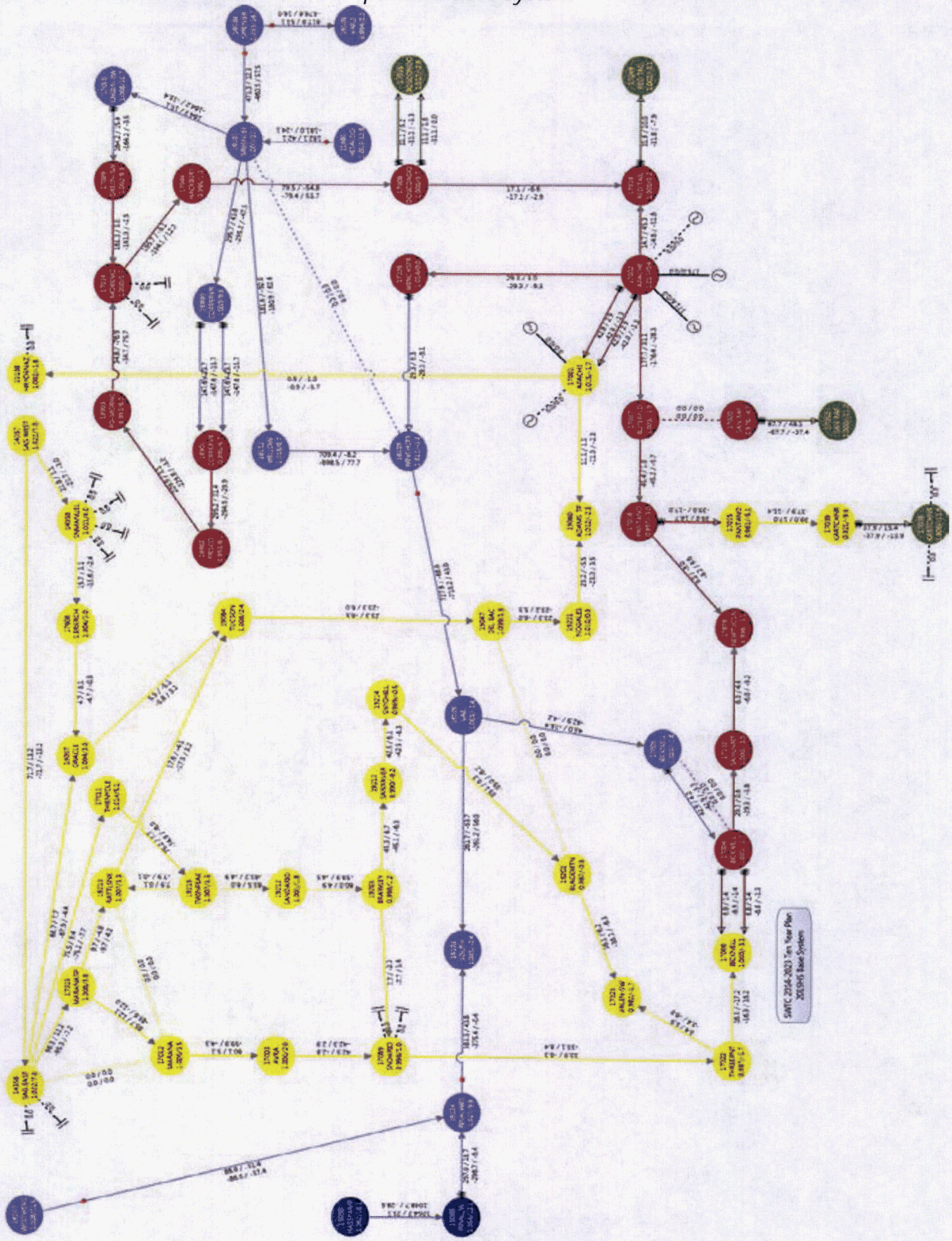
2014HS Southwest Transmission Cooperative Base System with Common Corridor outage of the Vail to South 345 kV & New Tucson to Sahuarita 230 kV Lines



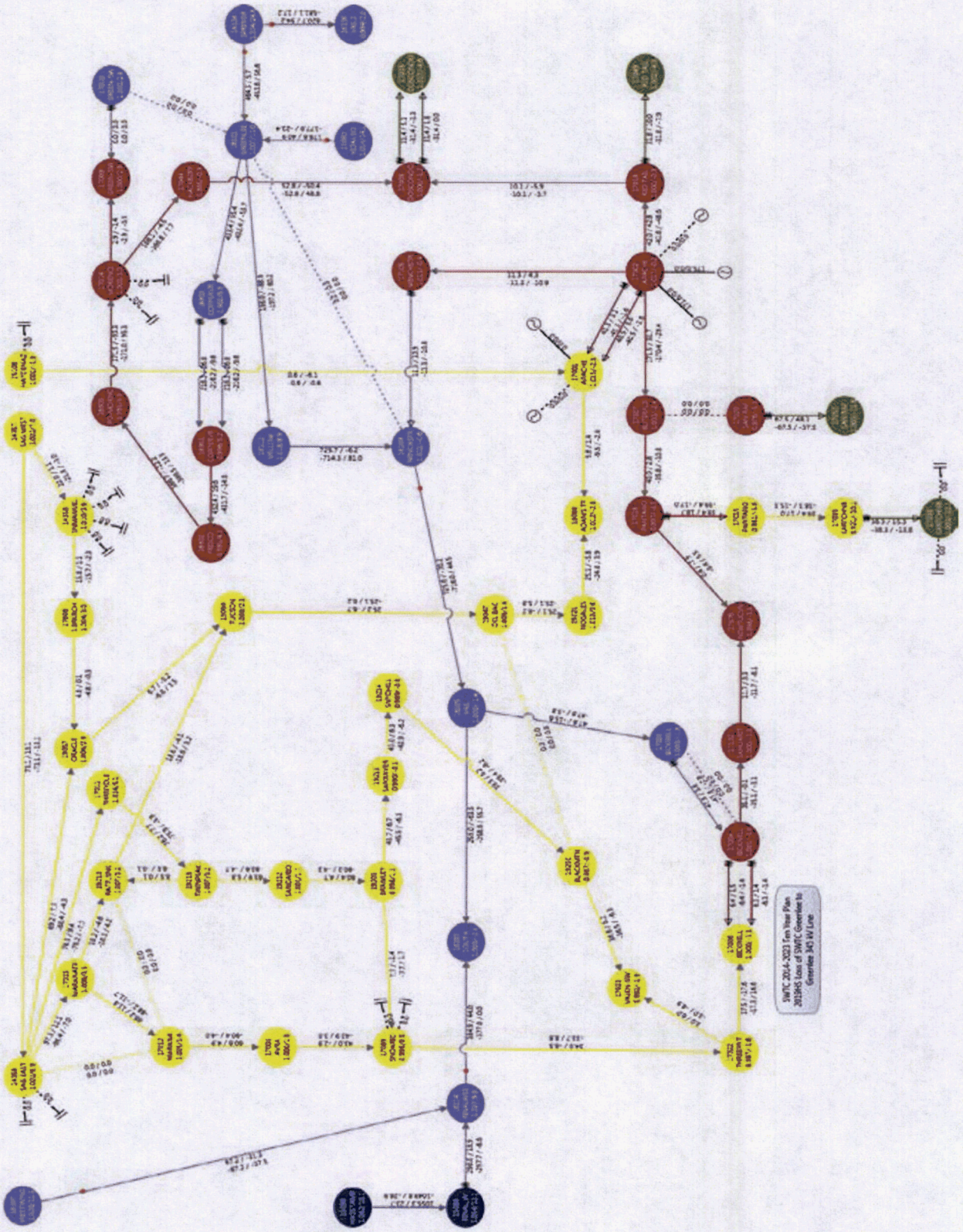
2014HS Southwest Transmission Cooperative Base System with Common Corridor outage of the Pinal West to South 345 kV and Bicknell to Three Points 115 kV Lines



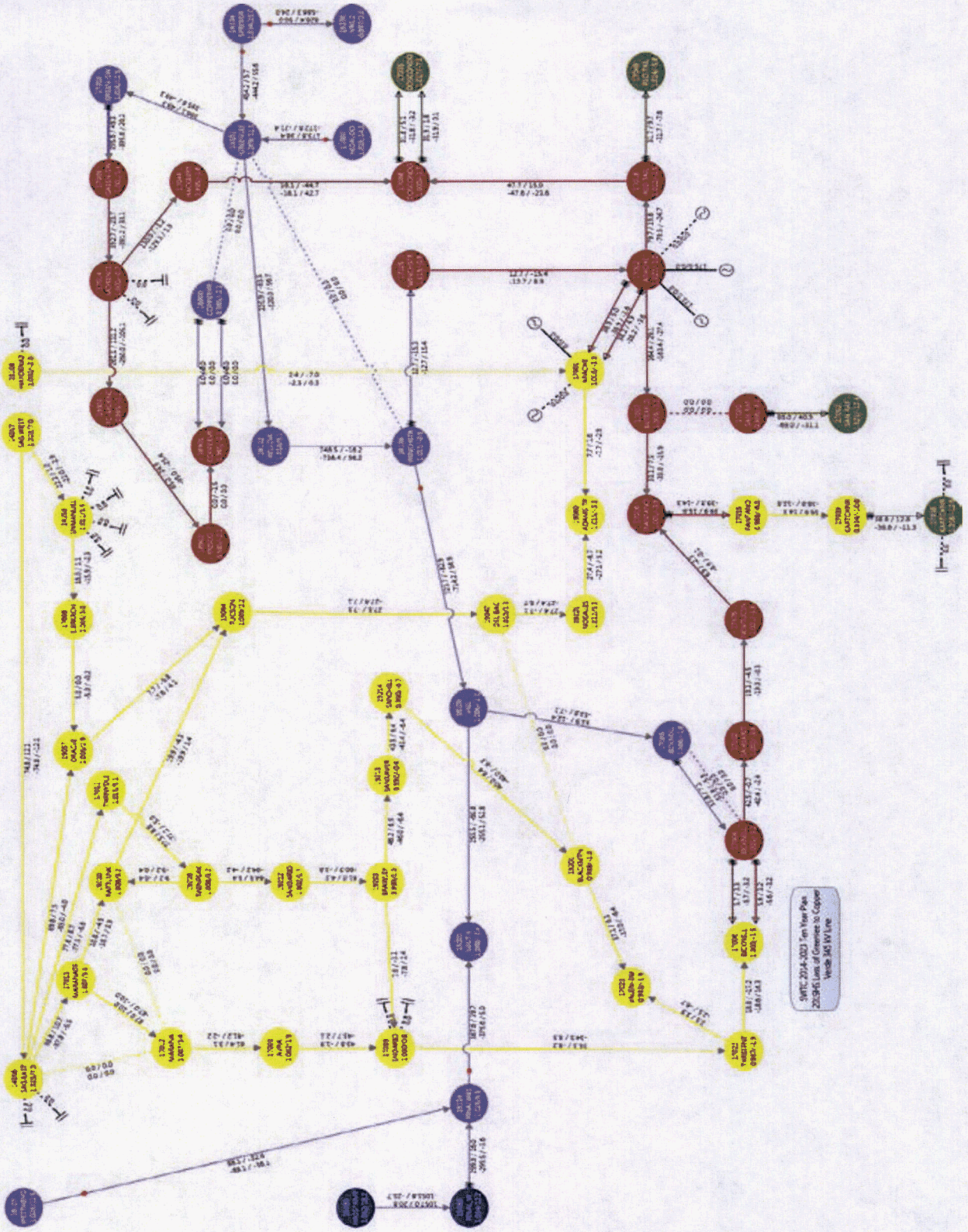
2019HS Southwest Transmission Cooperative Base System



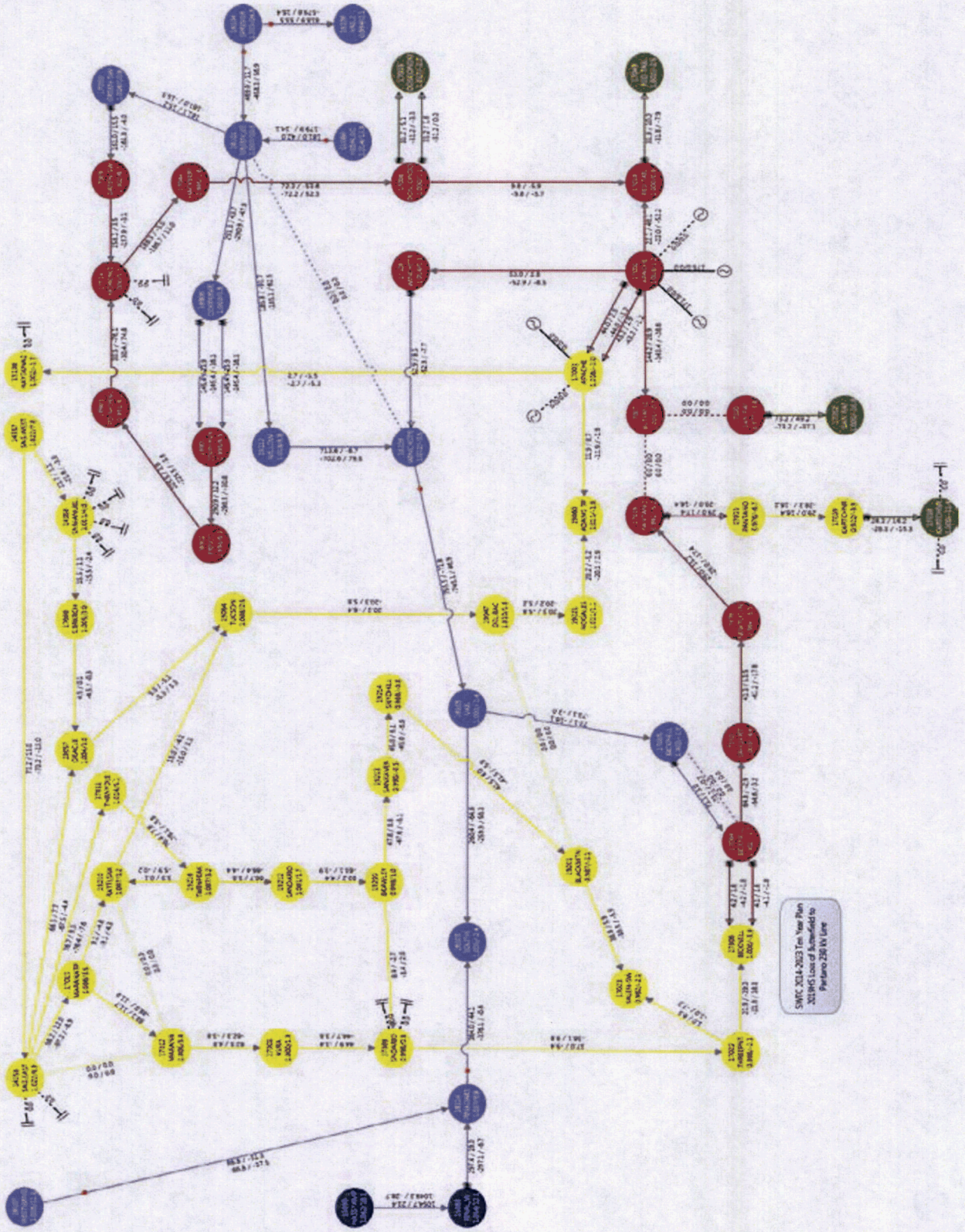
2019HS Southwest Transmission Cooperative Base System with Green-SW to Greenlee 345 kV Line out of service



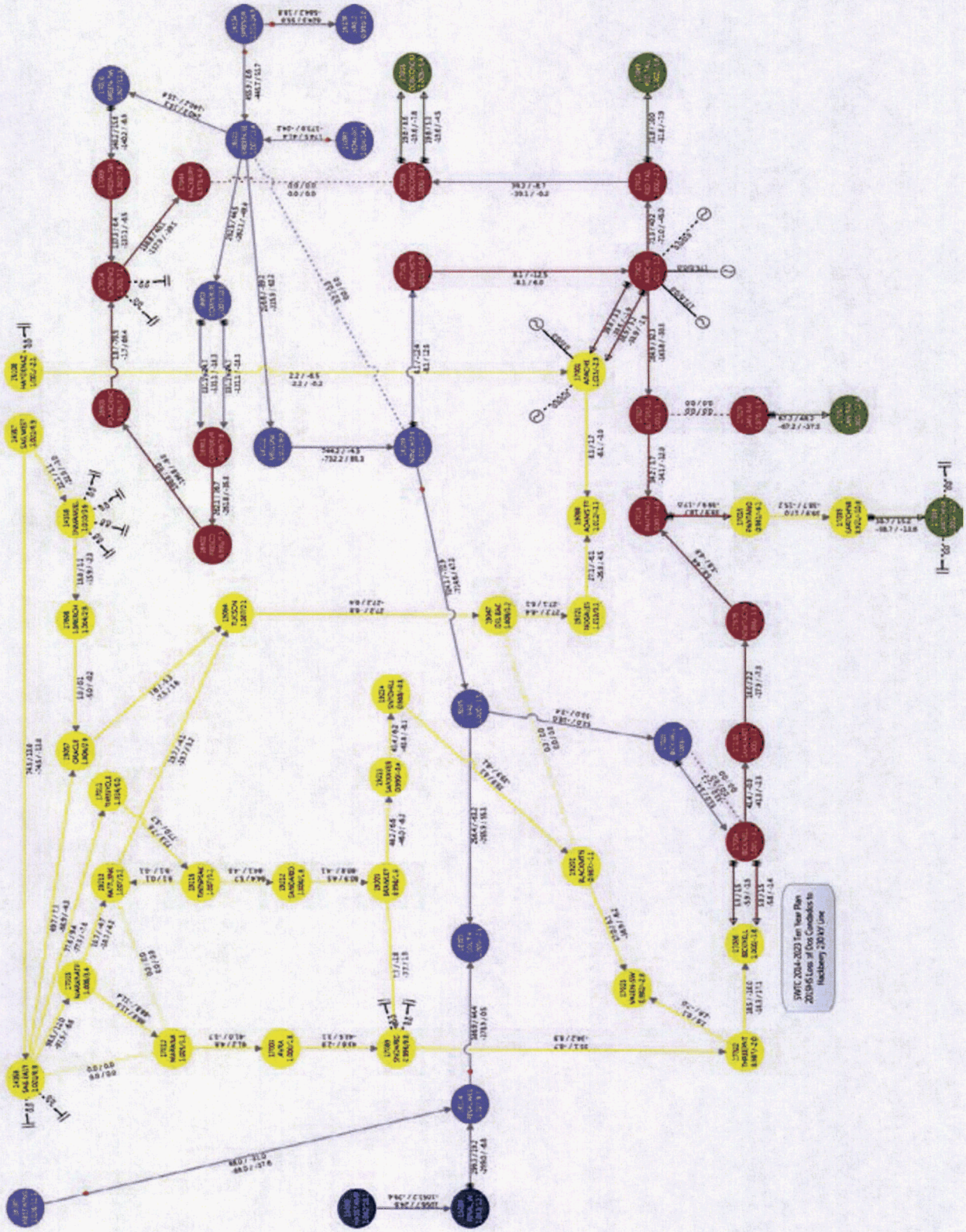
2019HS Southwest Transmission Cooperative Base System with Greenlee to Copper Verde 345 kV Line out of service



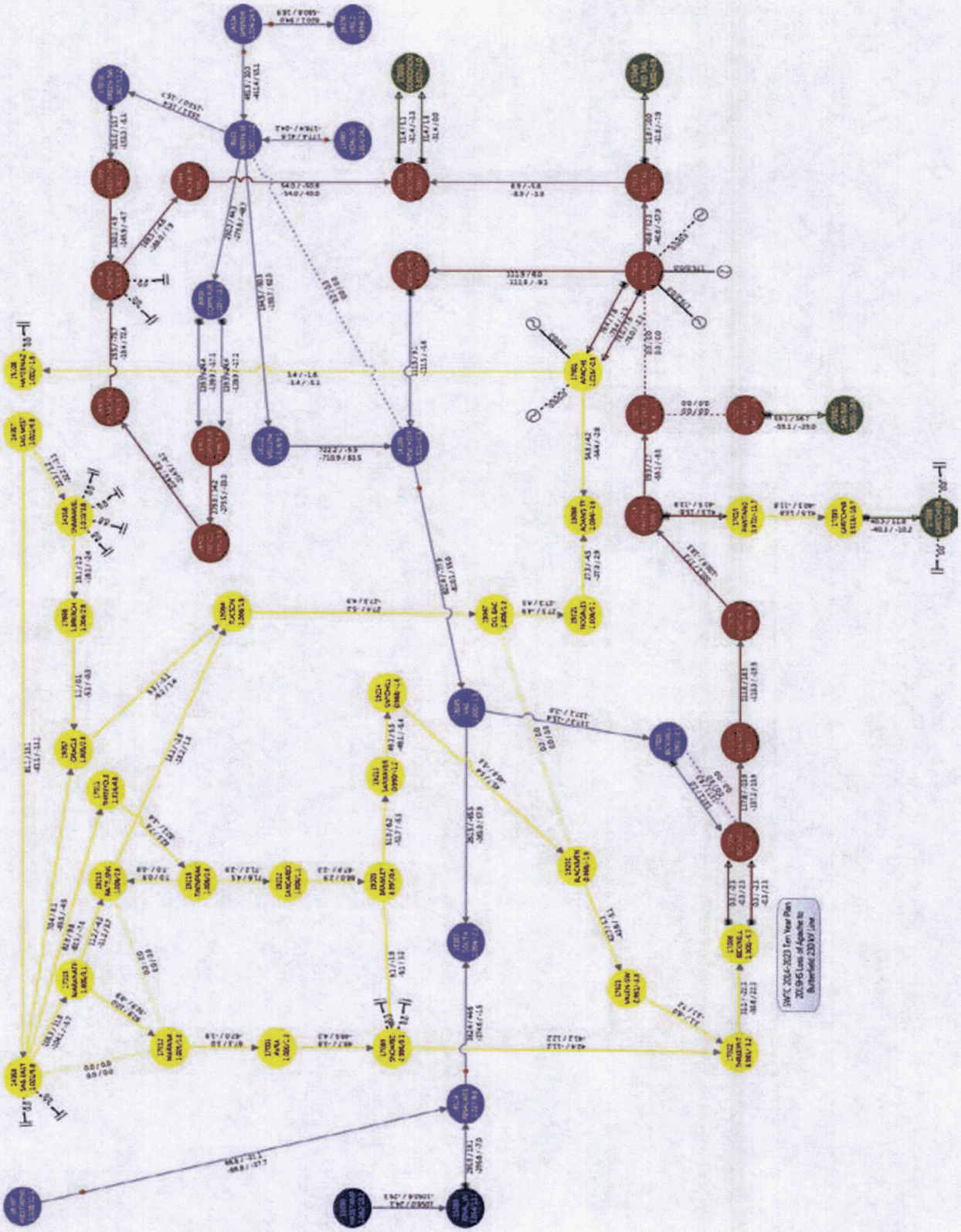
2019HS Southwest Transmission Cooperative Base System with Butterfield to Pantano 230 kV Line out of service



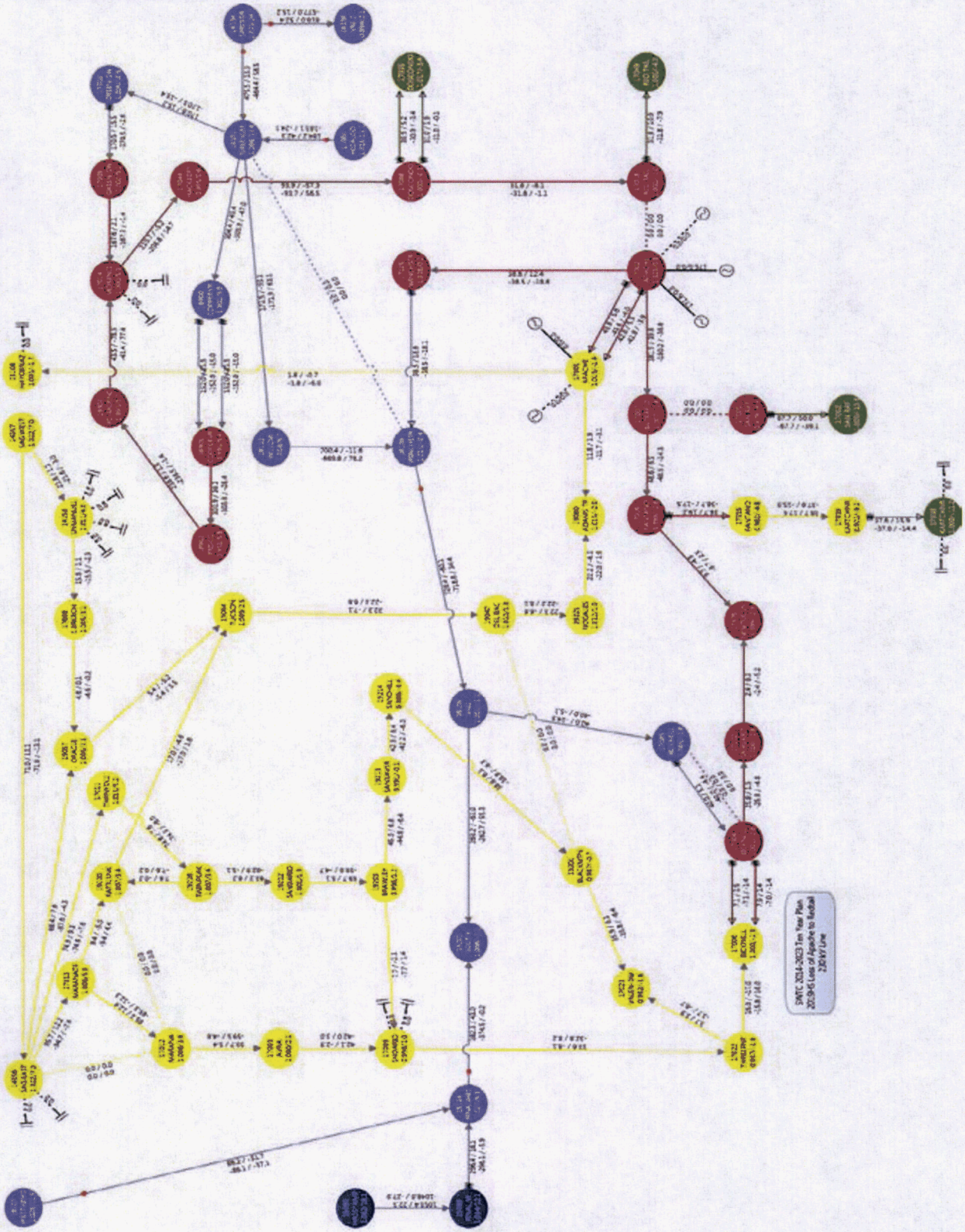
2019HS Southwest Transmission Cooperative Base System with Dos Condados to Hackberry 230 kV Line out of service



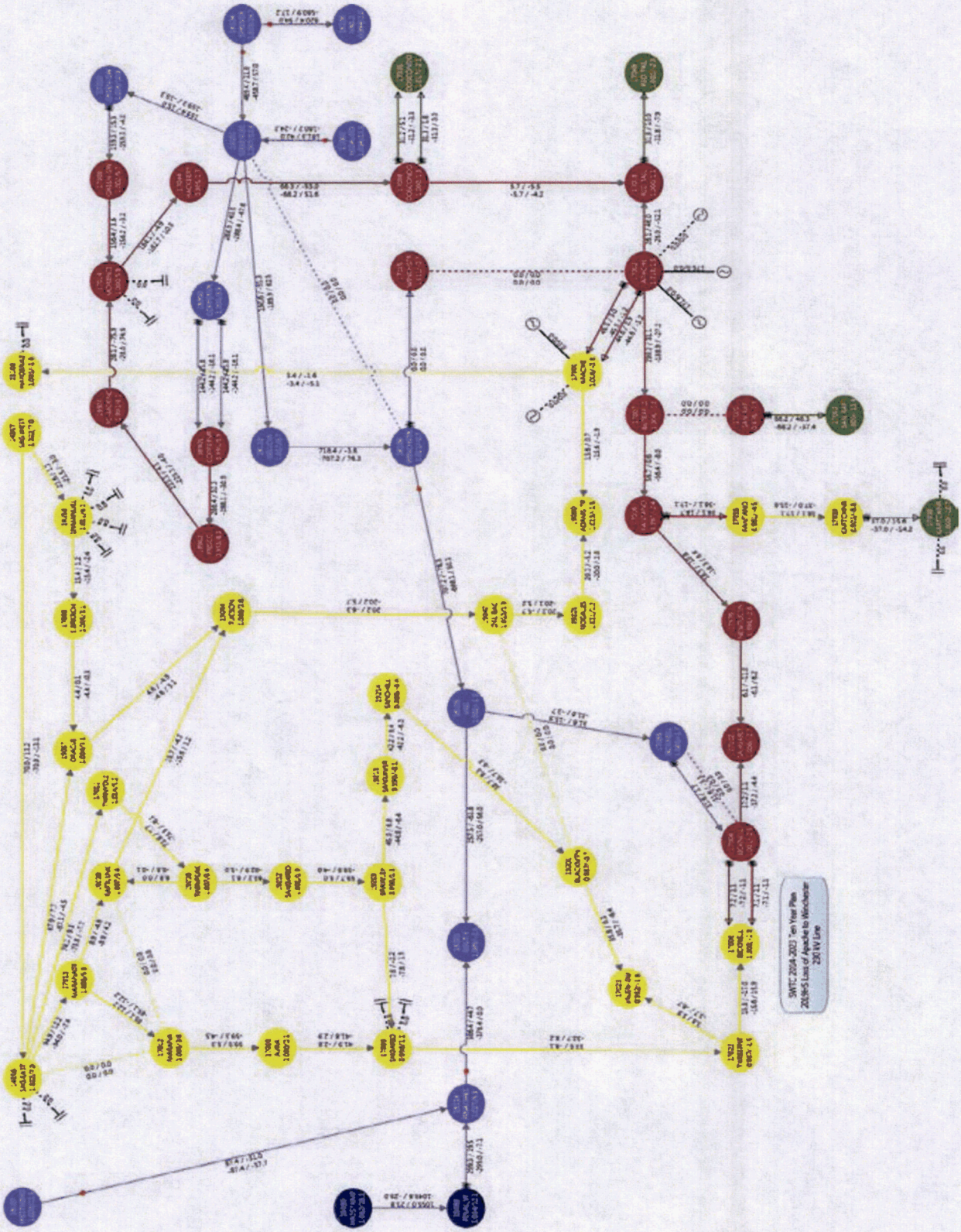
2019HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out of service



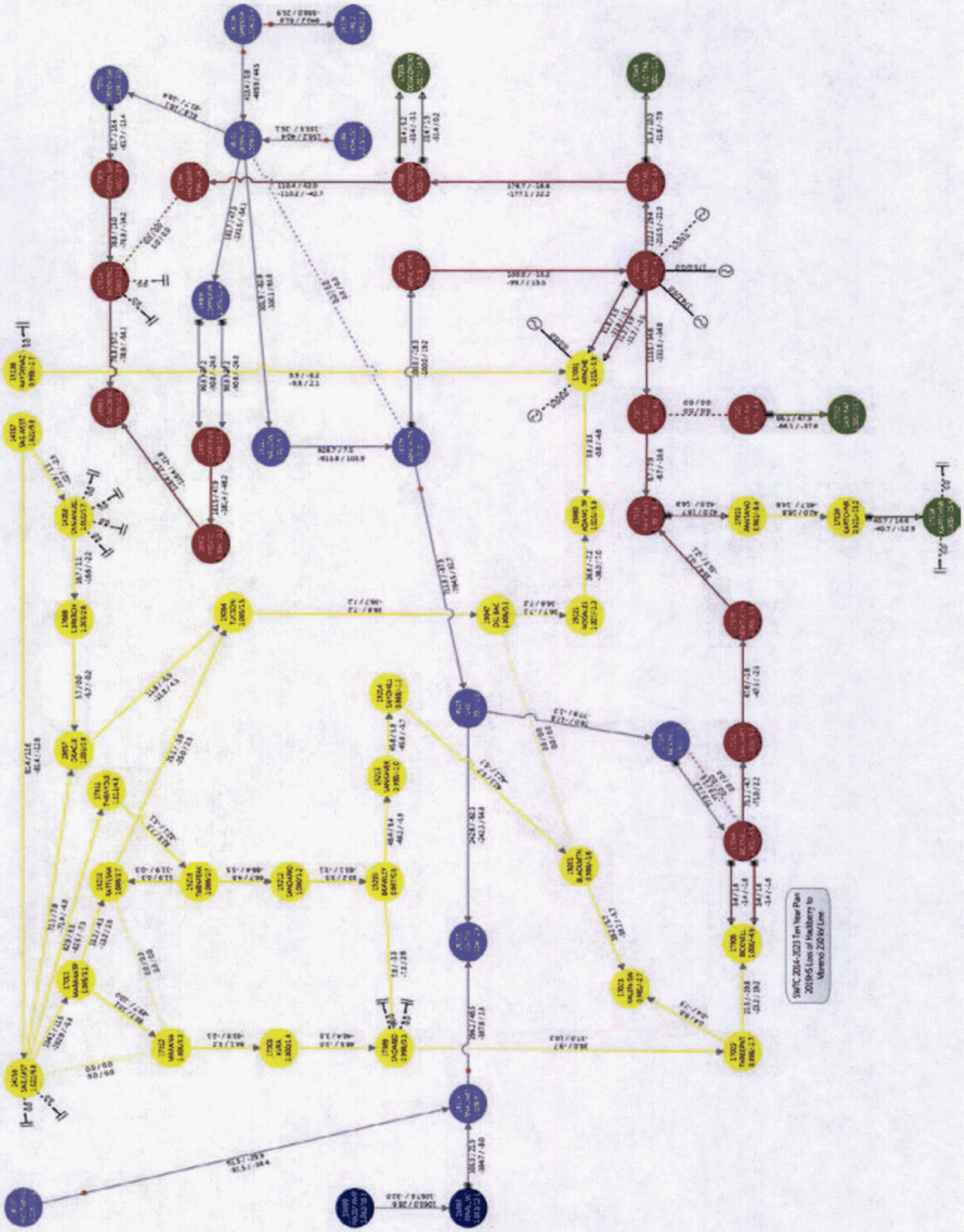
2019HS Southwest Transmission Cooperative Base System with Apache to Redtail 230 kV Line out of service



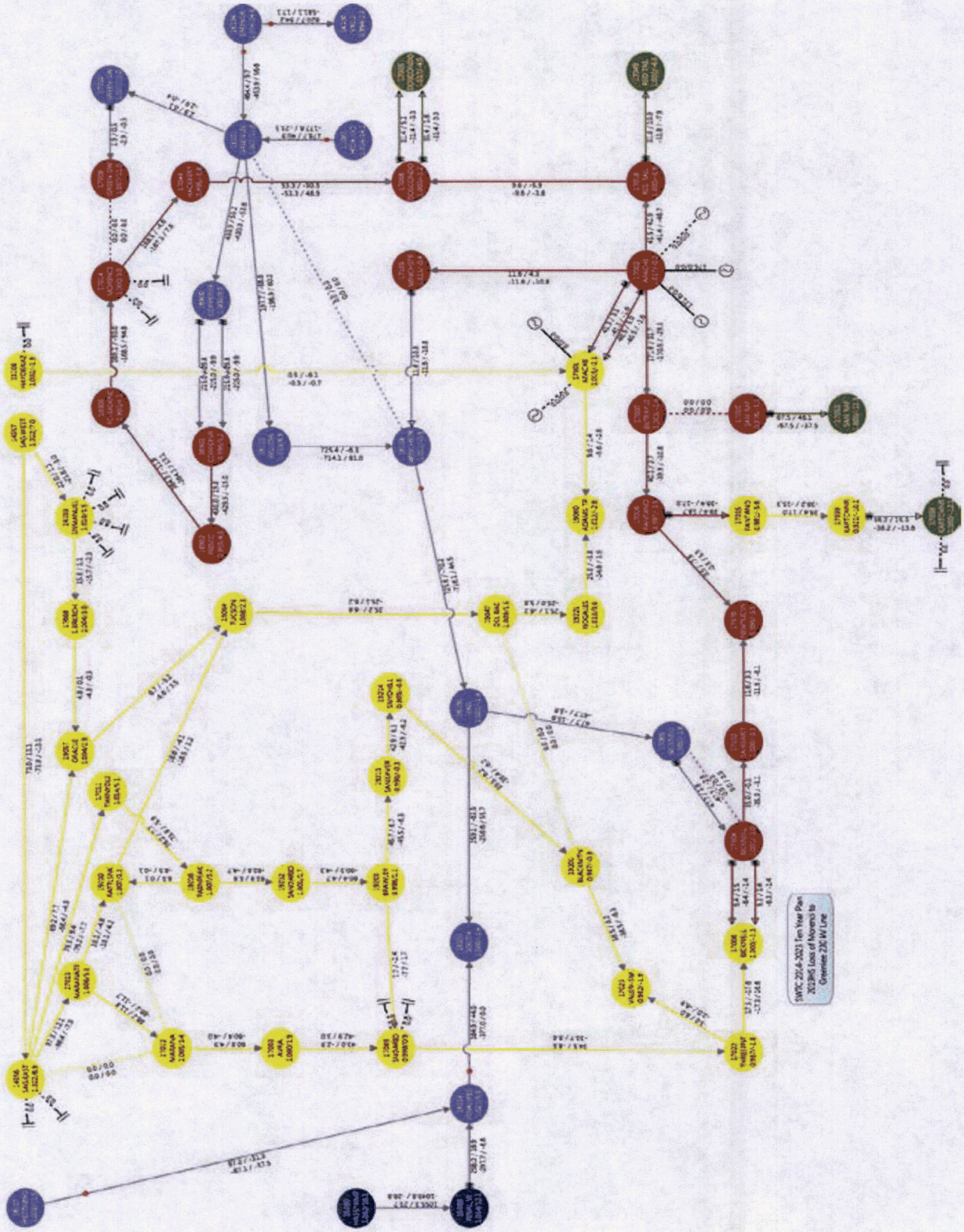
2019HS Southwest Transmission Cooperative Base System with Apache to Winchester 230 kV Line out of service



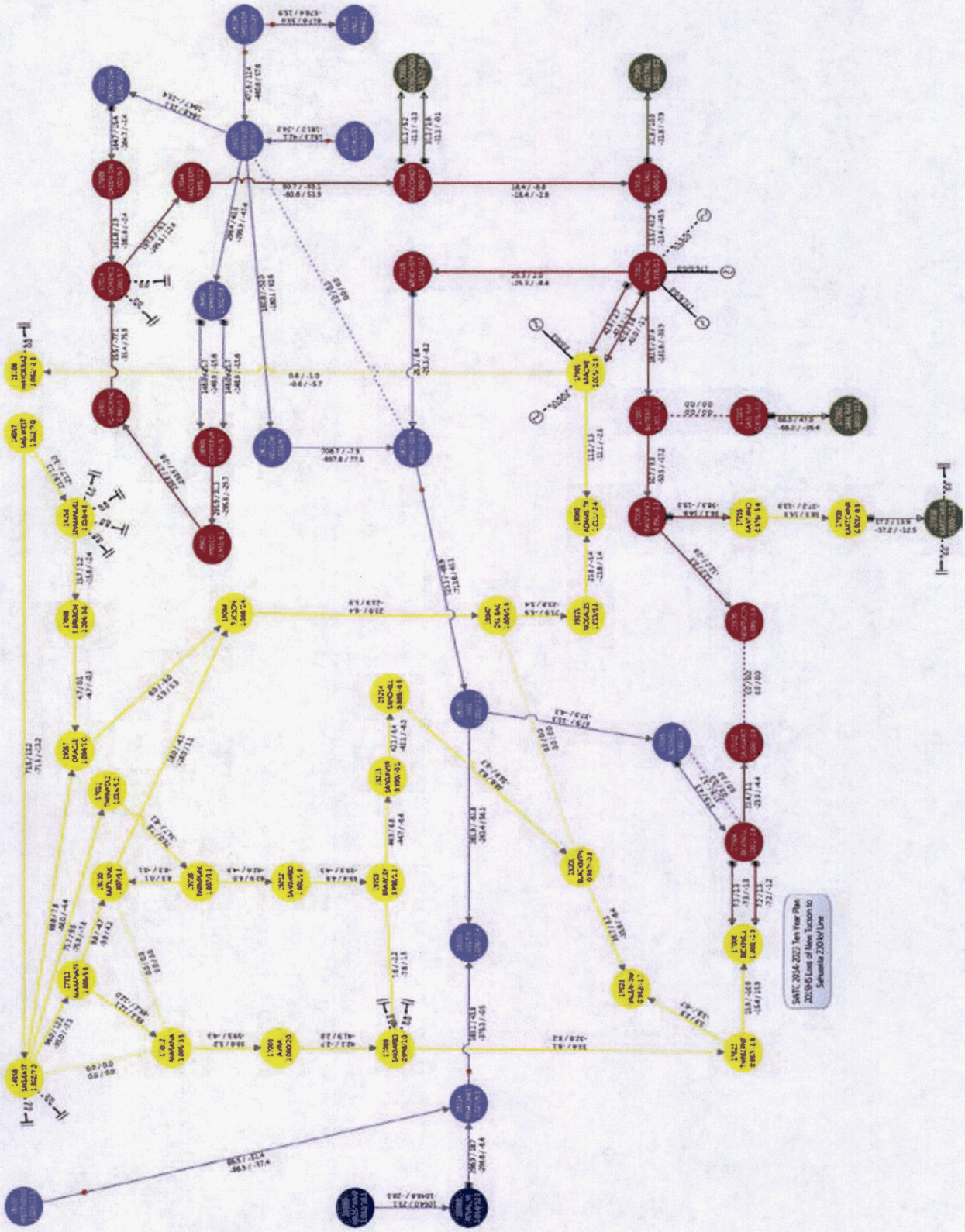
2019HS Southwest Transmission Cooperative Base System with Hackberry to Morenci 230 kV Line out of service



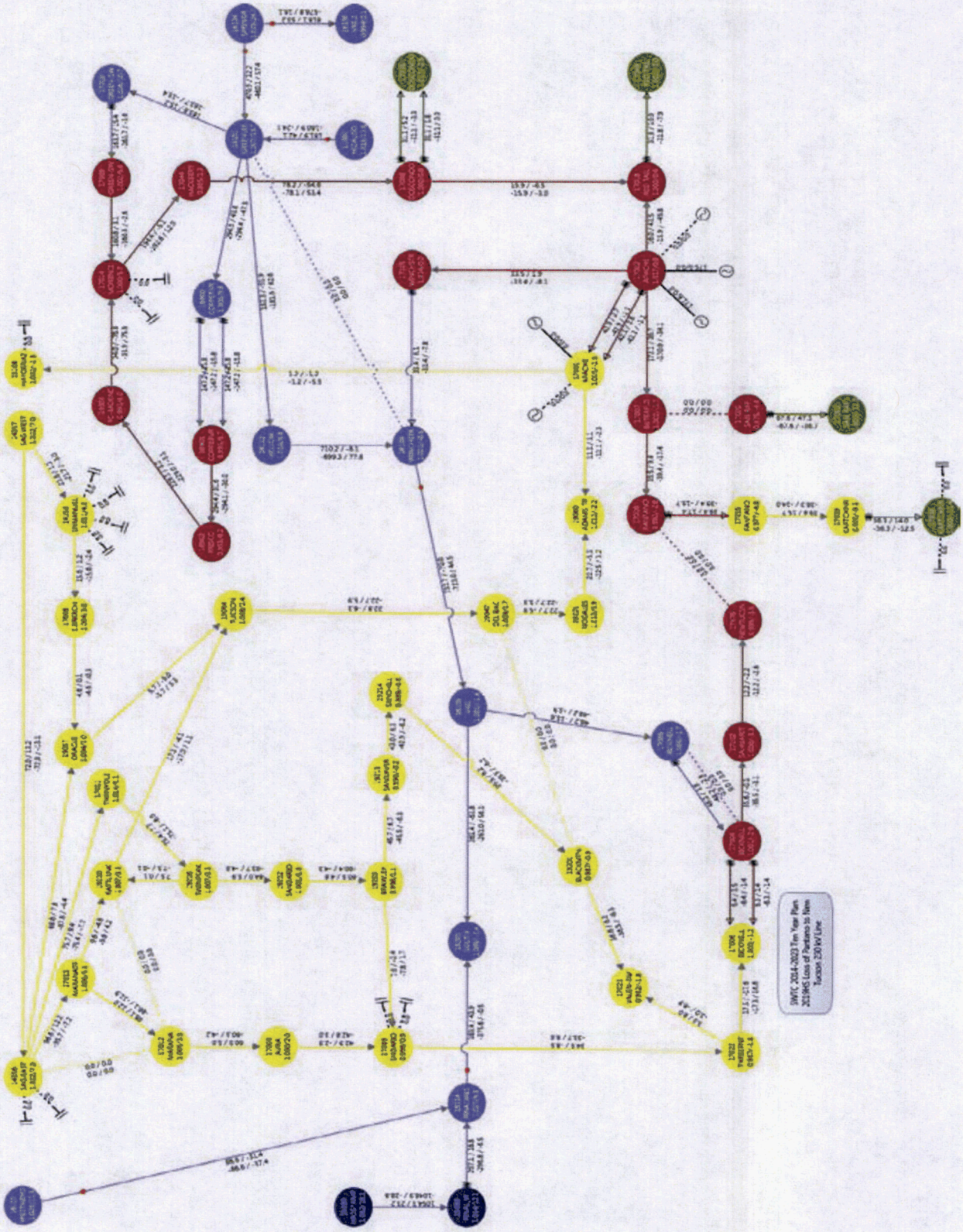
2019HS Southwest Transmission Cooperative Base System with Morenci to Green-SW 230 kV Line out of service



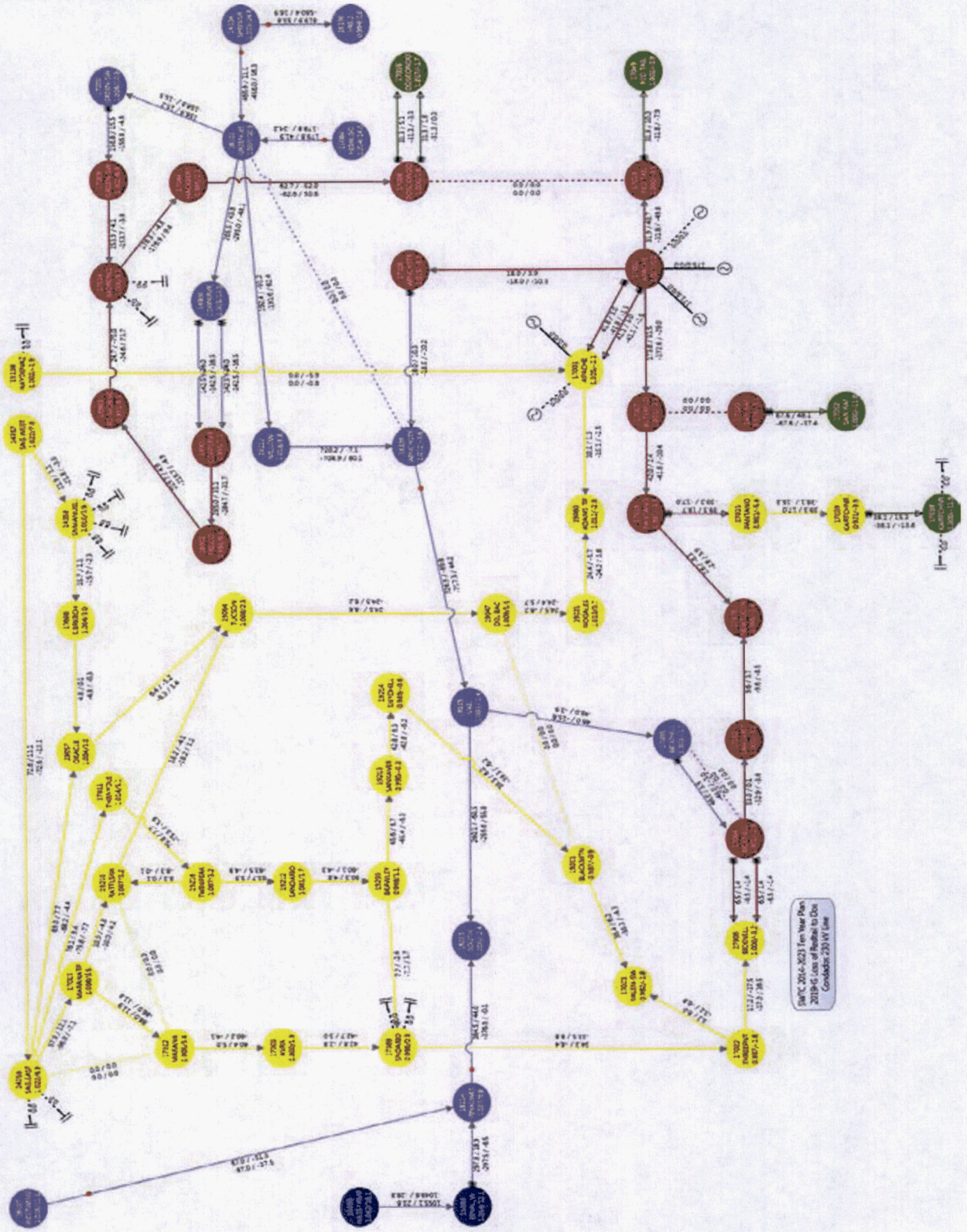
2019HS Southwest Transmission Cooperative Base System with New Tucson to Sahuarita 230 kV Line out of service



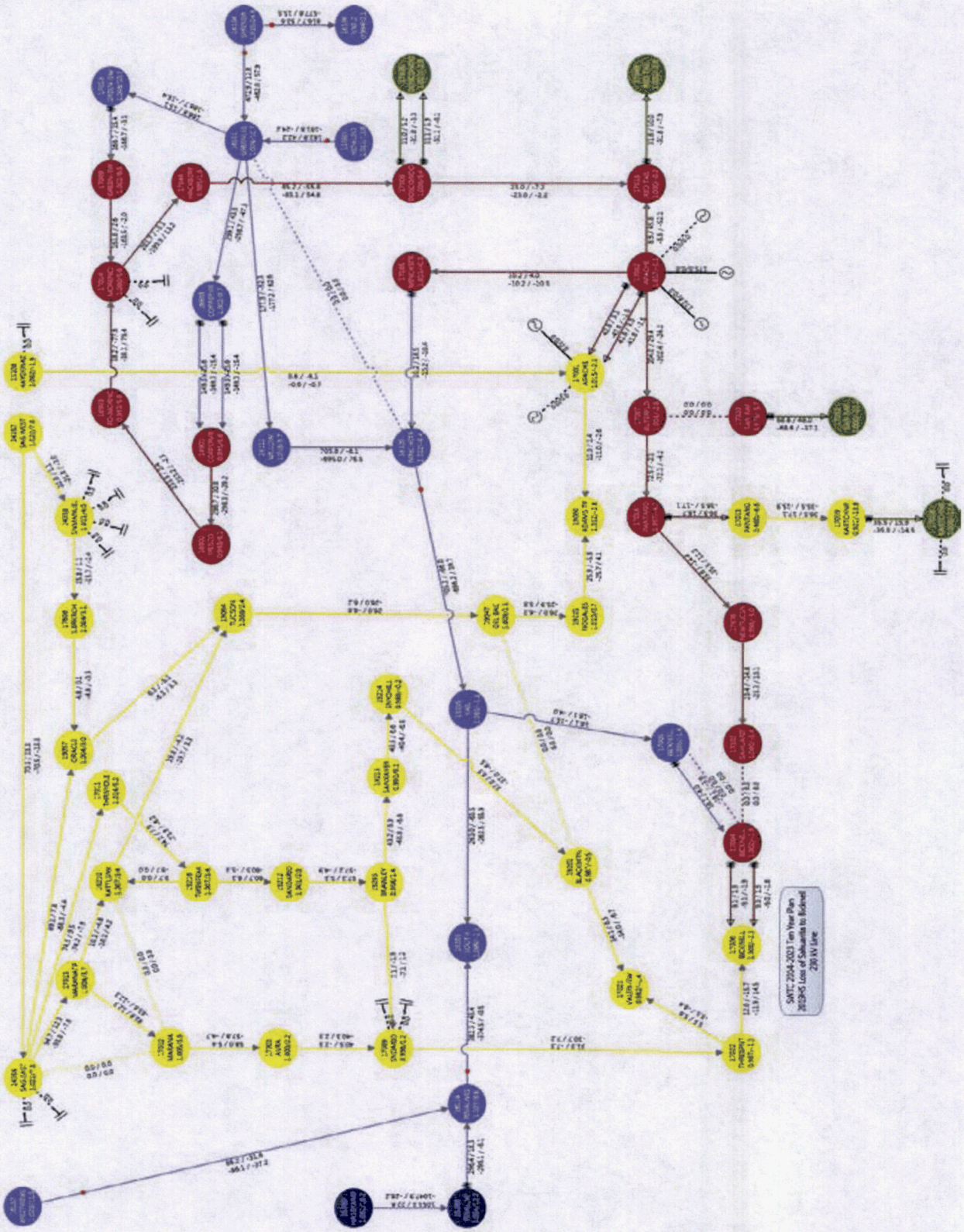
2019HS Southwest Transmission Cooperative Base System with Pantano to New Tucson 230 kV Line out of service



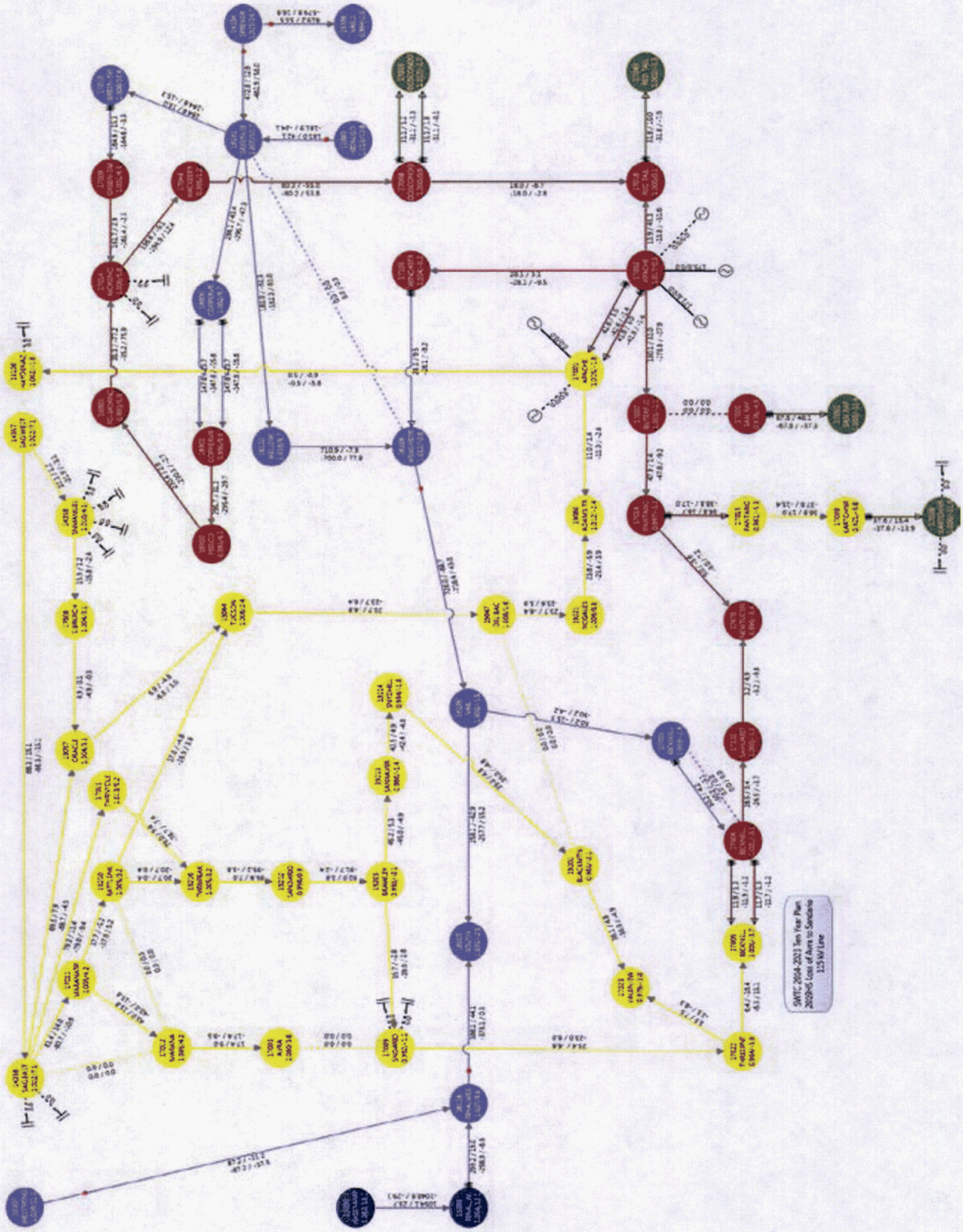
2019HS Southwest Transmission Cooperative Base System with Redtail to Dos Condados 230 kV Line out of service



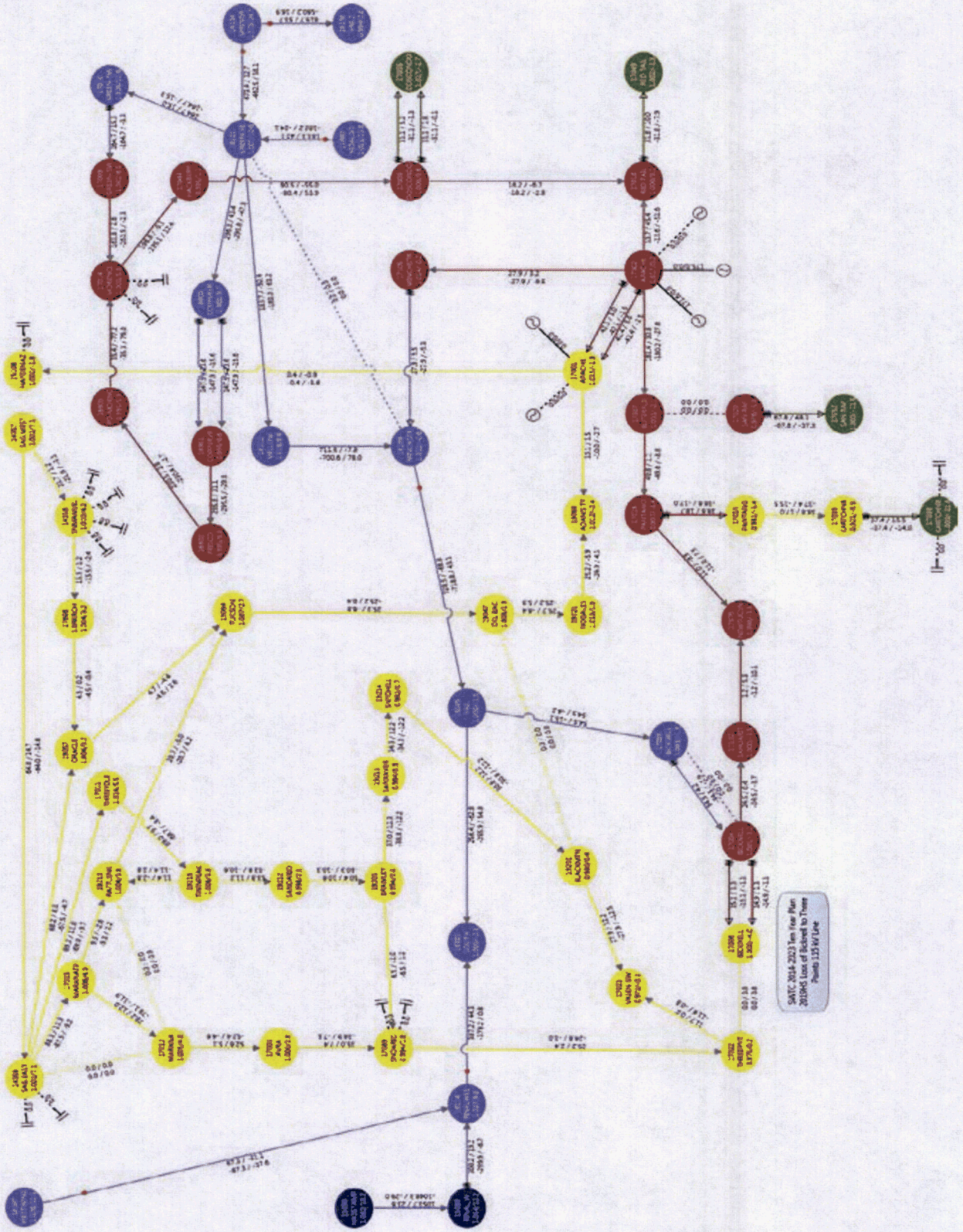
2019HS Southwest Transmission Cooperative Base System with Sahuarita to Bicknell 230 kV Line out of service



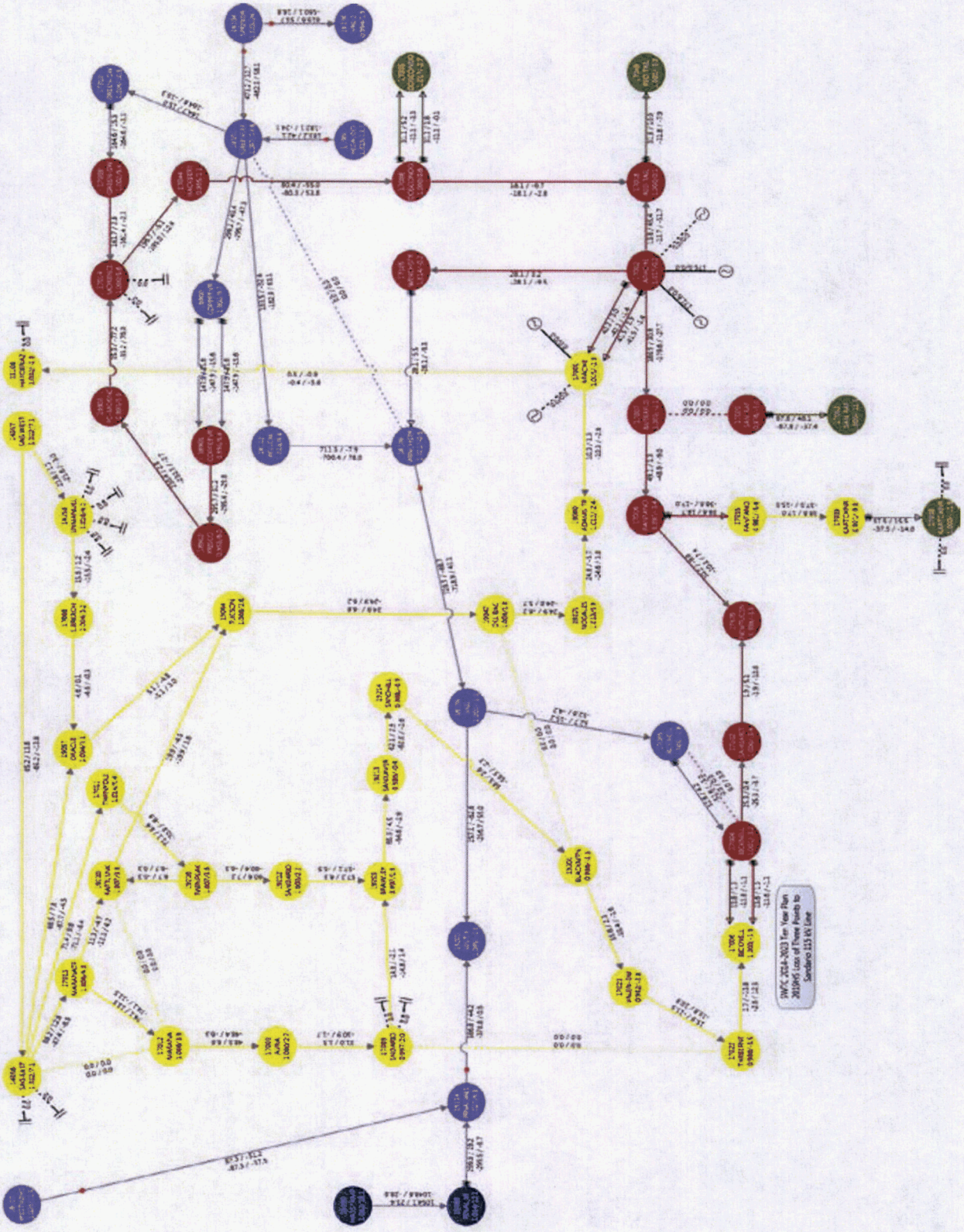
2019HS Southwest Transmission Cooperative Base System with Avra to Sandario 115 kV Line out of service



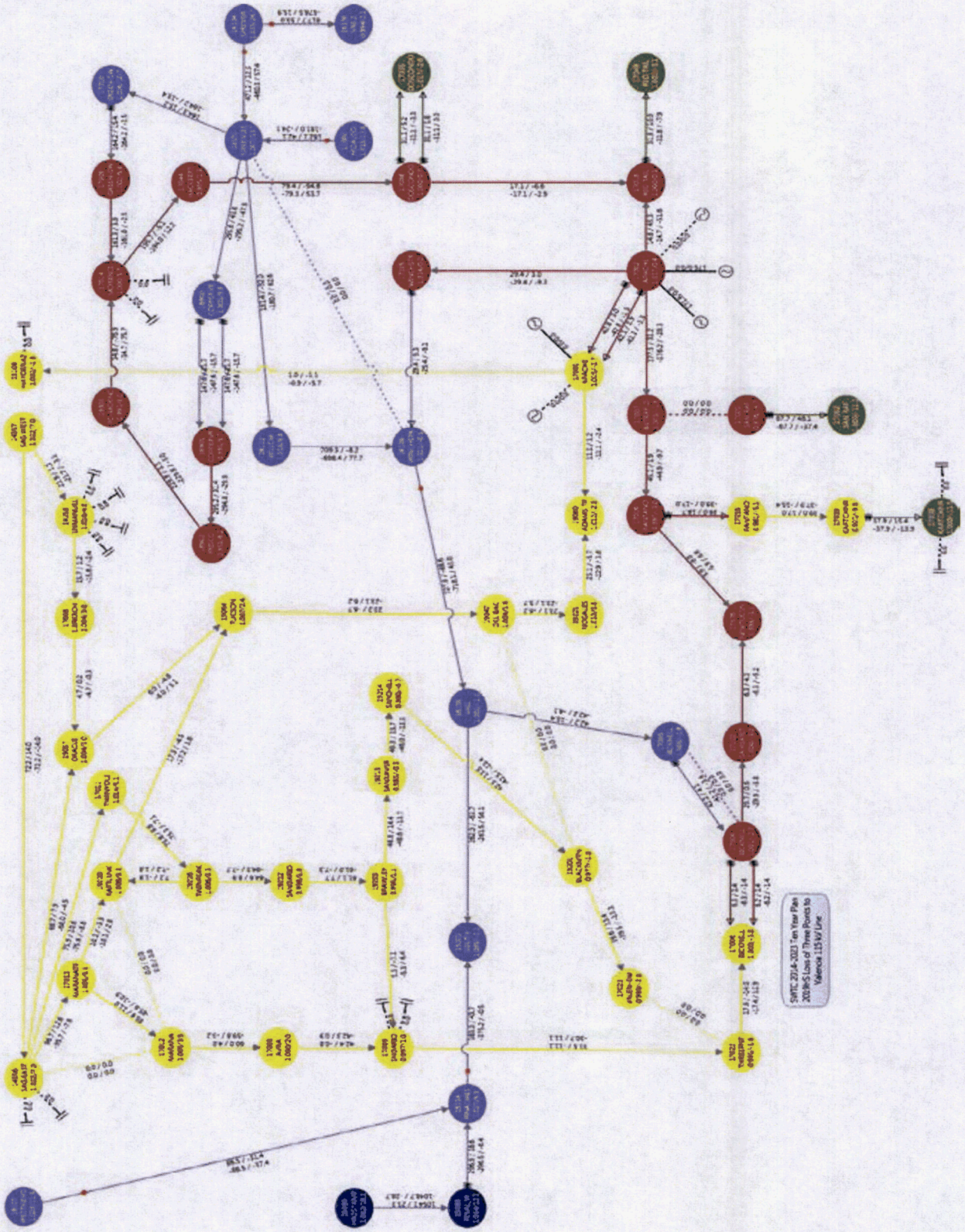
2019HS Southwest Transmission Cooperative Base System with Bicknell to Three Points 115 kV Line out of service



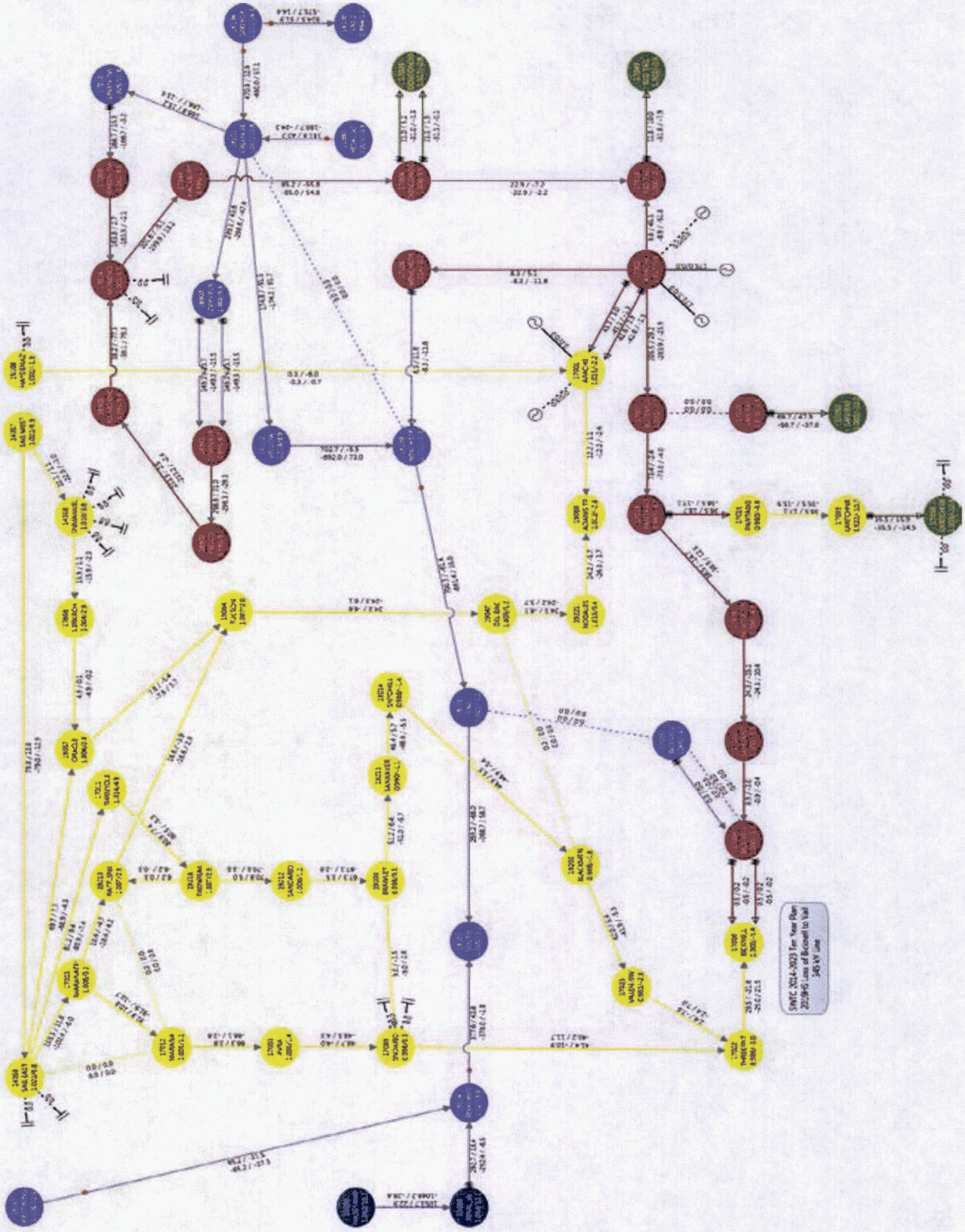
2019HS Southwest Transmission Cooperative Base System with Three Points to Sandario 115 kV Line out of service



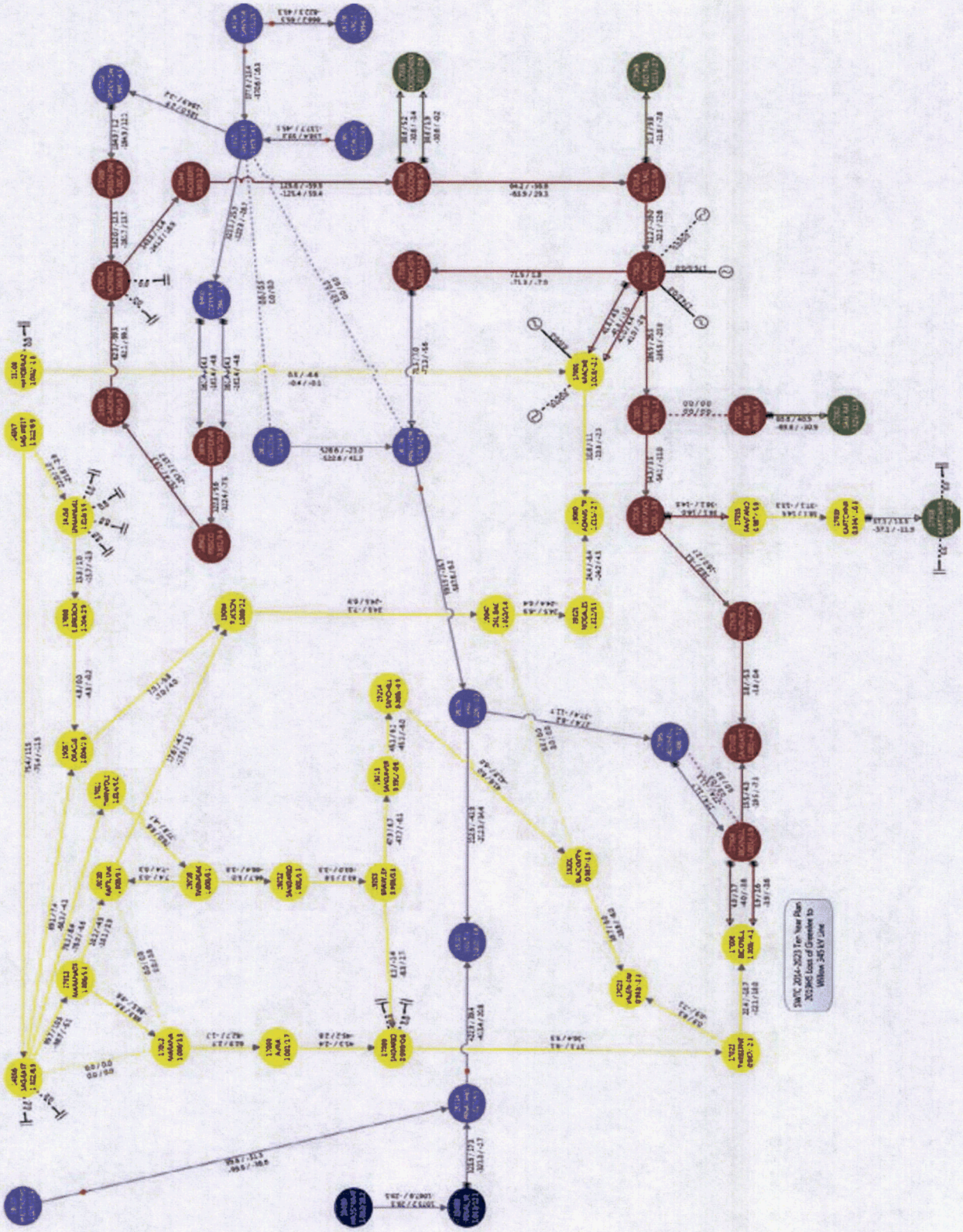
2019HS Southwest Transmission Cooperative Base System with Three Points to Valencia 115 kV Line out of service



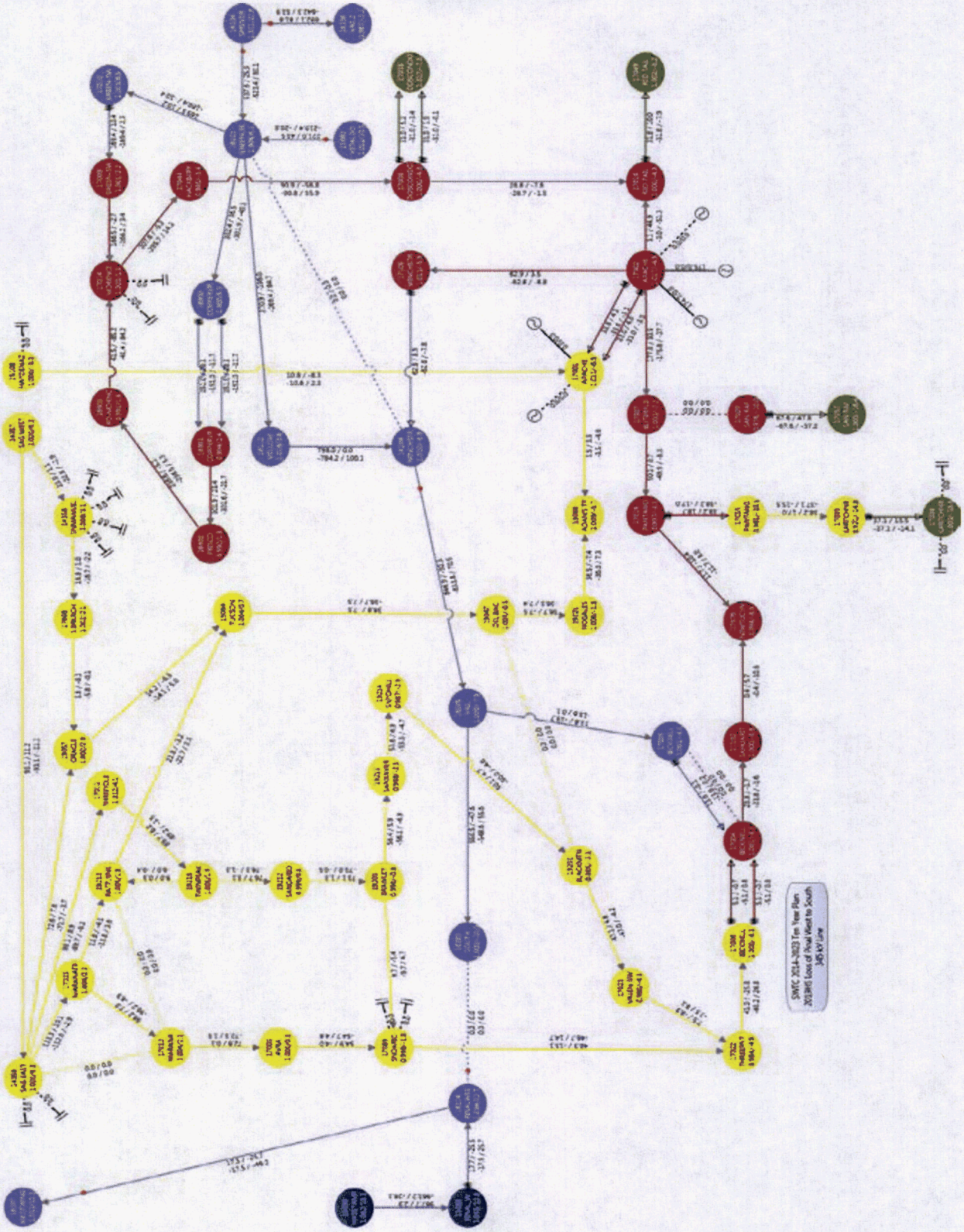
2019HS Southwest Transmission Cooperative Base System with Bicknell to Vail 345 kV Line out of service



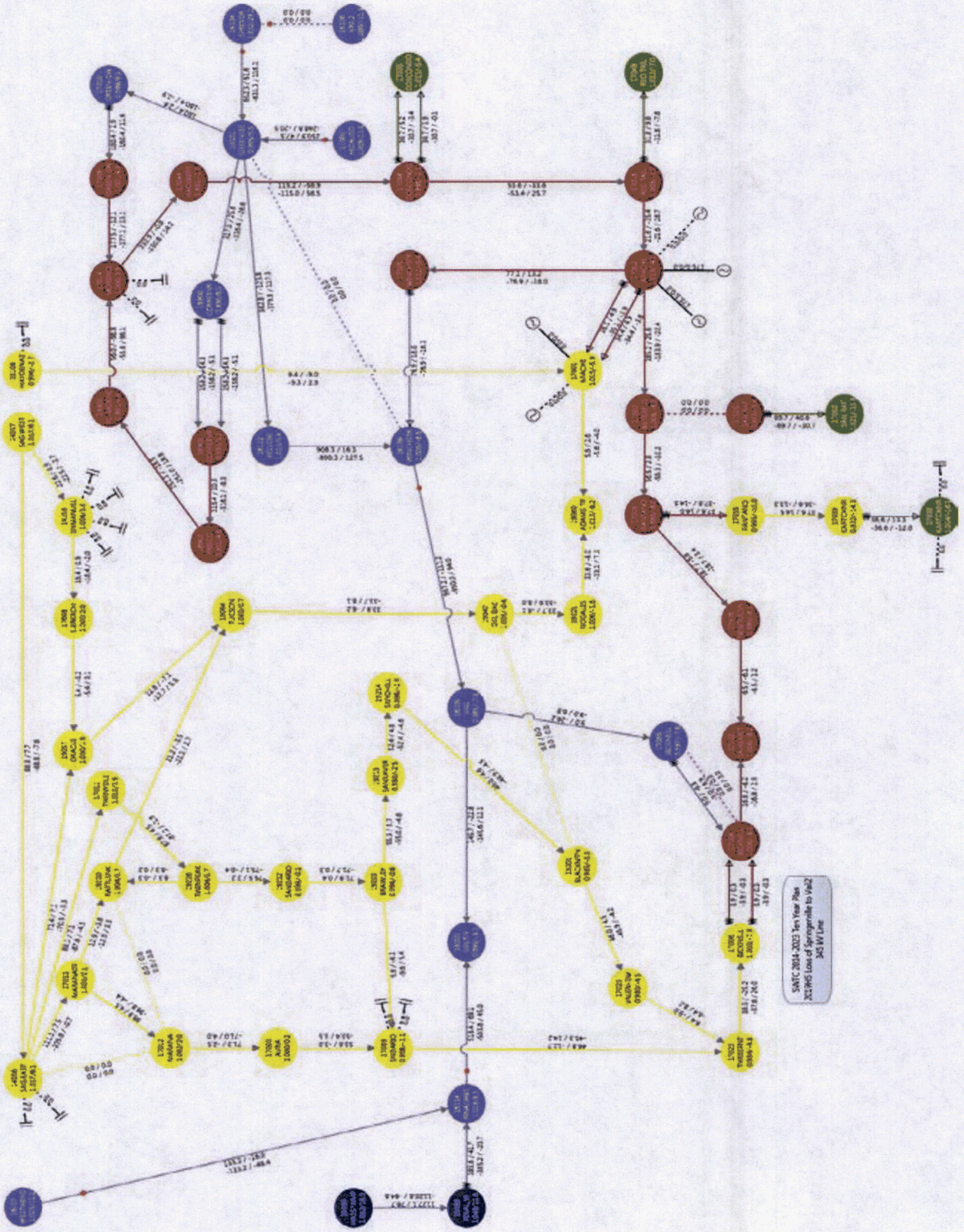
2019HS Southwest Transmission Cooperative Base System with Greenlee to Willow 345 kV Line out of service



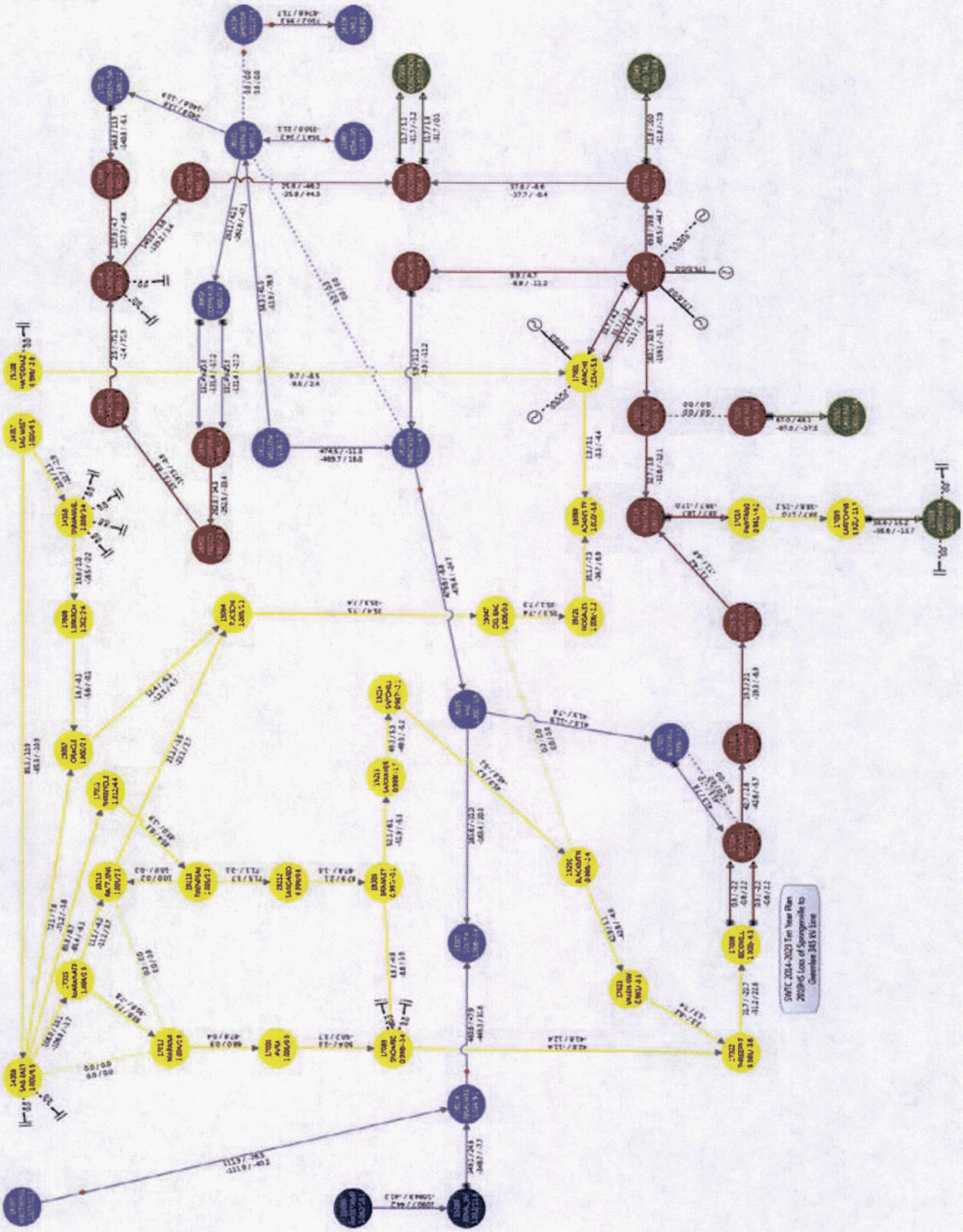
2019HS Southwest Transmission Cooperative Base System with Pinal West to South 345 kV Line out of service



2019HS Southwest Transmission Cooperative Base System with Springerville to Vail2 345 kV Line out of service



2019HS Southwest Transmission Cooperative Base System with Springerville to Greenlee 345 kV Line out of service



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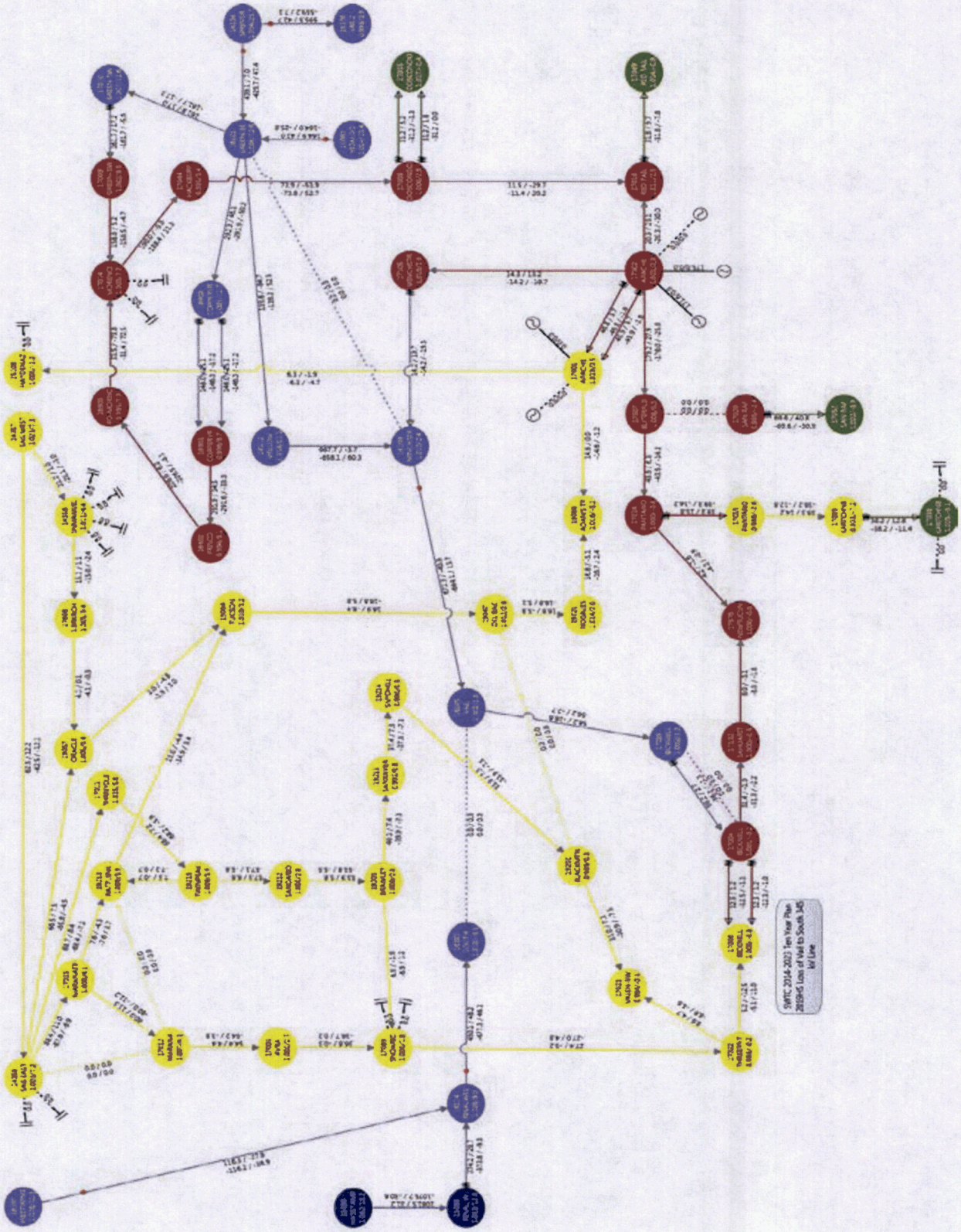
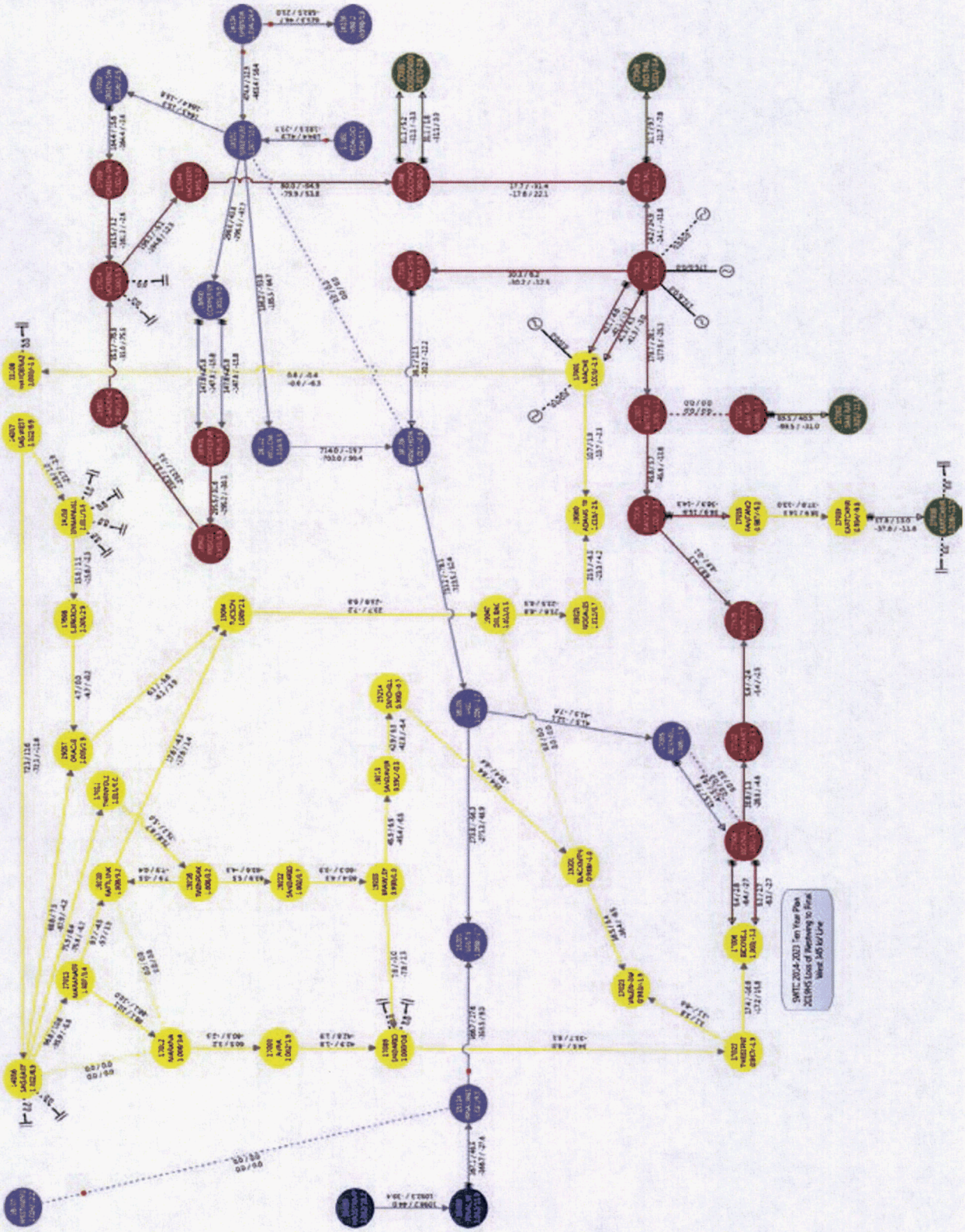
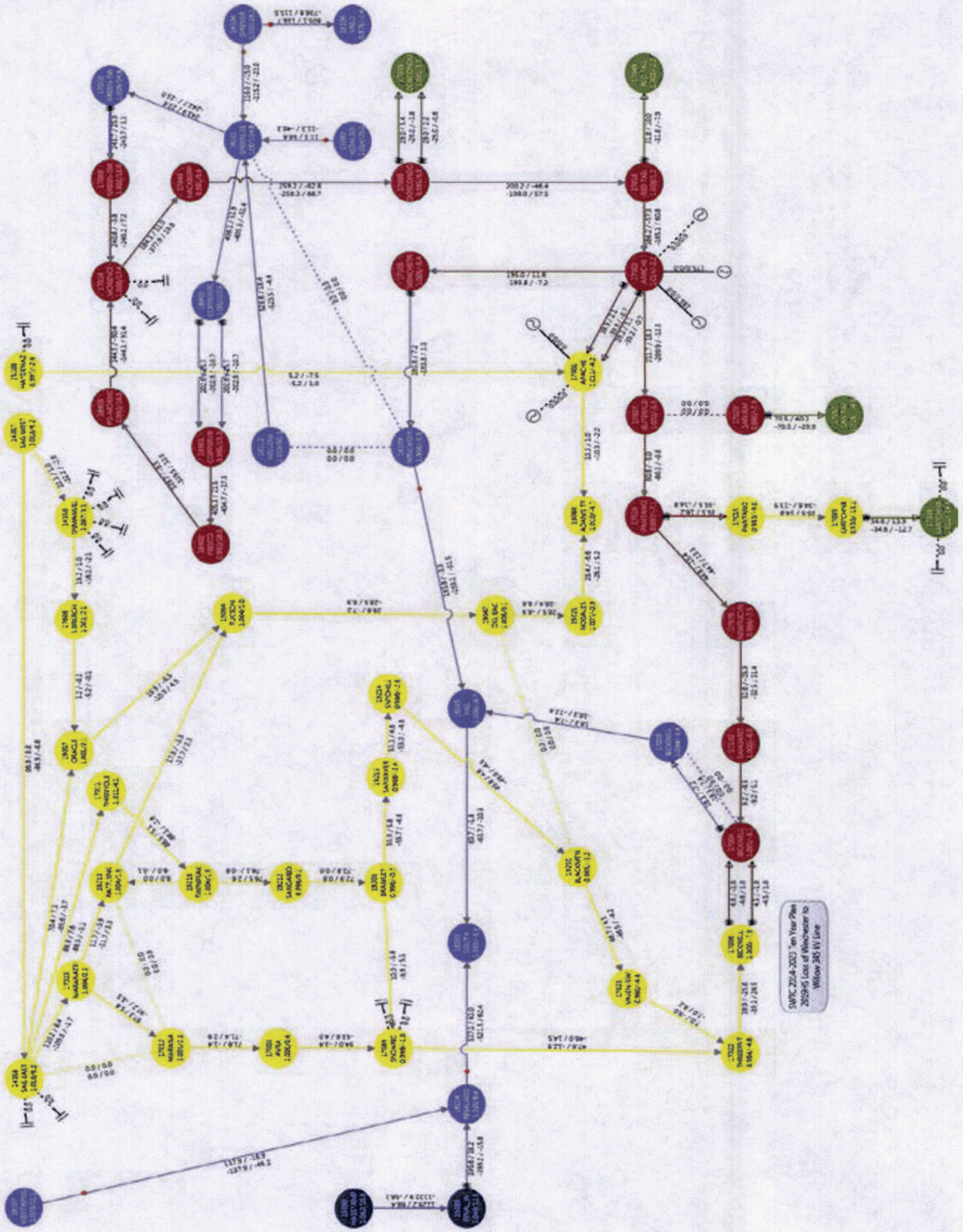


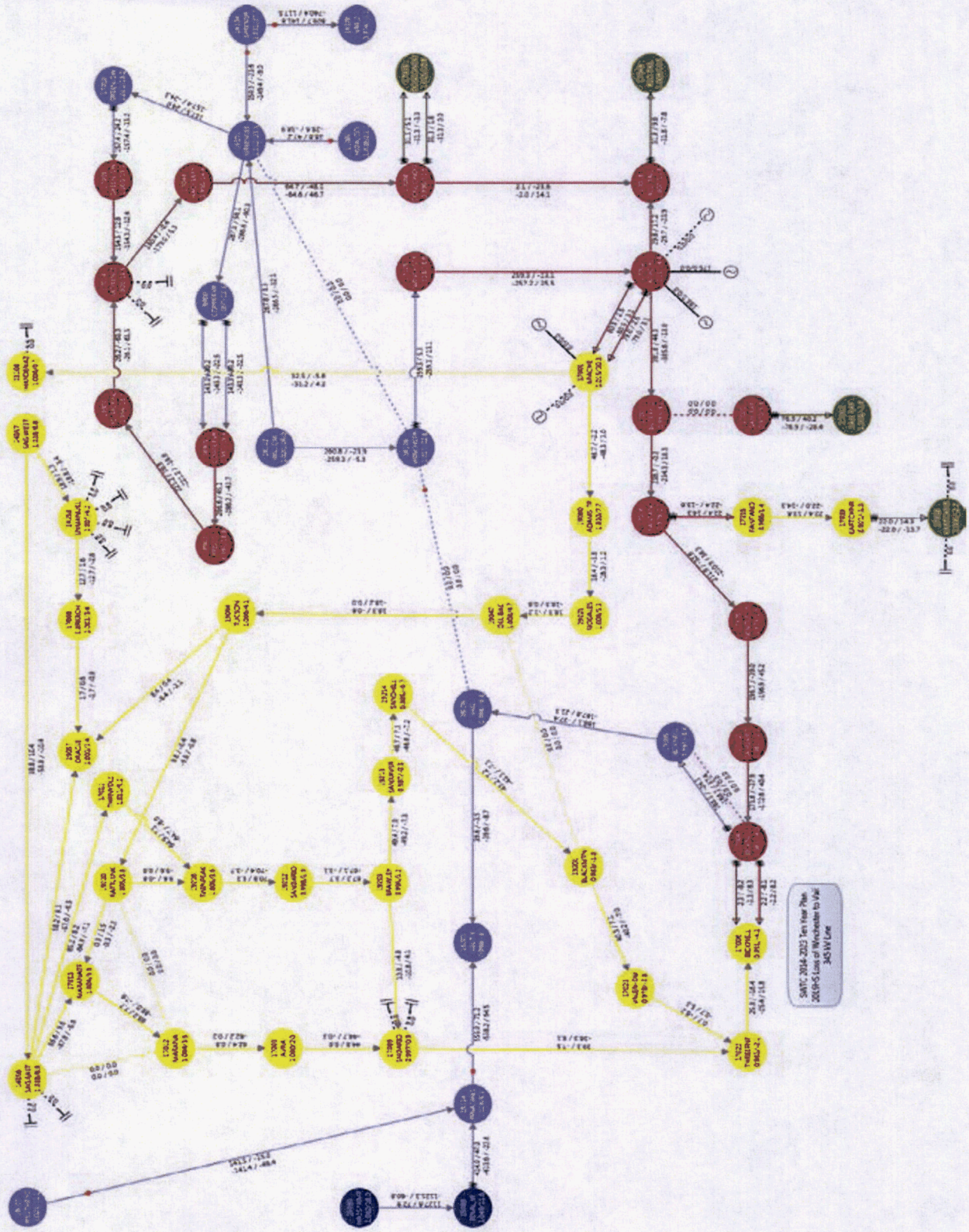
2019HS Southwest Transmission Cooperative Base System with Westwing to Pinal West 345 kV Line out of service



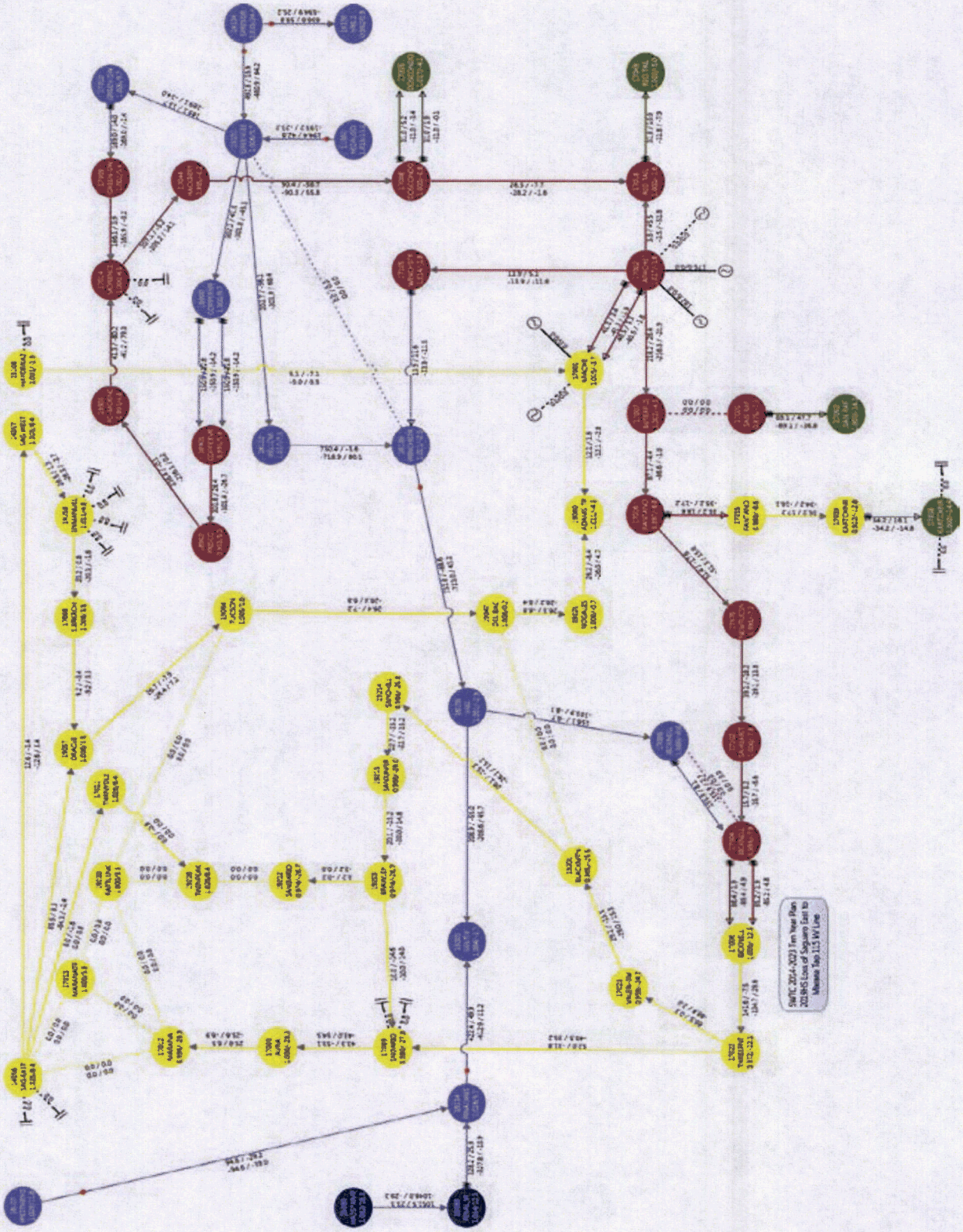
2019HS Southwest Transmission Cooperative Base System with Winchester to Willow 345 kV Line out of service



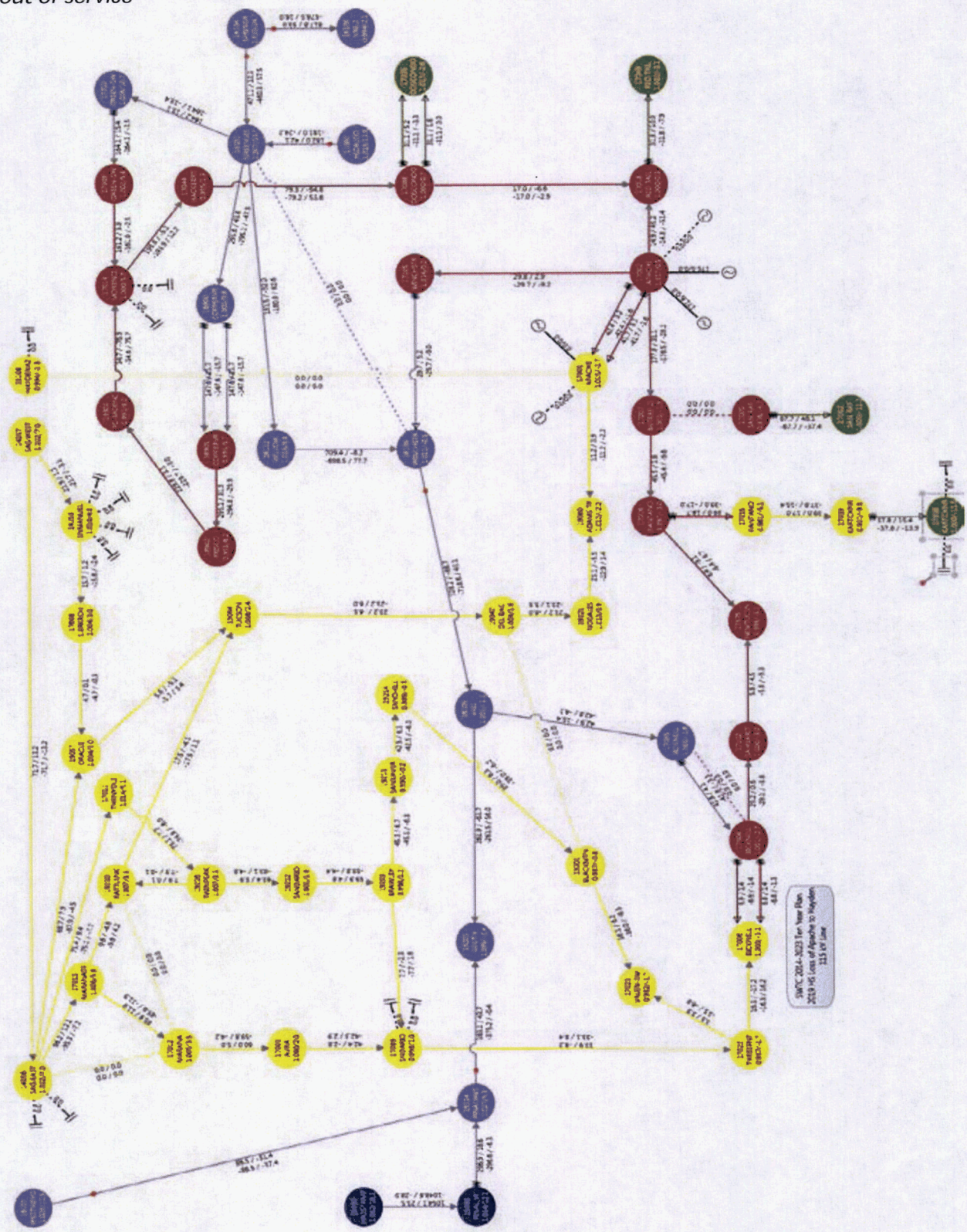
2019HS Southwest Transmission Cooperative Base System with Winchester to Vail 345 kV Line out of service



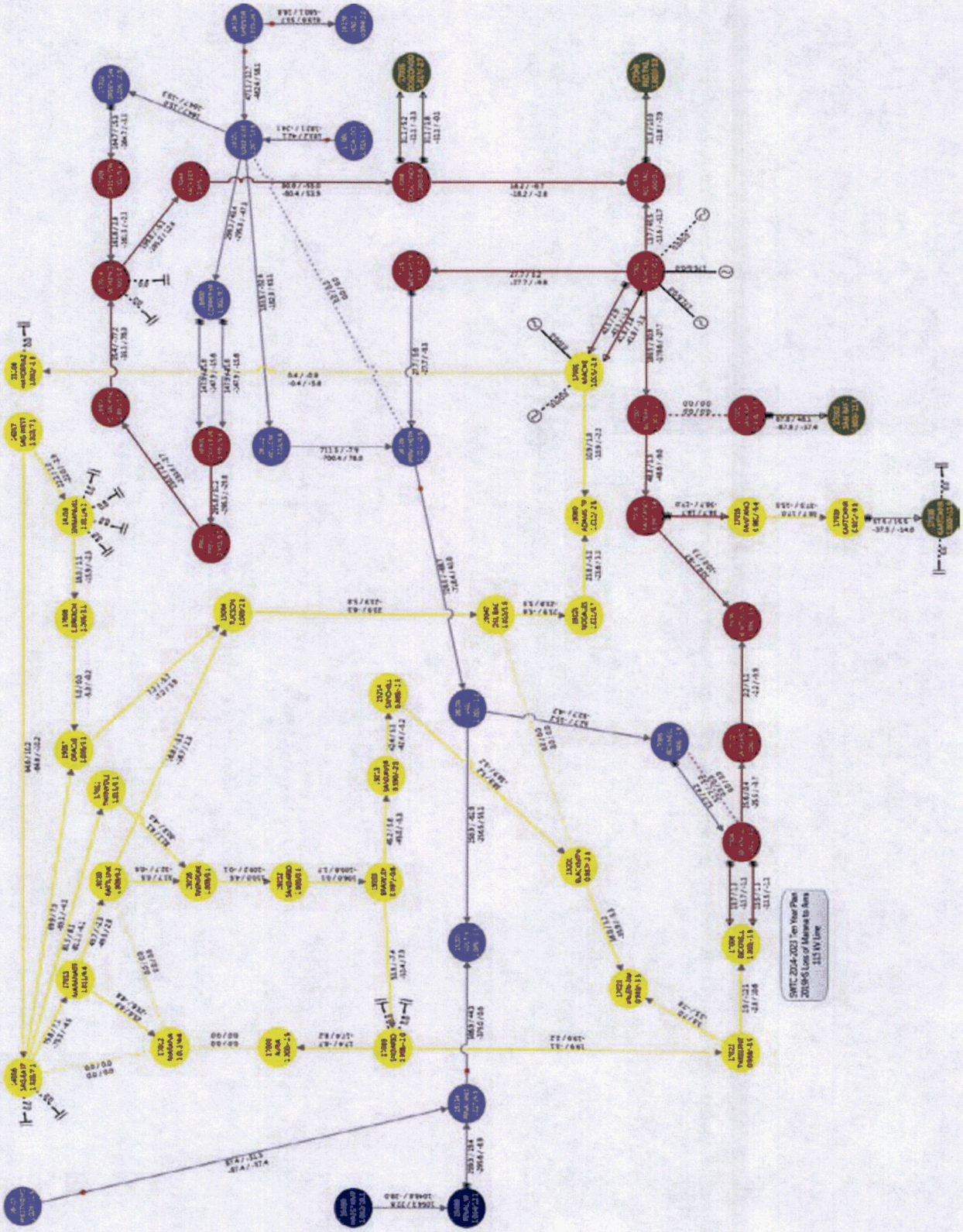
2019HS Southwest Transmission Cooperative Base System with Saguaro East to Marana 115 kV Line out of service



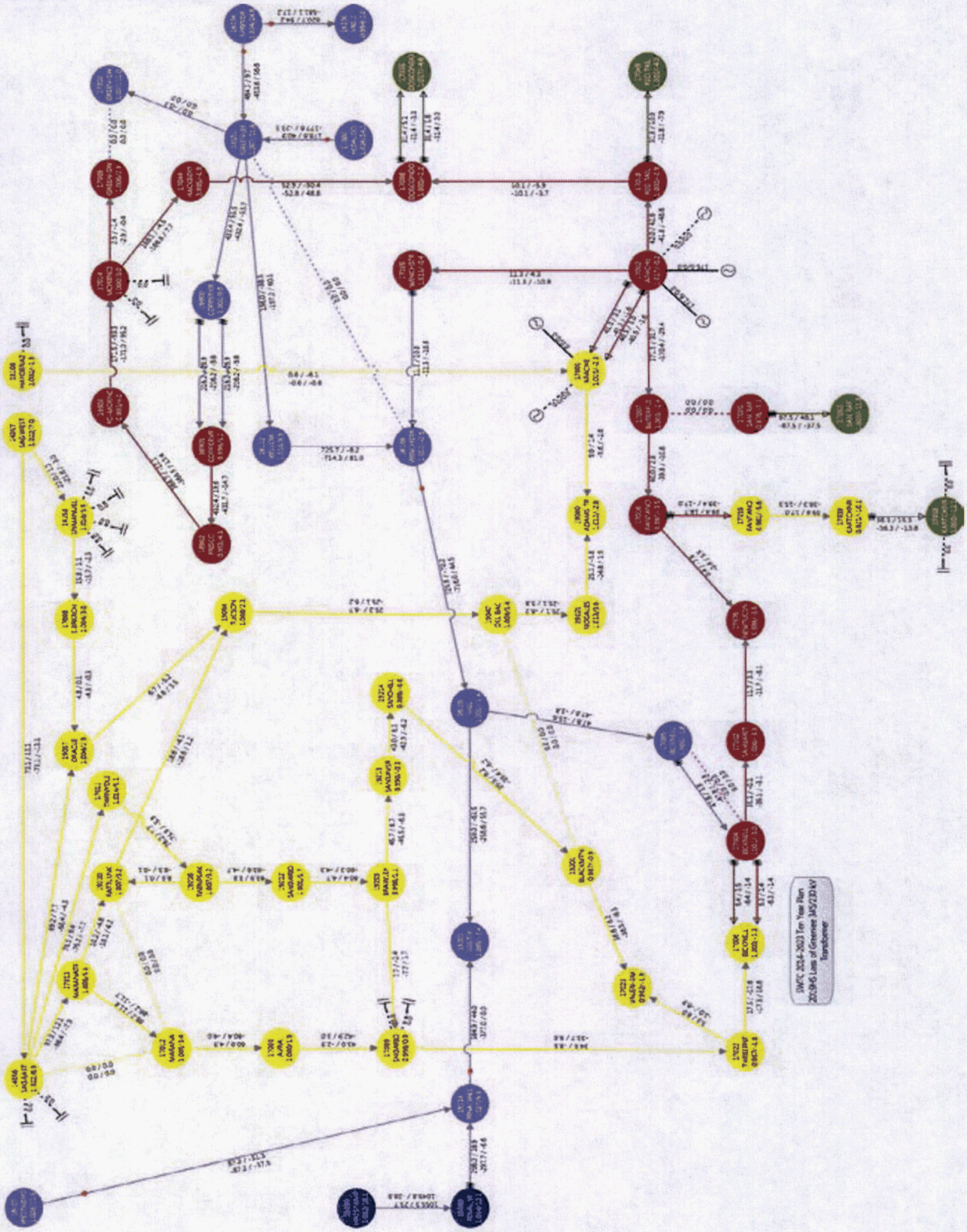
2019HS Southwest Transmission Cooperative Base System with Apache to Hayden 115 kV Line out of service



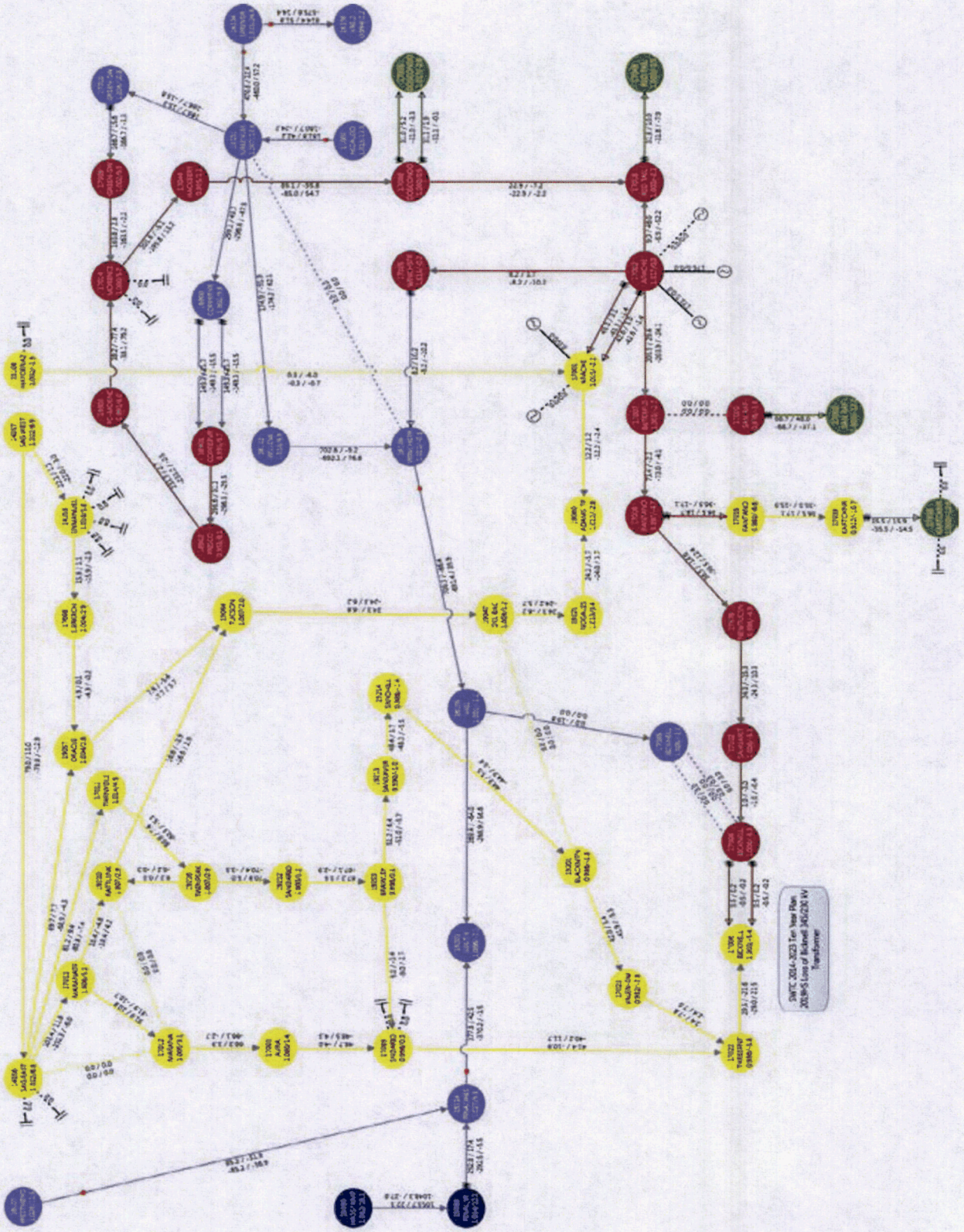
2019HS Southwest Transmission Cooperative Base System with Marana to Avra 115 kV Line out of service



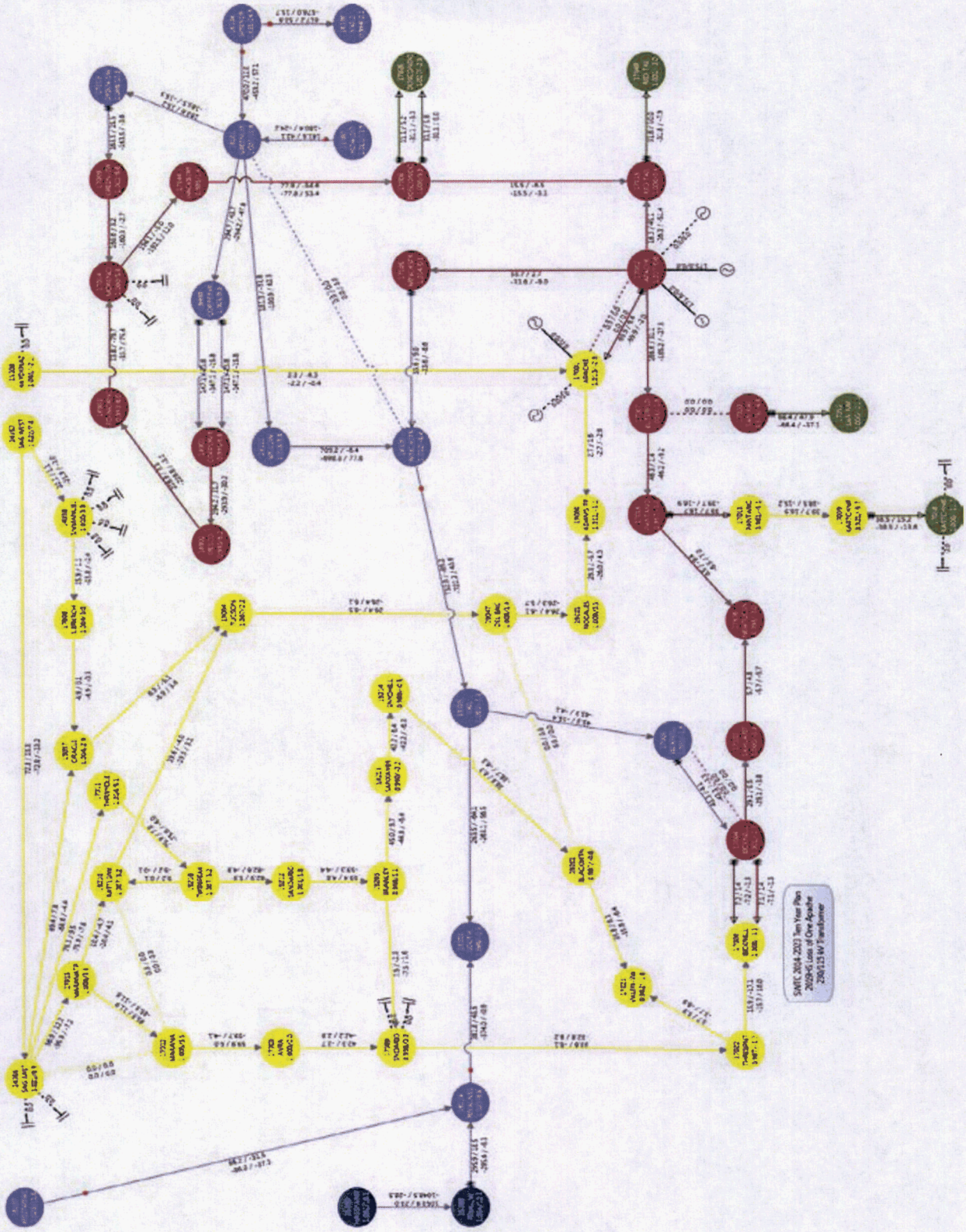
2019HS Southwest Transmission Cooperative Base System with Green-SW 345/230 kV Transformer out of service



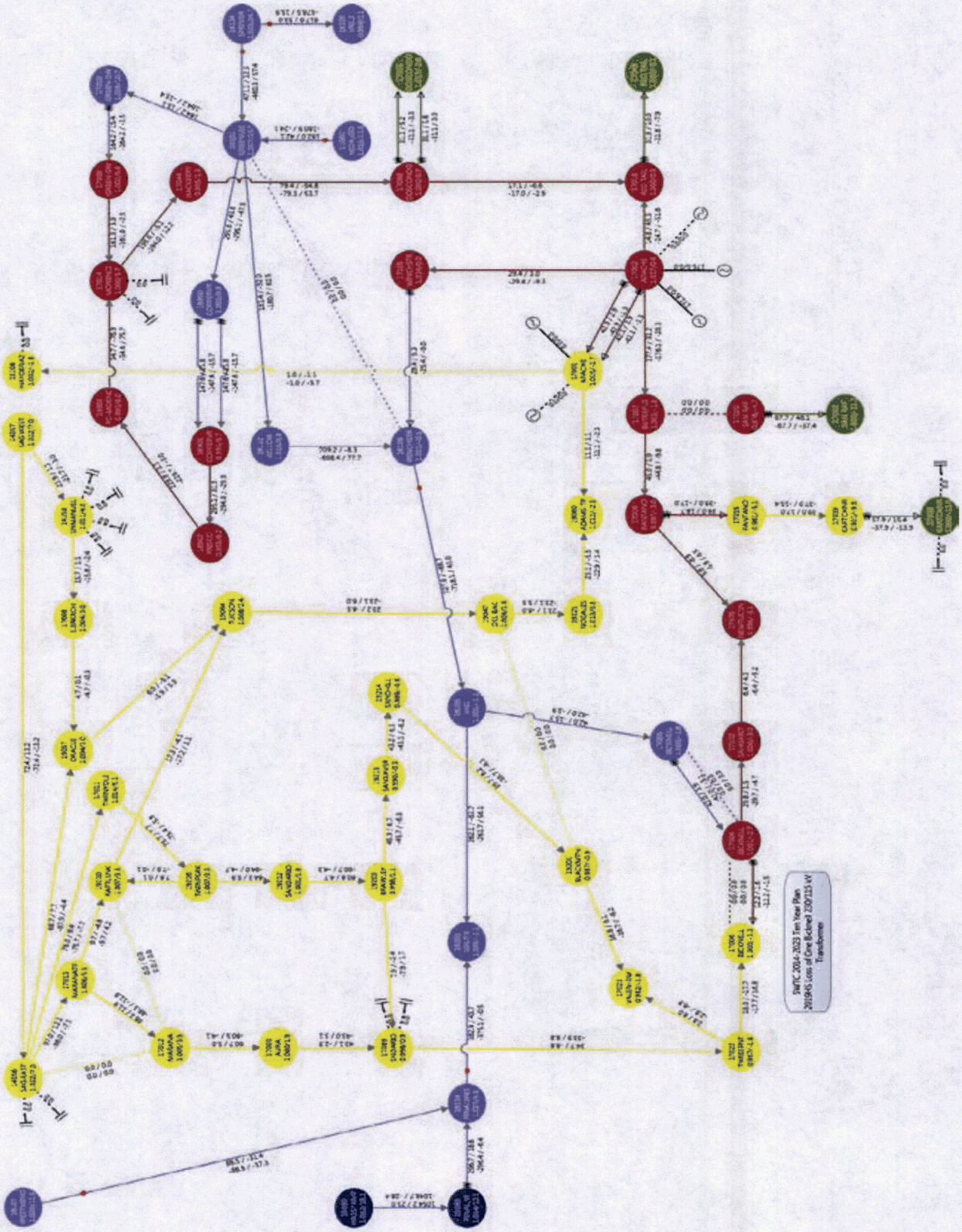
2019HS Southwest Transmission Cooperative Base System with Bicknell 345/230 kV Transformer out of service



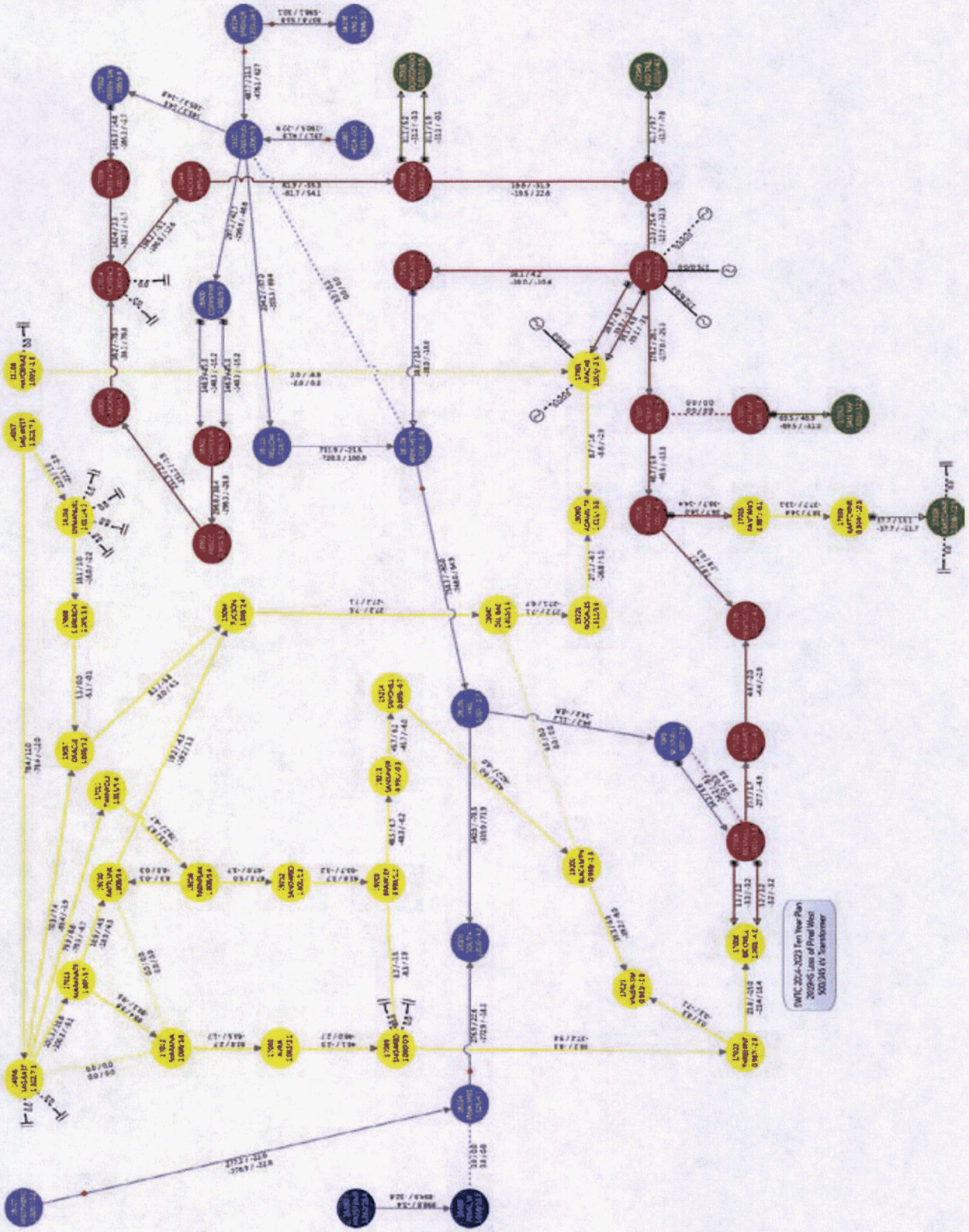
2019HS Southwest Transmission Cooperative Base System with one Apache 230/115 kV Transformer out of service



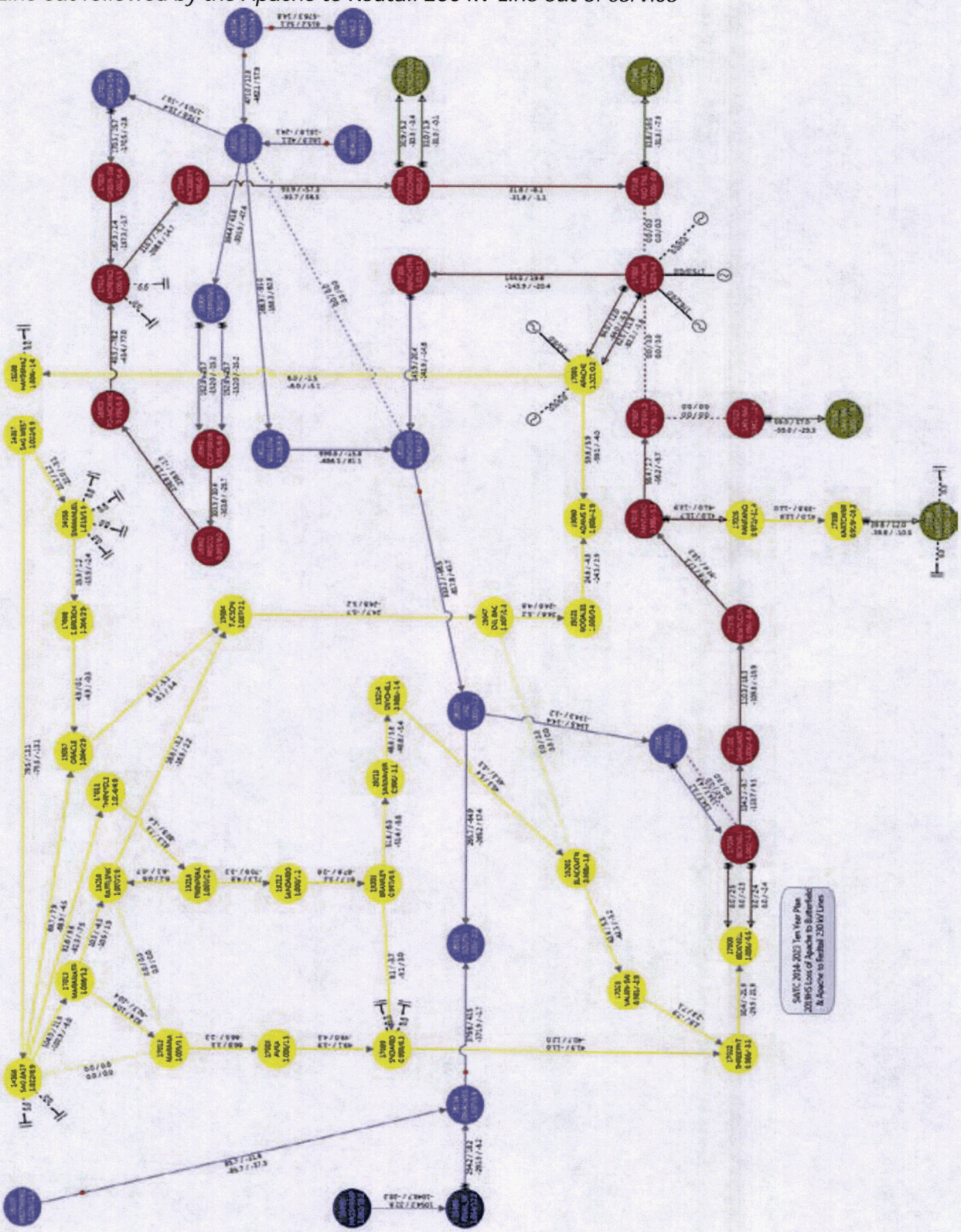
2019HS Southwest Transmission Cooperative Base System with one Bicknell 230/115 kV Transformer out of service



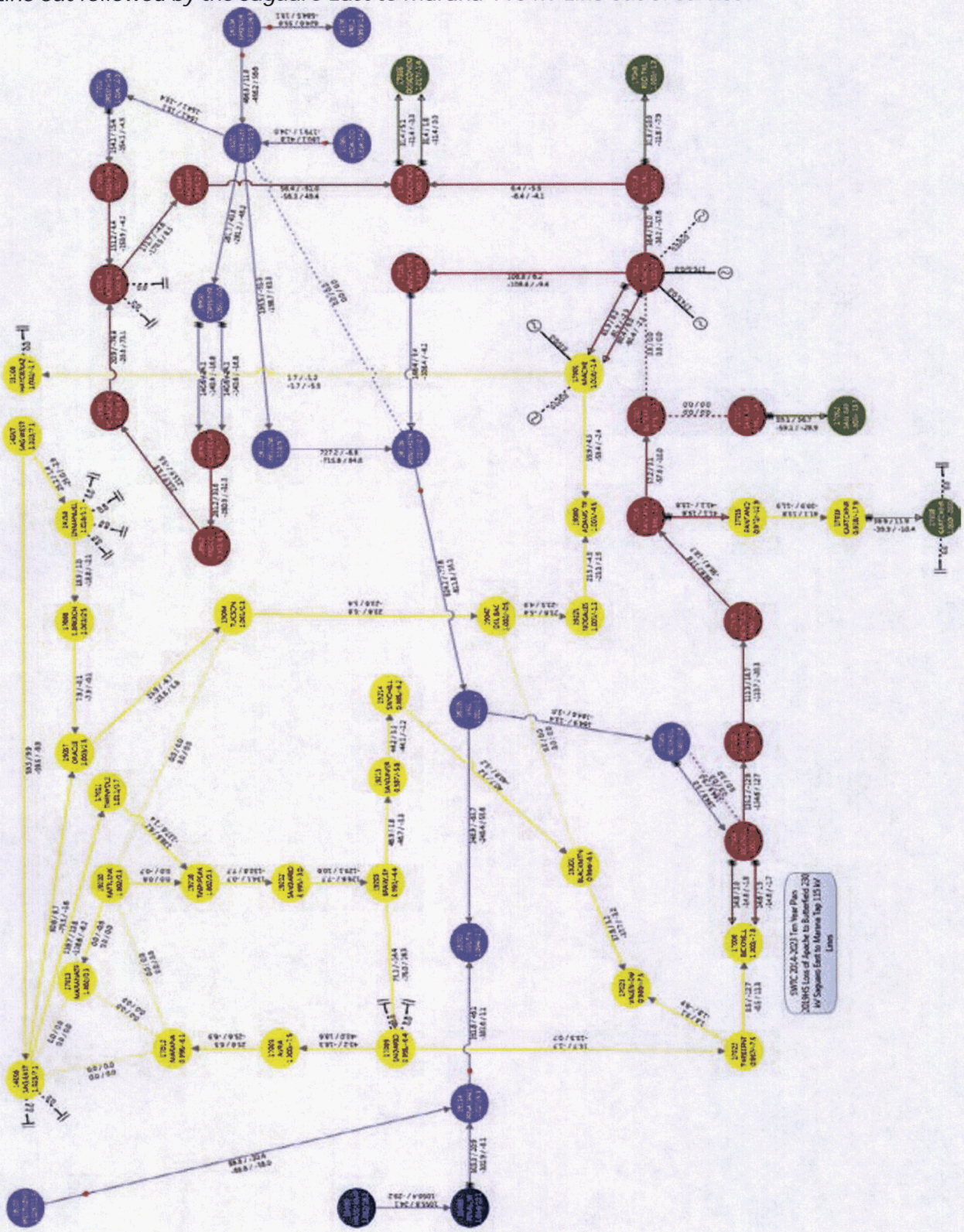
2019HS Southwest Transmission Cooperative Base System with Pinal West 500/345 kV Transformer out of service



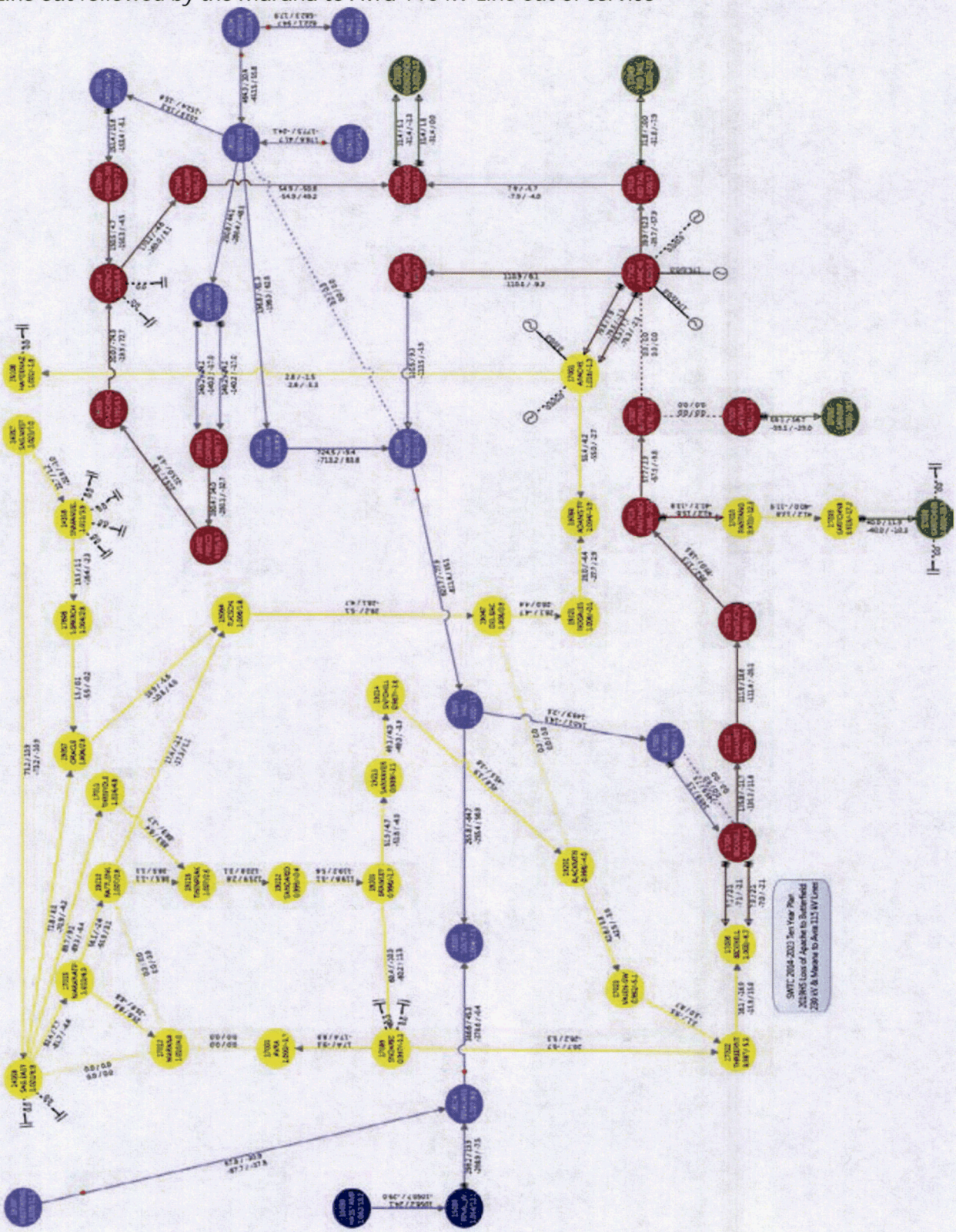
2019HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Apache to Redtail 230 kV Line out of service



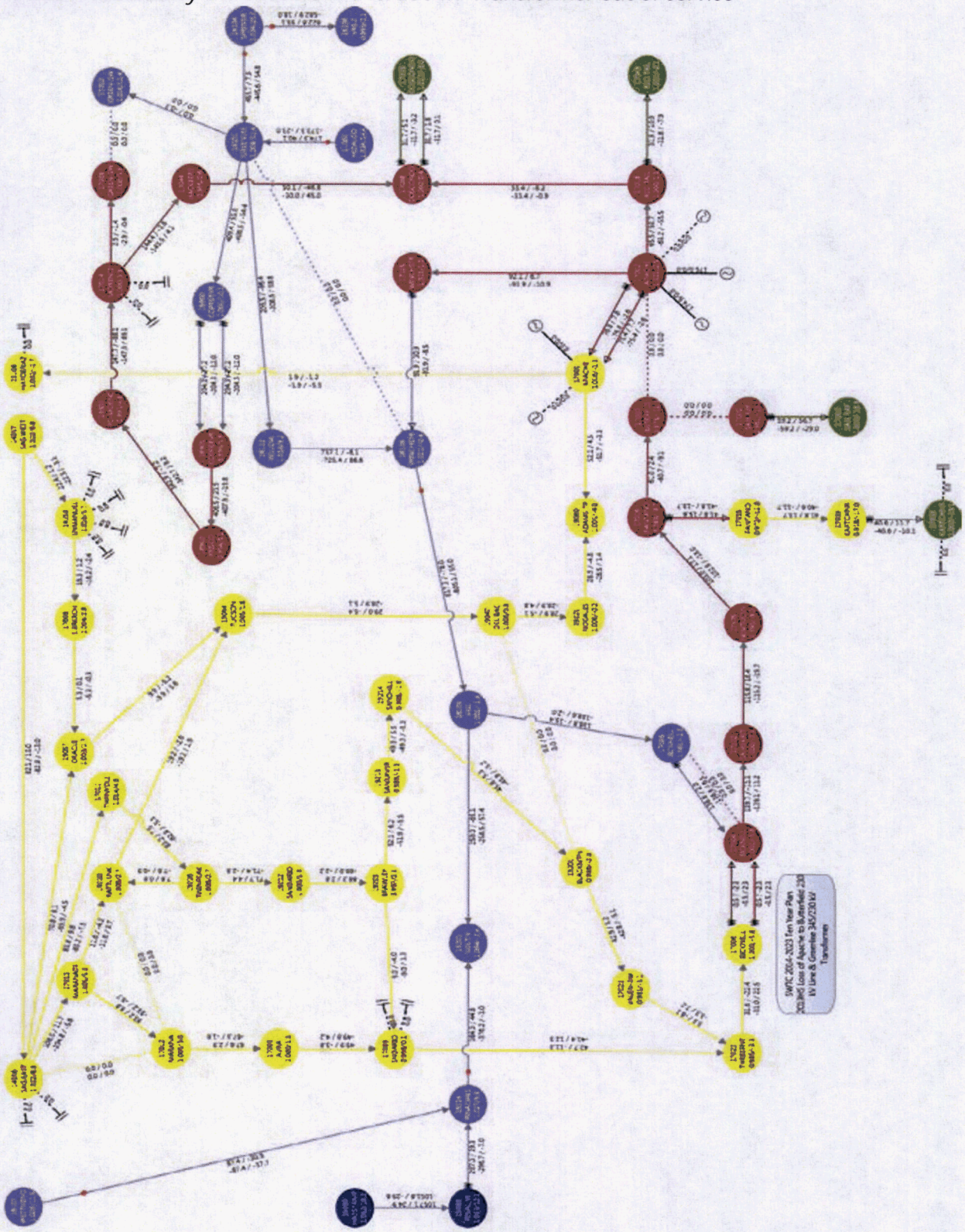
2019HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Saguaro East to Marana 115 kV Line out of service



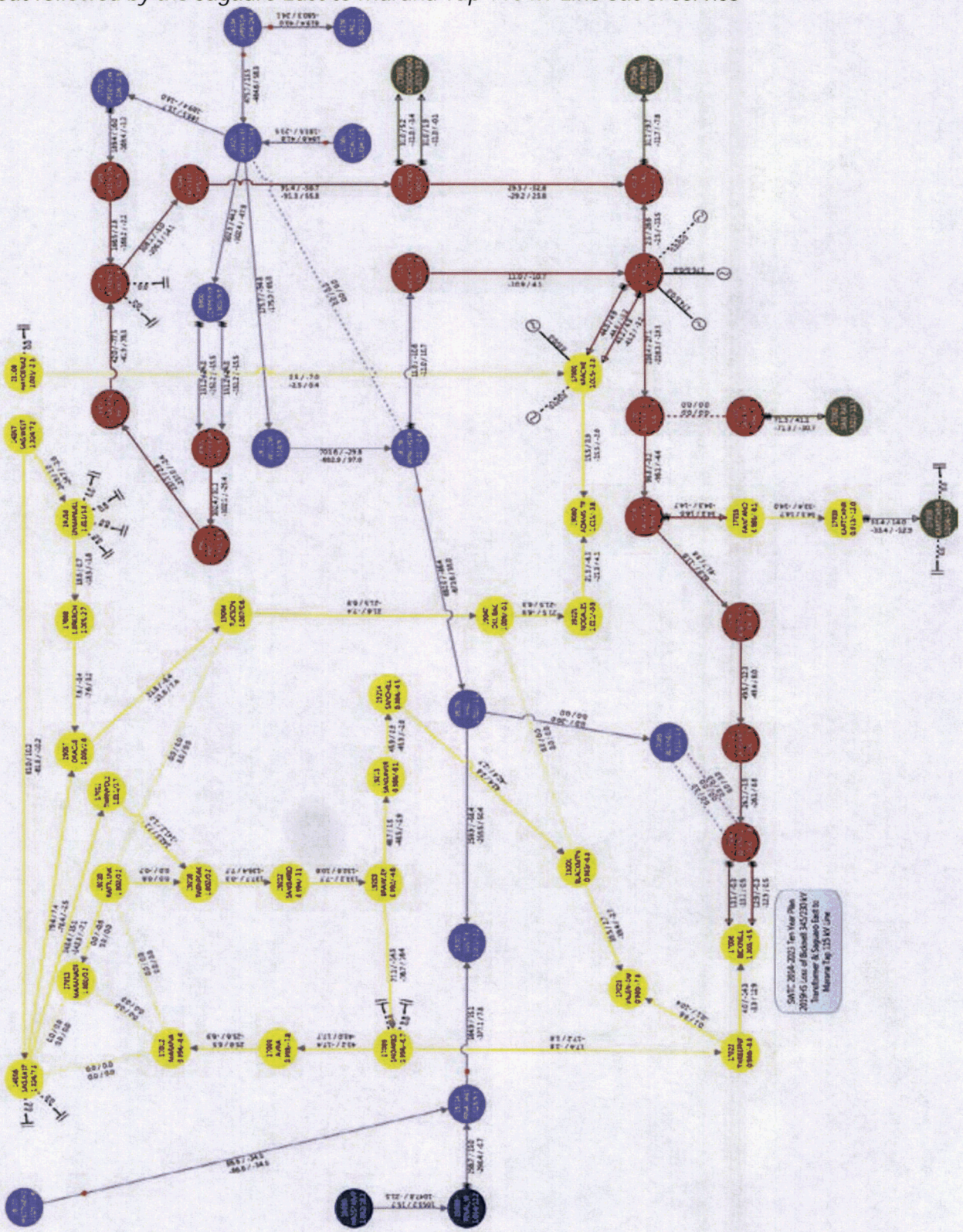
2019HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Marana to Avra 115 kV Line out of service



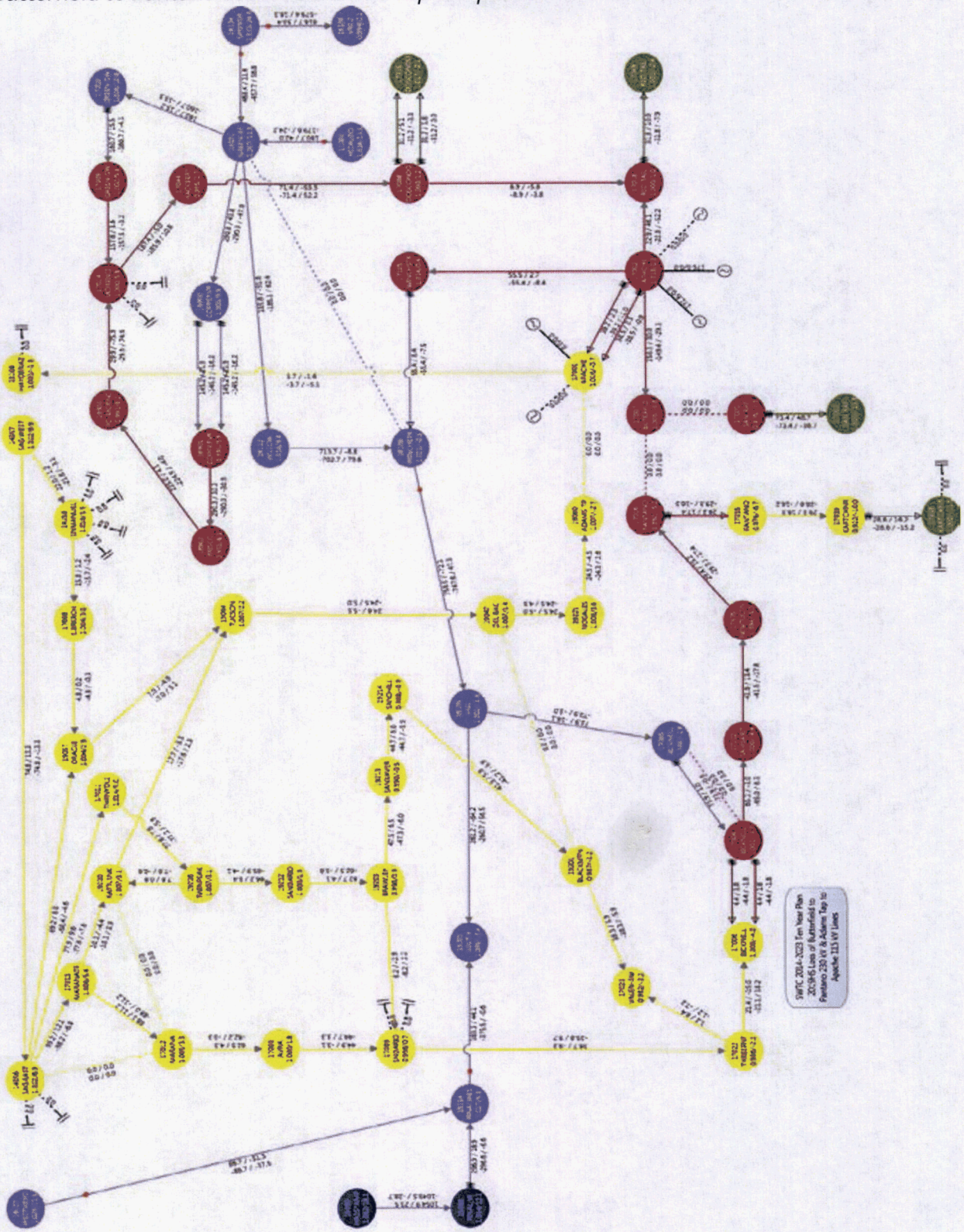
2019HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Green-SW 345/230 kV Transformer out of service



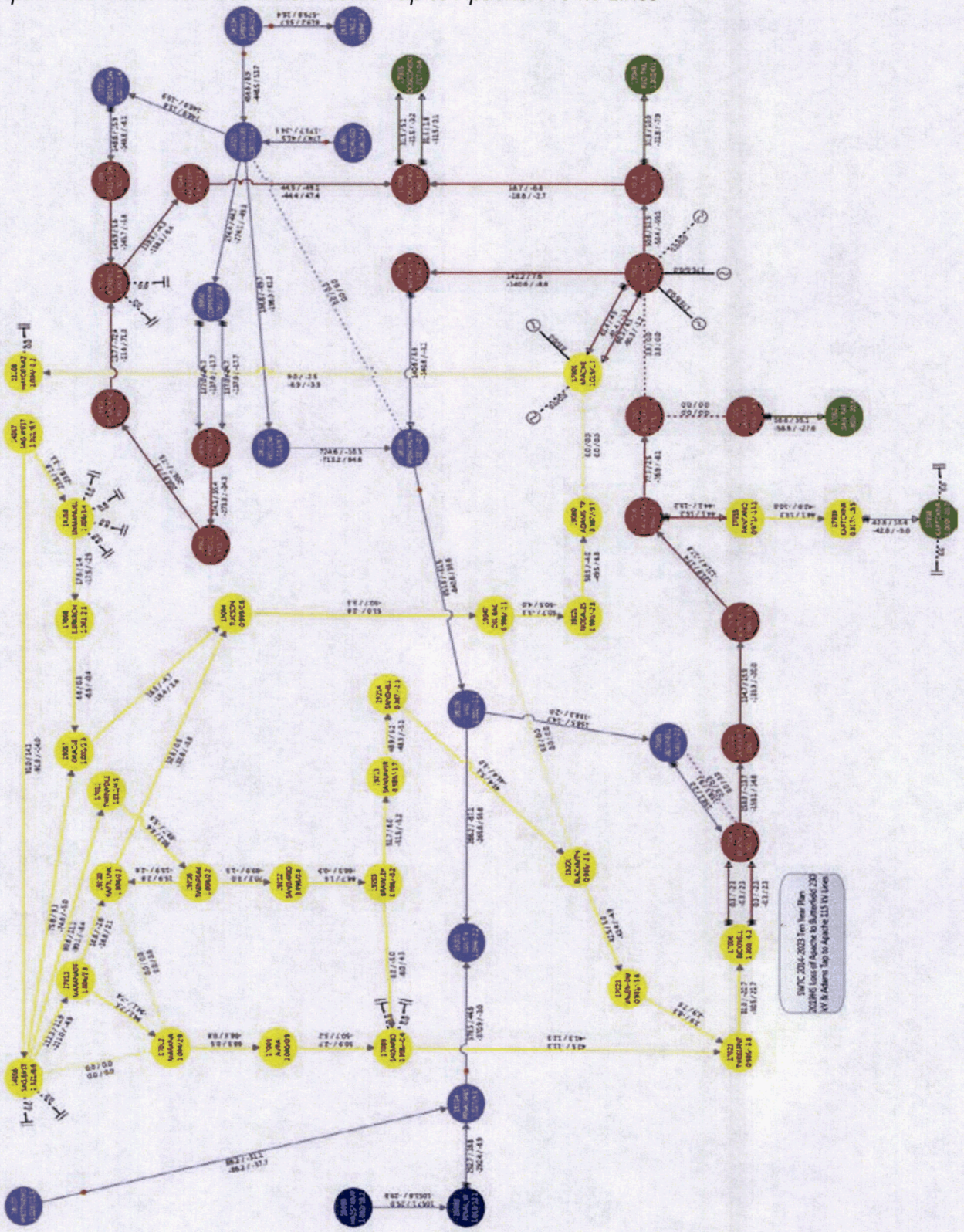
2019HS Southwest Transmission Cooperative Base System with Bicknell 345/230 kV Transformer out followed by the Saguaro East to Marana Tap 115 kV Line out of service



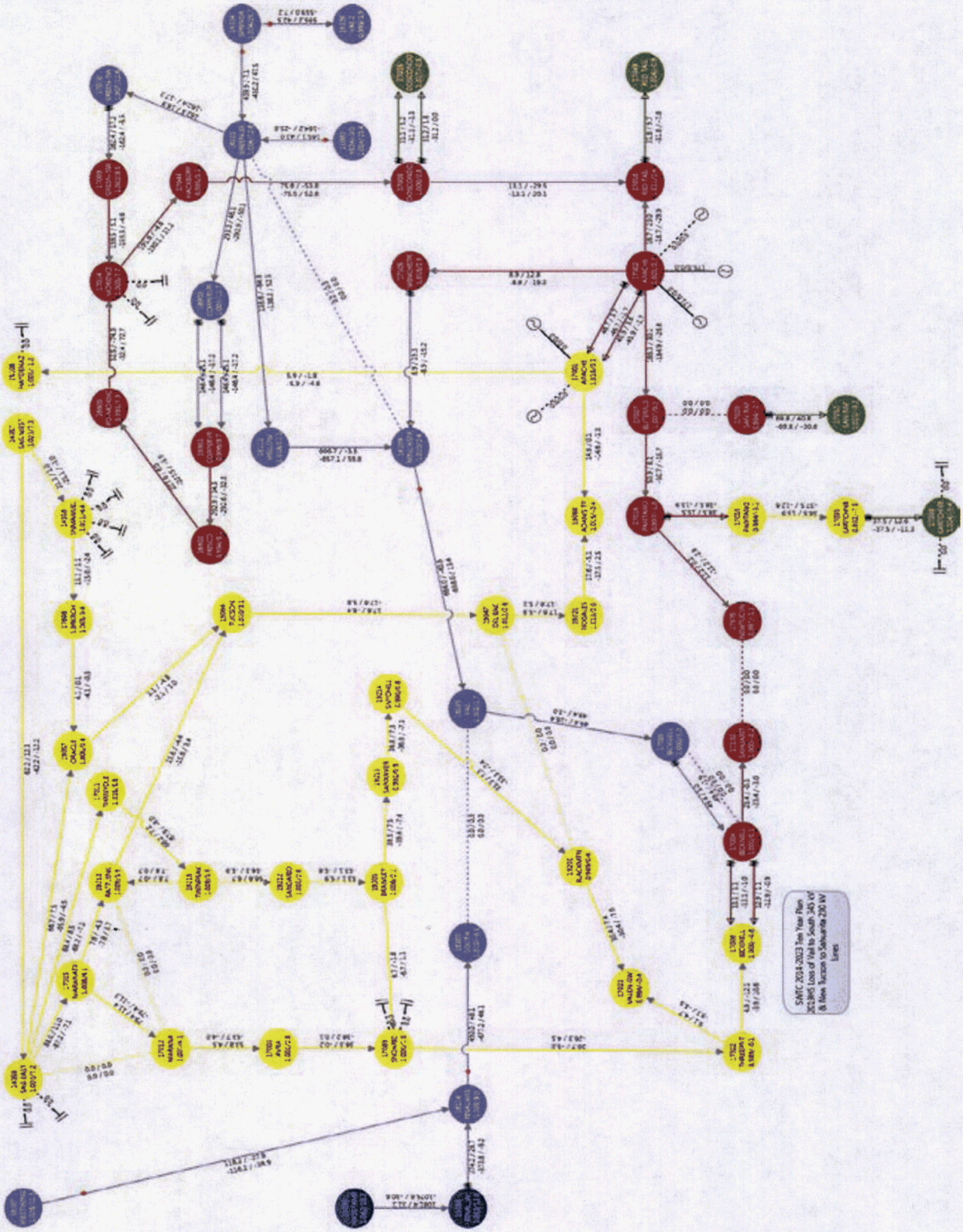
2019HS Southwest Transmission Cooperative Base System with Common Corridor outage of Butterfield to Pantano 230 kV & Adams Tap to Apache 115 kV Lines



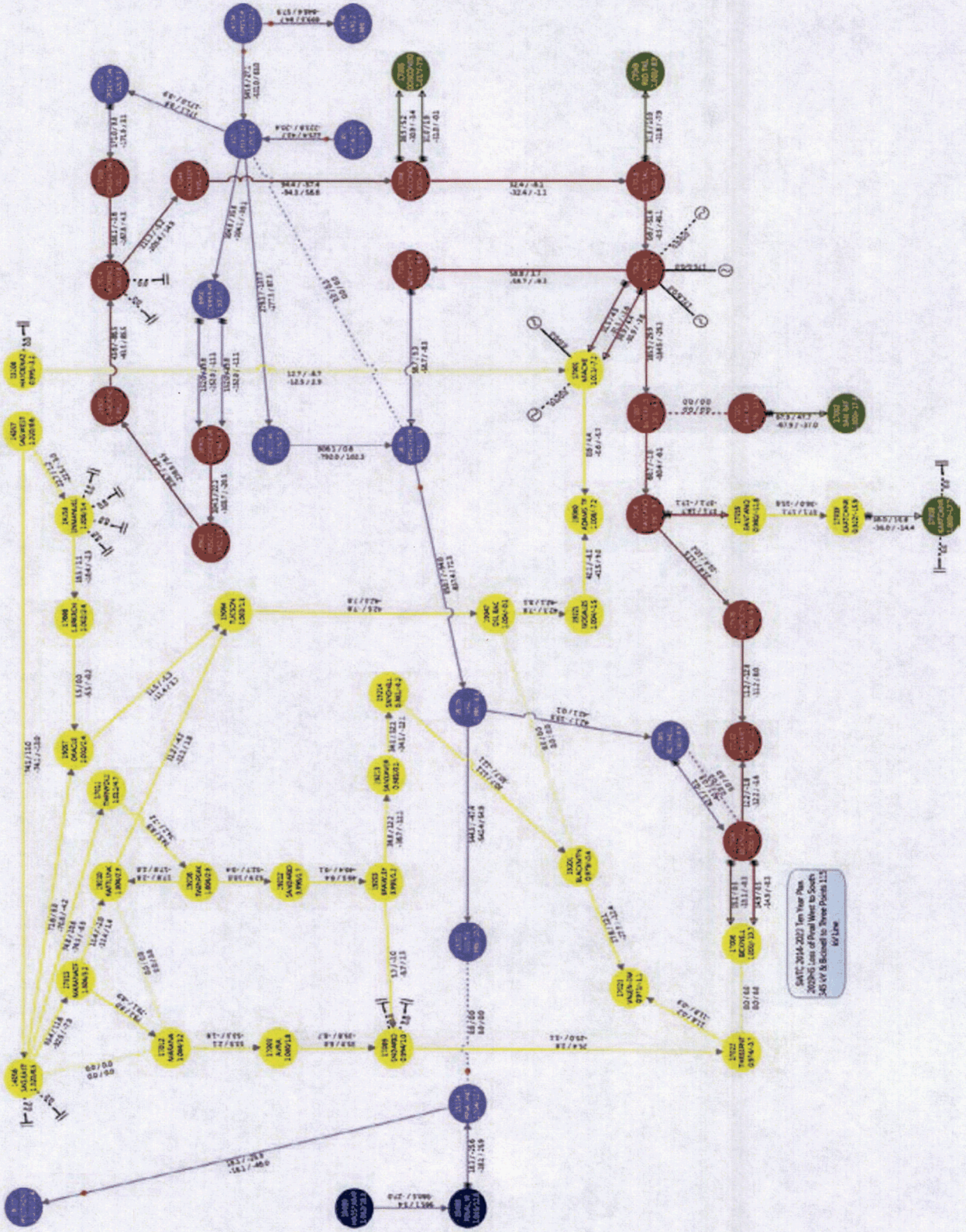
2019HS Southwest Transmission Cooperative Base System with Common Corridor outage of Apache to Butterfield 230 kV & Adams Tap to Apache 115 kV Lines



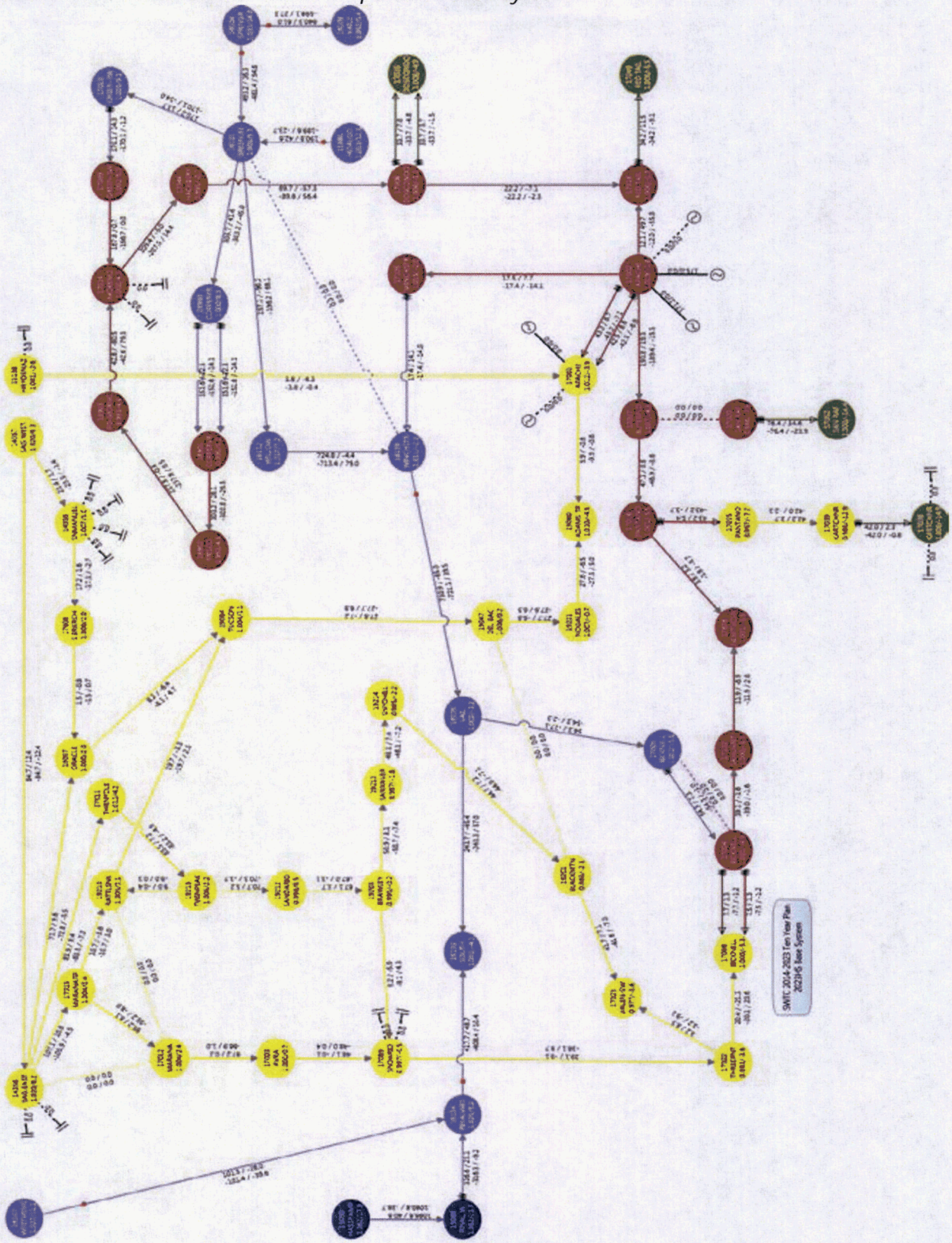
2019HS Southwest Transmission Cooperative Base System with Common Corridor outage of Vail to South 345 kV & New Tucson to Sahuarita 230 kV Lines



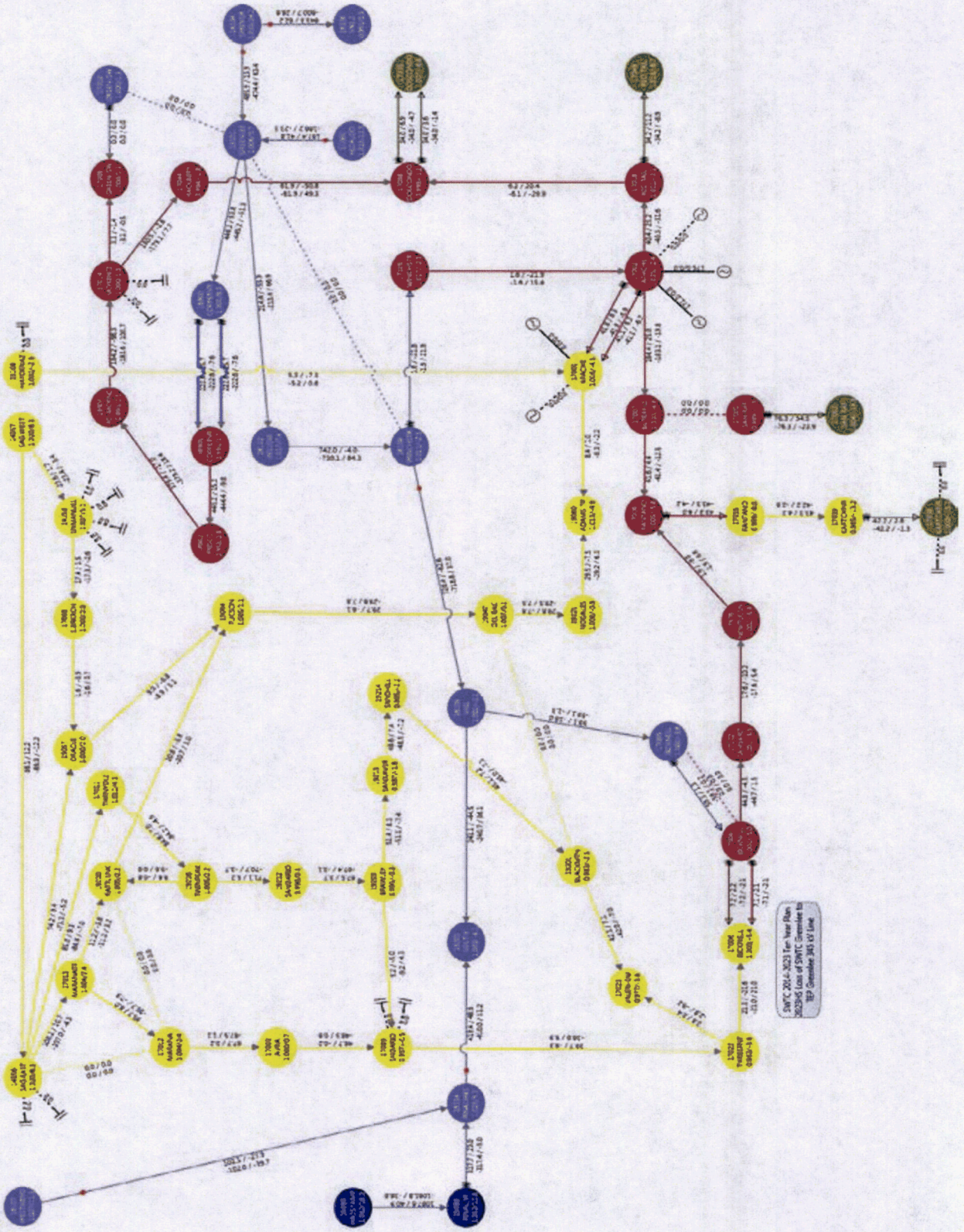
2019HS Southwest Transmission Cooperative Base System with Common Corridor outage of Pinal West to South 345 kV & Bicknell to Three Points 115 kV Lines



2023HS Southwest Transmission Cooperative Base System



2023HS Southwest Transmission Cooperative Base System with Green-SW to Greenlee 345 kV Line out of service



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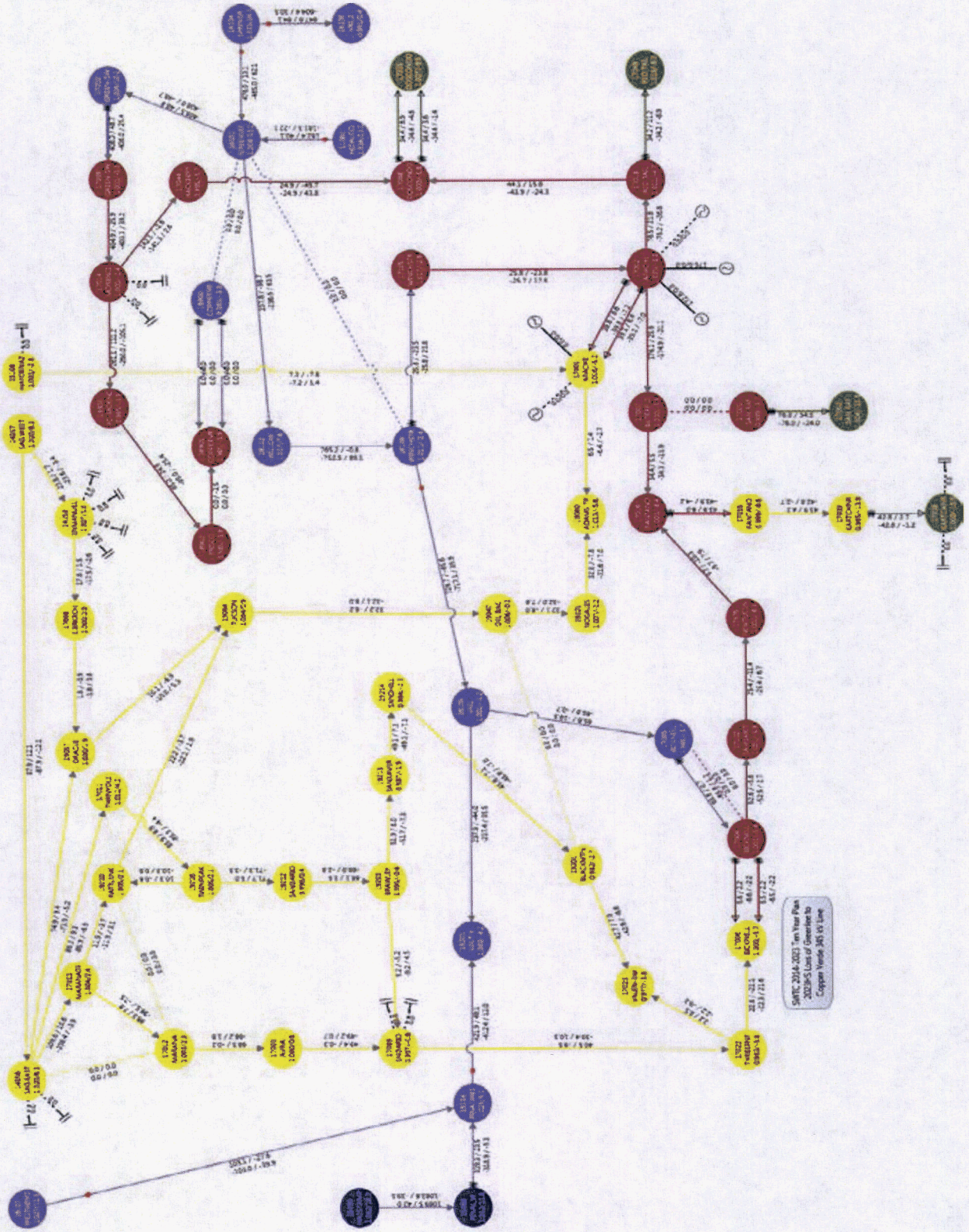
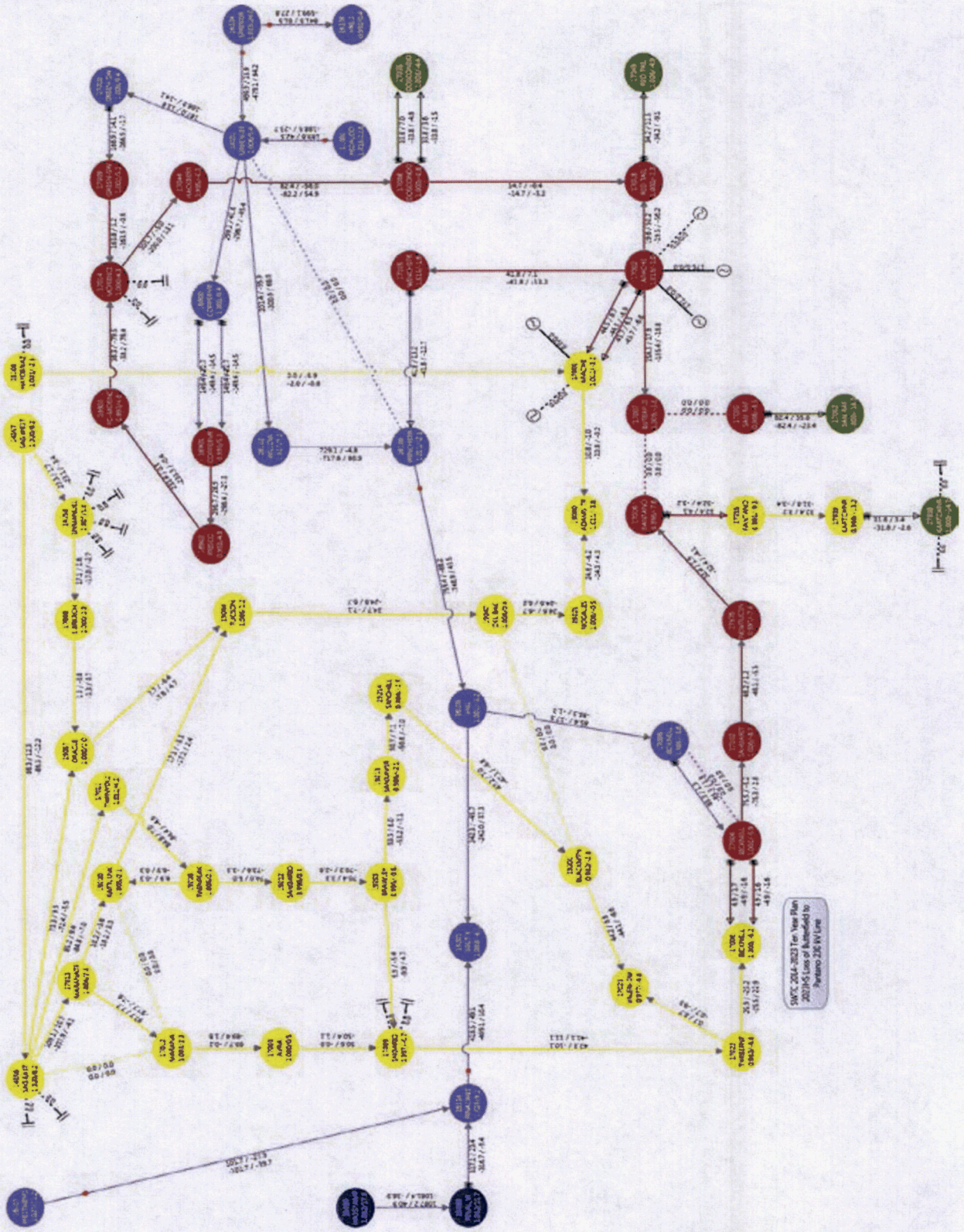
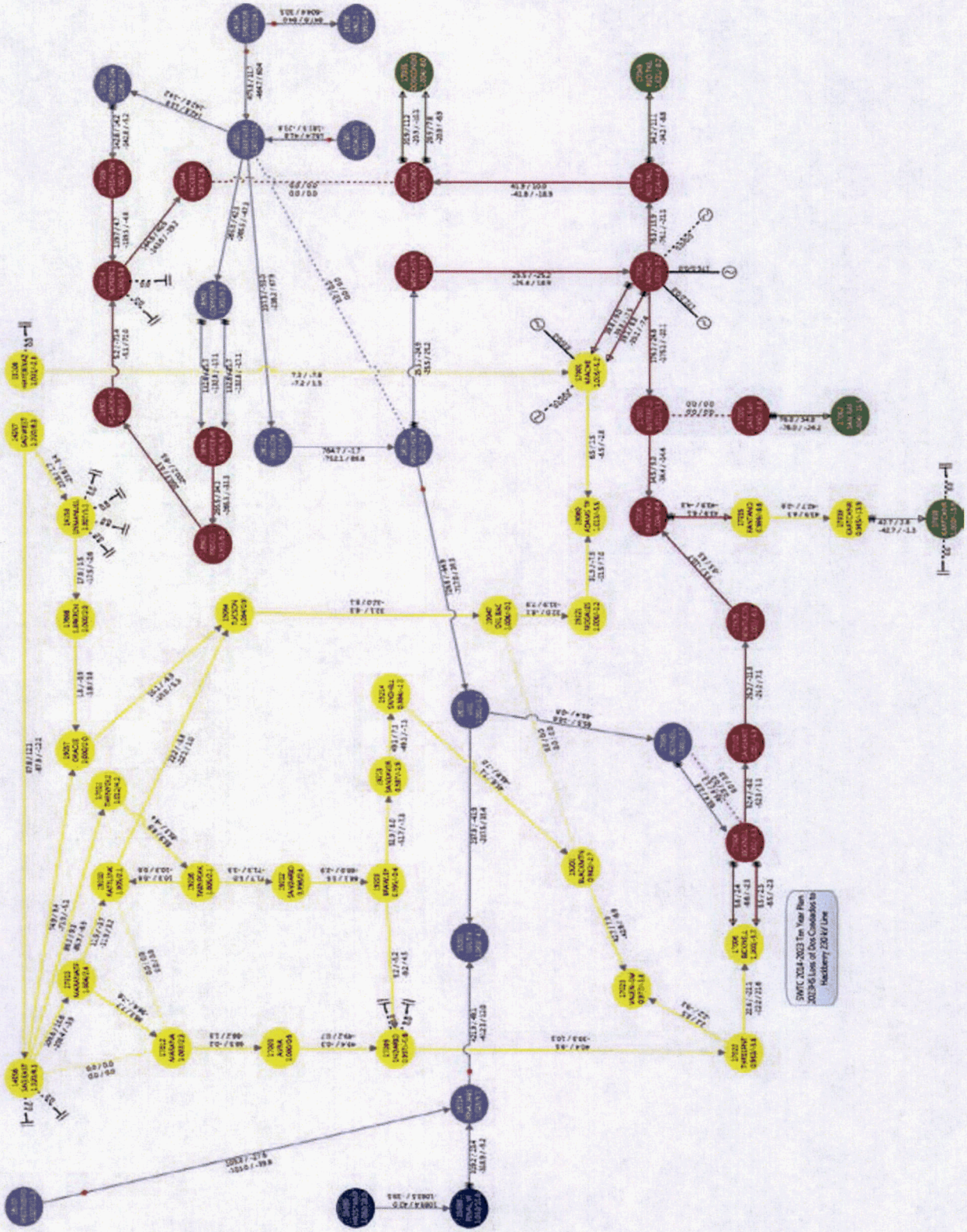


2023HS Southwest Transmission Cooperative Base System with Butterfield to Pantano 230 kV Line out of service



2023HS Southwest Transmission Cooperative Base System with Dos Condados to Hackberry 230 kV Line out of service



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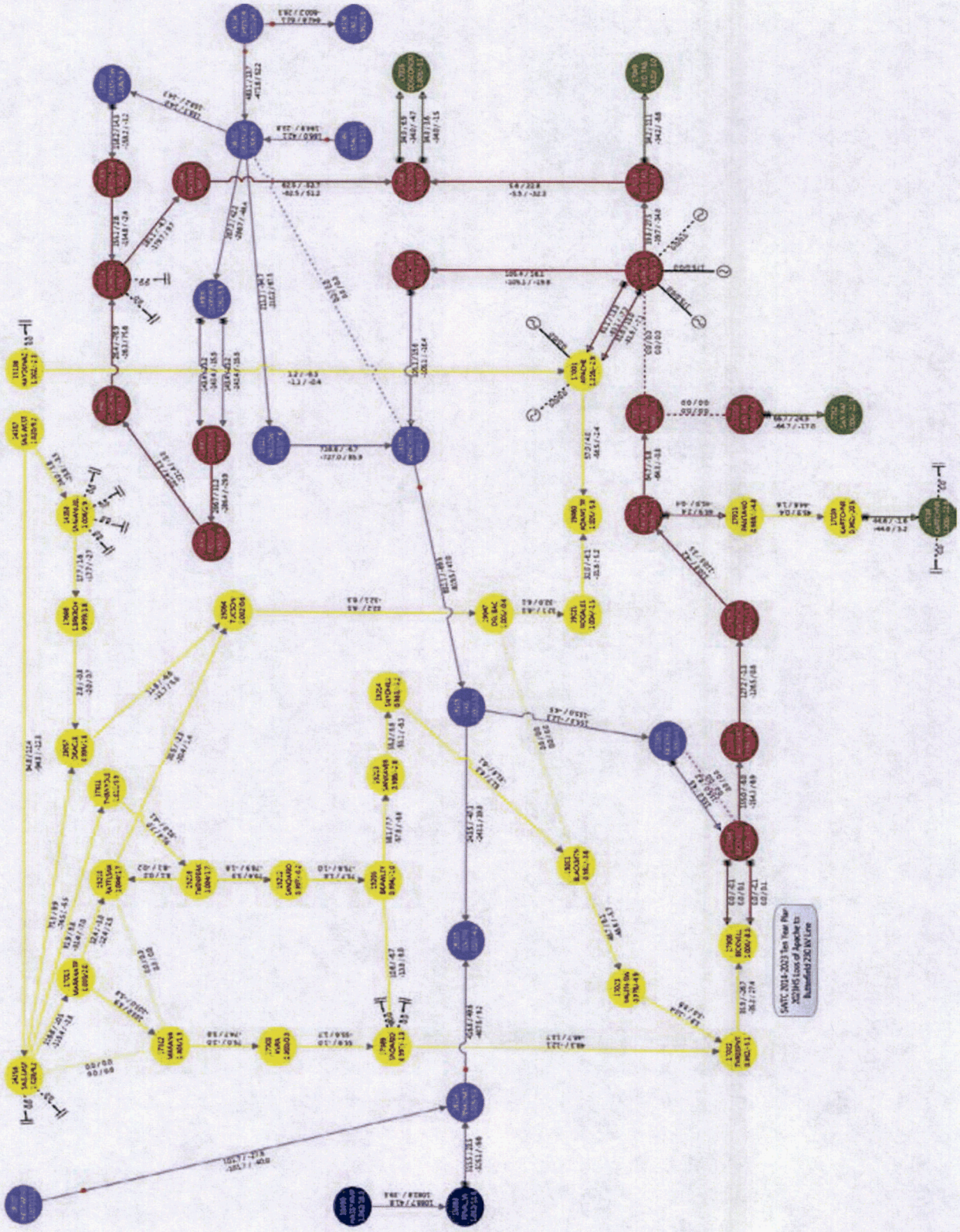
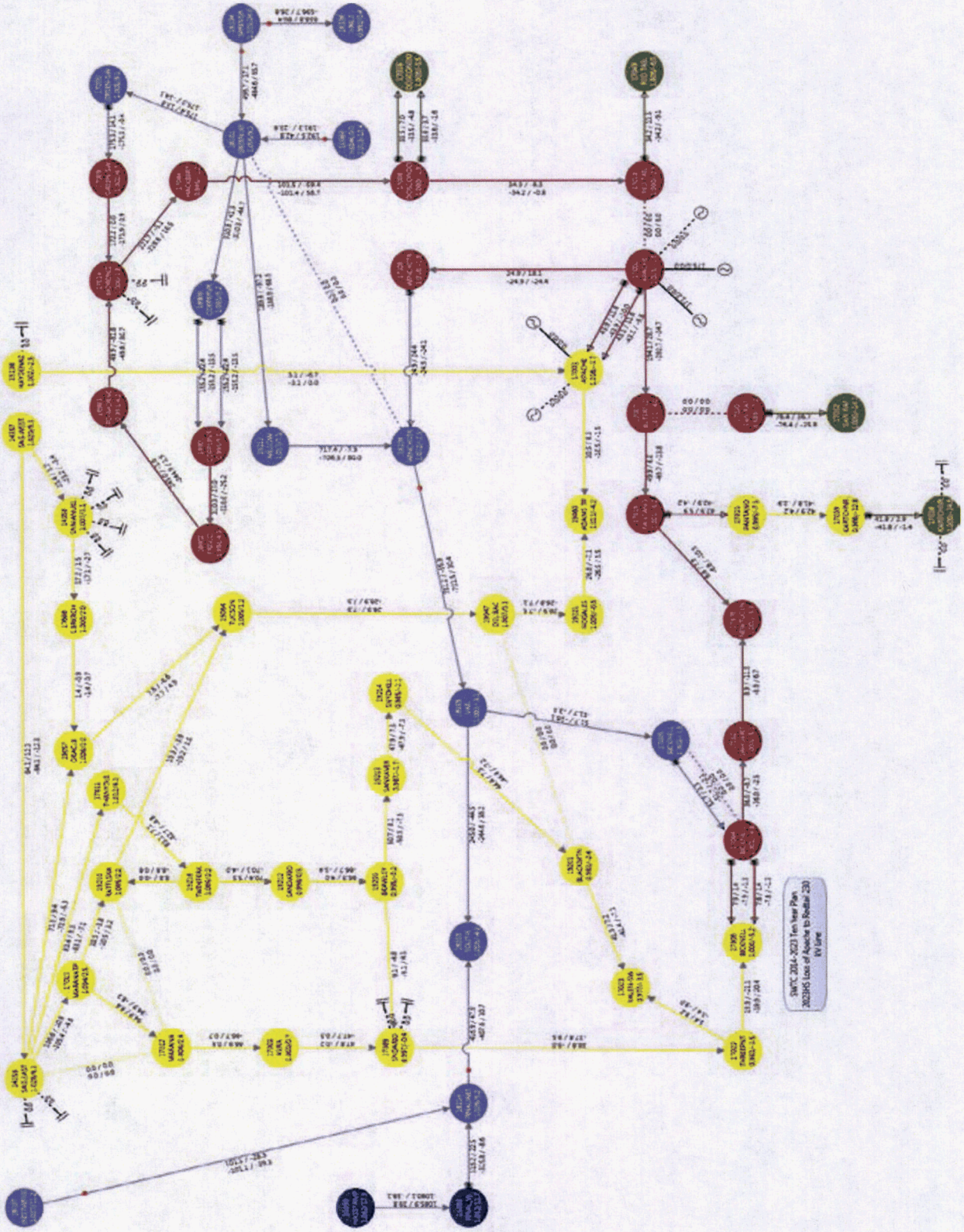
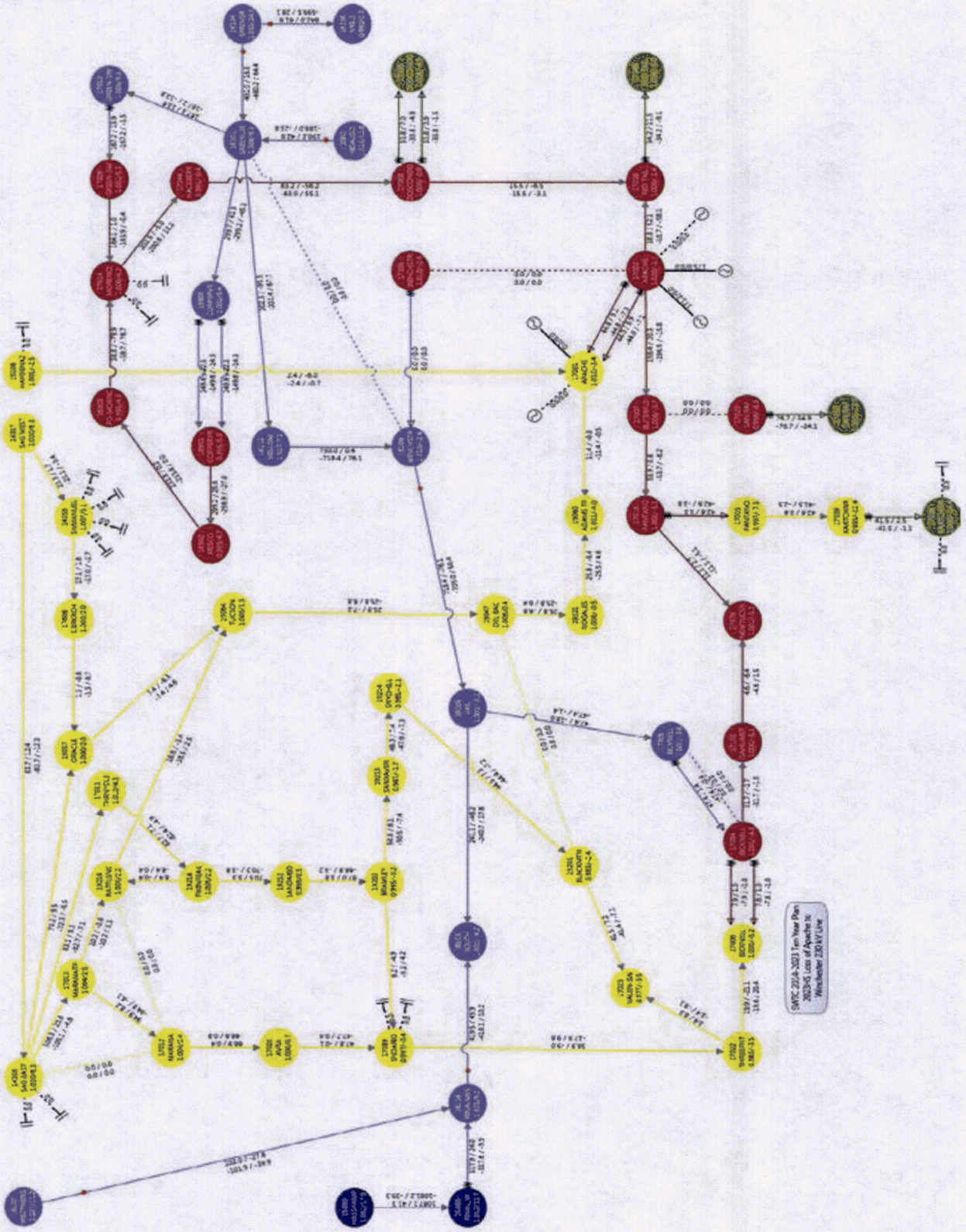


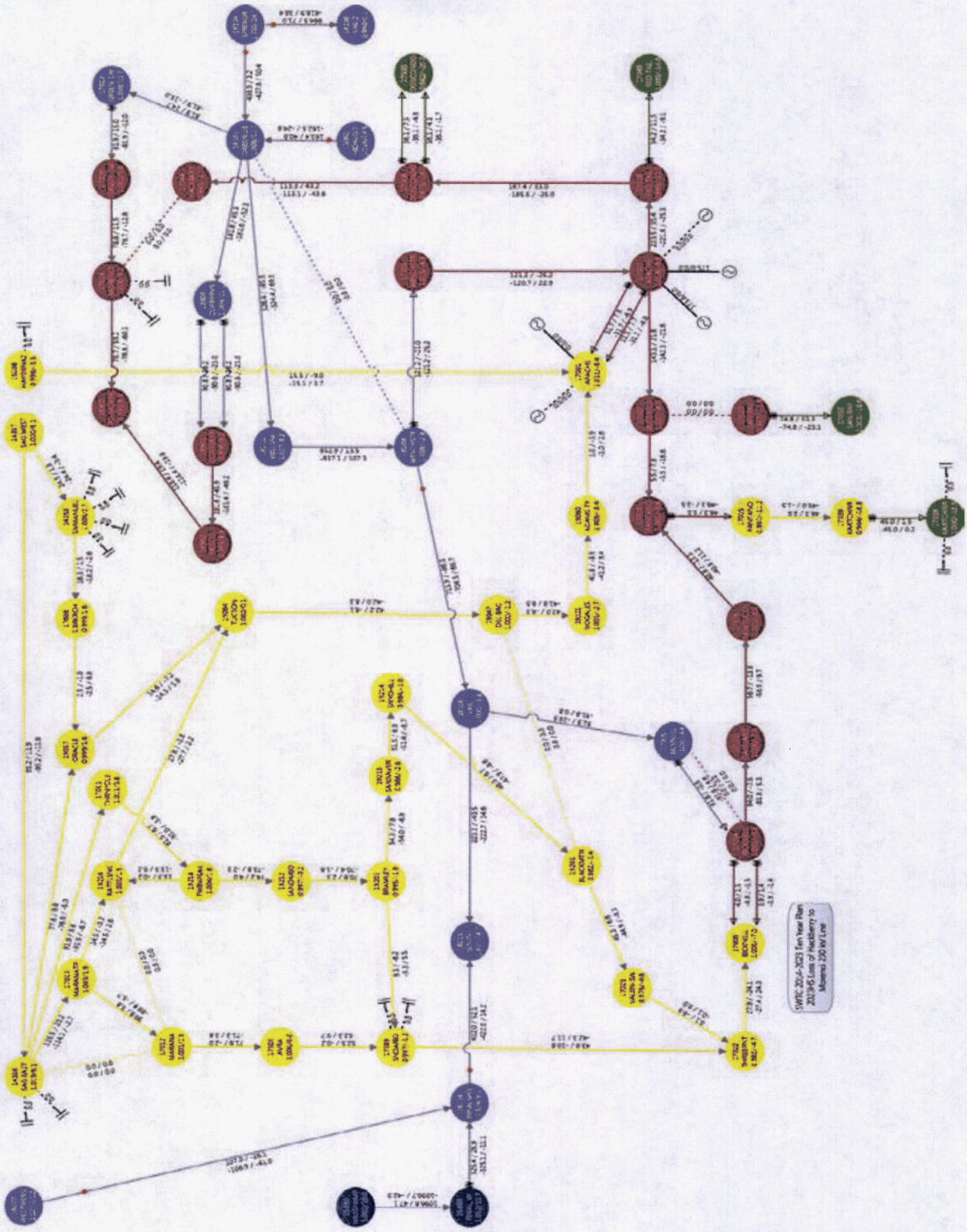
2023HS Southwest Transmission Cooperative Base System with Apache to Redtail 230 kV Line out of service



2023HS Southwest Transmission Cooperative Base System with Apache to Winchester 230 kV Line out of service



2023HS Southwest Transmission Cooperative Base System with Hackberry to Morenci 230 kV Line out of service



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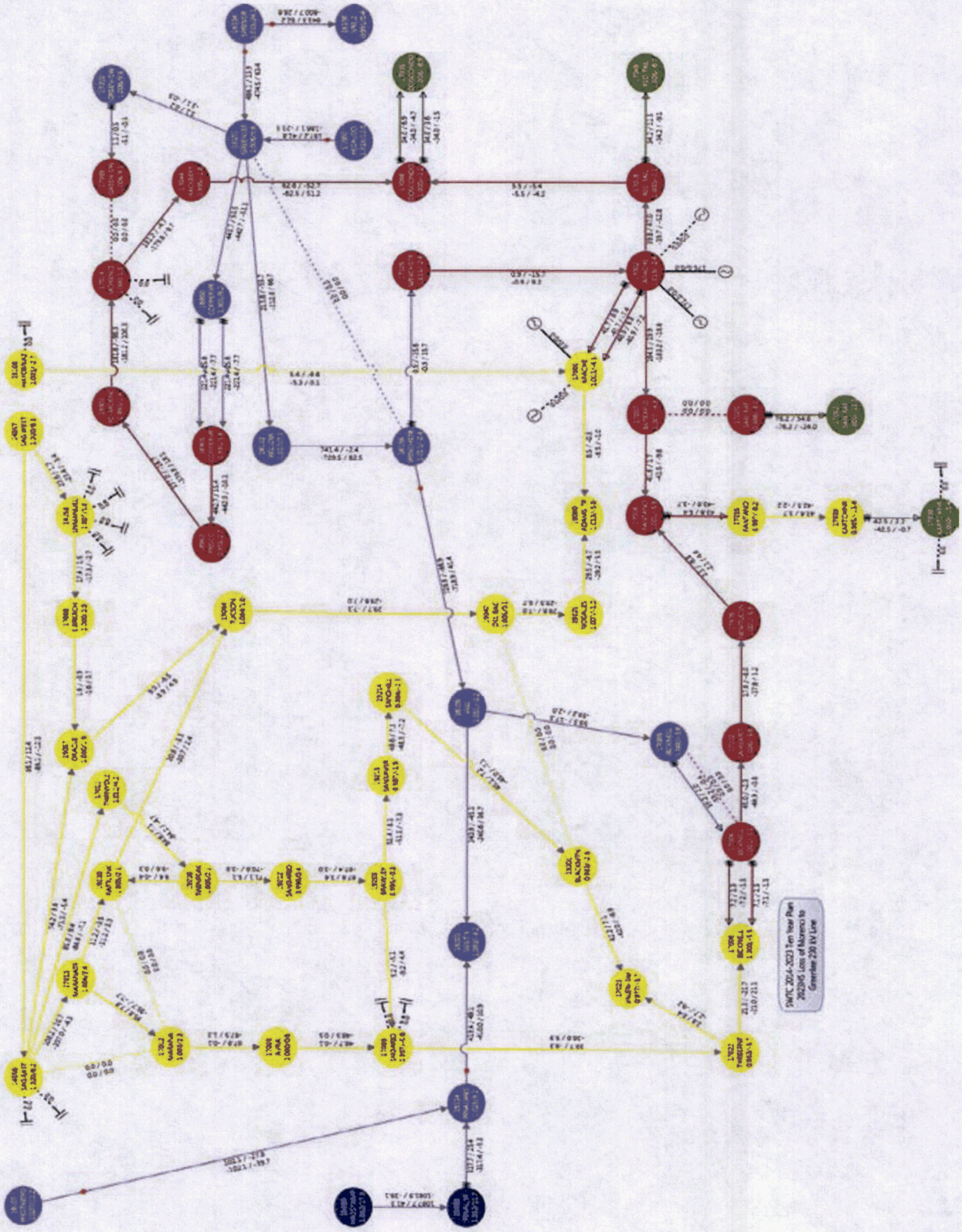

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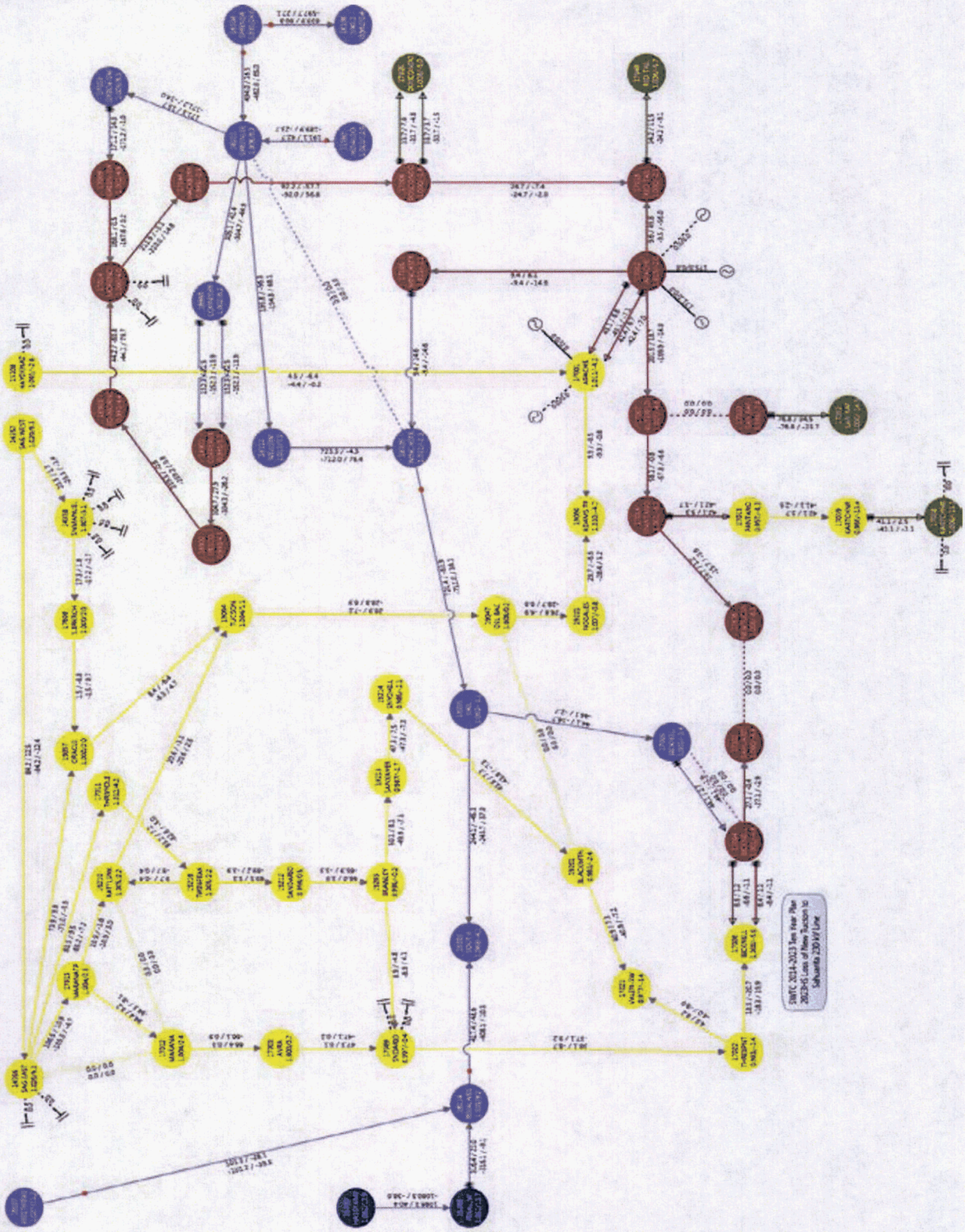

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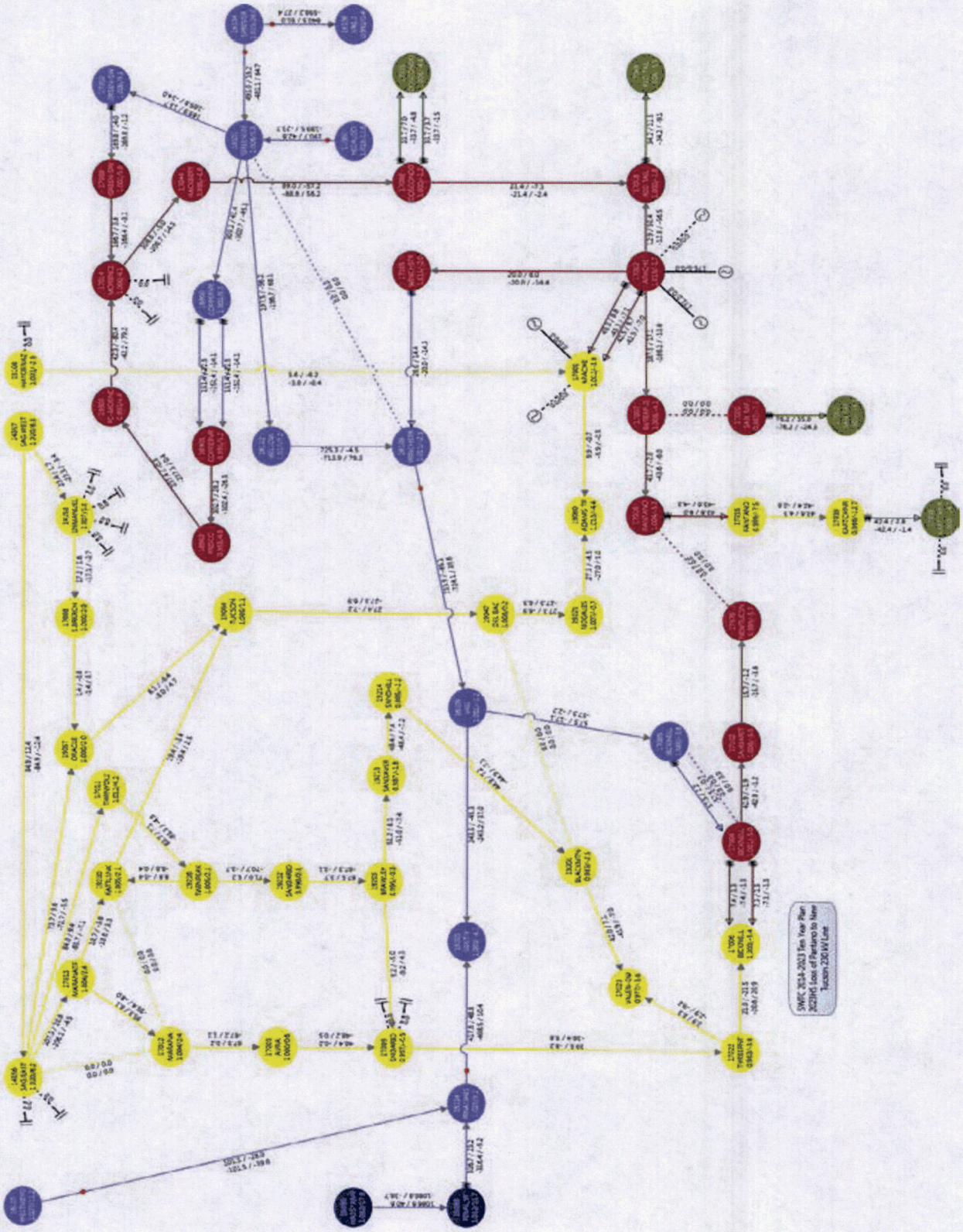

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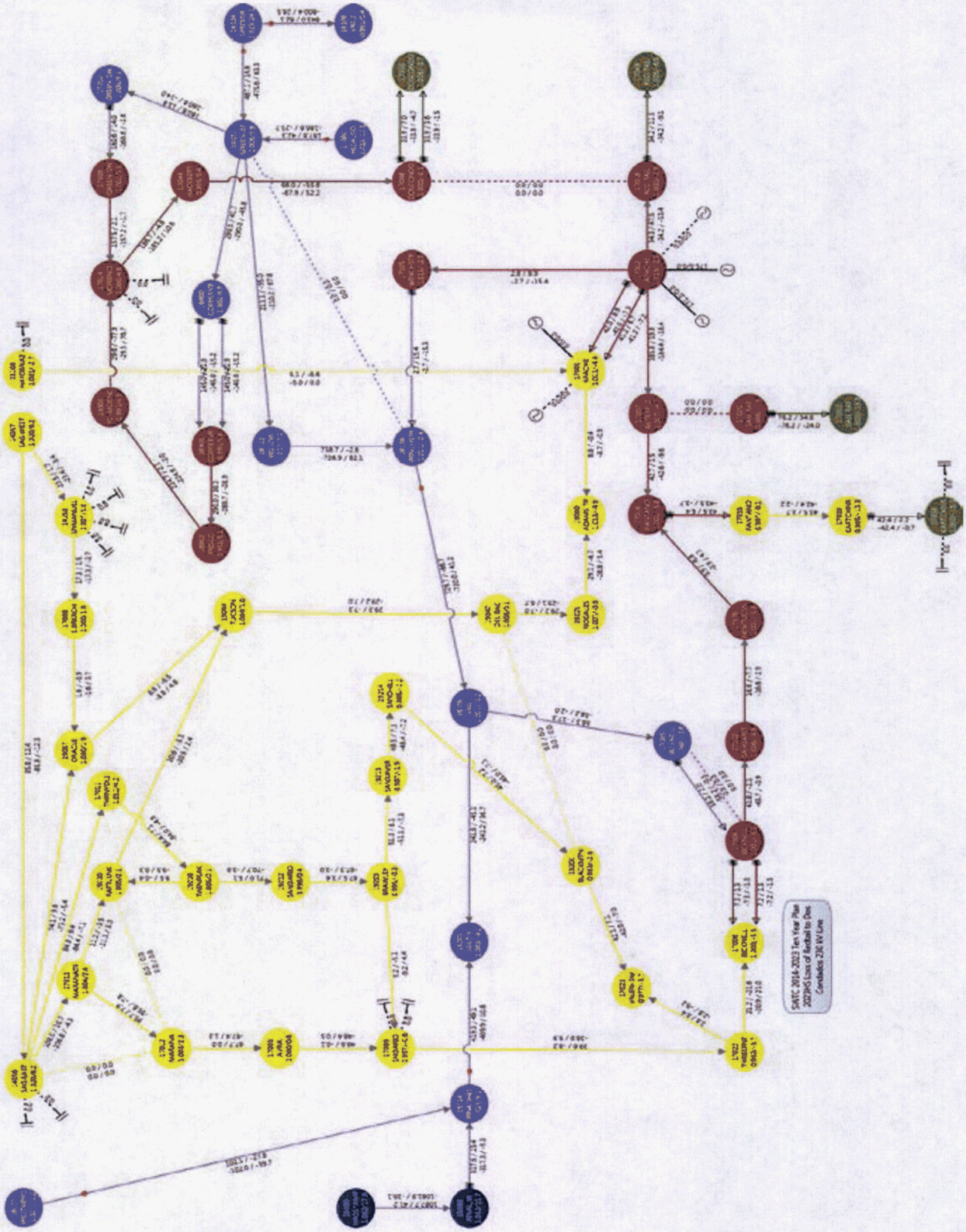

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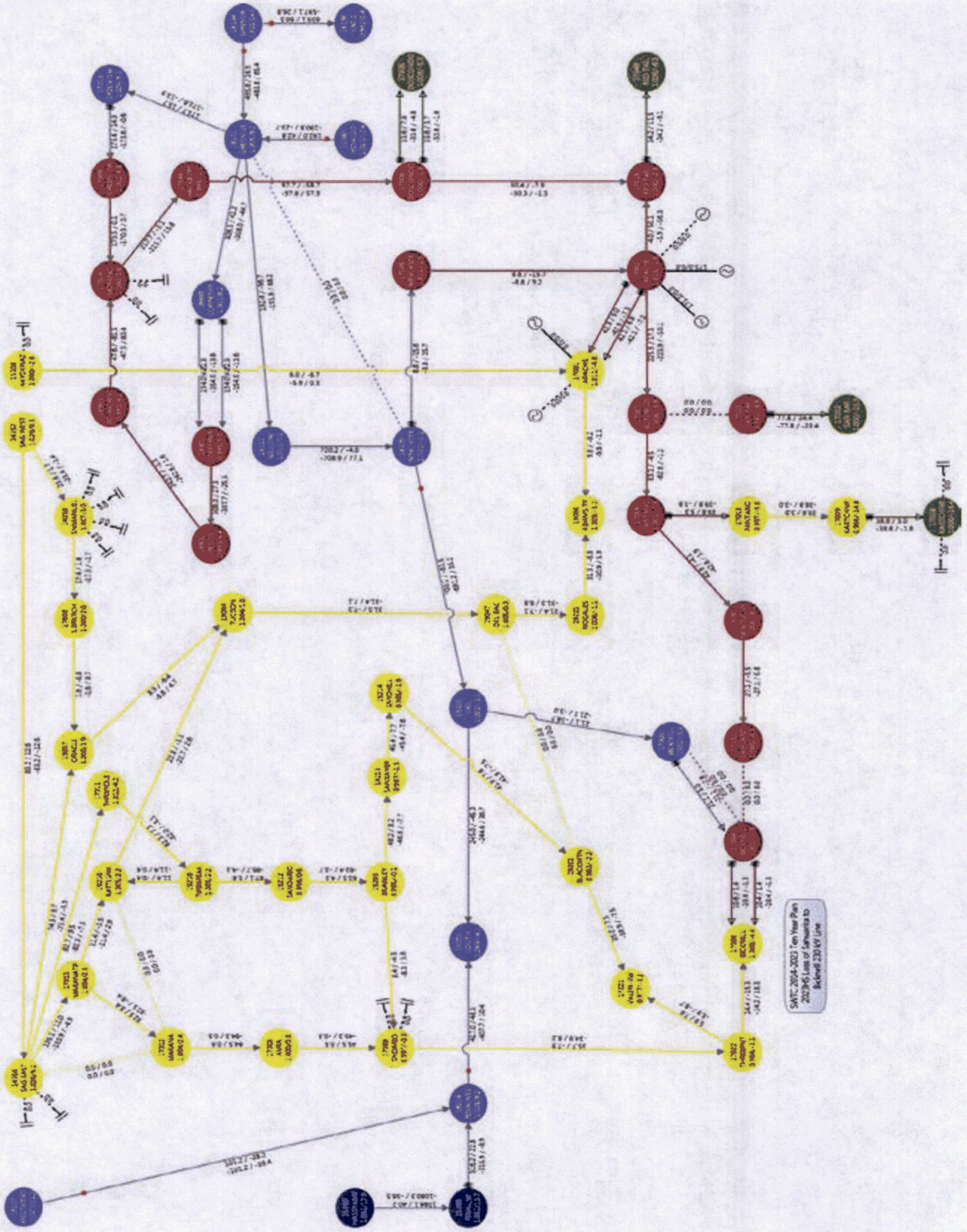
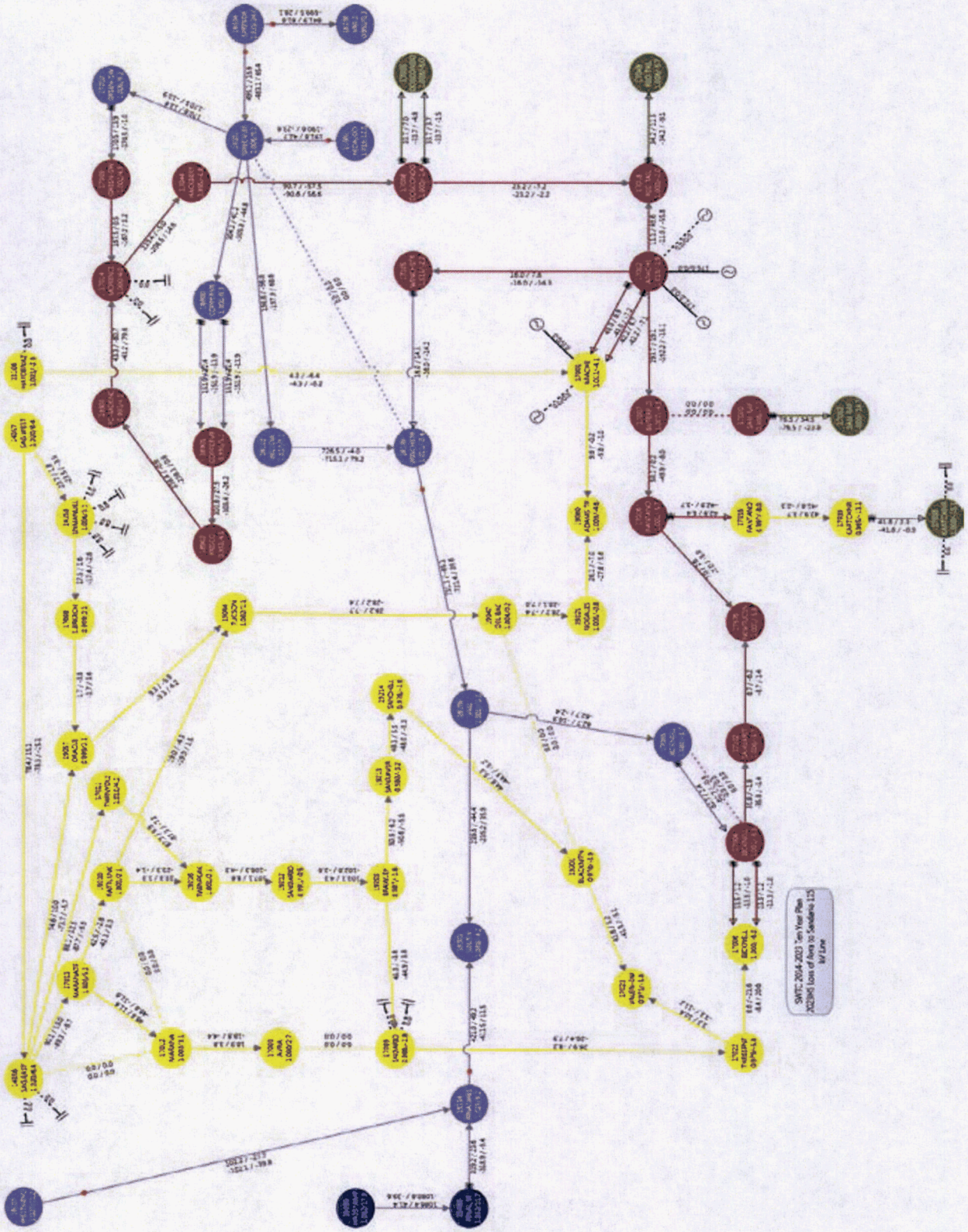
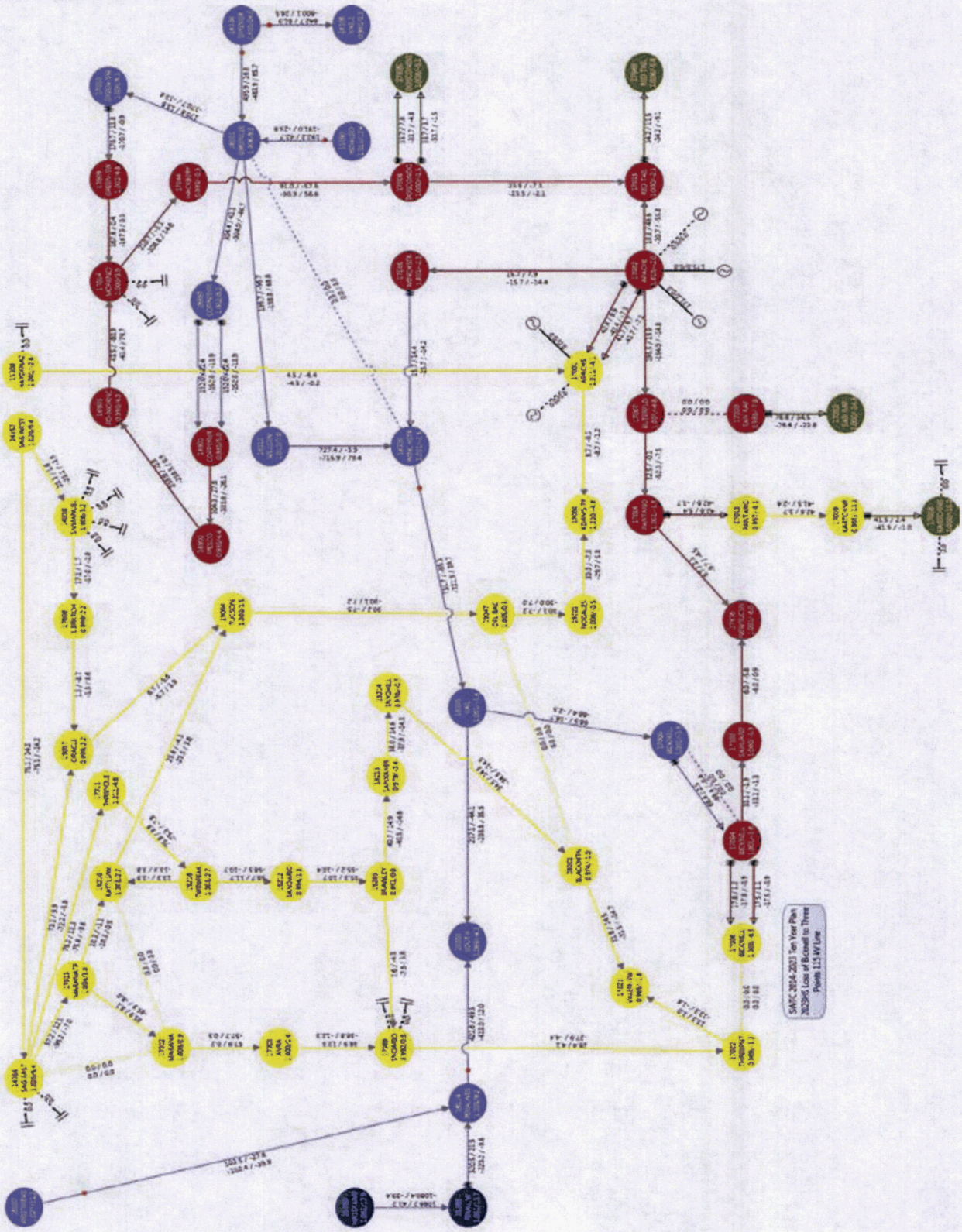


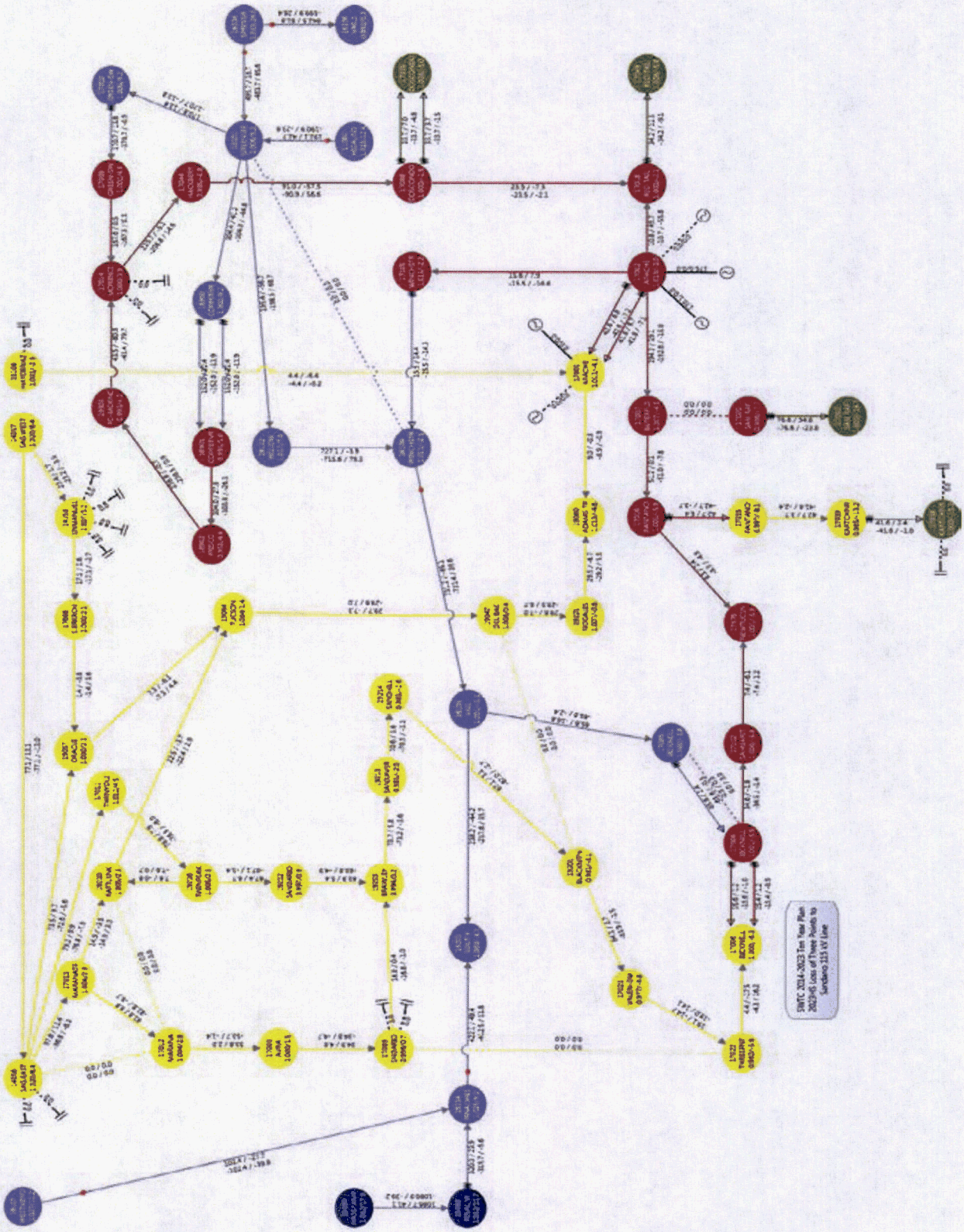
2023HS Southwest Transmission Cooperative Base System with Avra to Sandario 115 kV Line out of service



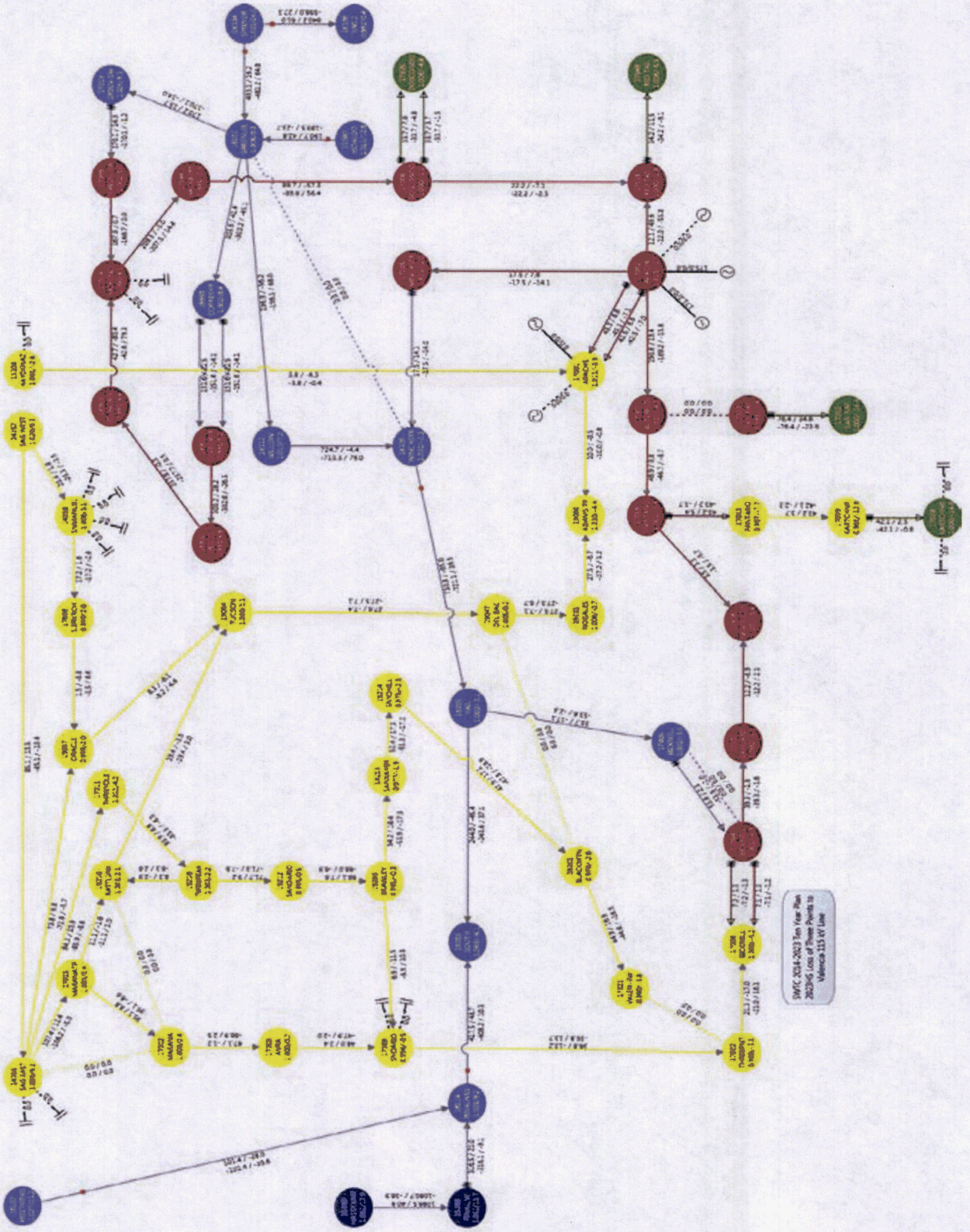
2023HS Southwest Transmission Cooperative Base System with Bicknell to Three Points 115 kV Line out of service



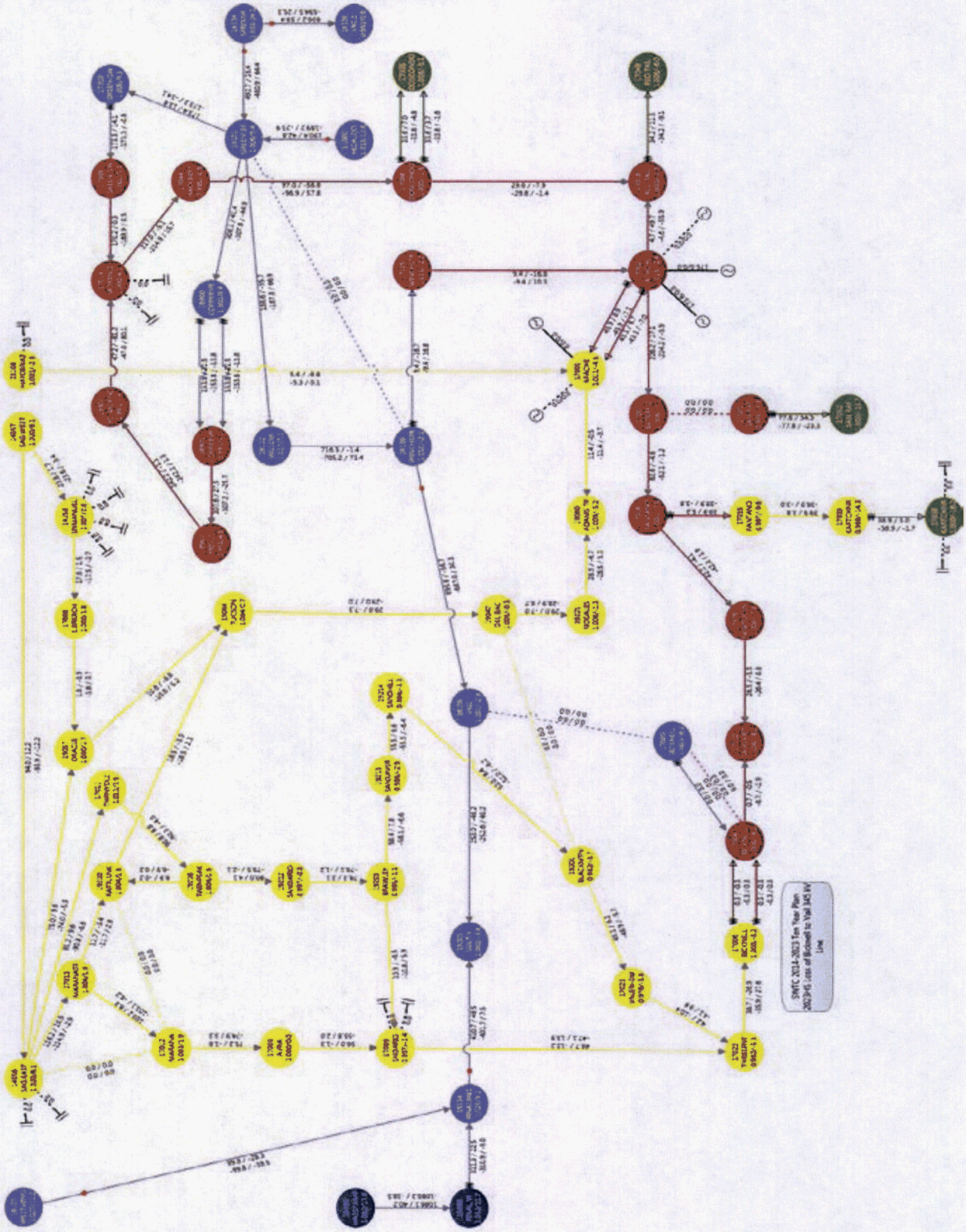
2023HS Southwest Transmission Cooperative Base System with Three Points to Sandario 115 kV Line out of service



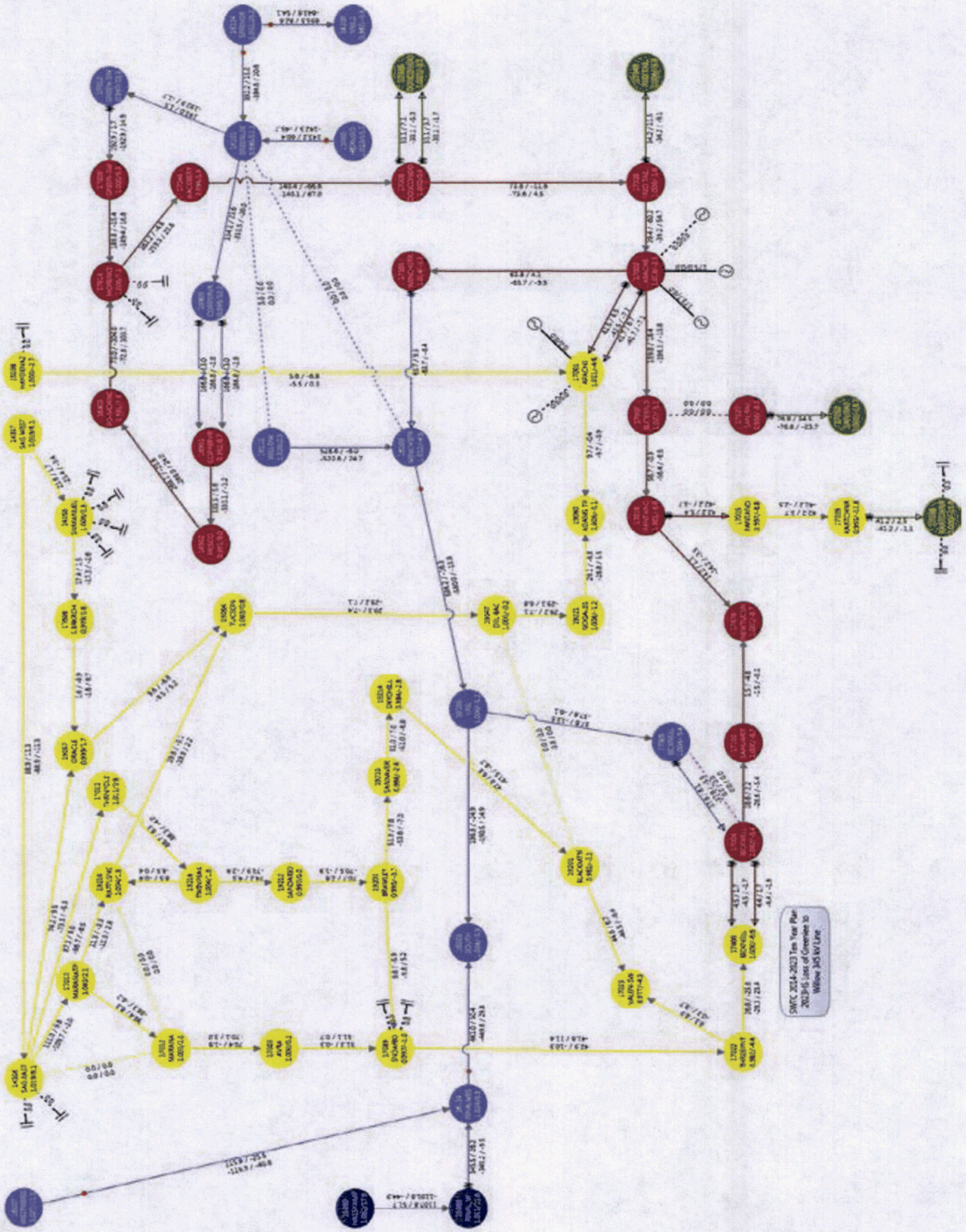
2023HS Southwest Transmission Cooperative Base System with Three Points to Valencia 115 kV Line out of service



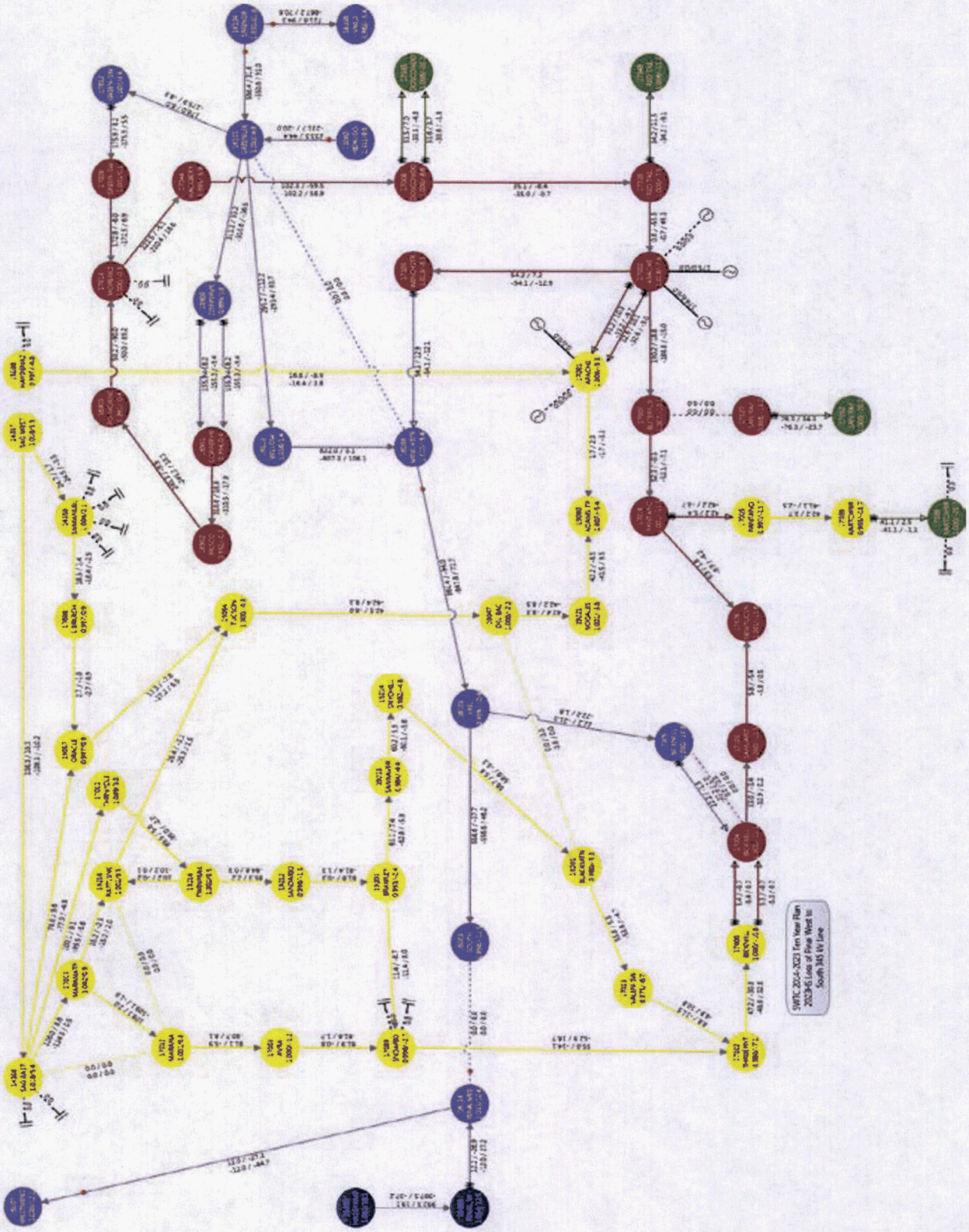
2023HS Southwest Transmission Cooperative Base System with Bicknell to Vail 345 kV Line out of service



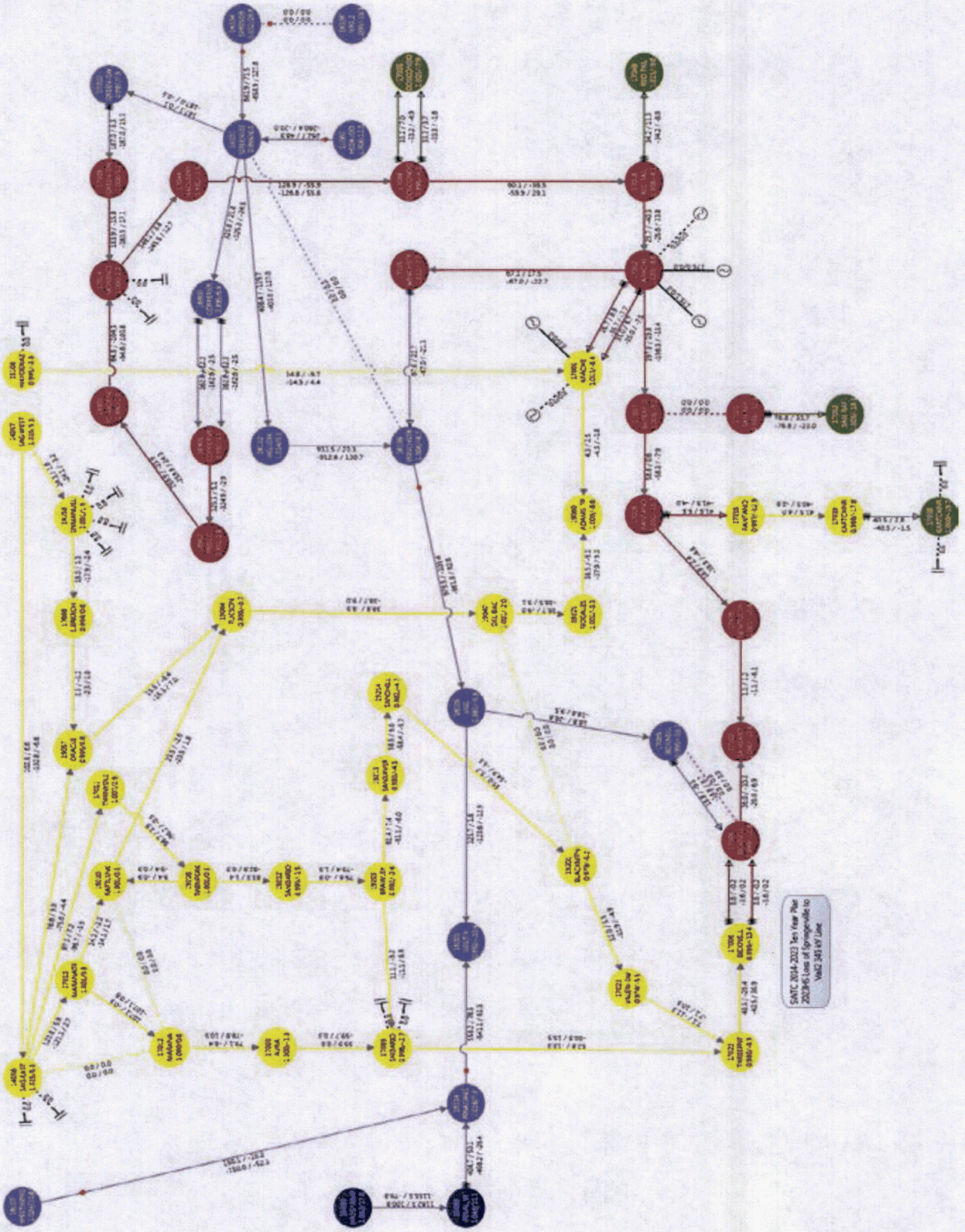
2023HS Southwest Transmission Cooperative Base System with Greenlee to Willow 345 kV Line out of service



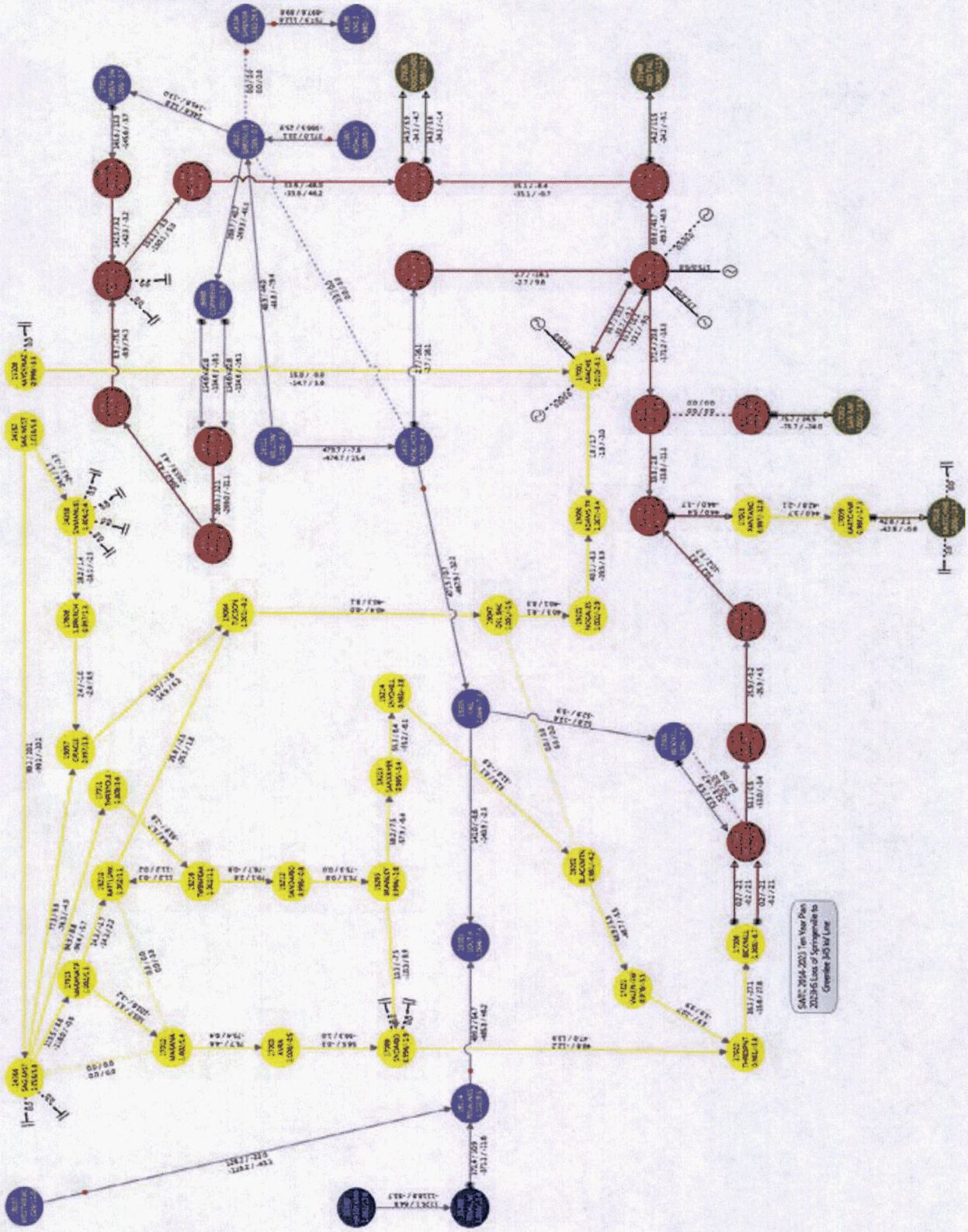
2023HS Southwest Transmission Cooperative Base System with Pinal West to South 345 kV Line out of service



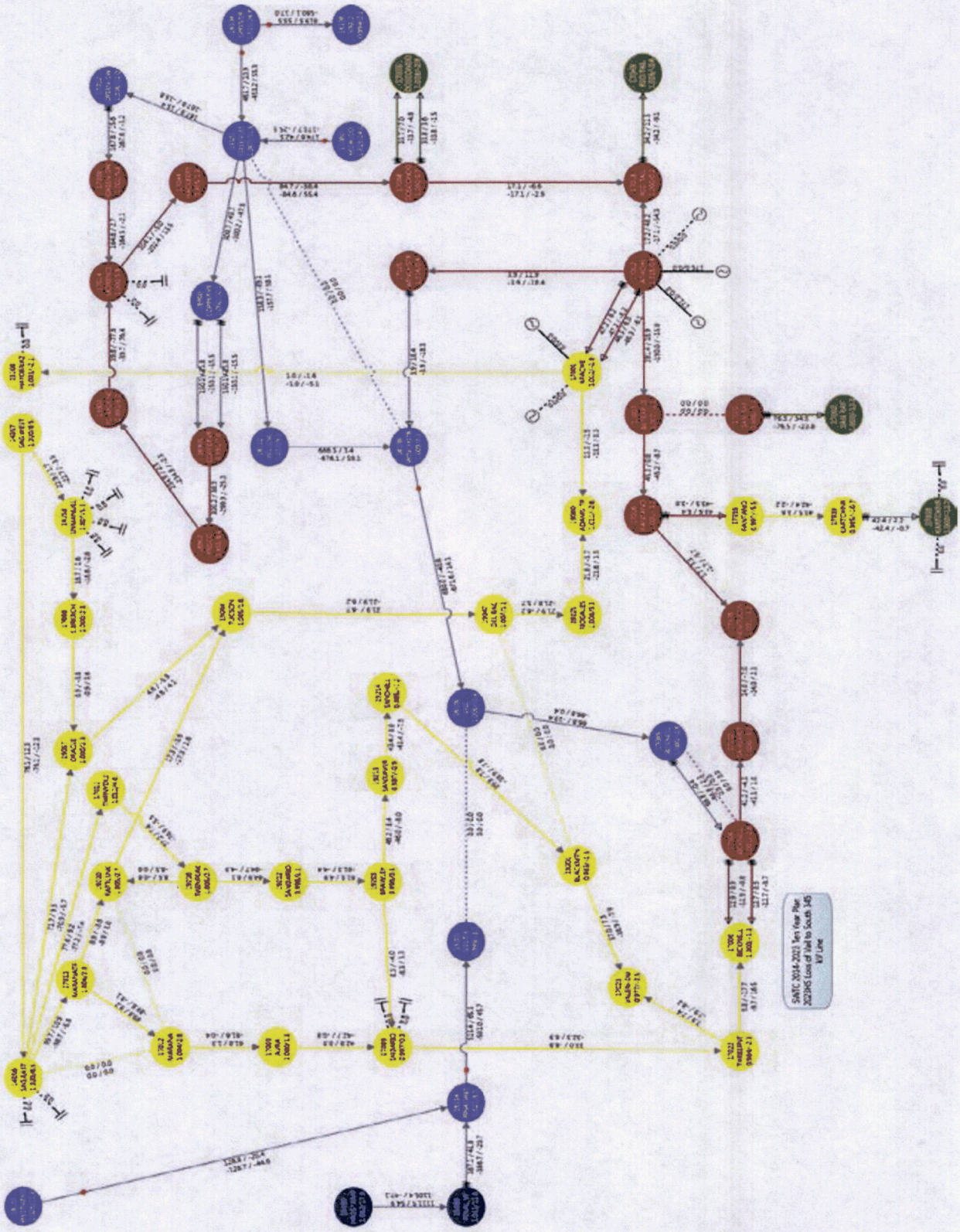
2023HS Southwest Transmission Cooperative Base System with Springerville to Vail2 345 kV Line out of service



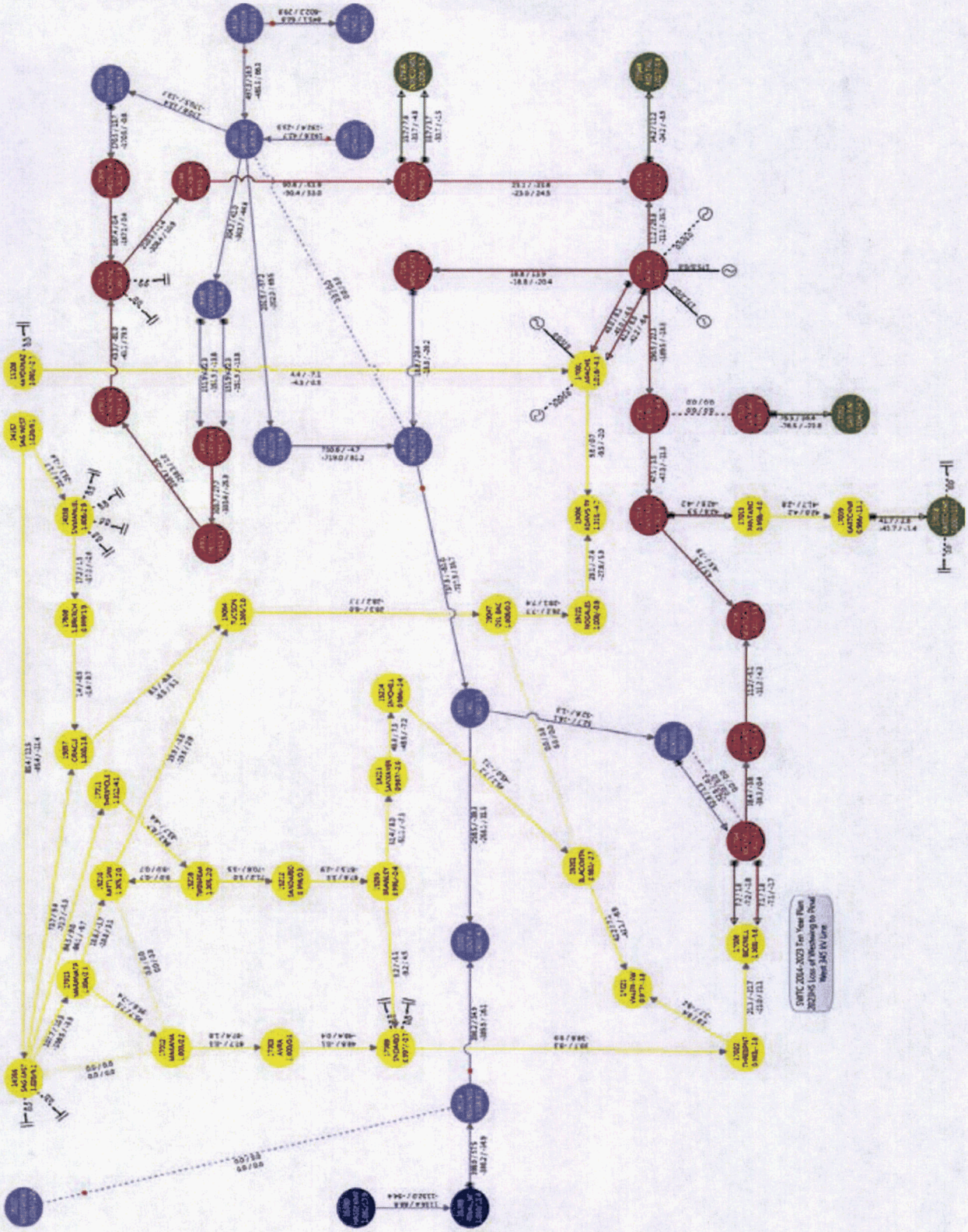
2023HS Southwest Transmission Cooperative Base System with Springerville to Greenlee 345 kV Line out of service



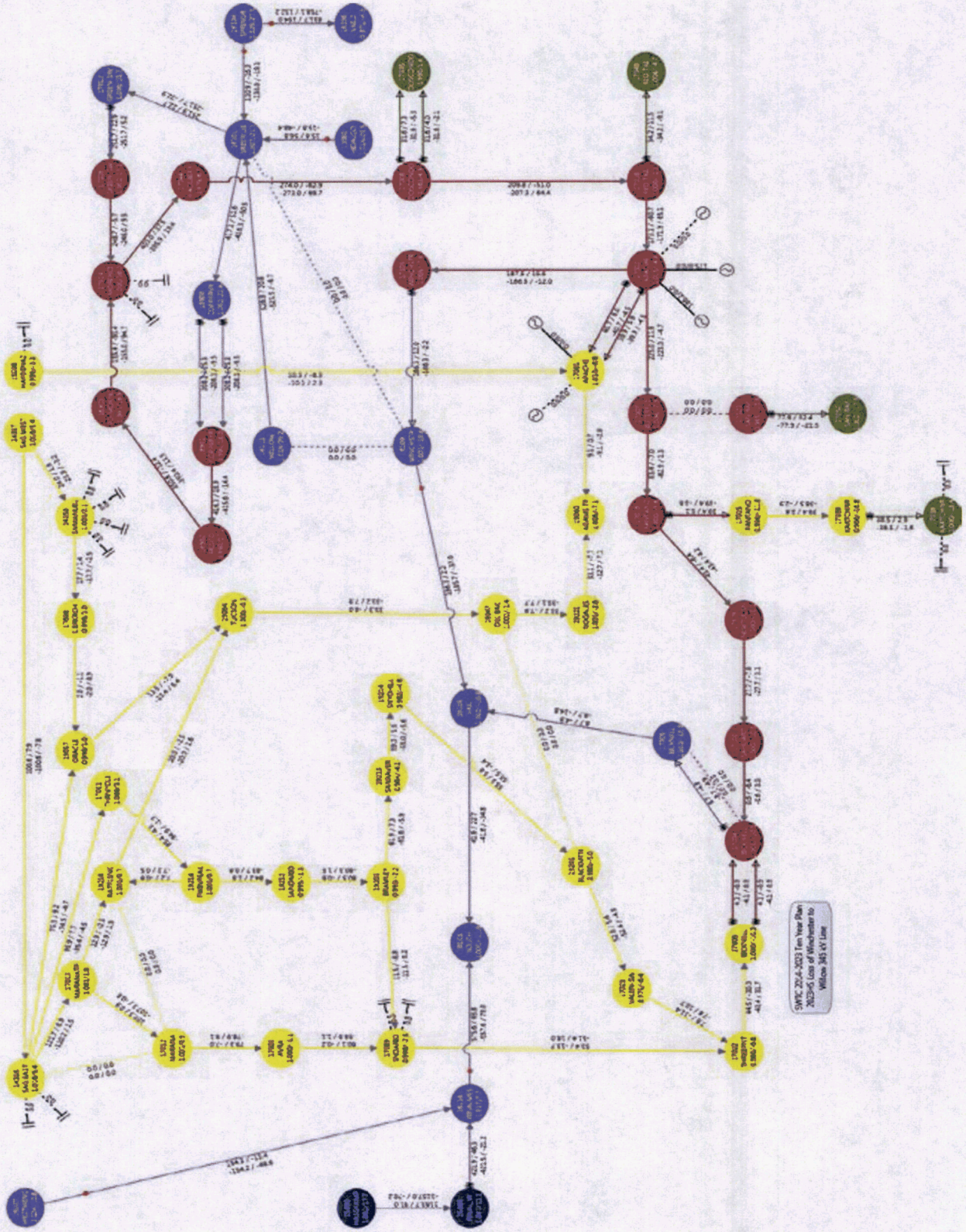
2023HS Southwest Transmission Cooperative Base System with Vail to South 345 kV Line out of service



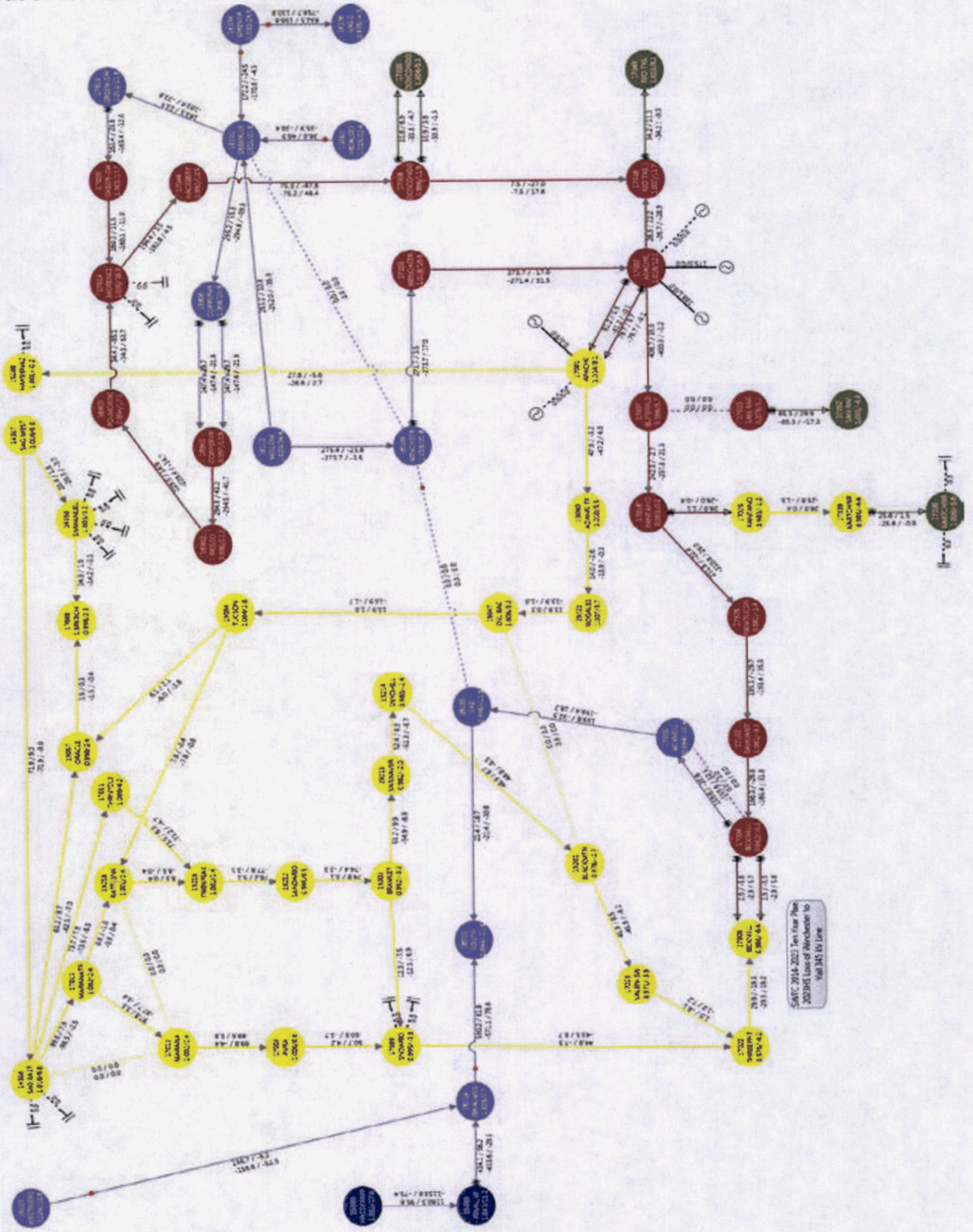
2023HS Southwest Transmission Cooperative Base System with Westwing to Pinal West 345 kV Line out of service



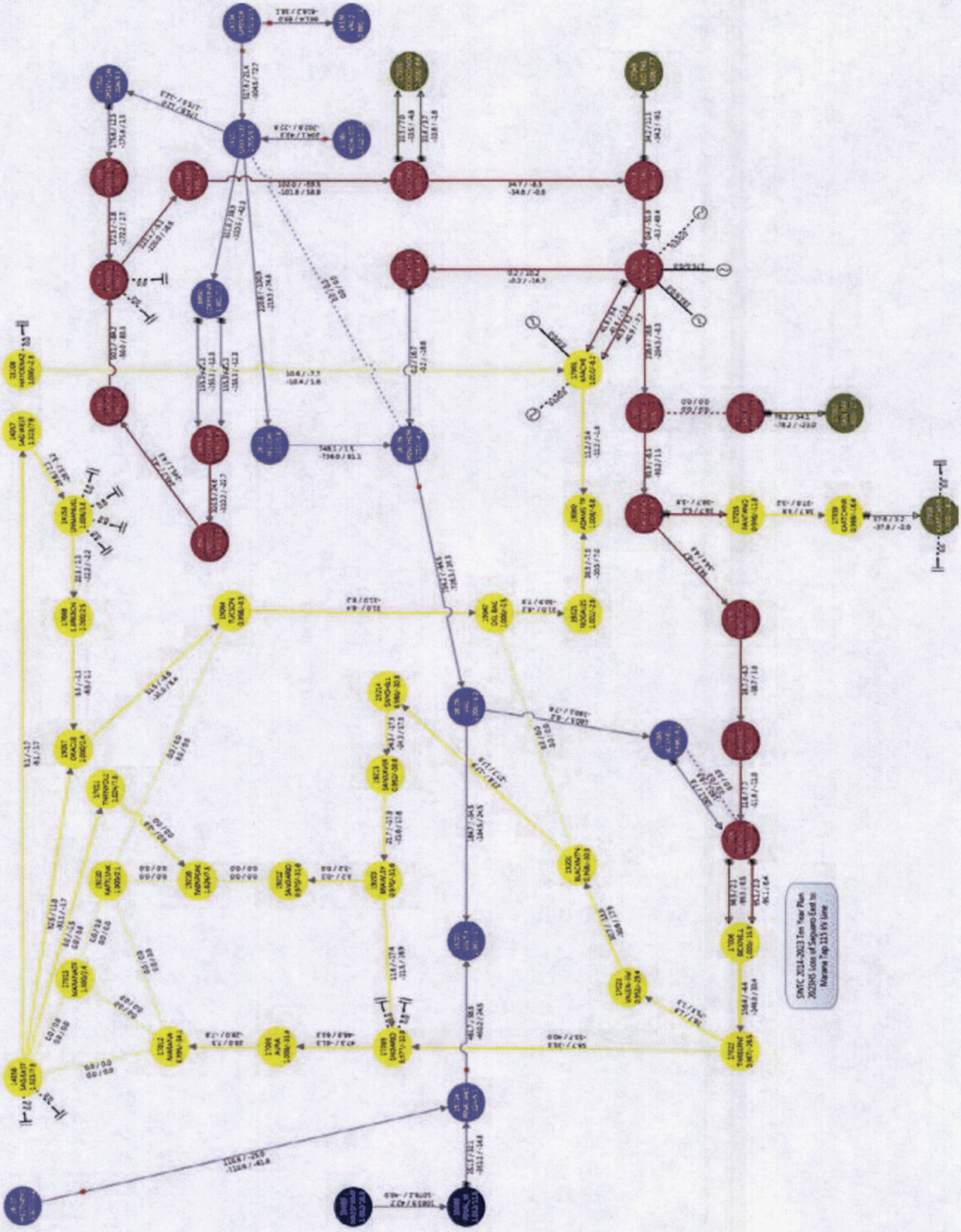
2023HS Southwest Transmission Cooperative Base System with Winchester to Willow 345 kV Line out of service



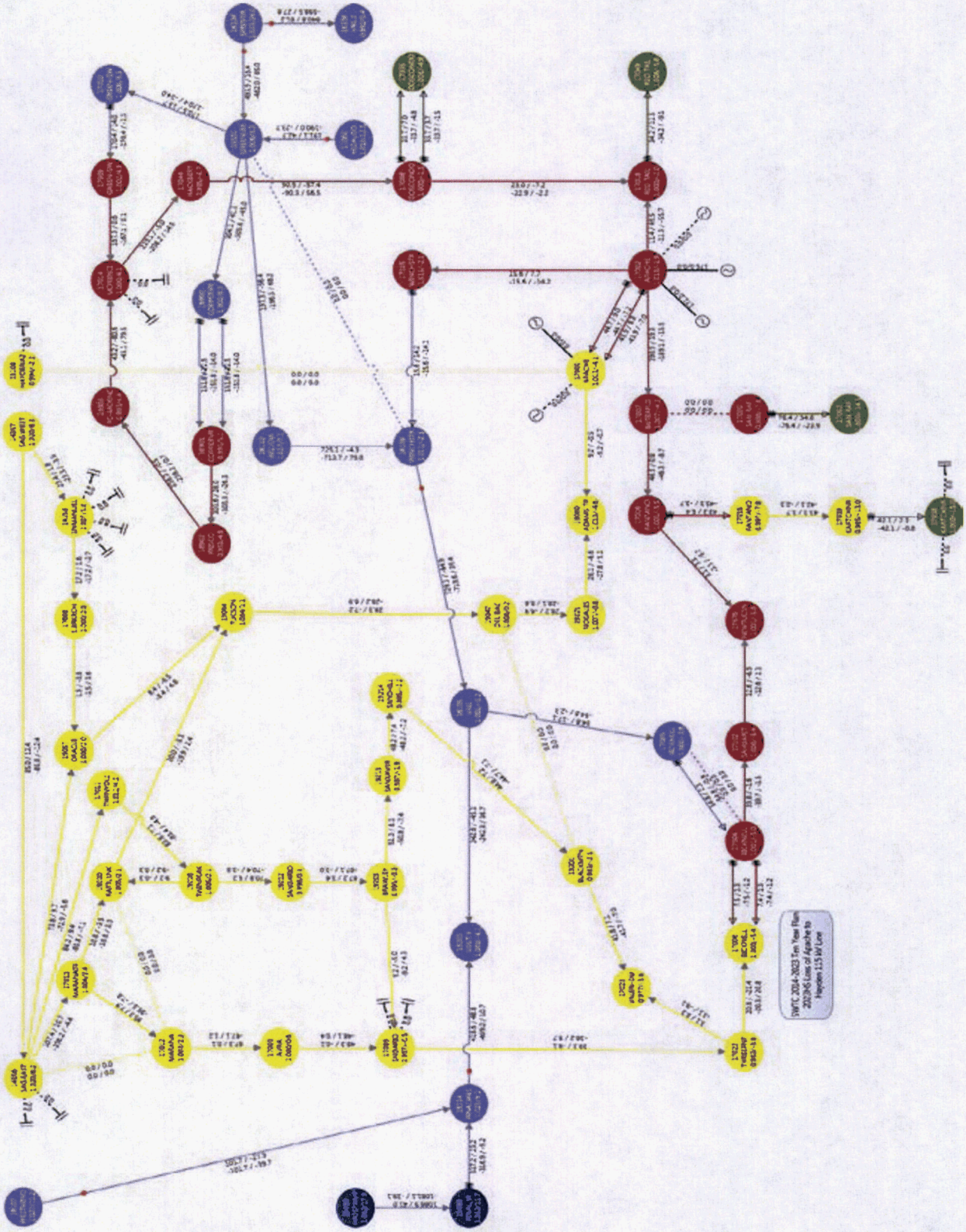
2023HS Southwest Transmission Cooperative Base System with Winchester to Vail 345 kV Line out of service



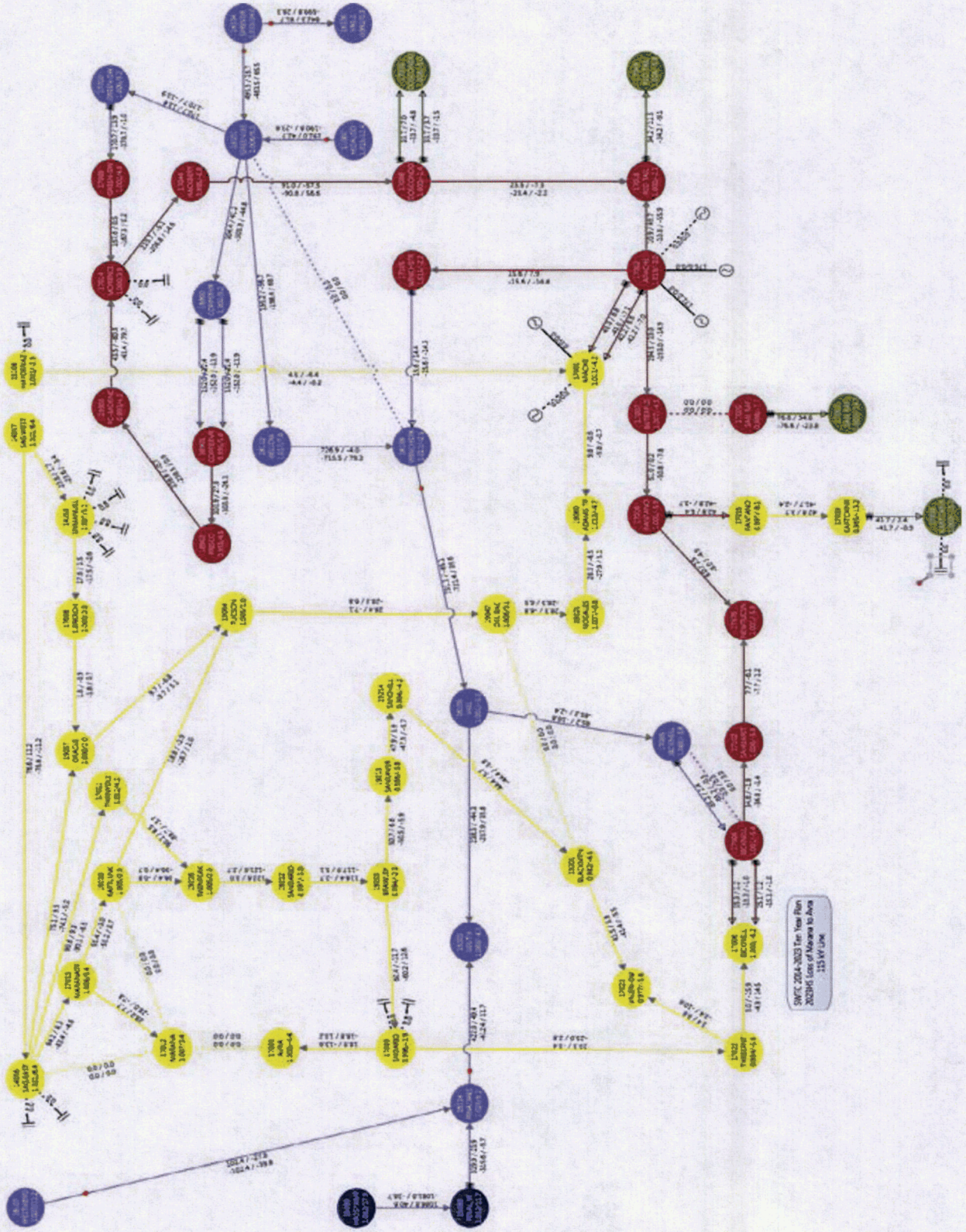
2023HS Southwest Transmission Cooperative Base System with Saguaro East to Marana Tap 115 kV Line out of service



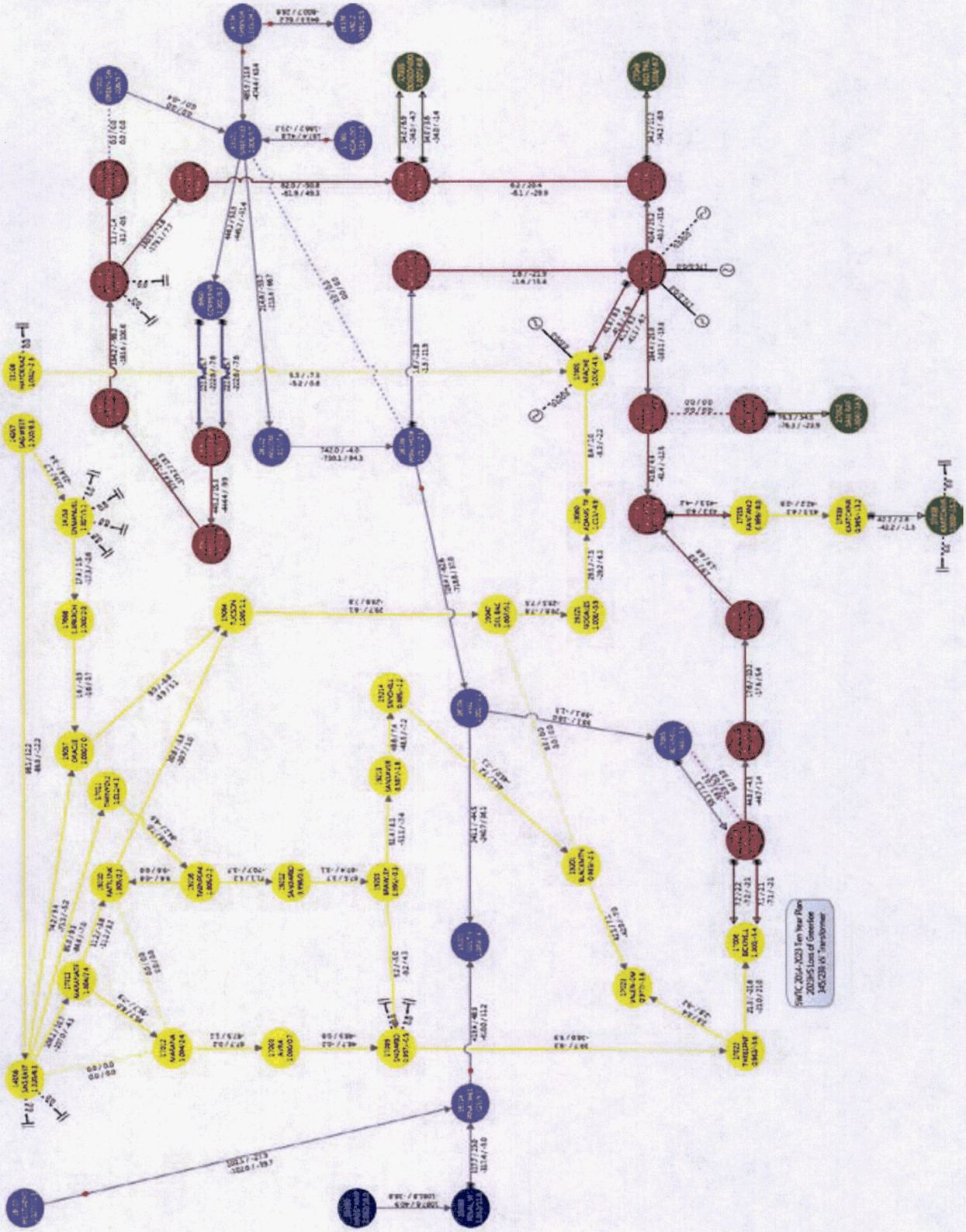
2023HS Southwest Transmission Cooperative Base System with Apache to Hayden 115 kV Line out of service



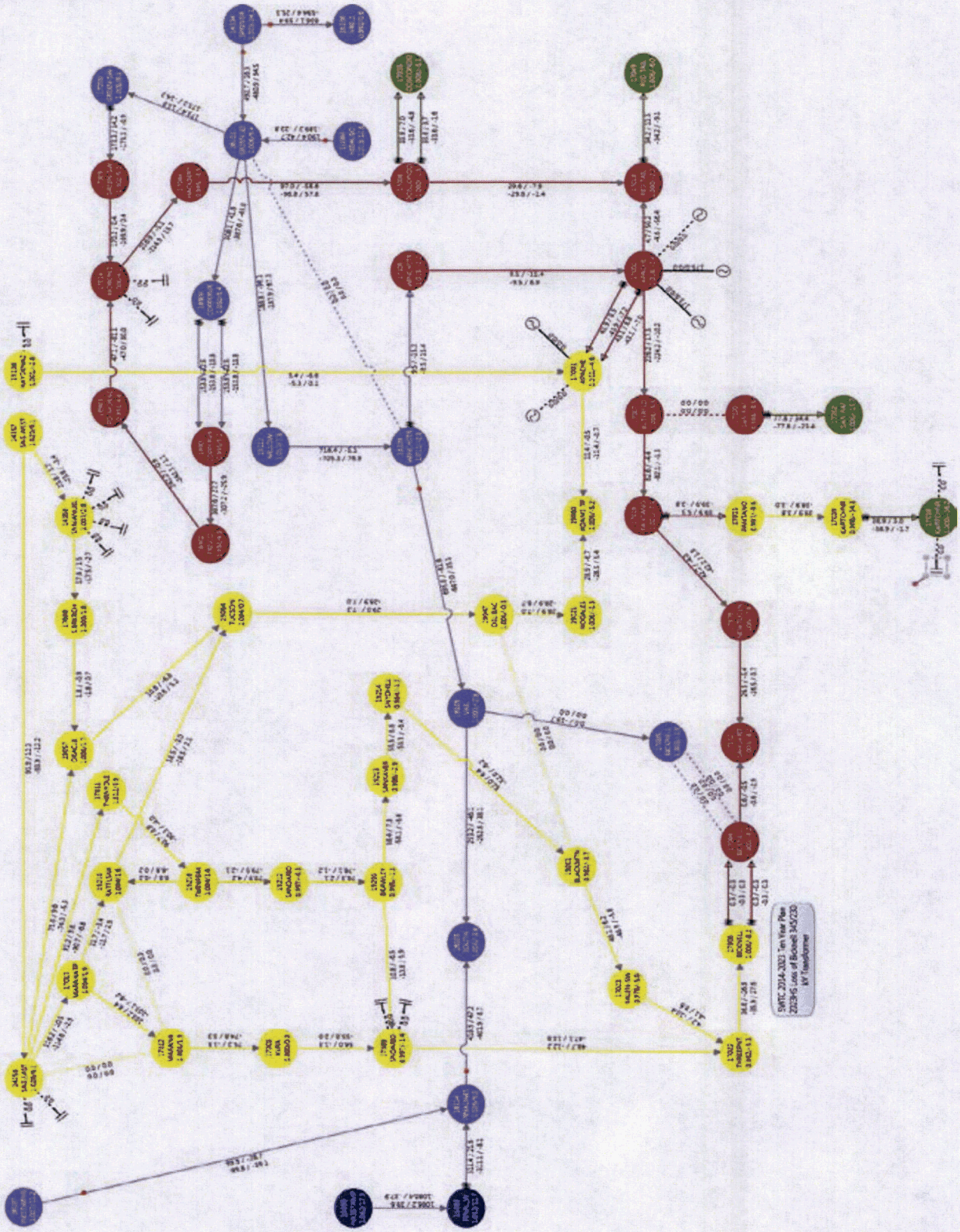
2023HS Southwest Transmission Cooperative Base System with Marana to Avra 115 kV Line out of service



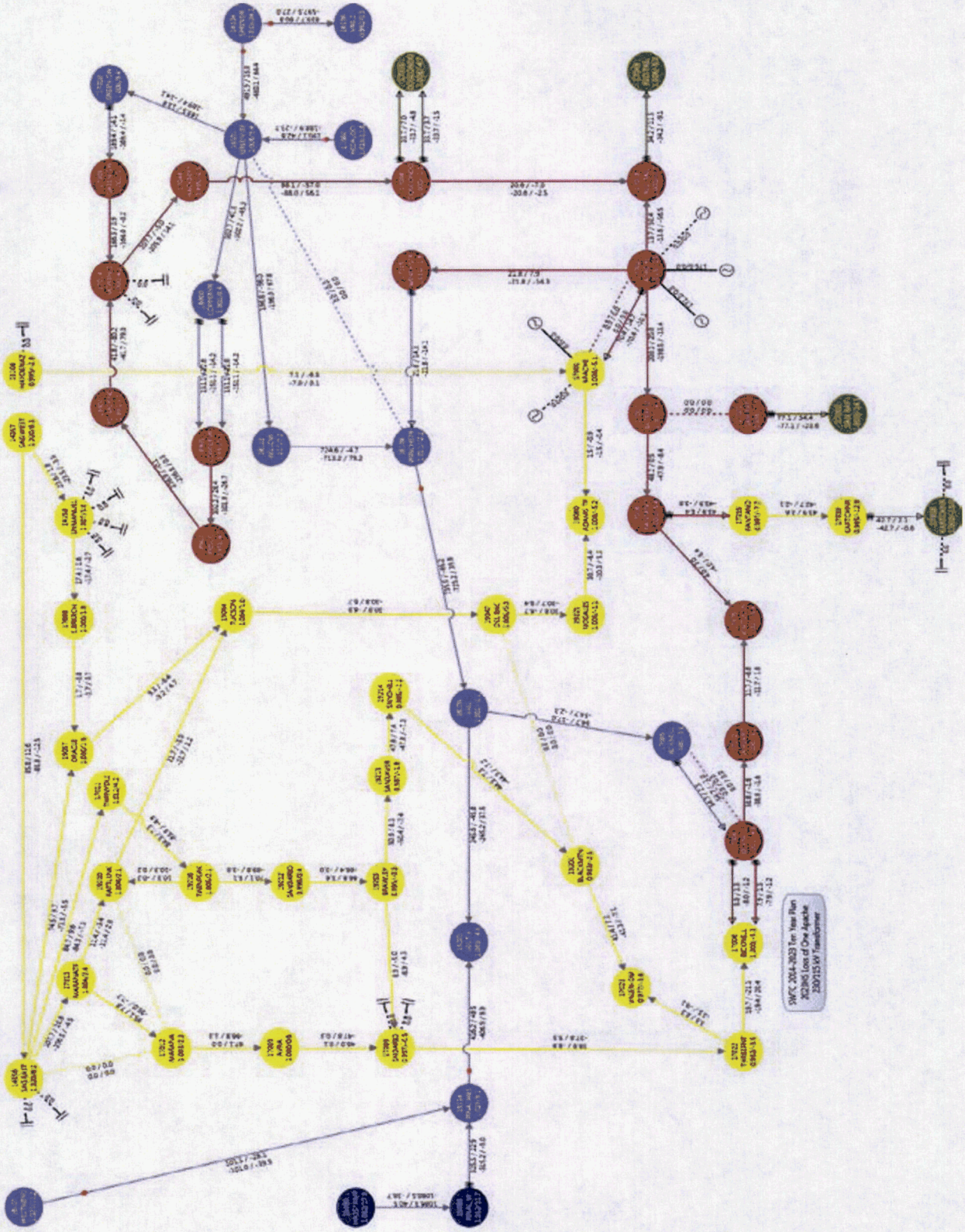
2023HS Southwest Transmission Cooperative Base System with Green-SW 345/230 kV Transformer out of service



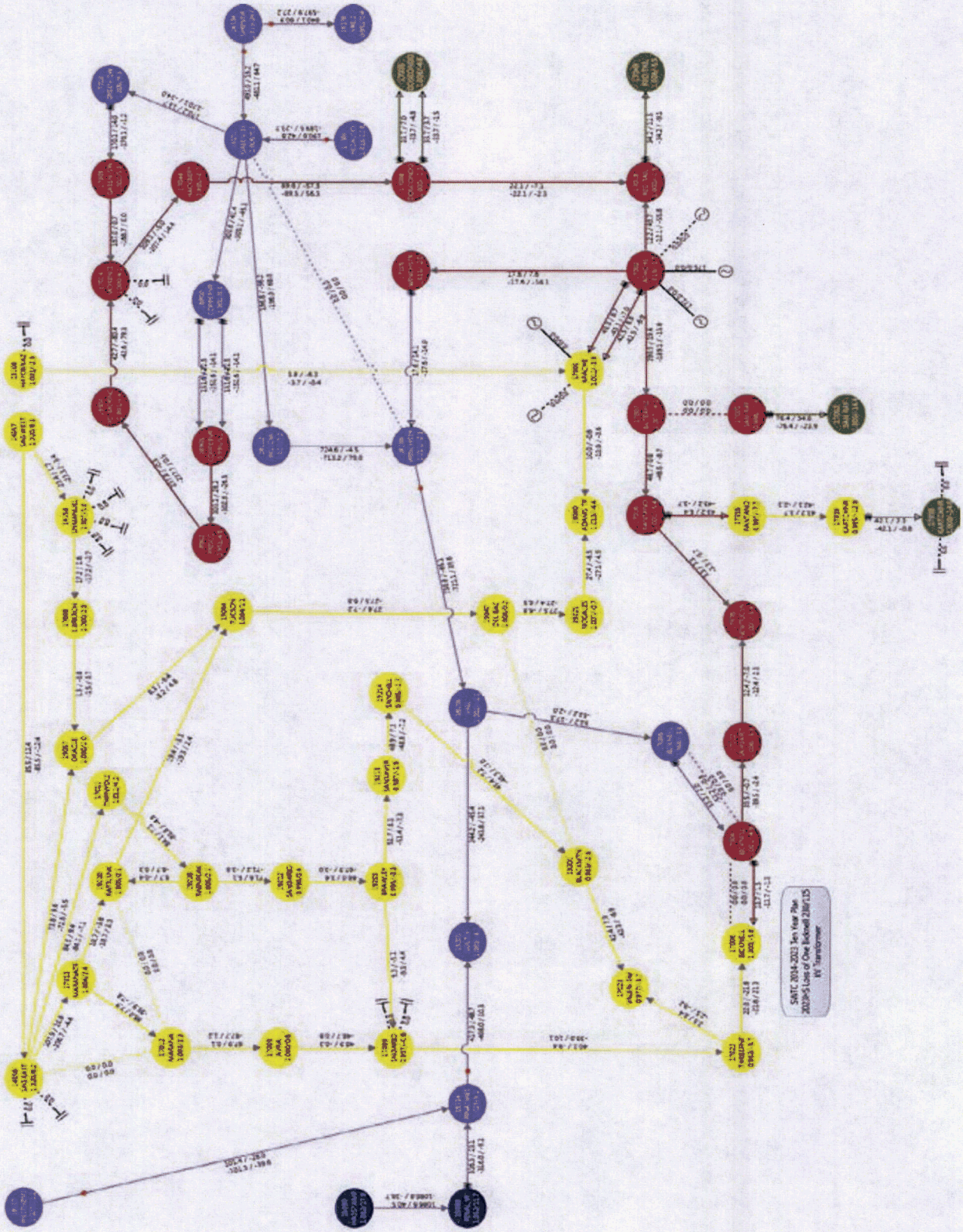
2023HS Southwest Transmission Cooperative Base System with Bicknell 345/230 kV Transformer out of service



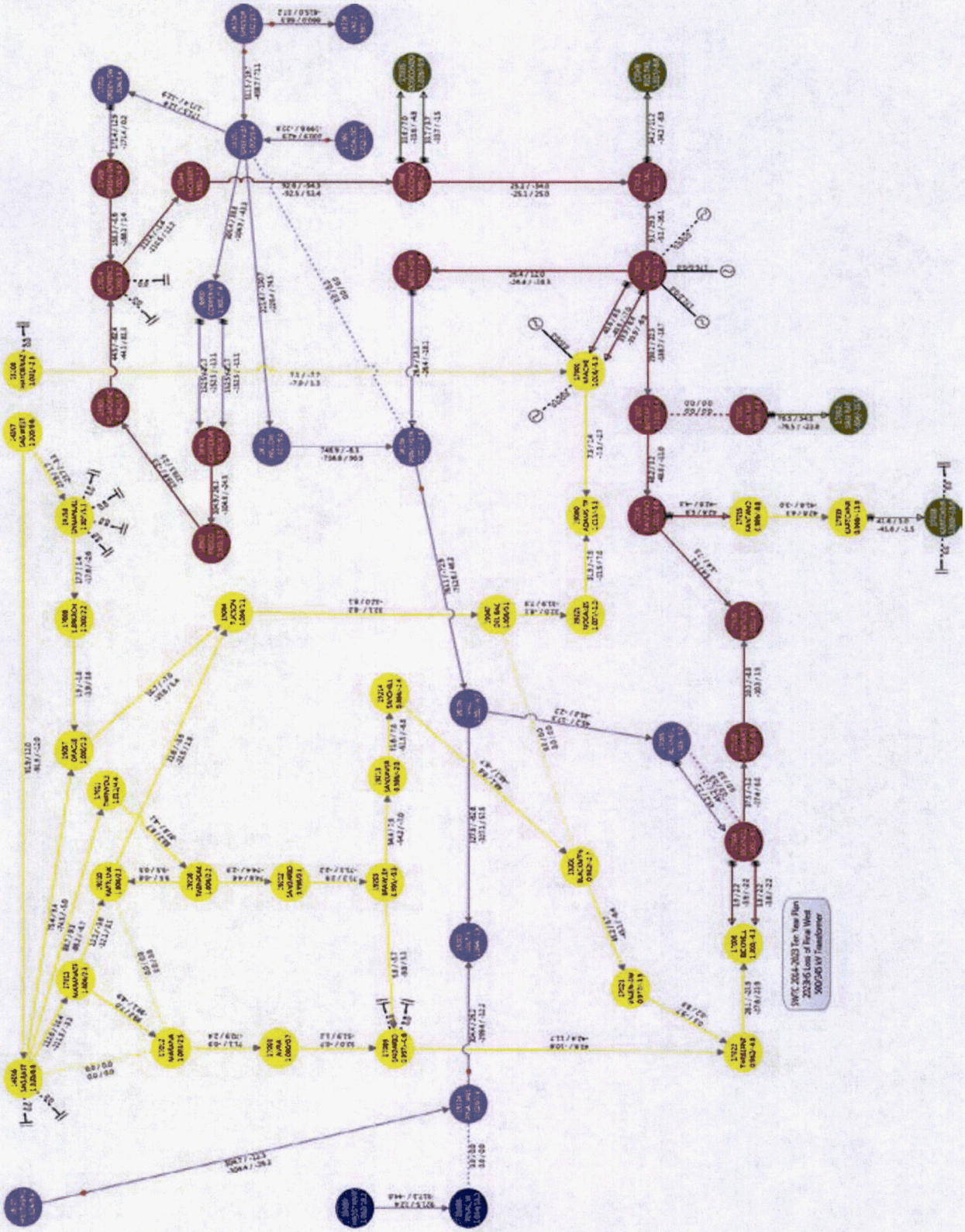
2023HS Southwest Transmission Cooperative Base System with one Apache 230/115 kV Transformer out of service



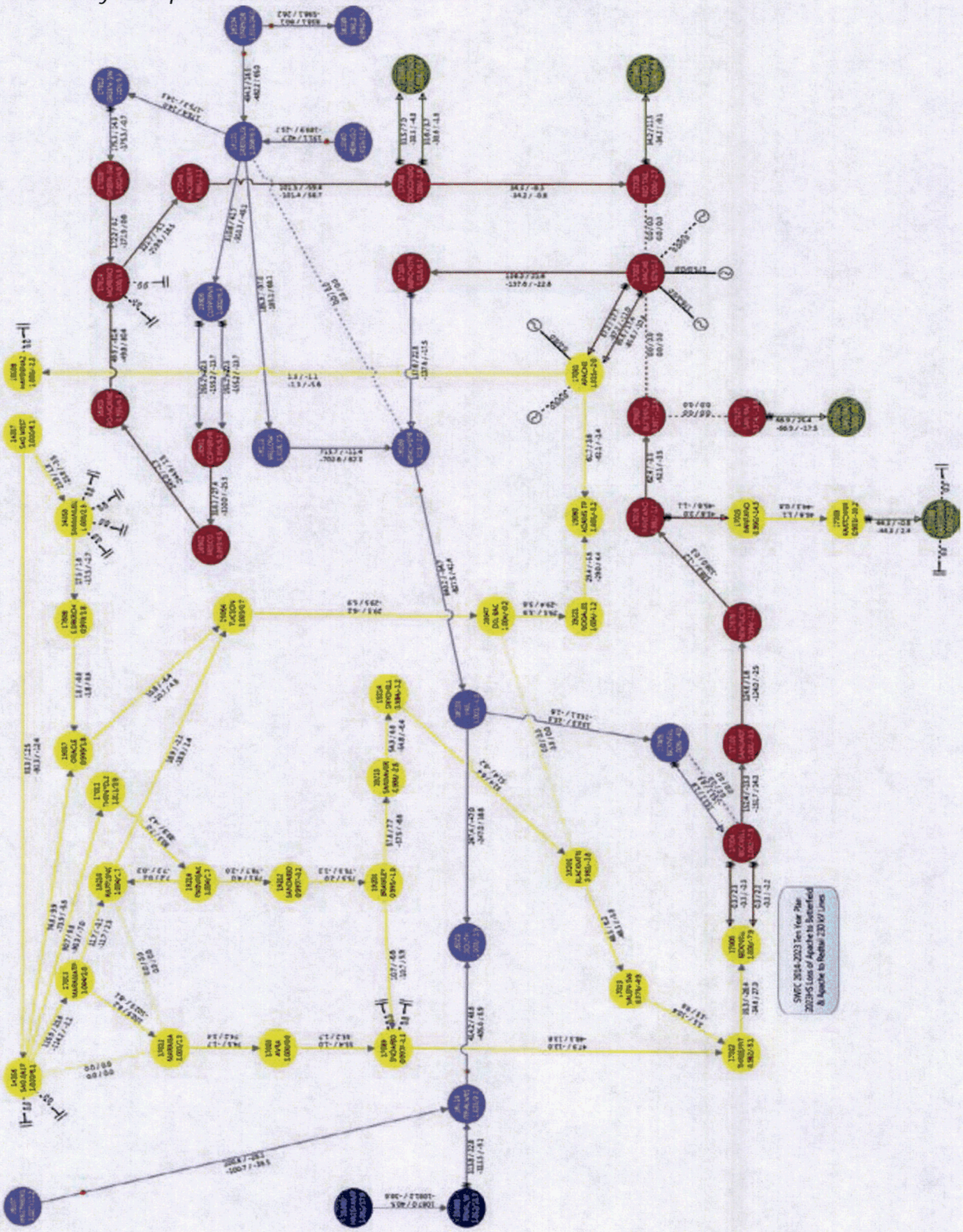
2023HS Southwest Transmission Cooperative Base System with one Bicknell 230/115 kV Transformer out of service



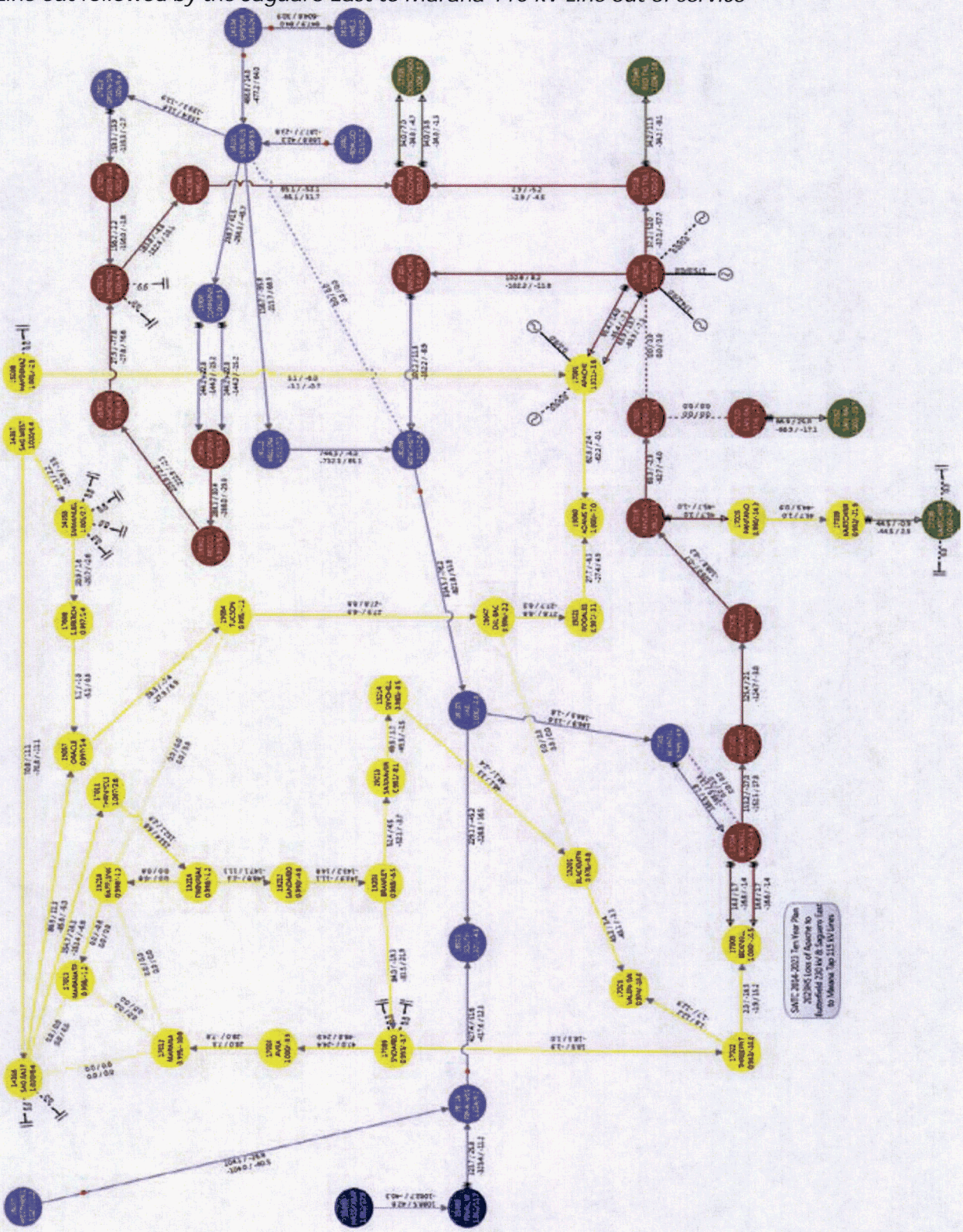
2023HS Southwest Transmission Cooperative Base System with Pinal West 500/345 kV Transformer out of service



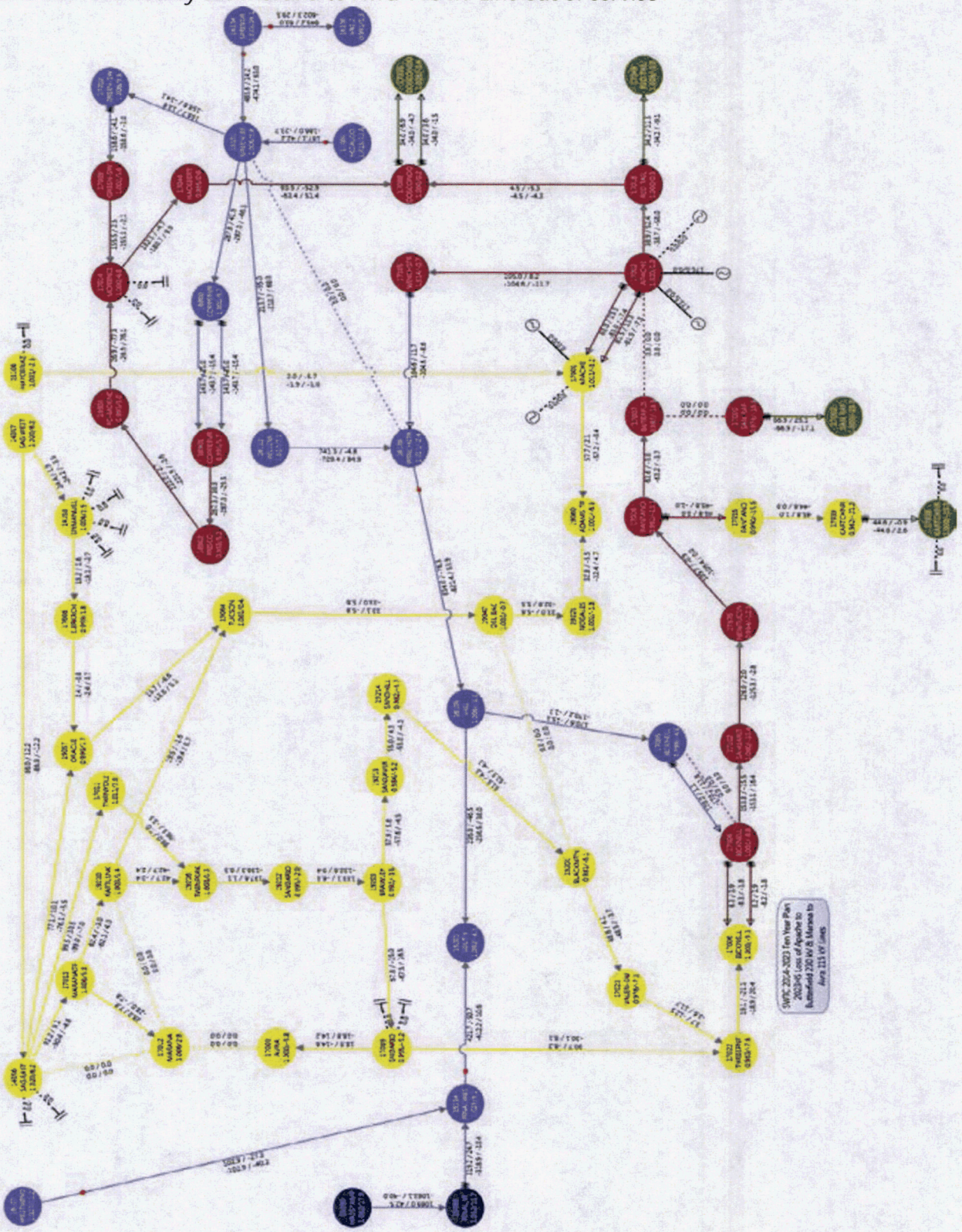
2023HS Southwest Transmission Cooperative Base System with Apache to Butterfield out followed by the Apache to Redtail 230 kV Line out of service



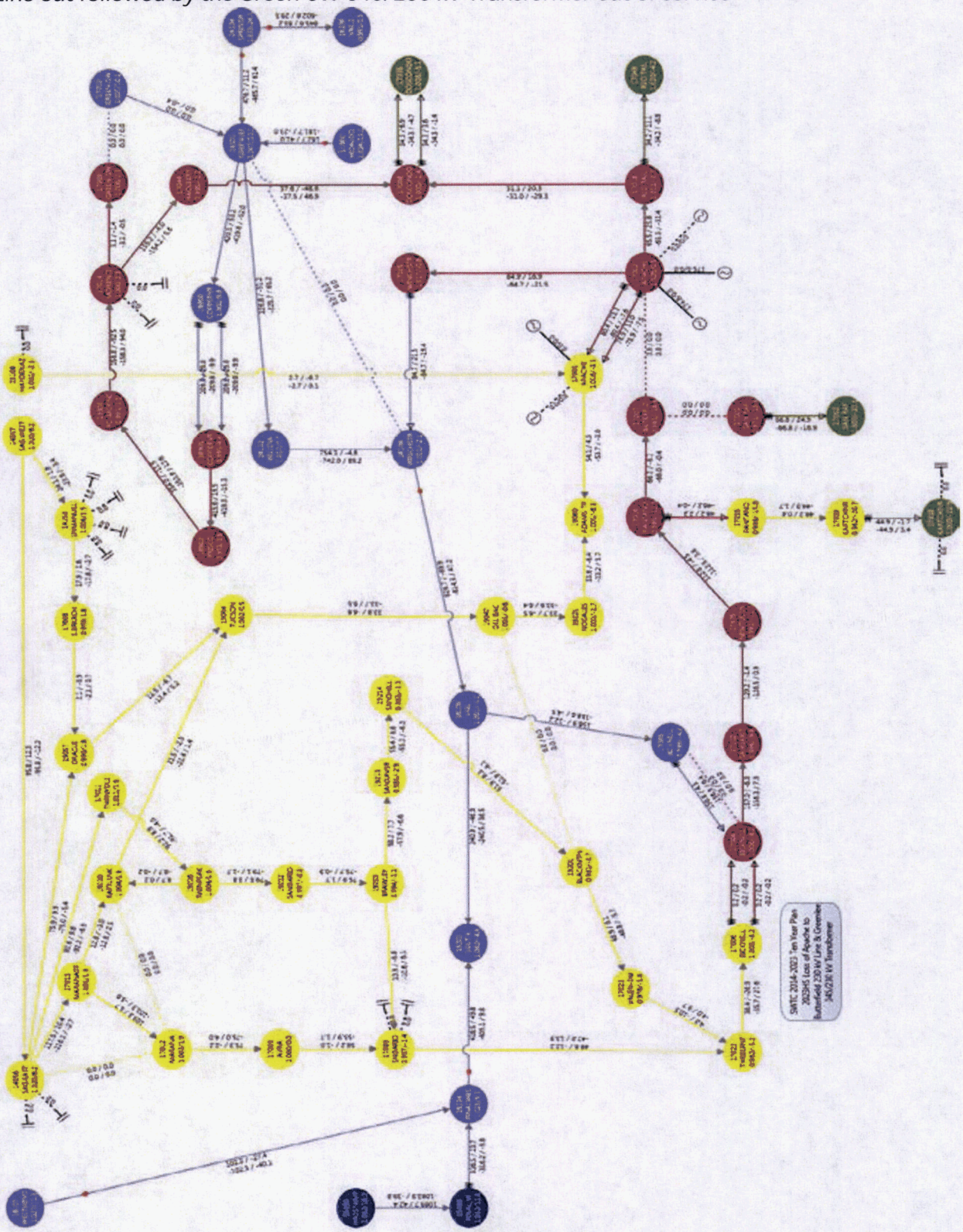
2023HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Saguaro East to Marana 115 kV Line out of service



2023HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Marana to Avra 115 kV Line out of service



2023HS Southwest Transmission Cooperative Base System with Apache to Butterfield 230 kV Line out followed by the Green-SW 345/230 kV Transformer out of service



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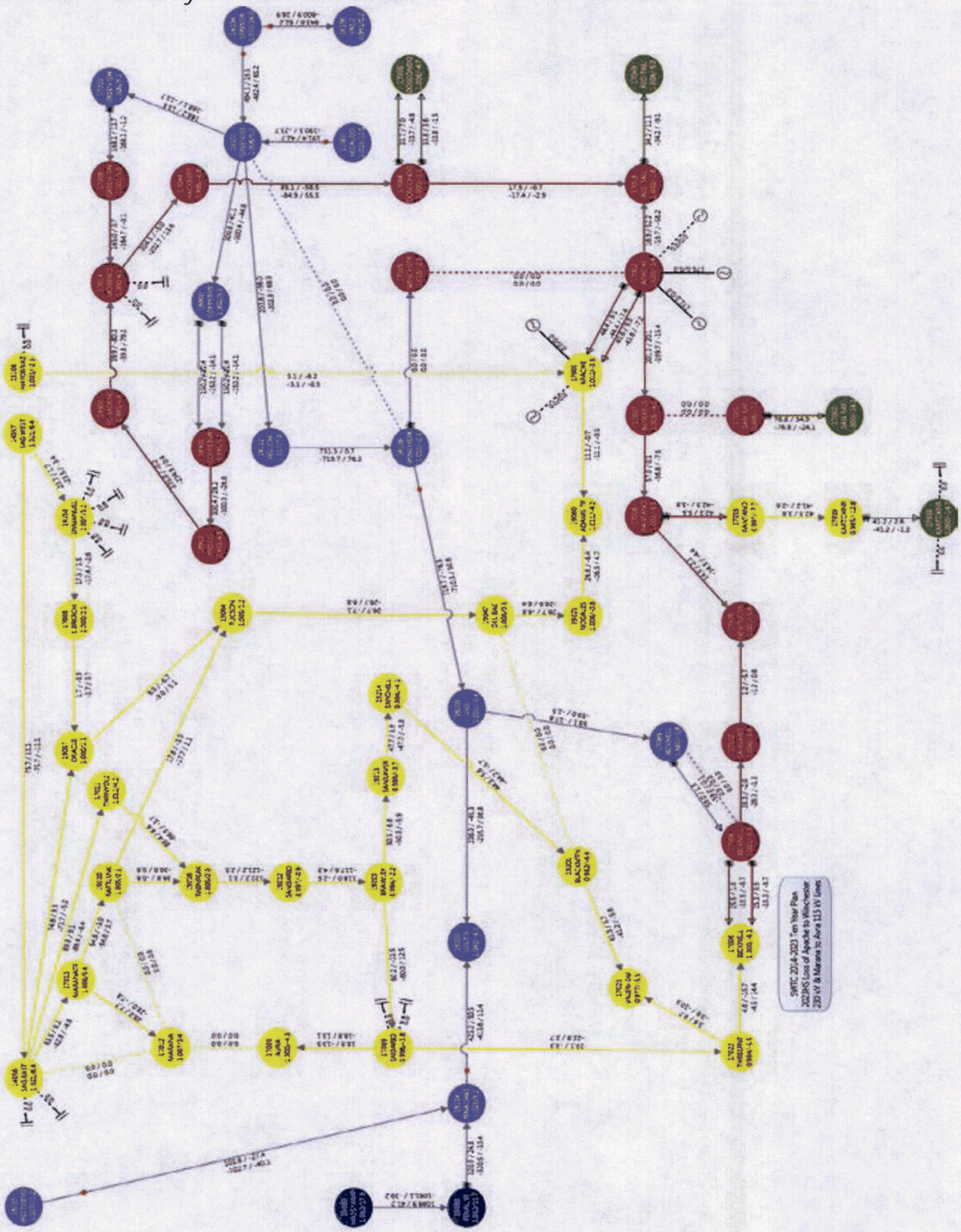
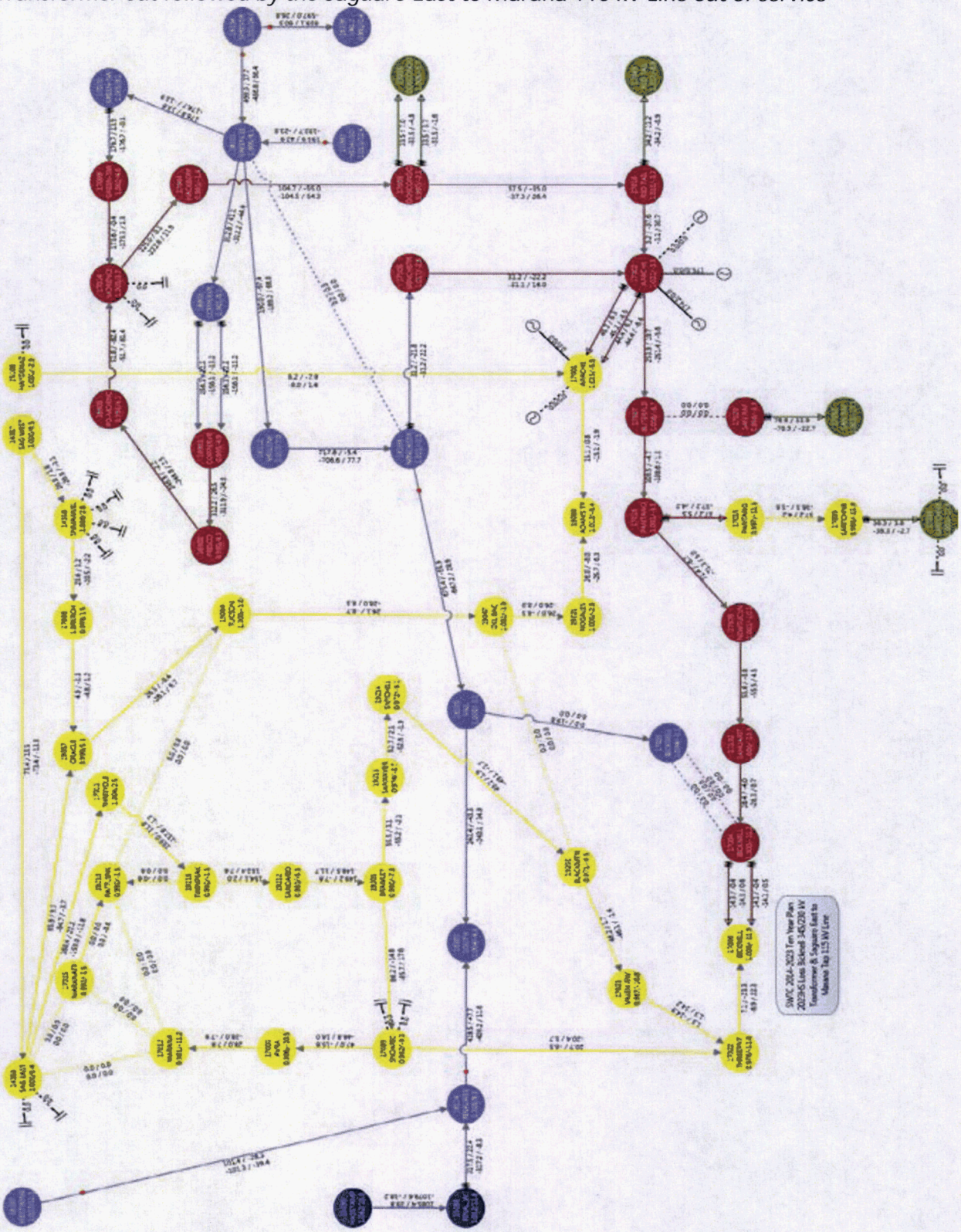
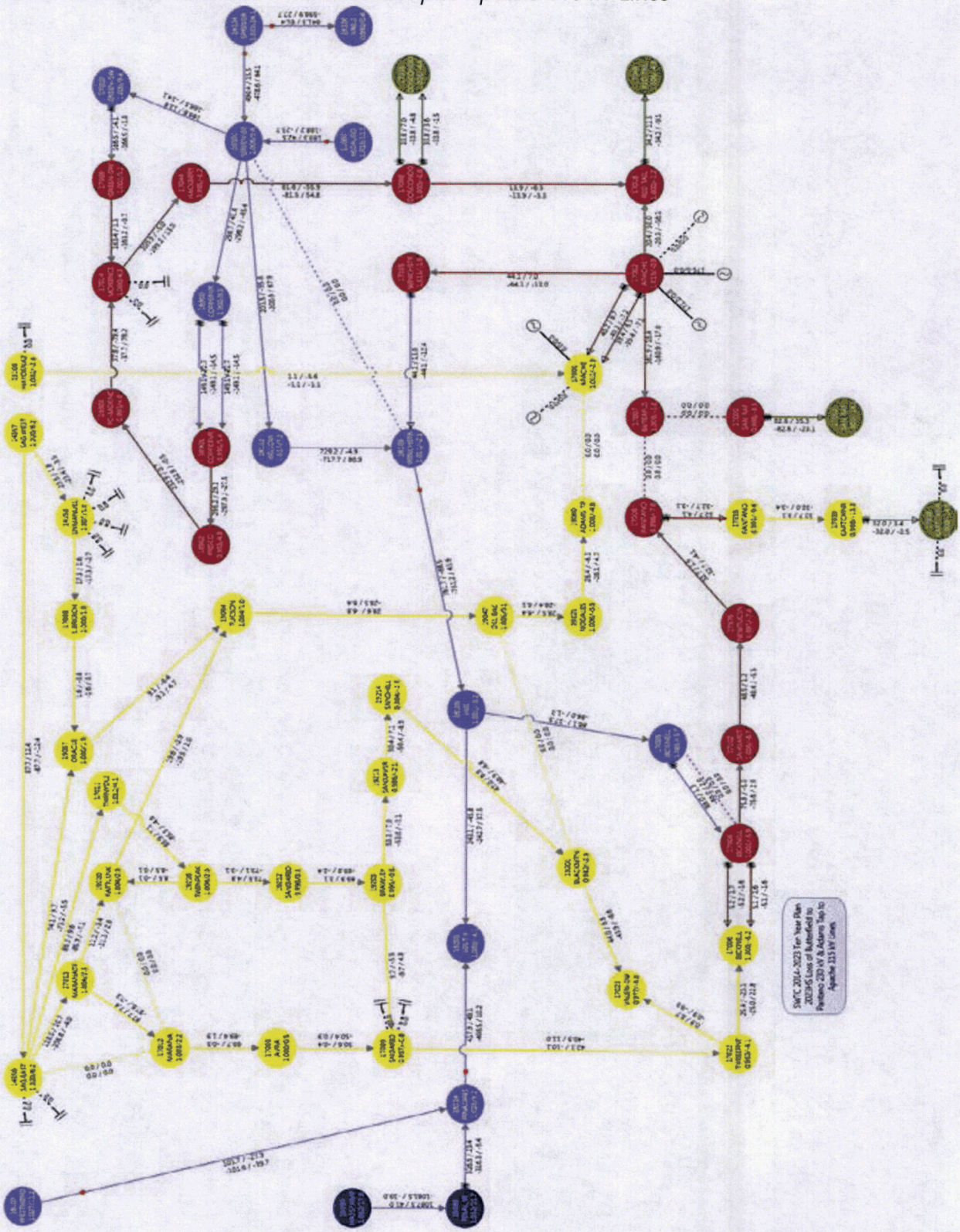


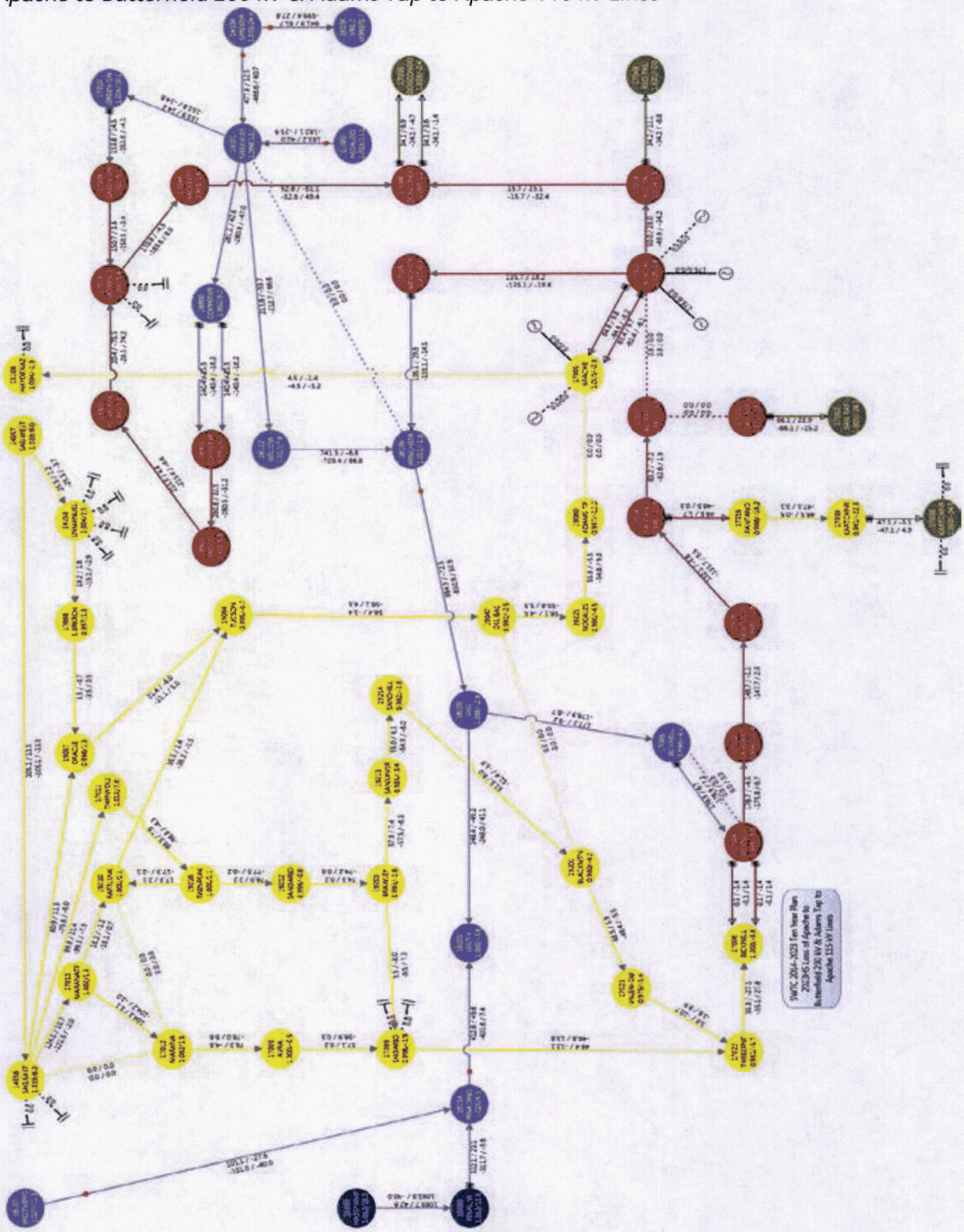
2023HS Southwest Transmission Cooperative Base System with Greenlee 345/230 kV Transformer out followed by the Saguaro East to Marana 115 kV Line out of service



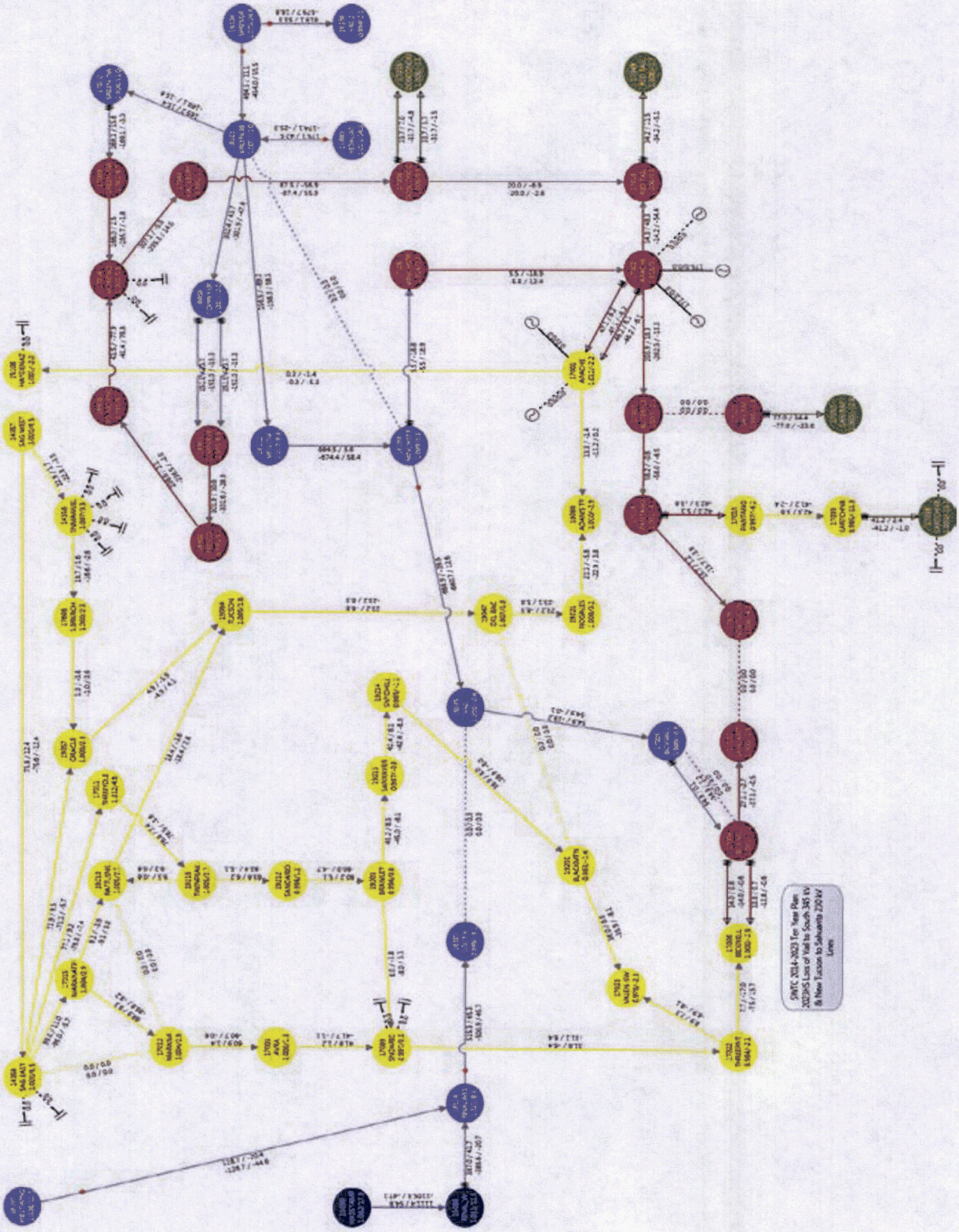
2023HS Southwest Transmission Cooperative Base System with Common Corridor outage of the Butterfield to Pantano 230 kV & Adams Tap to Apache 115 kV Lines



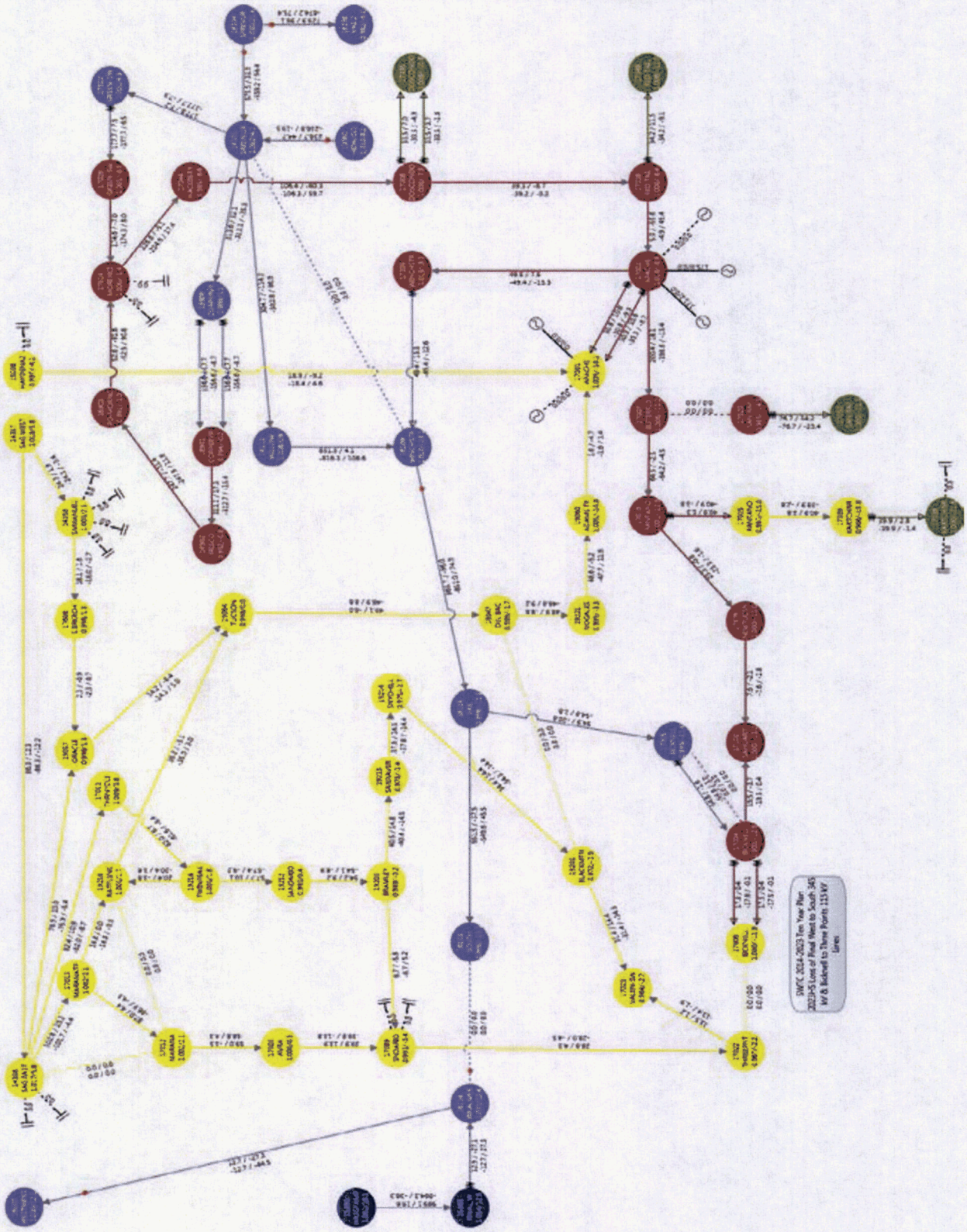
2023HS Southwest Transmission Cooperative Base System with Common Corridor outage of the Apache to Butterfield 230 kV & Adams Tap to Apache 115 kV Lines



2023HS Southwest Transmission Cooperative Base System with Common Corridor outage of the Vail to South 345 kV & New Tucson to Sahuarita 230 kV Lines



2023HS Southwest Transmission Cooperative Base System with Common Corridor outage of the Pinal West to South 345 kV & Bicknell to Three Points 115 kV Lines



APPENDIX D

REACTIVE MARGIN Q-V PLOTS

2014HS Apache – Butterfield 230 kV Outage 169
2014HS Apache – Redtail 230 kV Outage. 172
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2014HS Saguaro East – Marana Tap 115 kV Outage 178
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2019HS Apache – Butterfield 230 kV Outage 193
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2019HS Saguaro East – Marana Tap 115 kV Outage 202
2019LW Apache – Butterfield 230 kV Outage 205
2019LW Apache – Redtail 230 kV Outage 208
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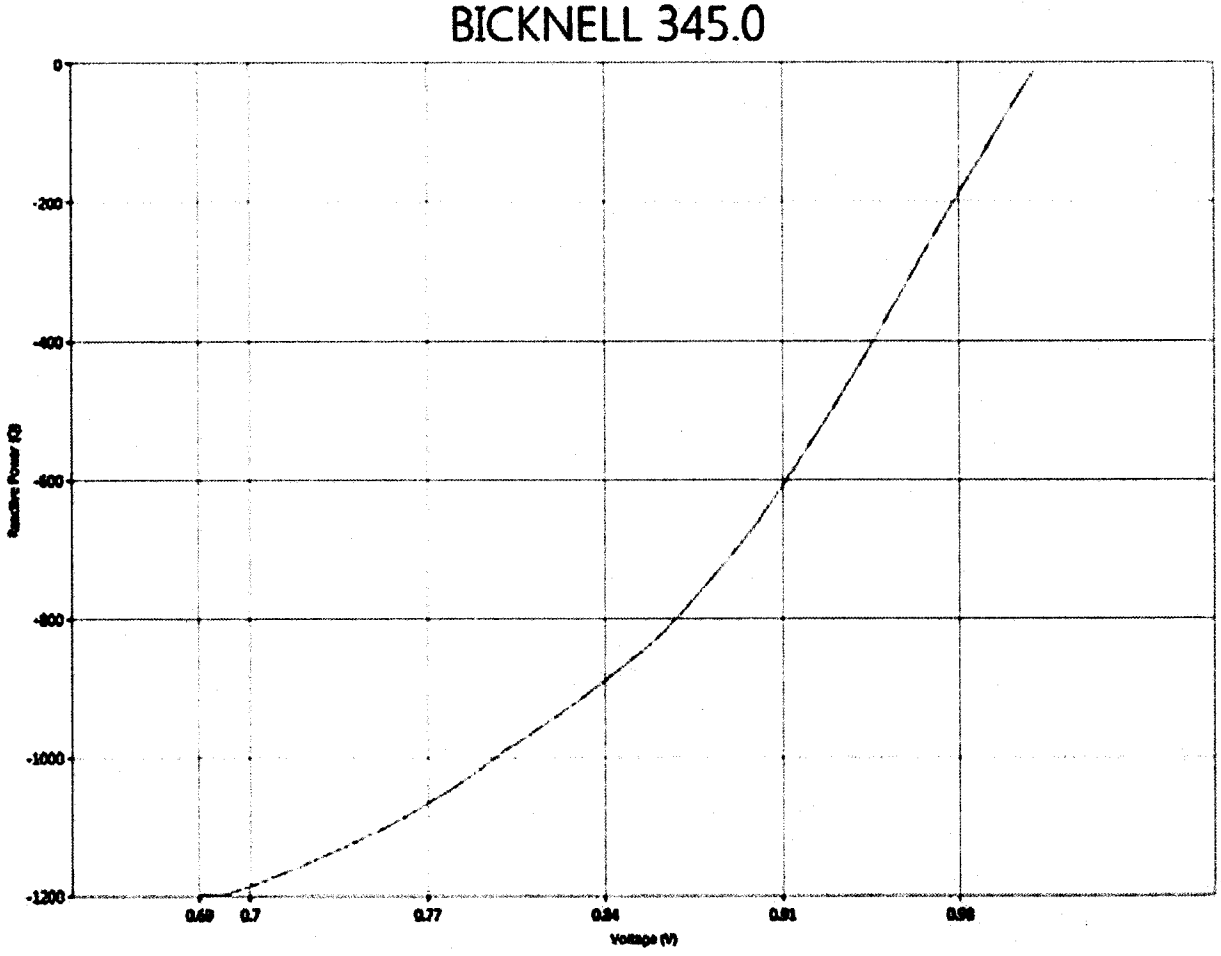
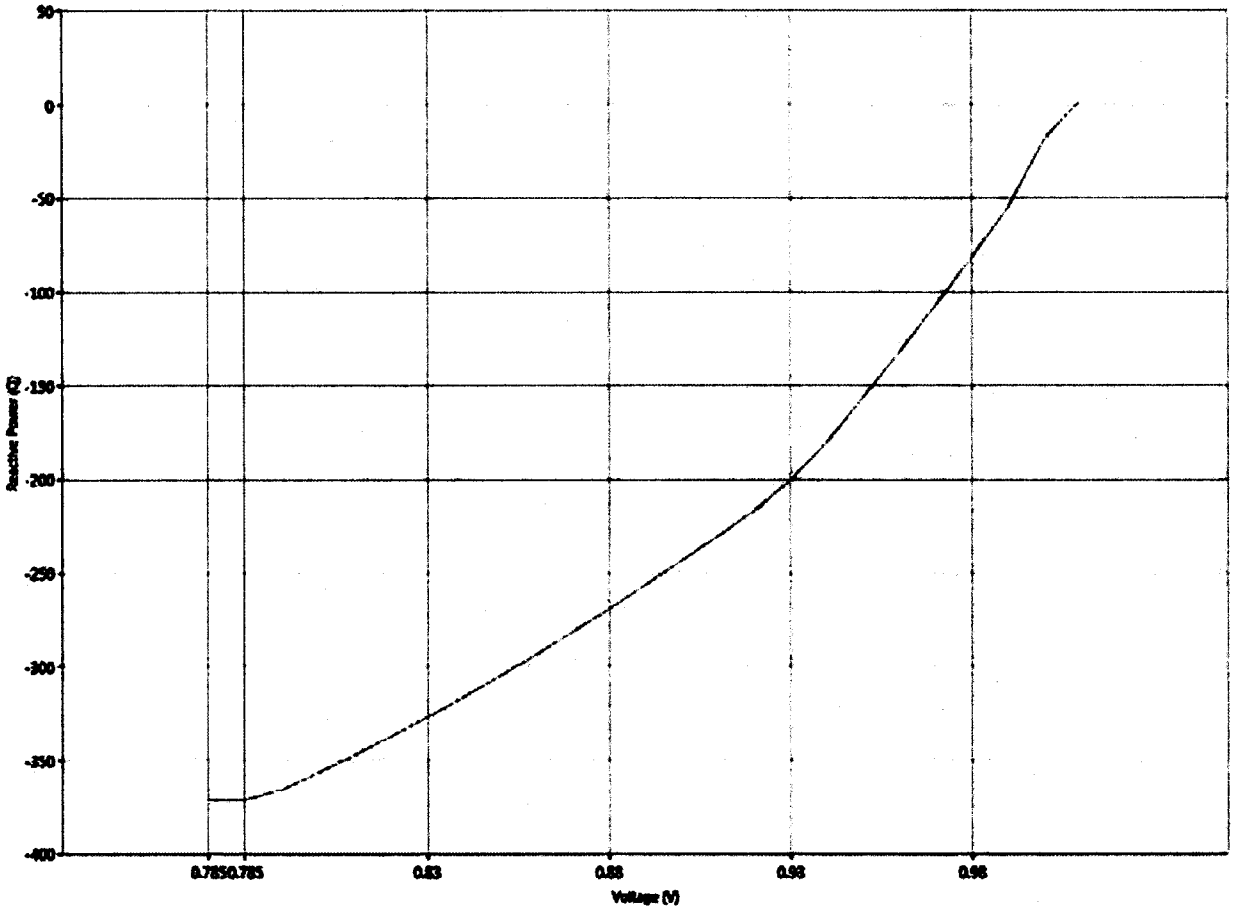
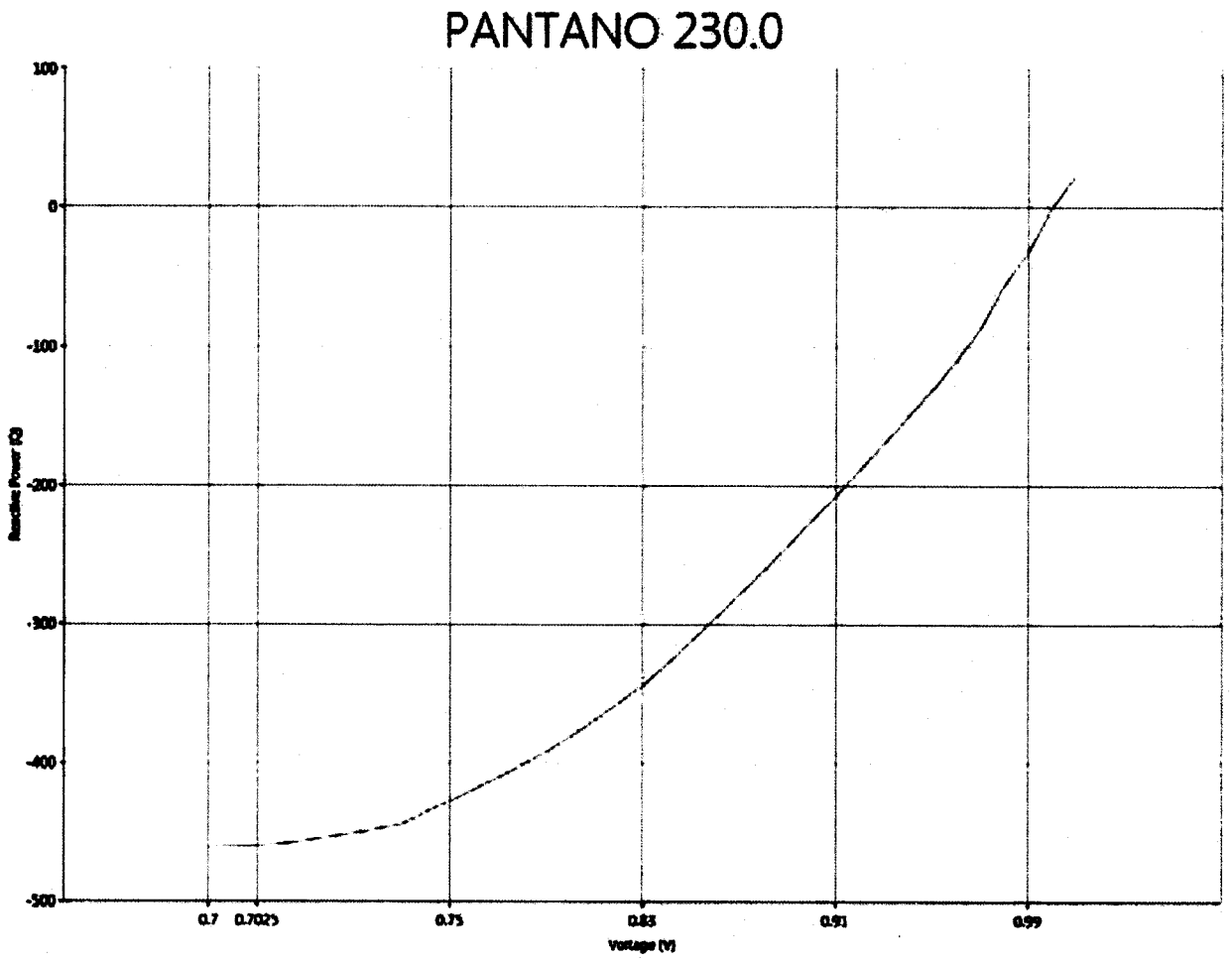
2019LW Saguaro East – Marana Tap 115 kV Outage 214
2023HS Apache – Butterfield 230 kV Outage 217
2023HS Apache – Redtail 230 kV Outage. 220
2023HS Bicknell – Vail 345 kV Outage 223
2023HS Saguaro East – MaranaTap 115 kV Outage. 226
2023LW Apache – Butterfield 230 kV Outage 229
2023LW Apache – Redtail 230 kV Outage 232
2023LW Bicknell – Vail 345 kV Outage. 235
2023LW Saguaro East – Marana Tap 115 kV Outage 238

2014HS – Apache to Butterfield 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

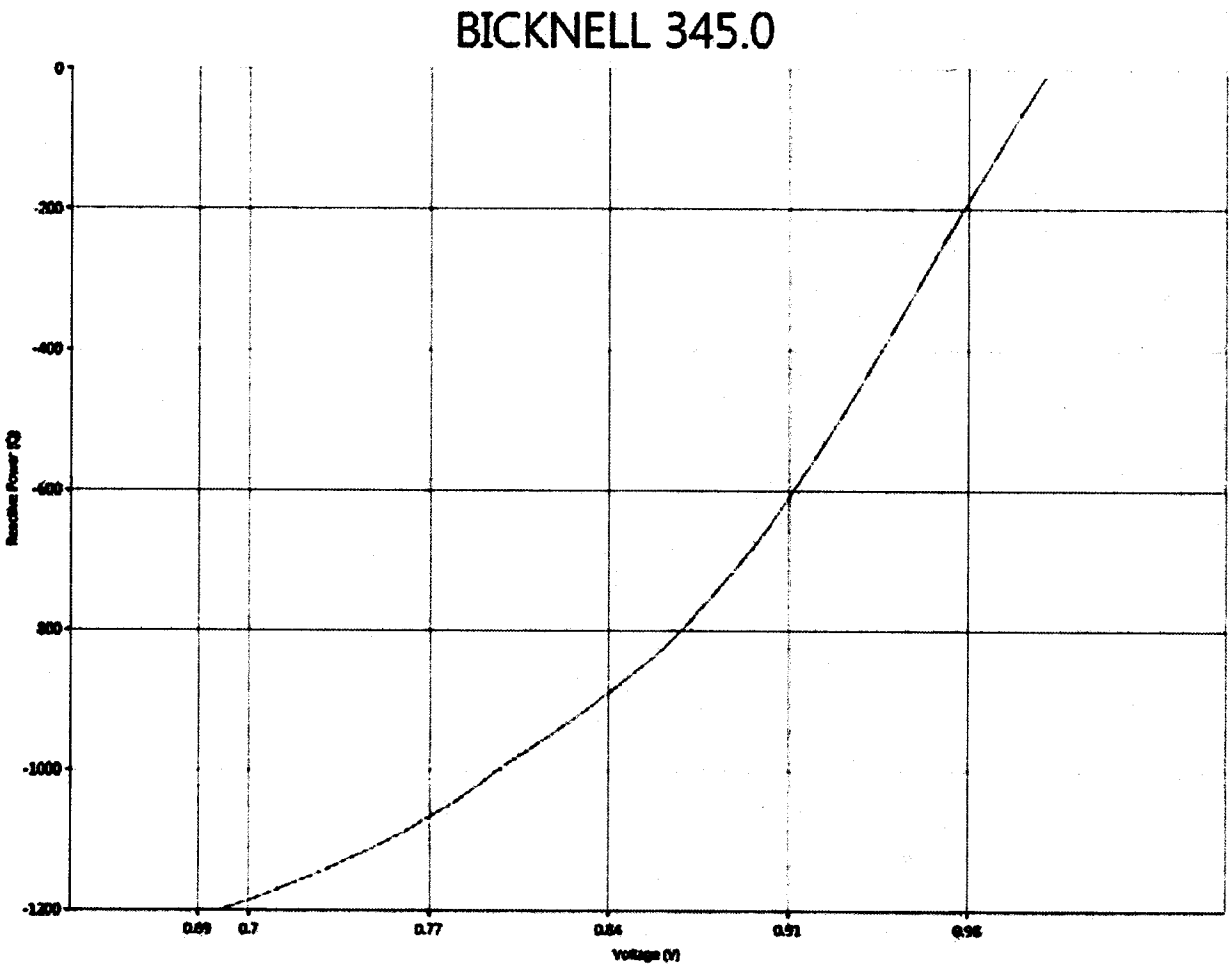


MARANA 115.0

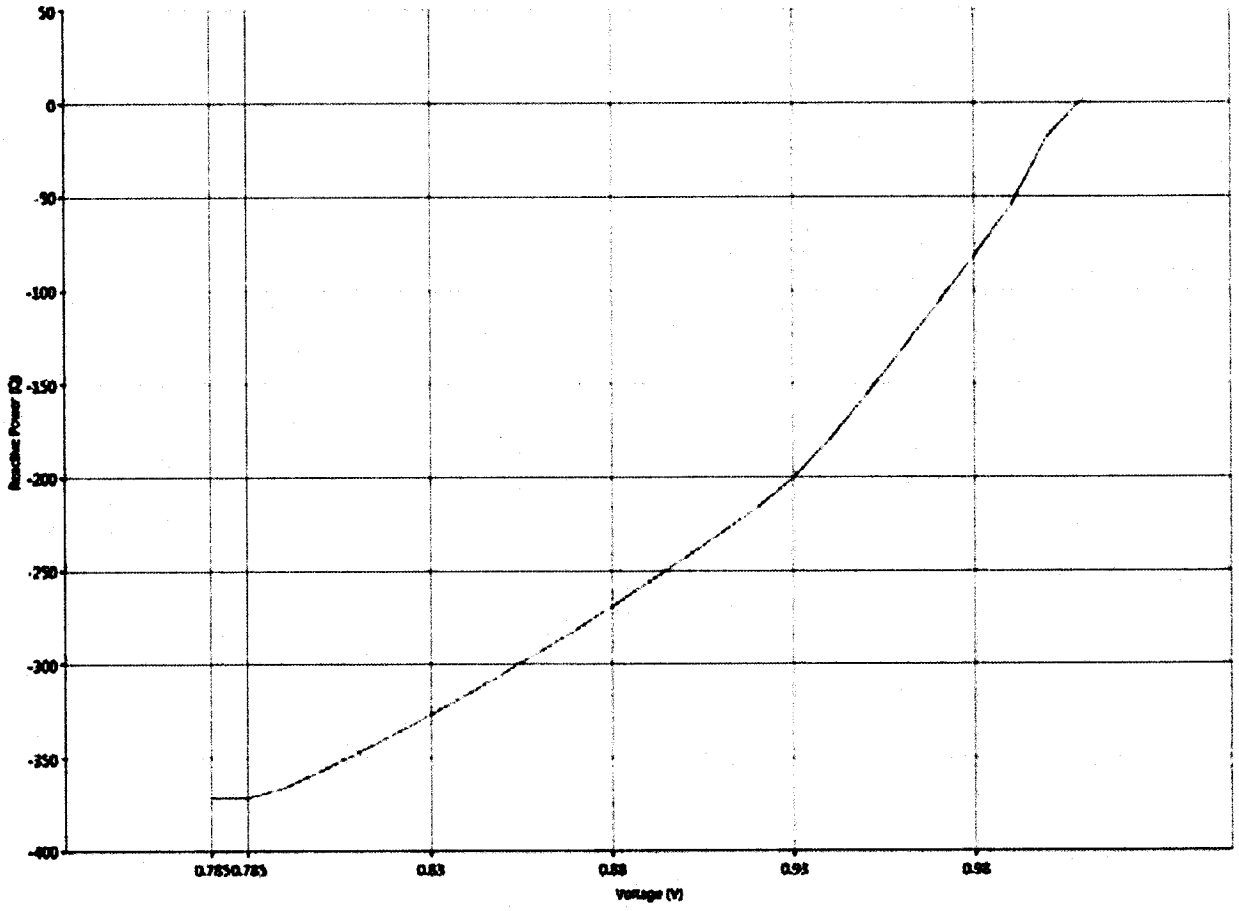

90
0
-50
-100
-150
-200
-250
-300
-350
-400
Reactive Power (Q)
0.7850.785
0.83
0.88
0.93
0.98
Voltage (V)

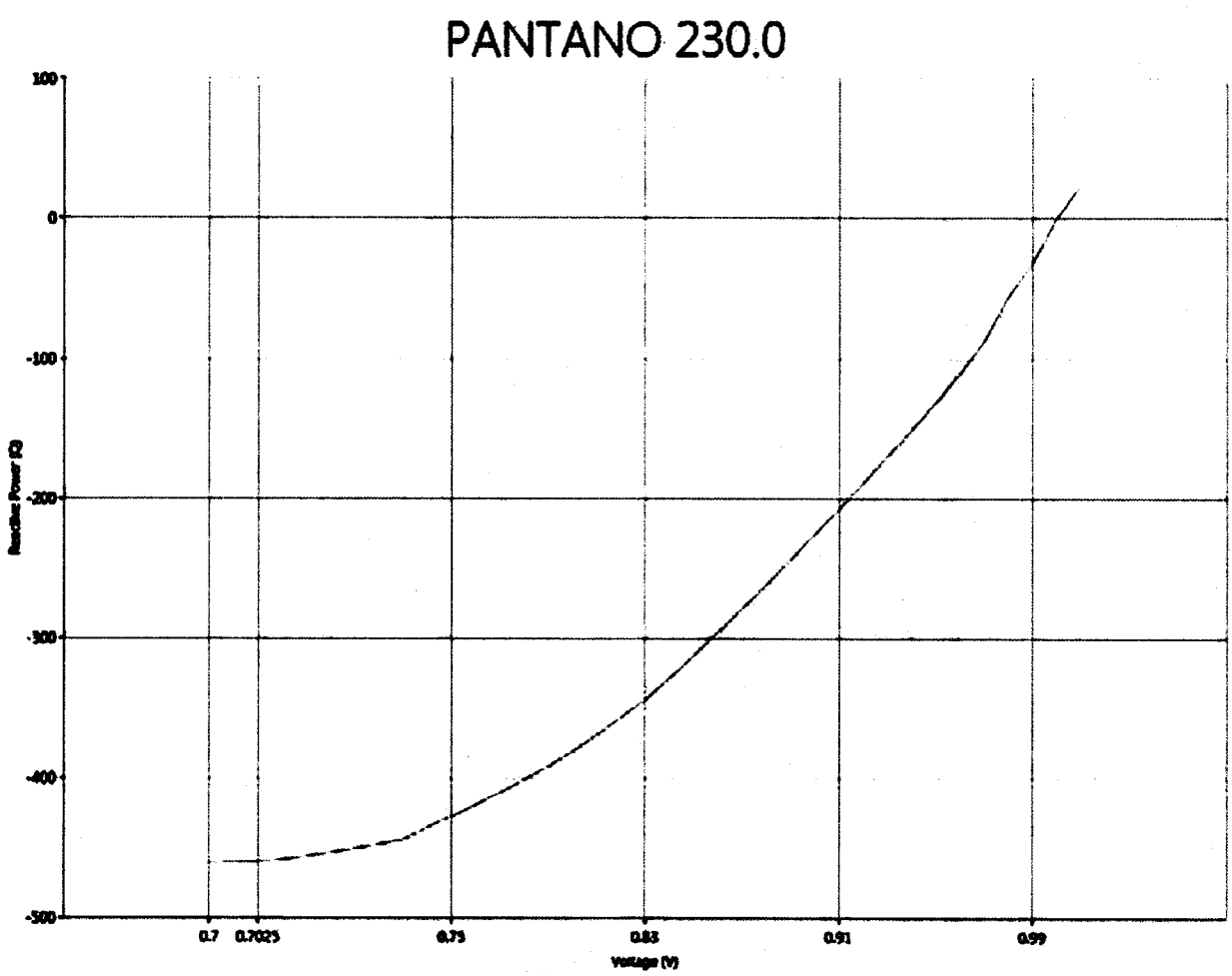

PANTANO 230.0
100
0
-100
-200
-300
-400
-500
Reactive Power (Q)
0.7
0.7025
0.75
0.83
0.91
0.99
Voltage (V)

2014HS – Apache to Redtail 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

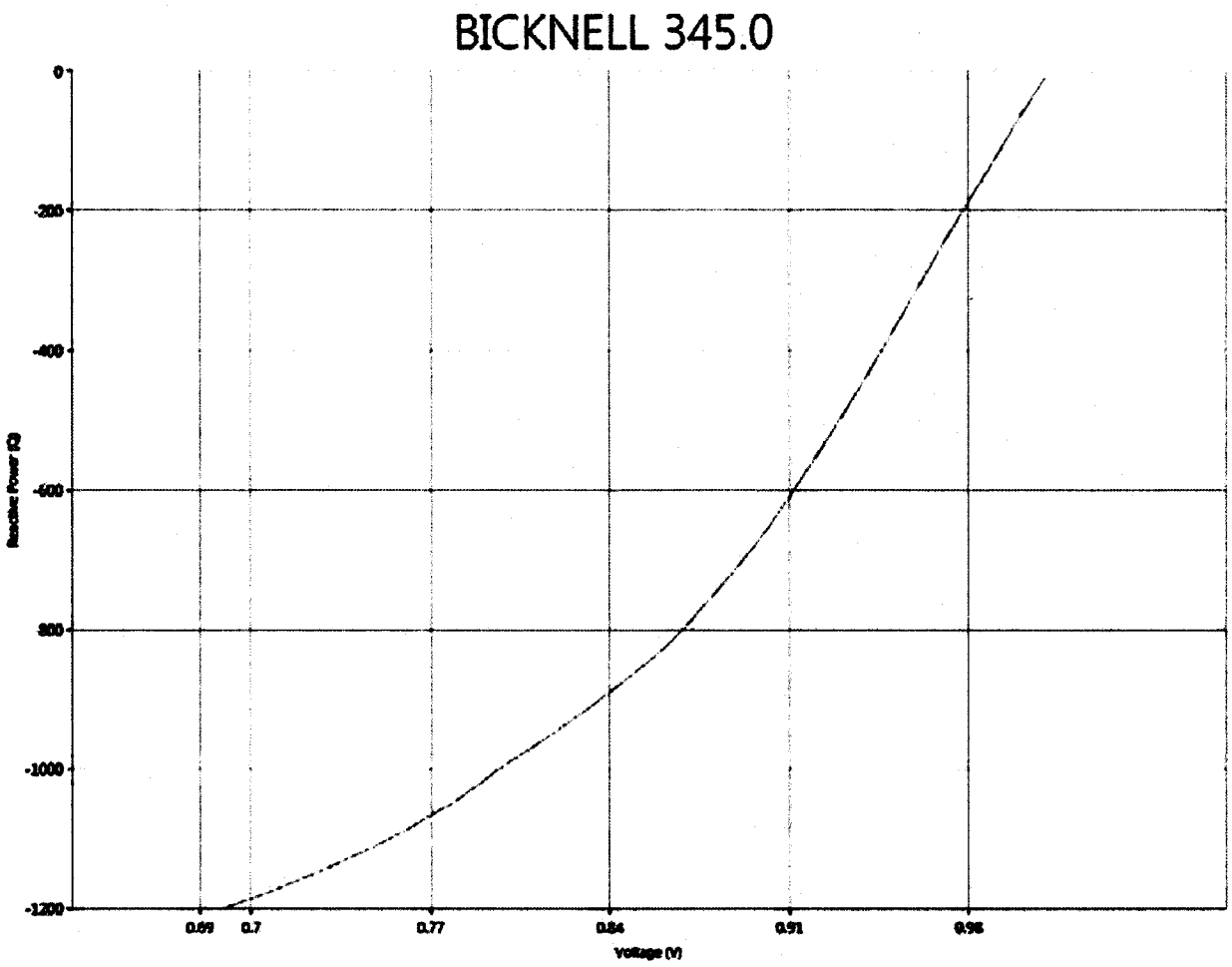


MARANA 115.0

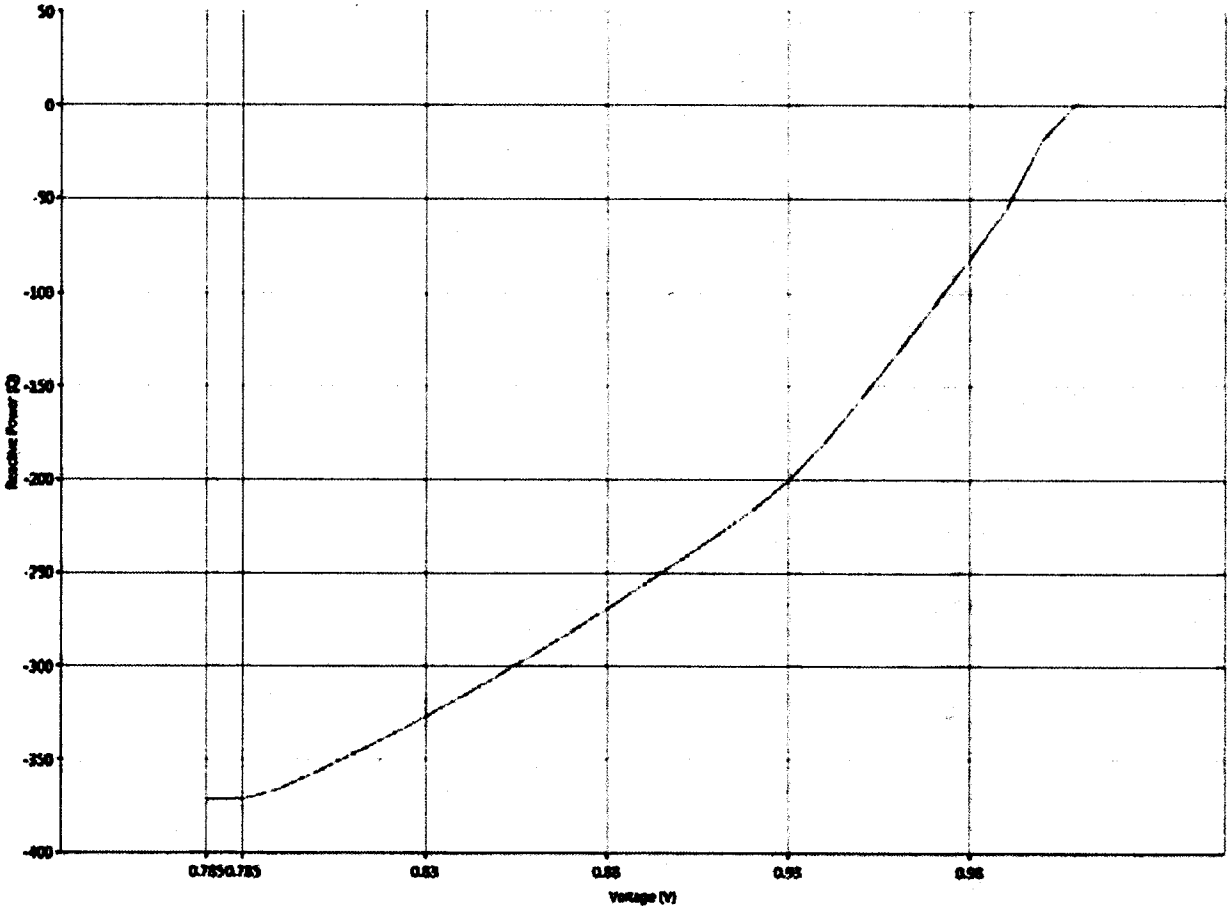

50
0
-50
-100
-150
-200
-250
-300
-350
-400
Reactive Power (Q)
0.7850.785
0.83
0.88
0.93
0.98
Voltage (V)

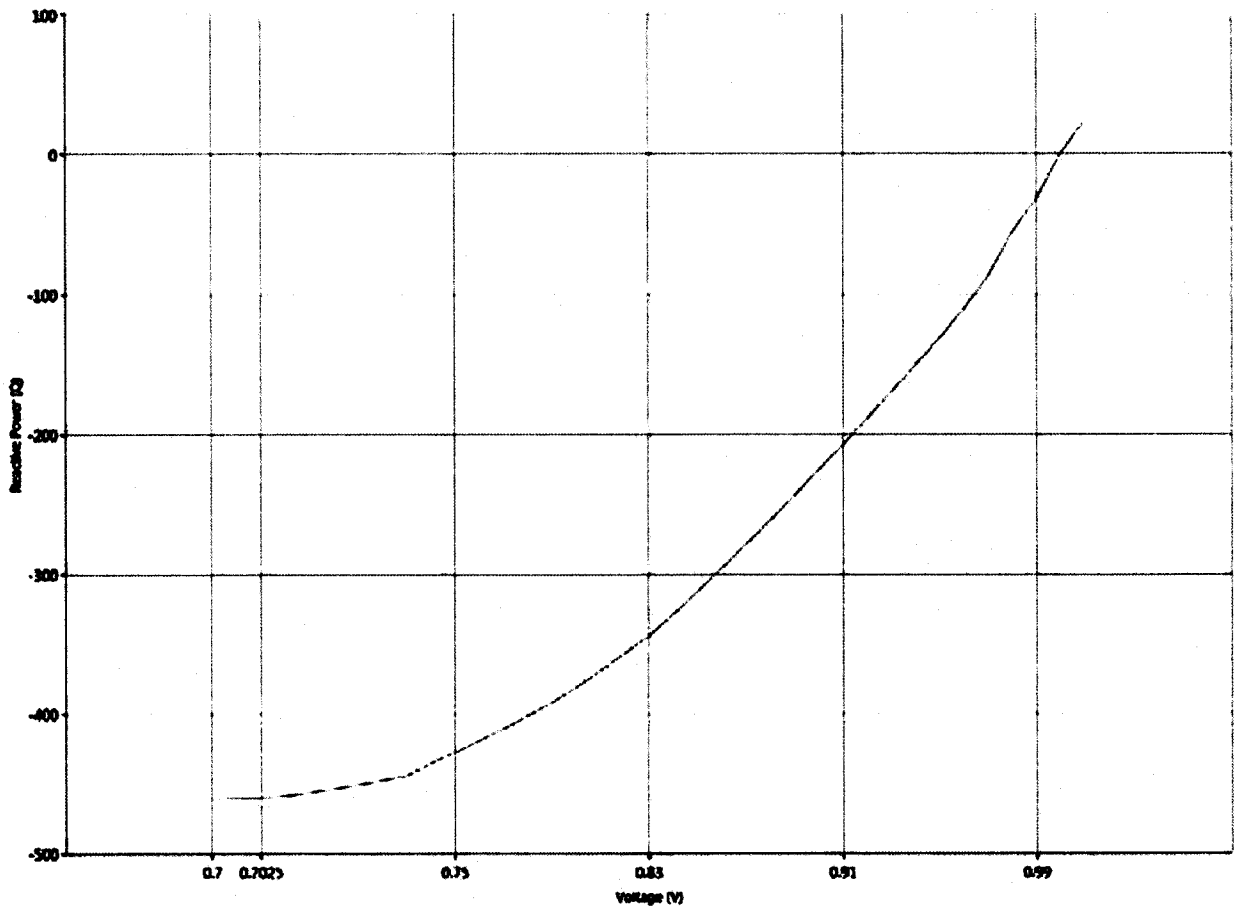

PANTANO 230.0
100
0
-100
-200
-300
-400
-500
0.7
0.7025
0.75
0.83
0.91
0.99
Voltage (V)

2014HS – Bicknell to Vail 345 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

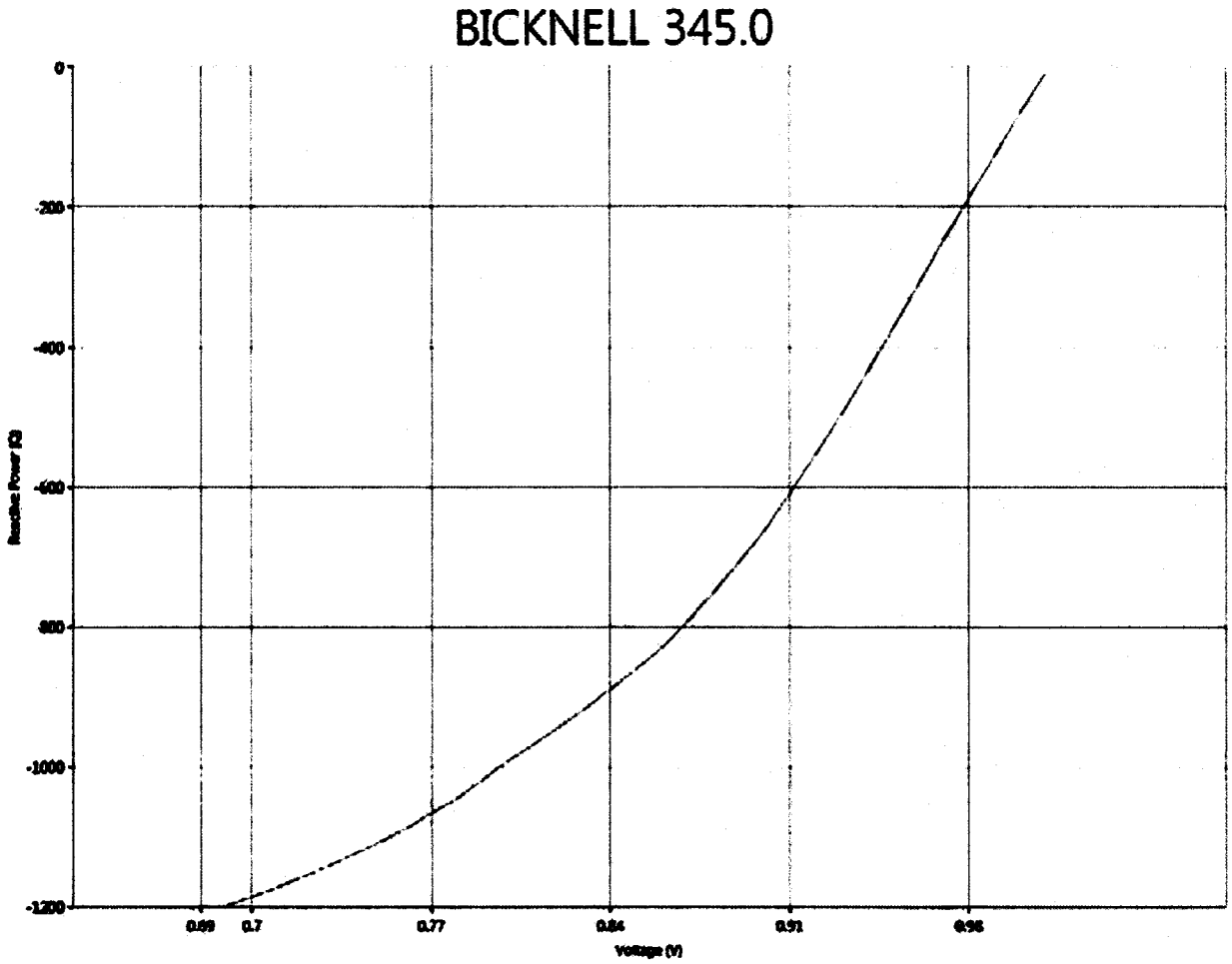


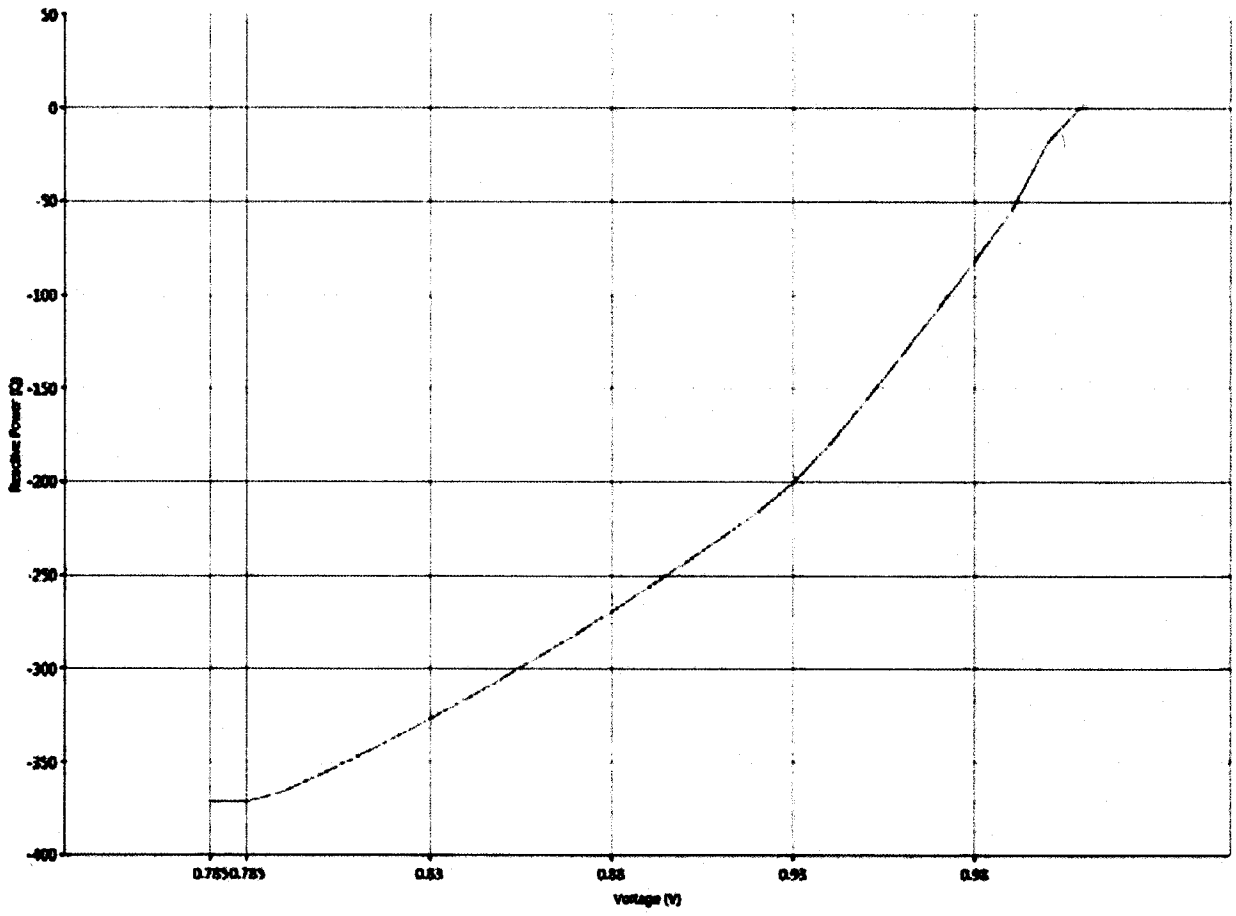
MARANA 115.0

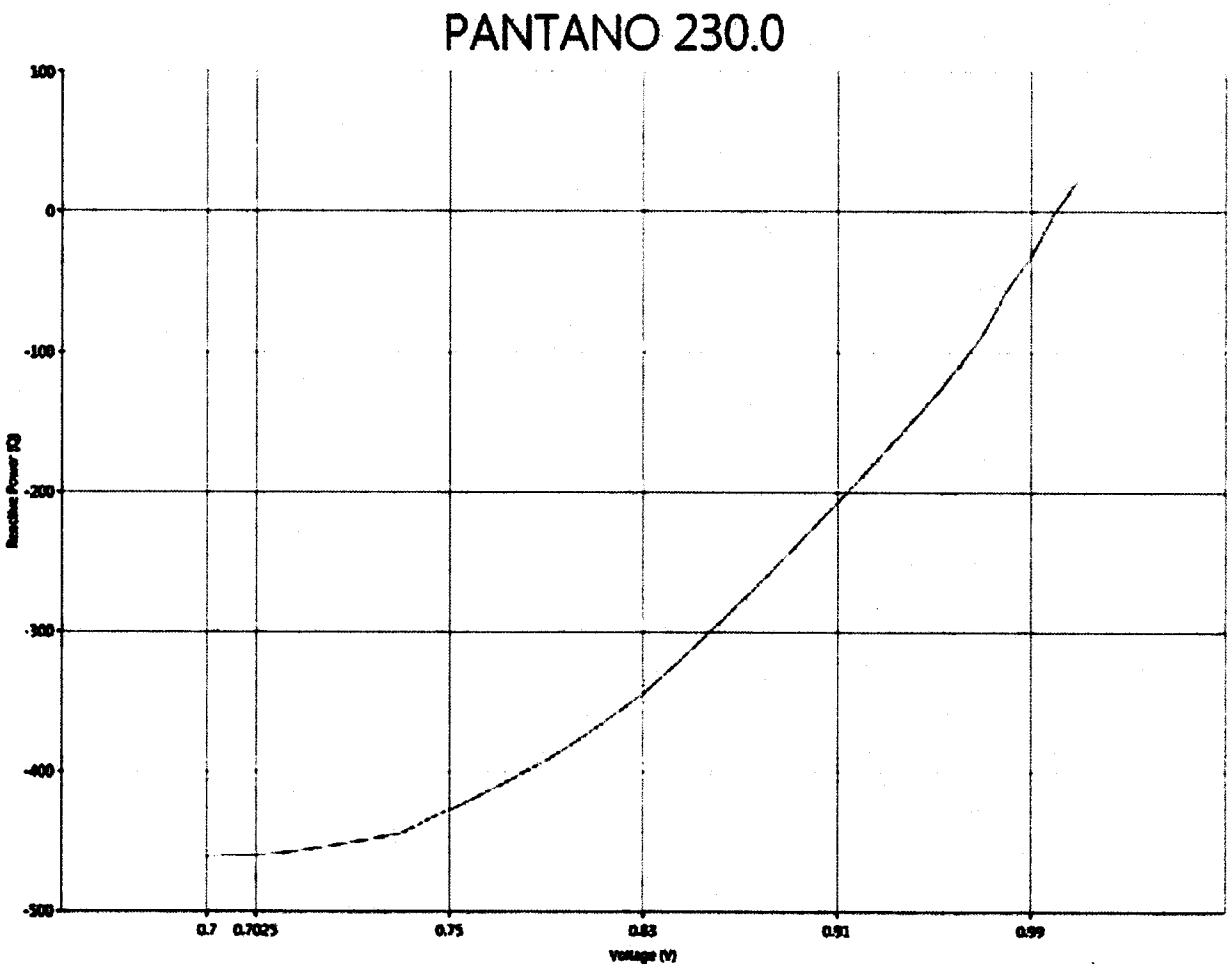

50
0
-50
-100
-150
-200
-250
-300
-350
-400
Reactive Power (Q)
0.785
0.785
0.83
0.88
0.93
0.98
Voltage (V)


PANTANO 230.0
100
0
-100
-200
-300
-400
-500
Reactive Power (Q)
0.7
0.7025
0.75
0.83
0.91
0.99
Voltage (V)

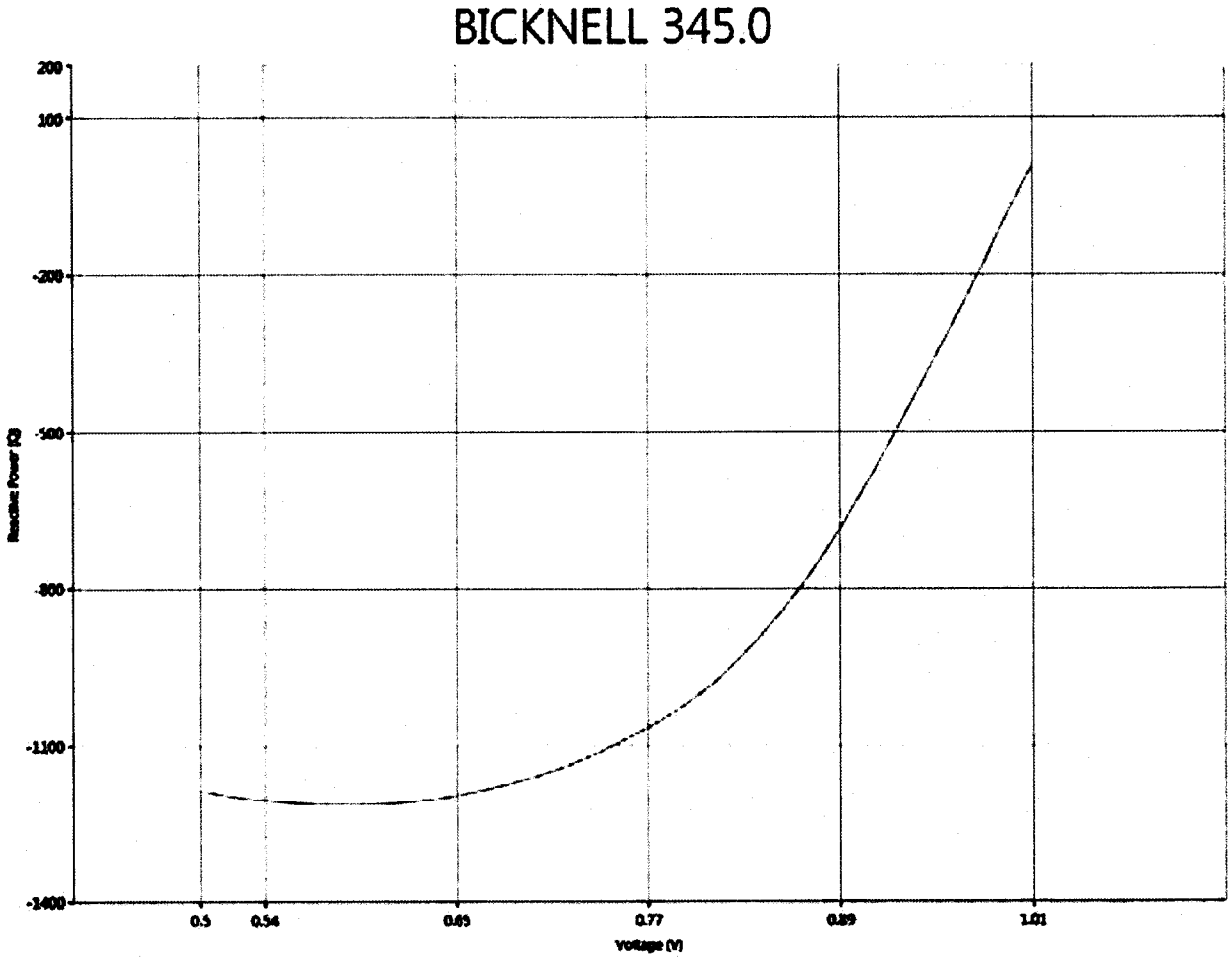
2014HS – Saguaro East to Marana Tap 115 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



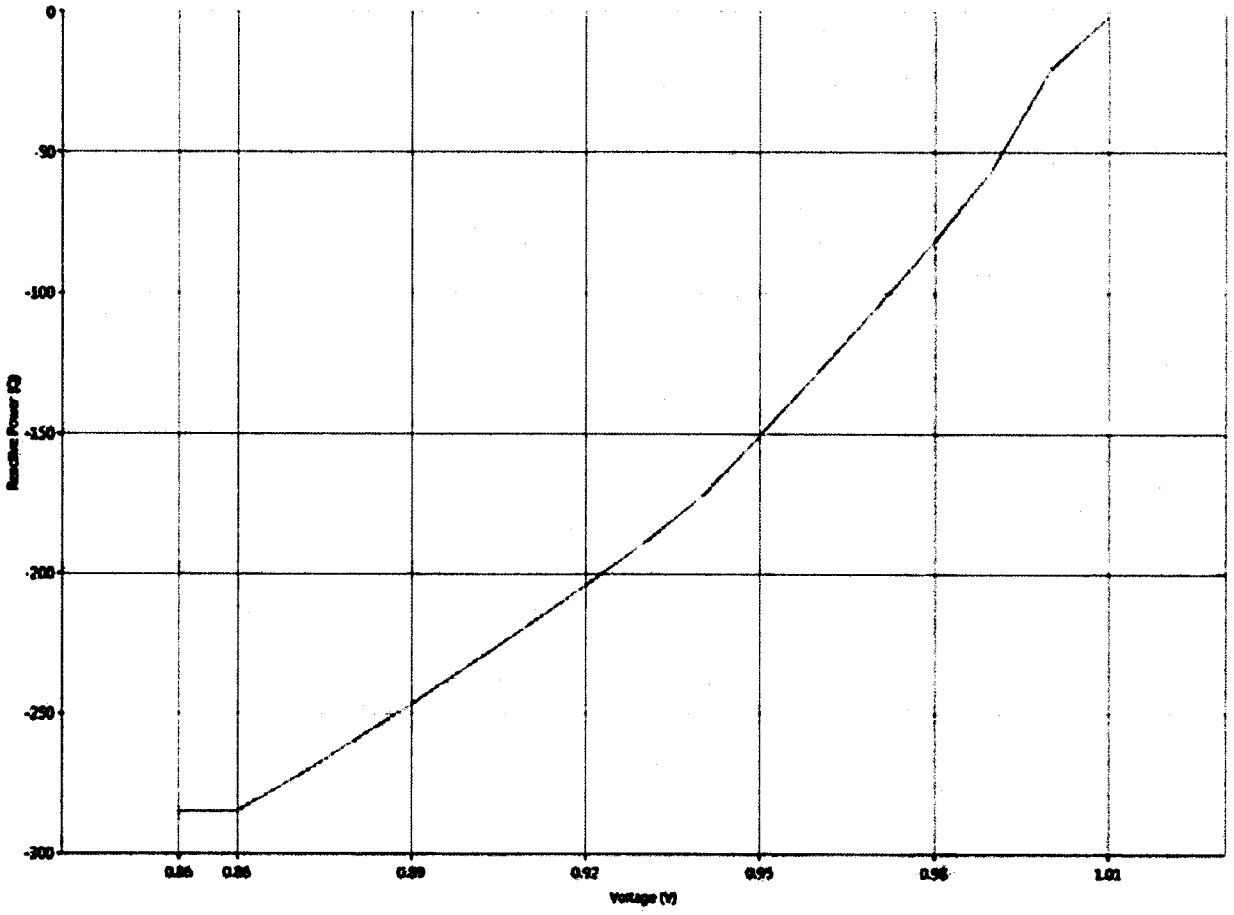

MARANA 115.0
50
0
-50
-100
-150
-200
-250
-300
-350
-400
Reactive Power (Q)
0.785
0.785
0.83
0.88
0.93
0.98
Voltage (V)

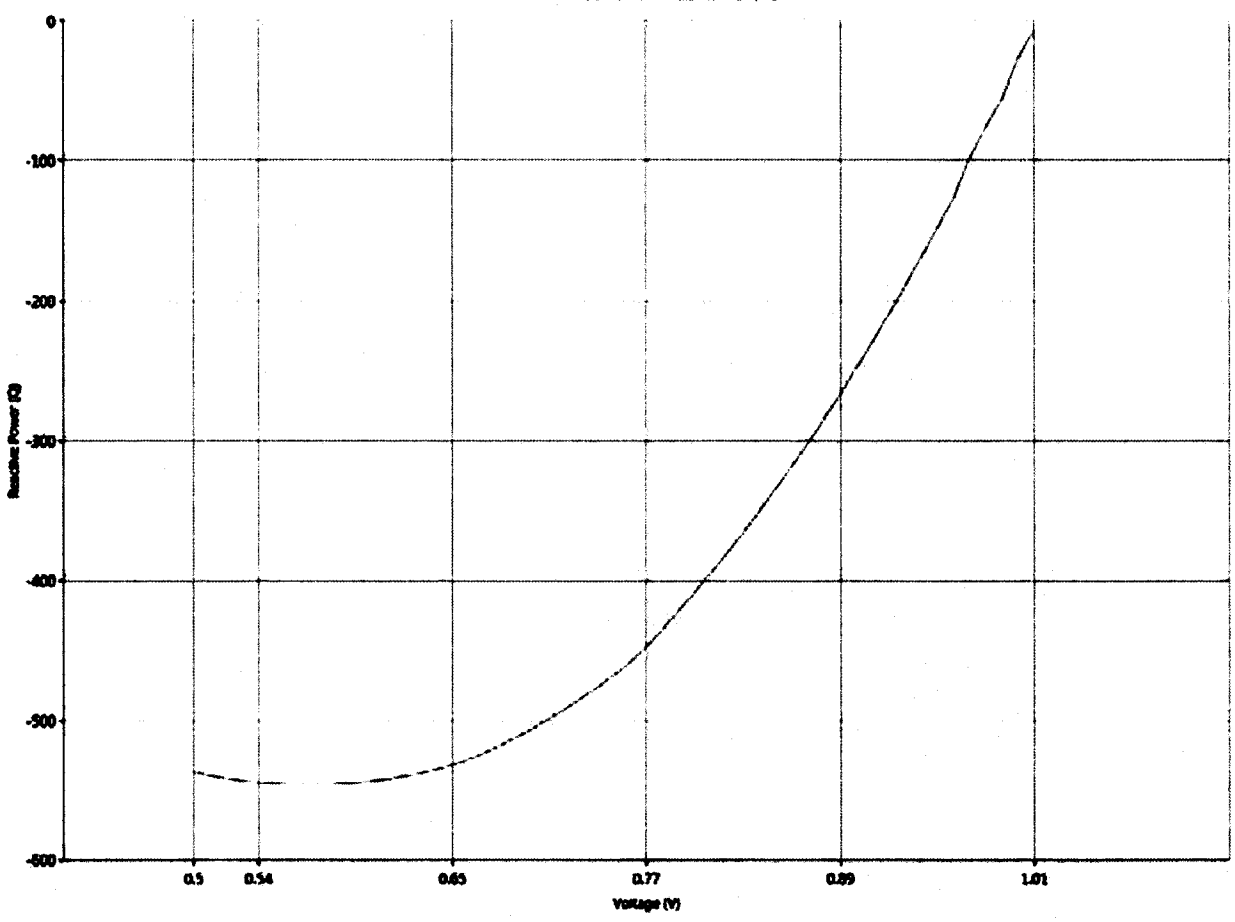

PANTANO 230.0
100
0
-100
-200
-300
-400
-500
Reactive Power (Q)
0.7
0.7025
0.75
0.83
0.91
0.99
Voltage (V)

2014LW – Apache to Butterfield 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

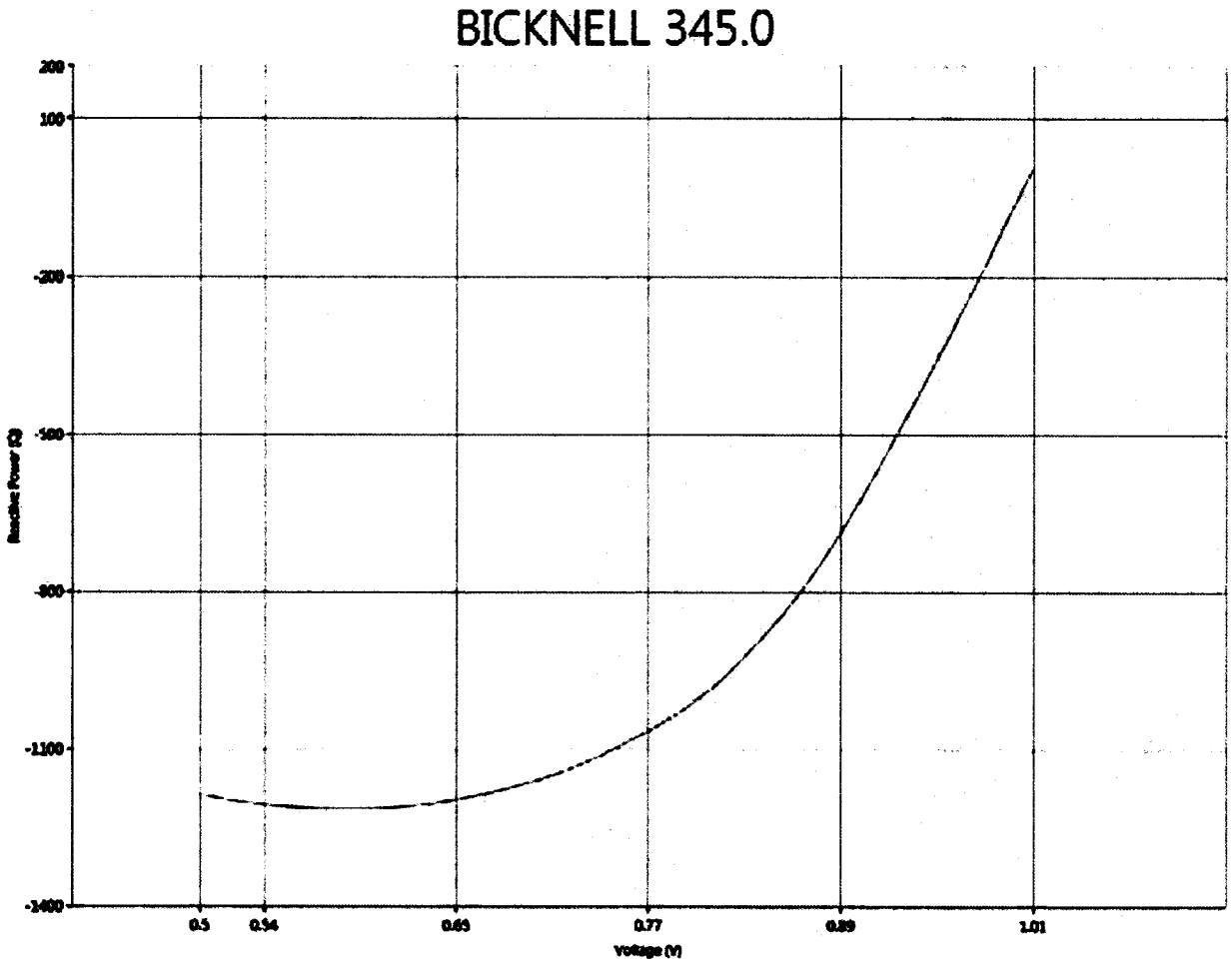


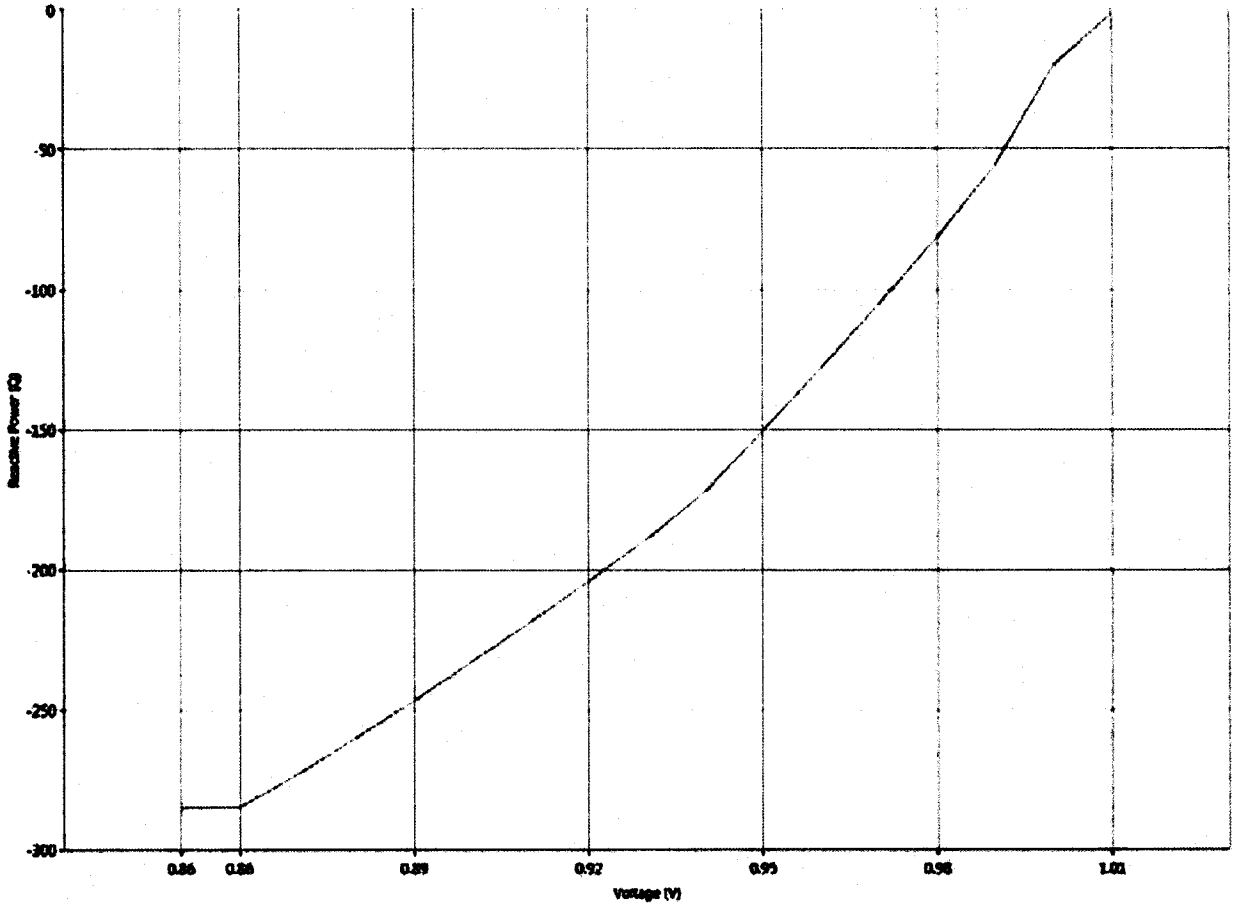
MARANA 115.0

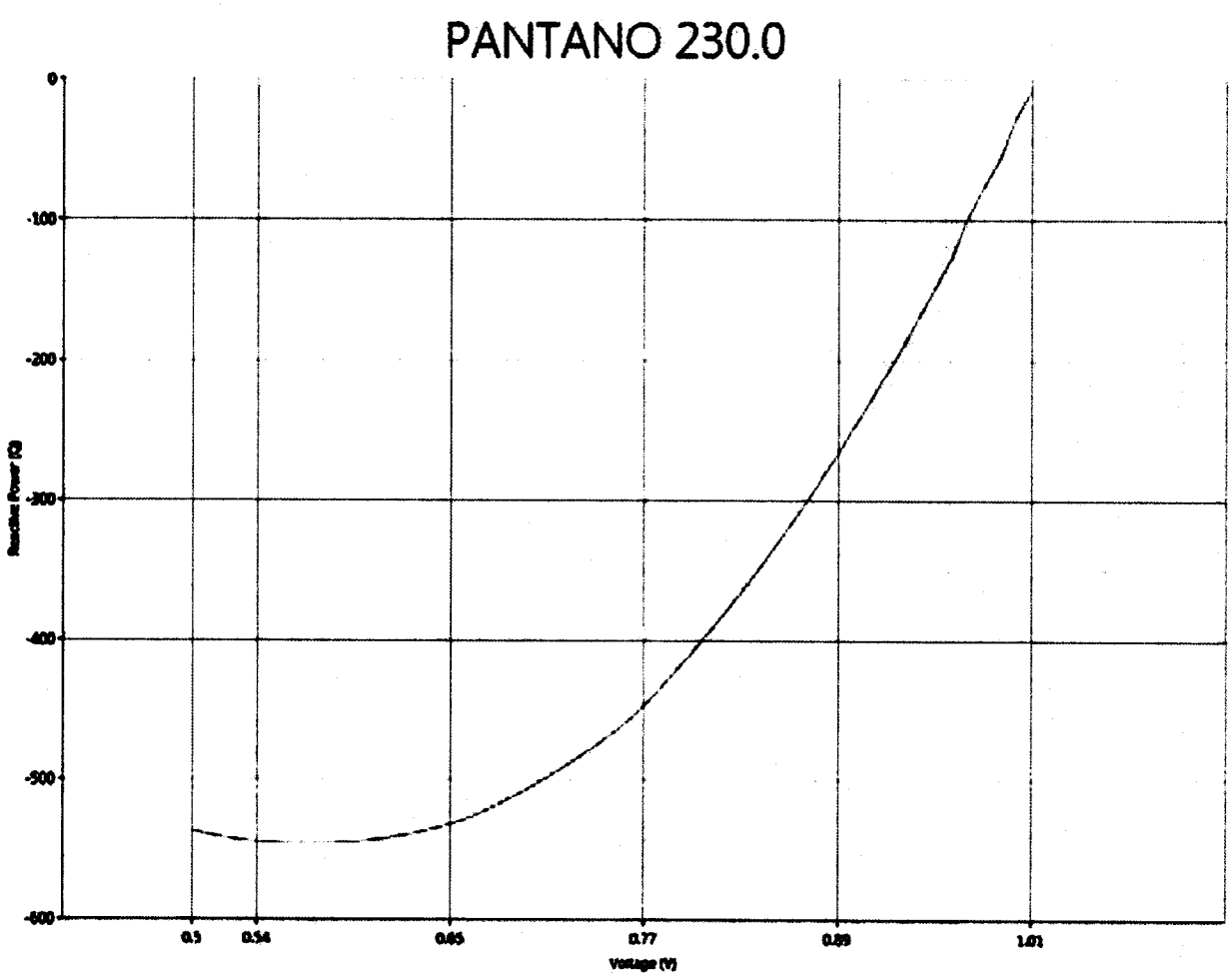

0
-50
-100
-150
-200
-250
-300
Reactive Power (Q)
0.86
0.89
0.92
0.95
0.98
1.01
Voltage (V)


PANTANO 230.0
0
-100
-200
-300
-400
-500
-600
0.5
0.54
0.65
0.77
0.89
1.01
Voltage (V)

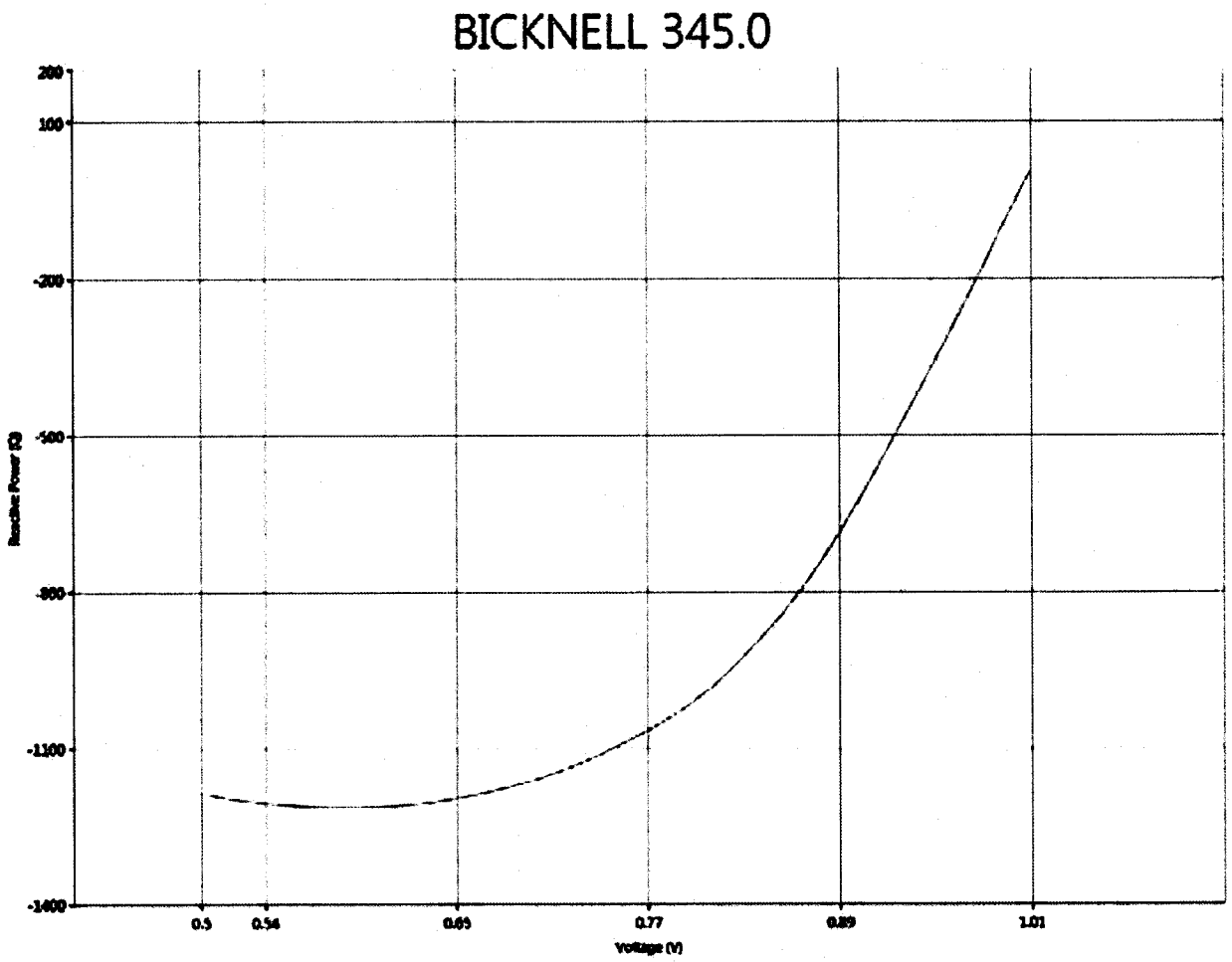
2014LW – Apache to Redtail 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

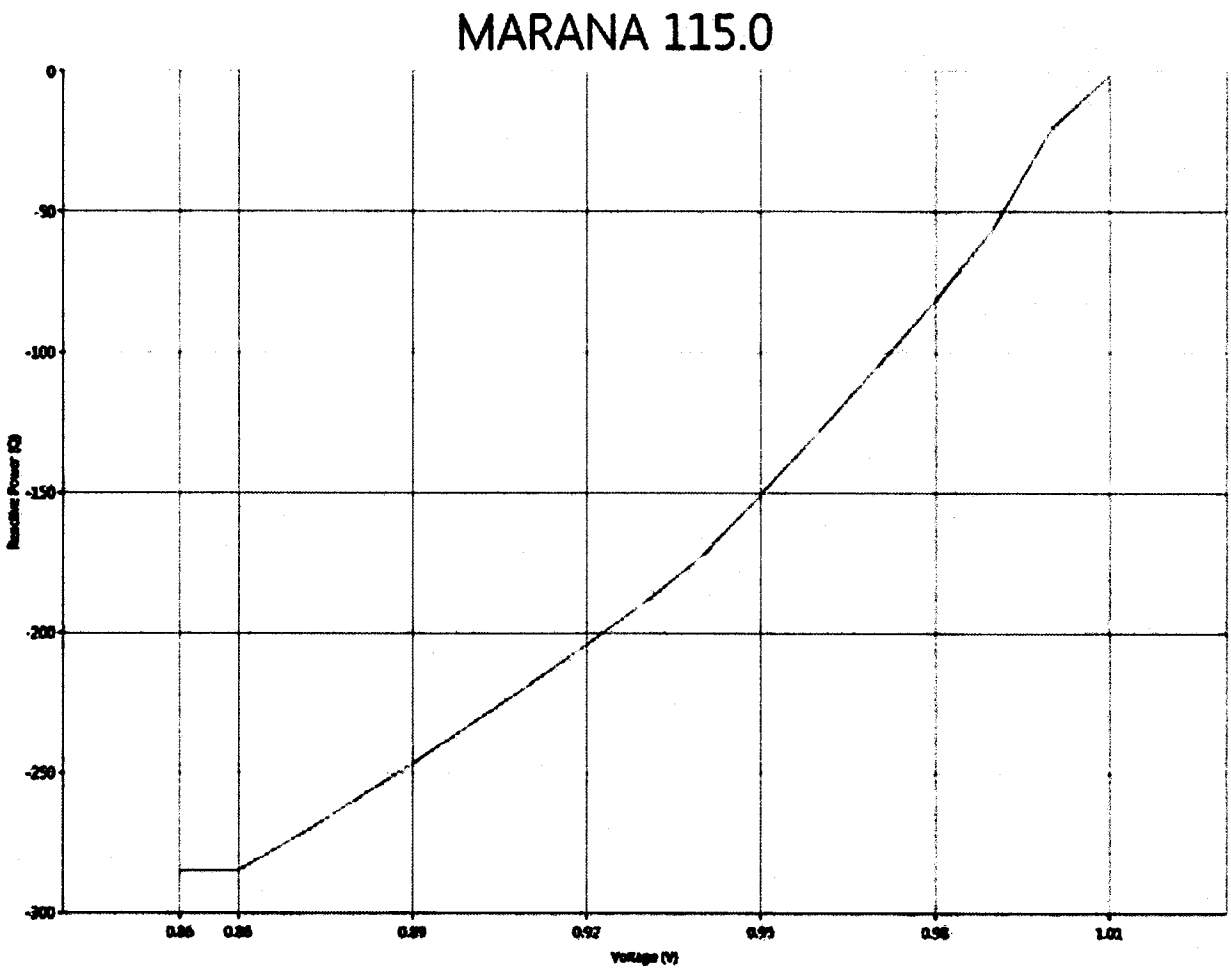


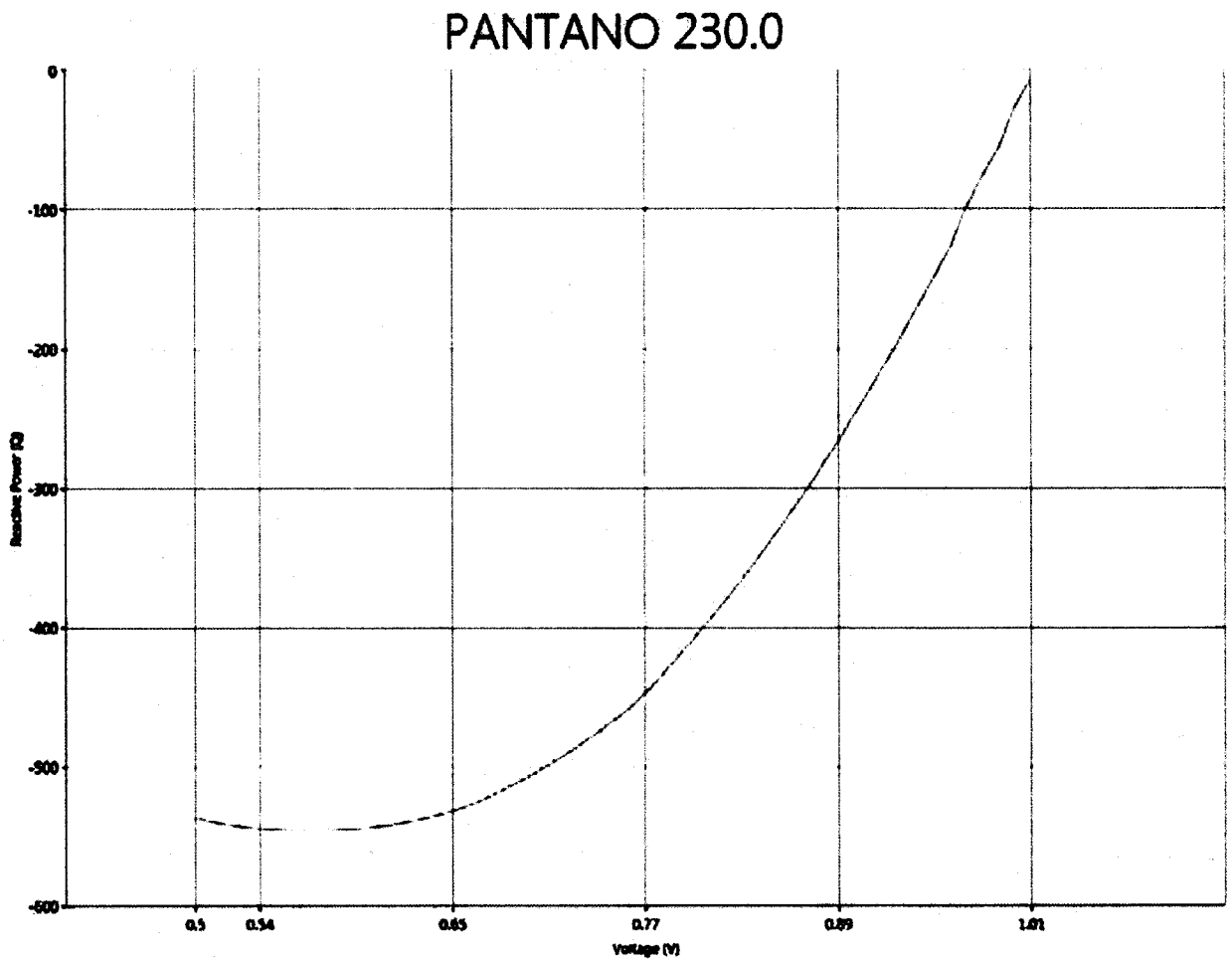

MARANA 115.0
0
-50
-100
-150
-200
-250
-300
0.86
0.89
0.92
0.95
0.98
1.01
Voltage (V)


PANTANO 230.0
0
-100
-200
-300
-400
-500
-600
0.77
1.01

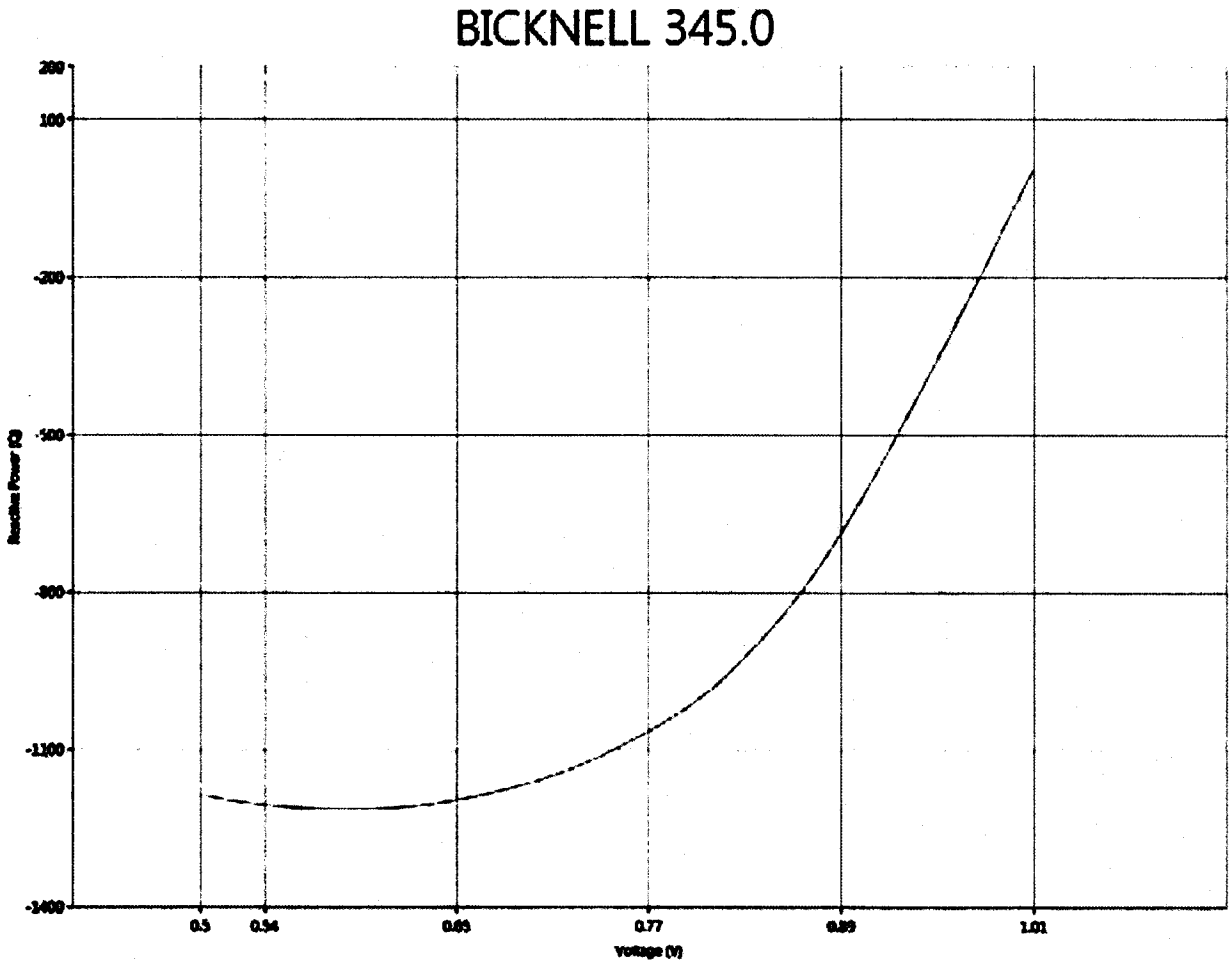
2014LW – Bicknell to Vail 345 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

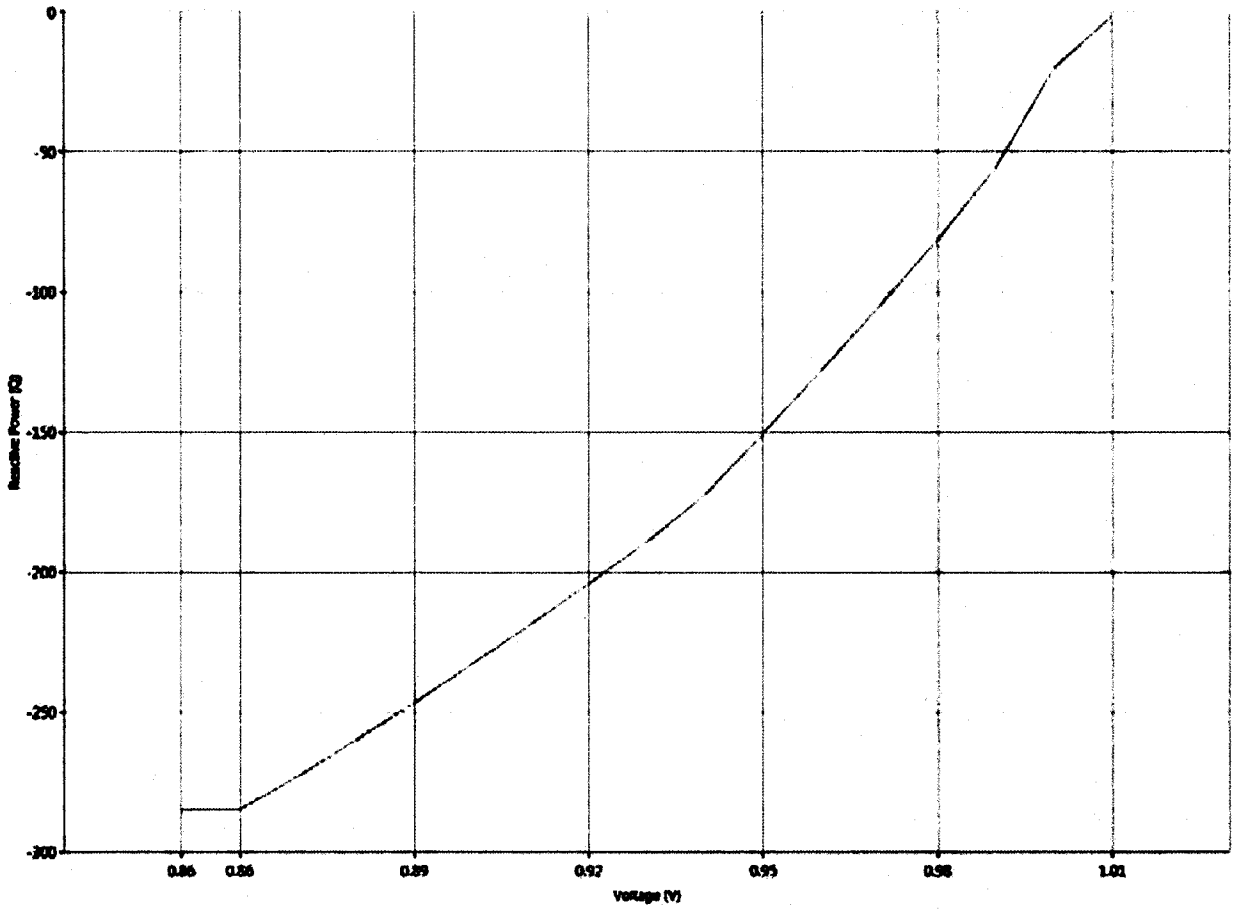


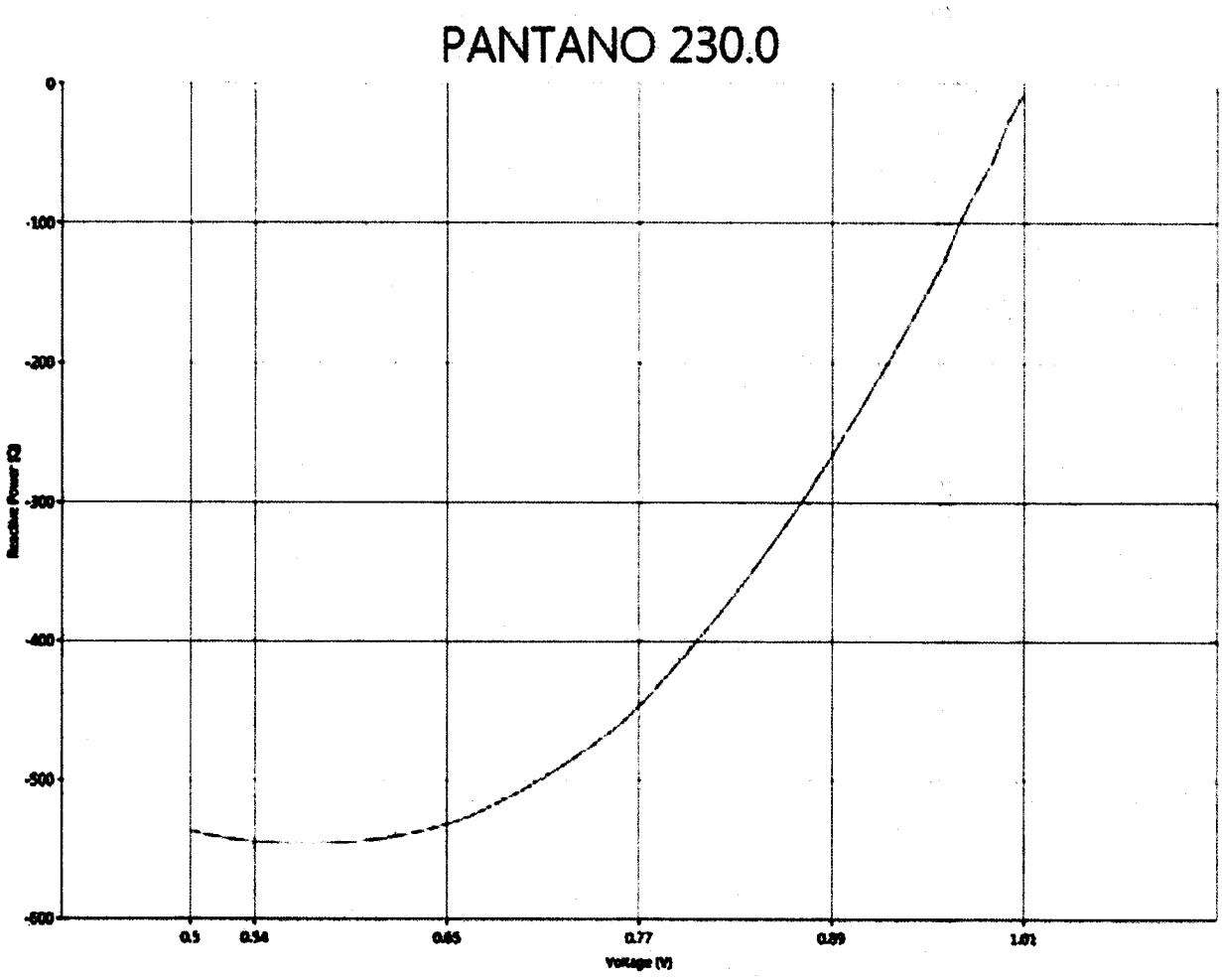

MARANA 115.0
0
-50
-100
-150
-200
-250
-300
Reactive Power (Q
0.86
0.88
0.89
0.92
0.95
0.98
1.01
Voltage (V)


PANTANO 230.0
0
-100
-200
-300
-400
-500
0.5
0.54
0.65
0.77
0.89
1.01
Voltage (V)

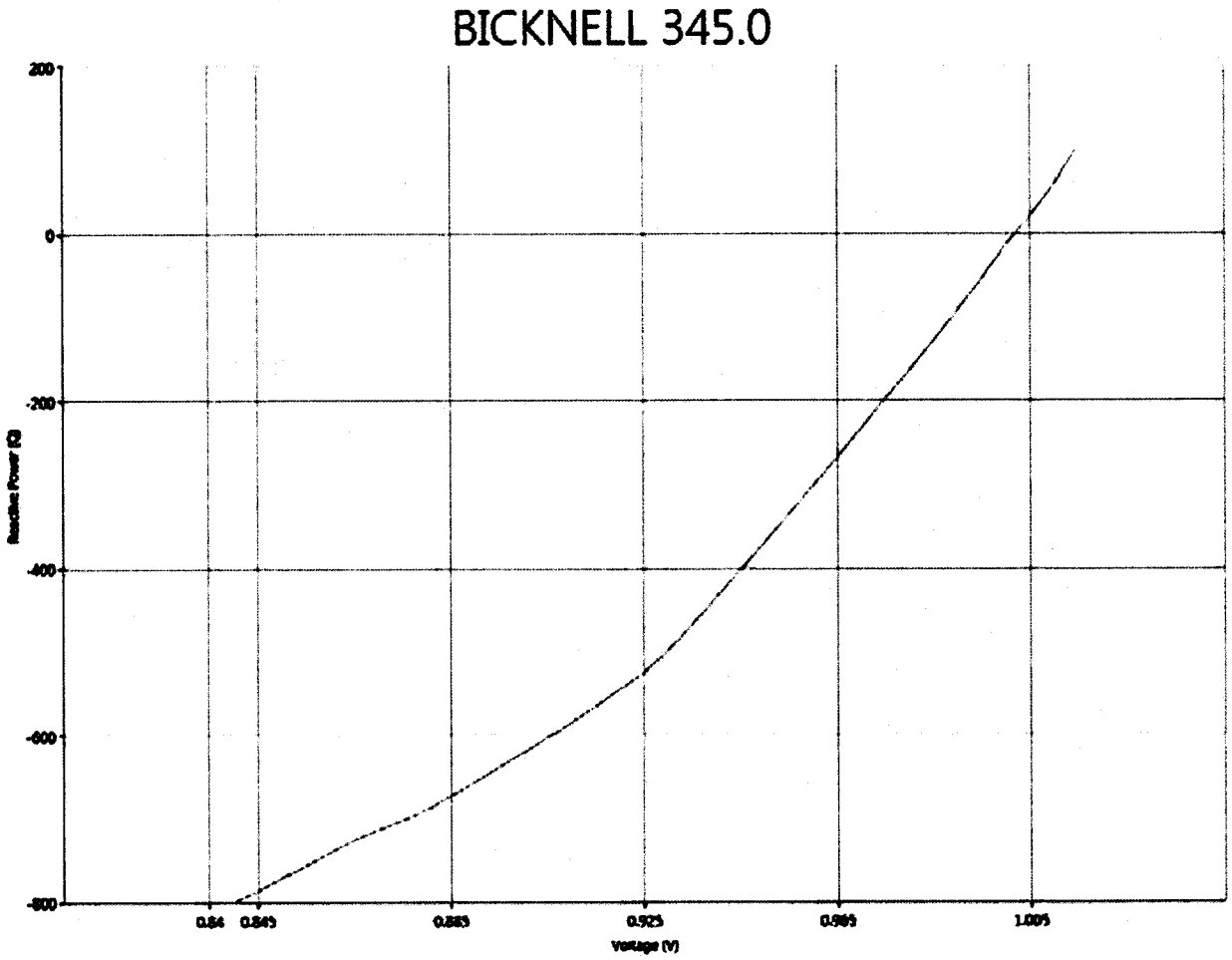
2014LW – Saguaro to Marana Tap 115 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



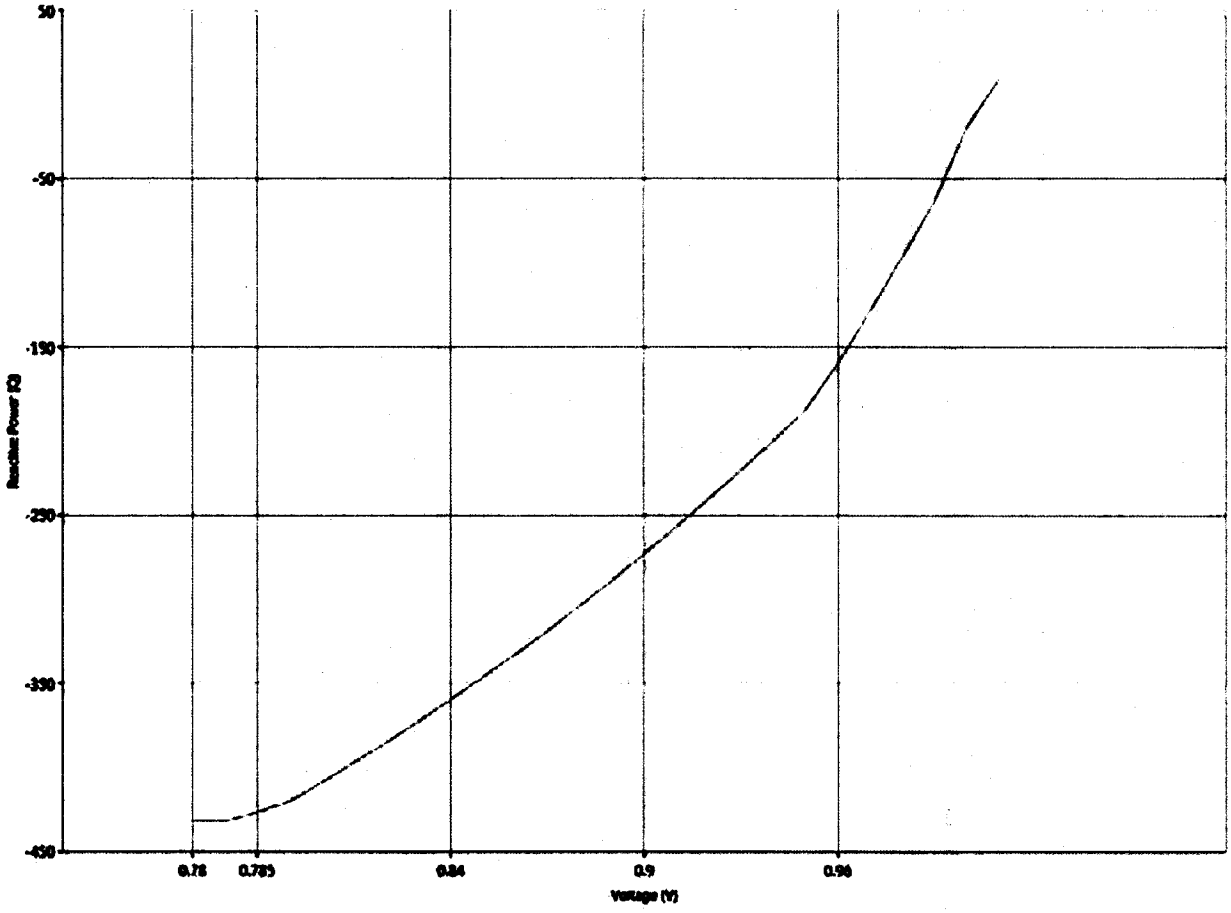

MARANA 115.0
0
-50
-100
-150
-200
-250
-300
Reactive Power (Q)
0.86
0.86
0.89
0.92
0.95
0.98
1.01
Voltage (V)

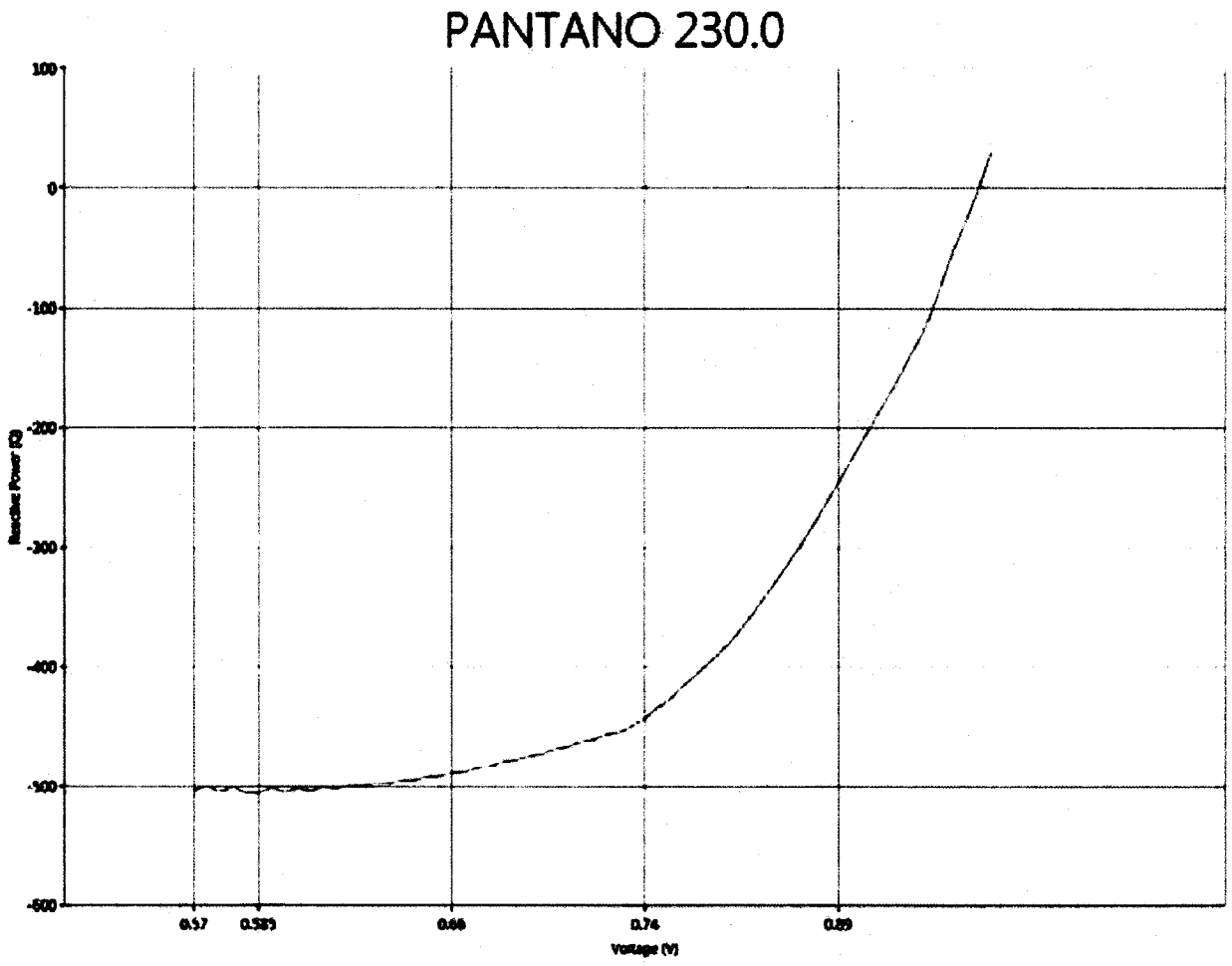

PANTANO 230.0
0
-100
-200
-300
-400
-500
-600
0.5
0.54
0.65
0.77
0.89
1.01
Voltage (V)

2019HS – Apache to Butterfield 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

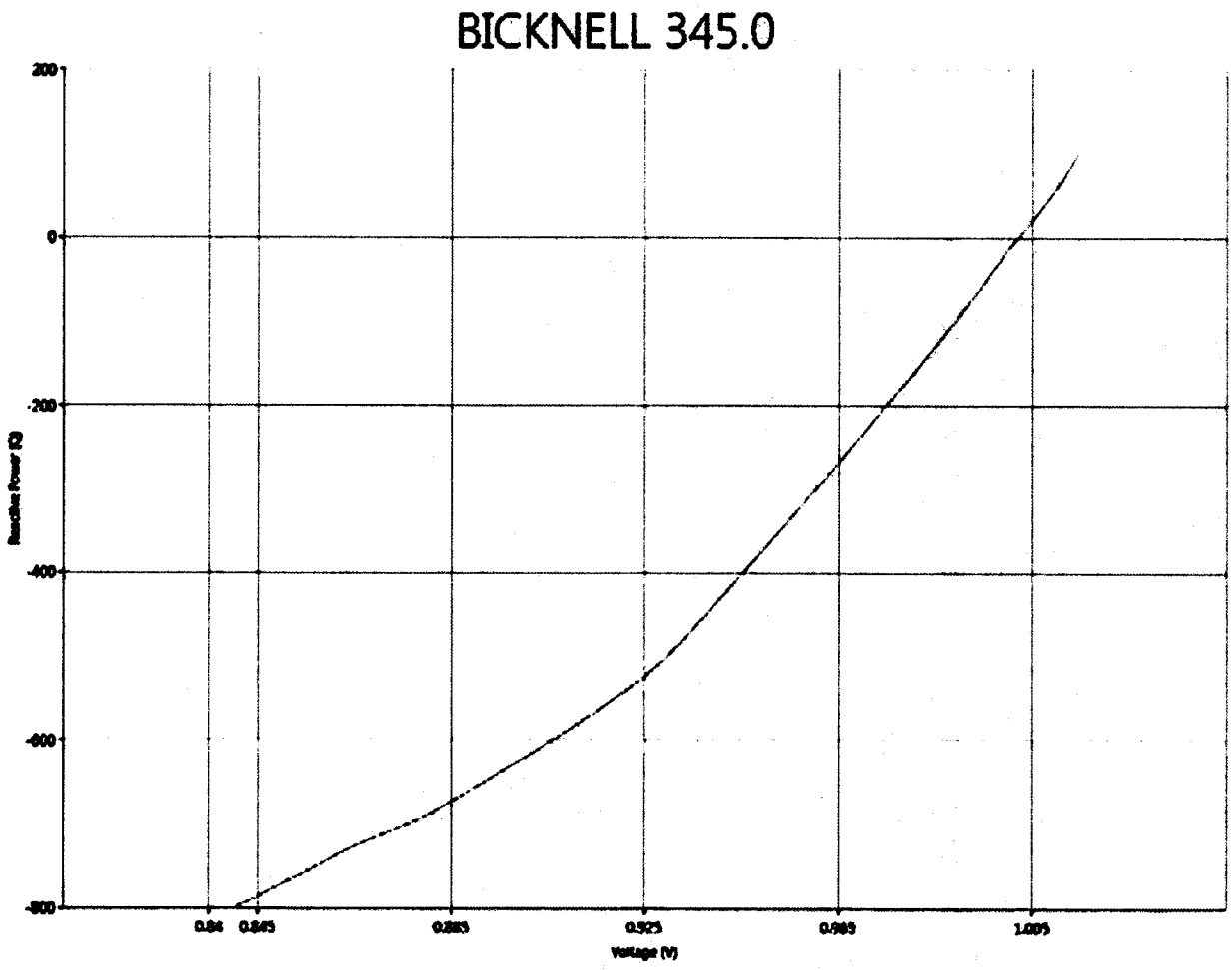


MARANA 115.0

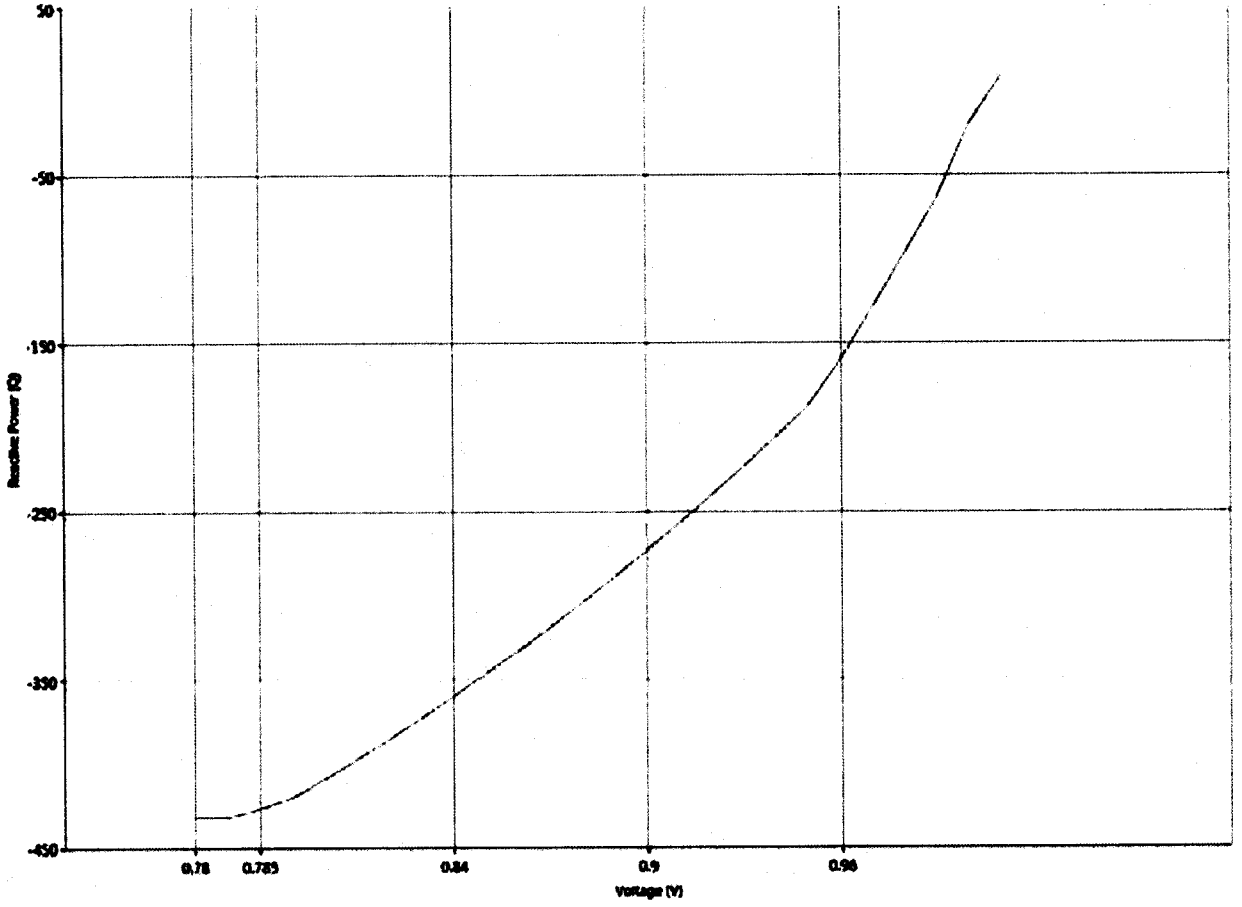

50
-50
-150
-250
-350
-450
Reactive Power (Q)
0.78
0.785
0.84
0.9
0.96
Voltage (V)


PANTANO 230.0
100
0
-100
-200
-300
-400
-500
Reactive Power (Q)
0.57
0.585
0.66
0.74
0.89
Voltage (V)

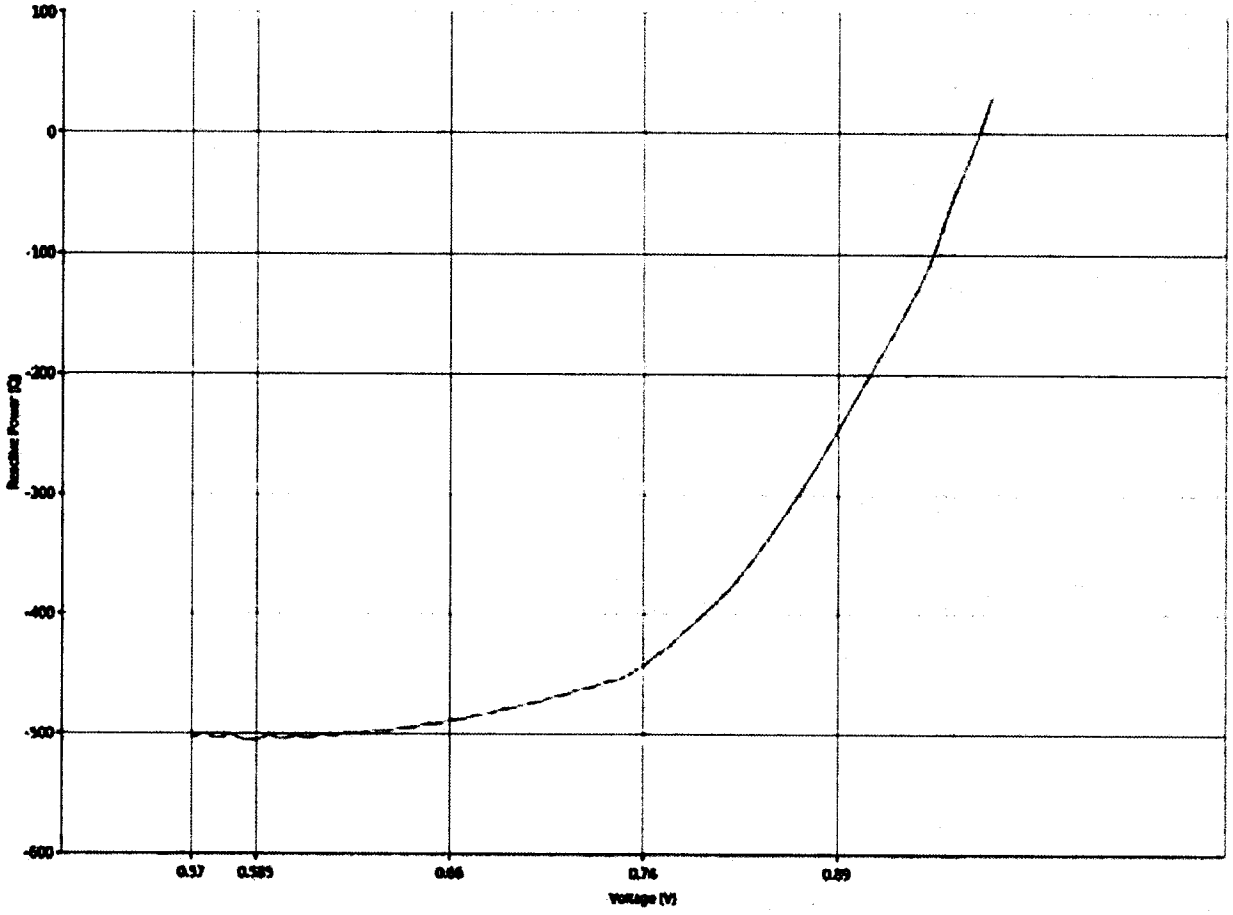
2019HS – Apache to Redtail 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



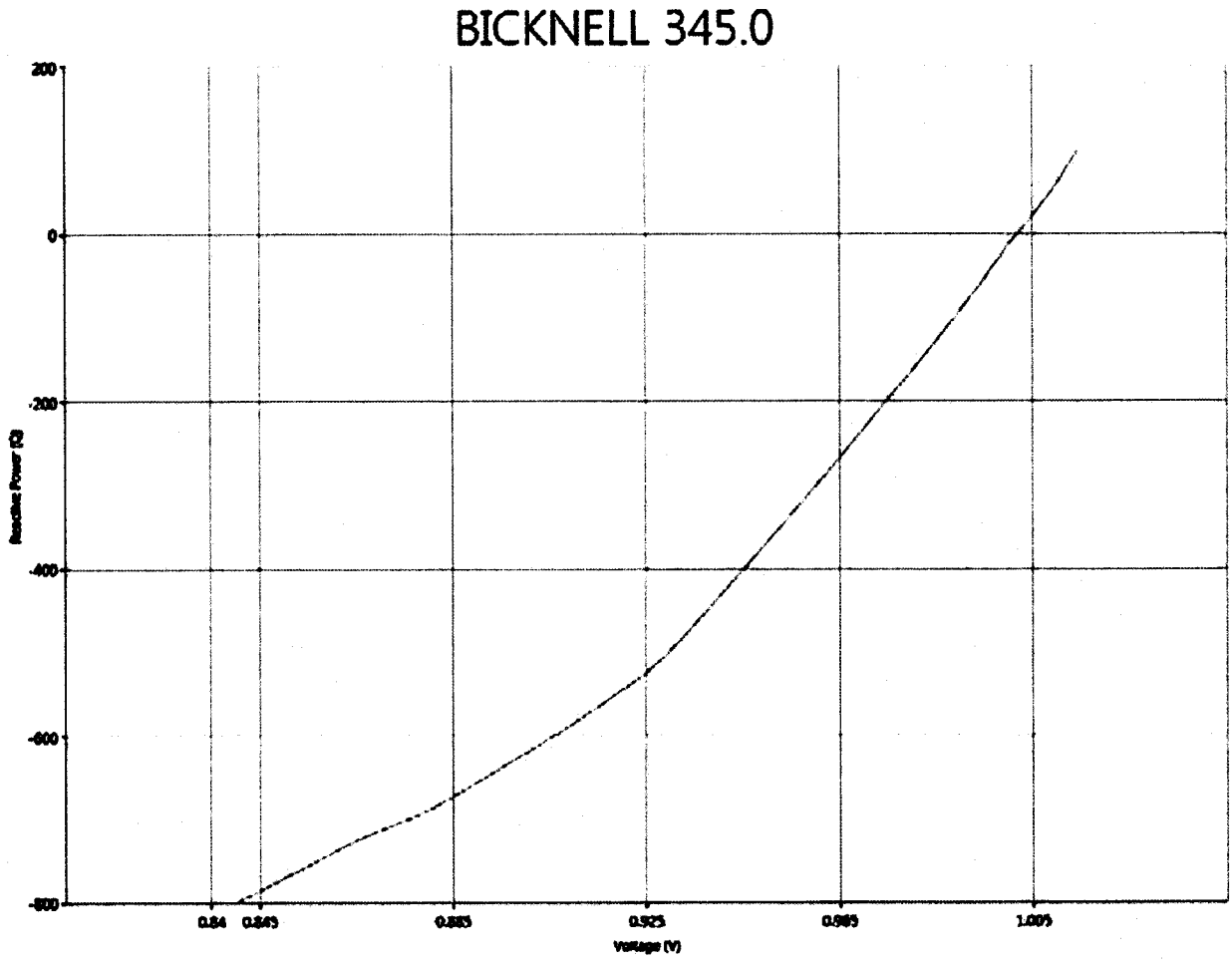
MARANA 115.0

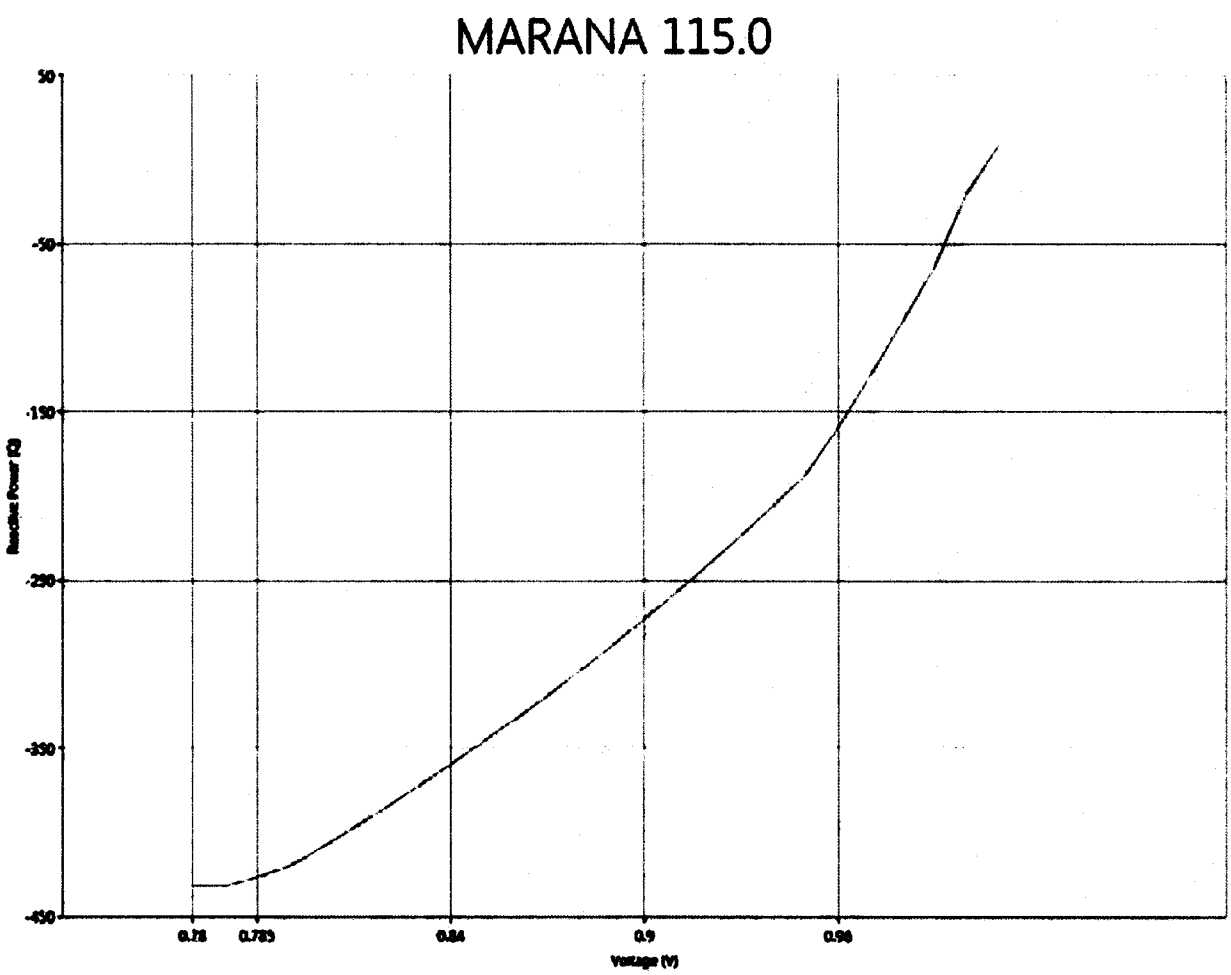

50
-50
-150
-250
-350
-450
Reactive Power (Q)
0.78
0.785
0.84
0.9
0.96
Voltage (V)

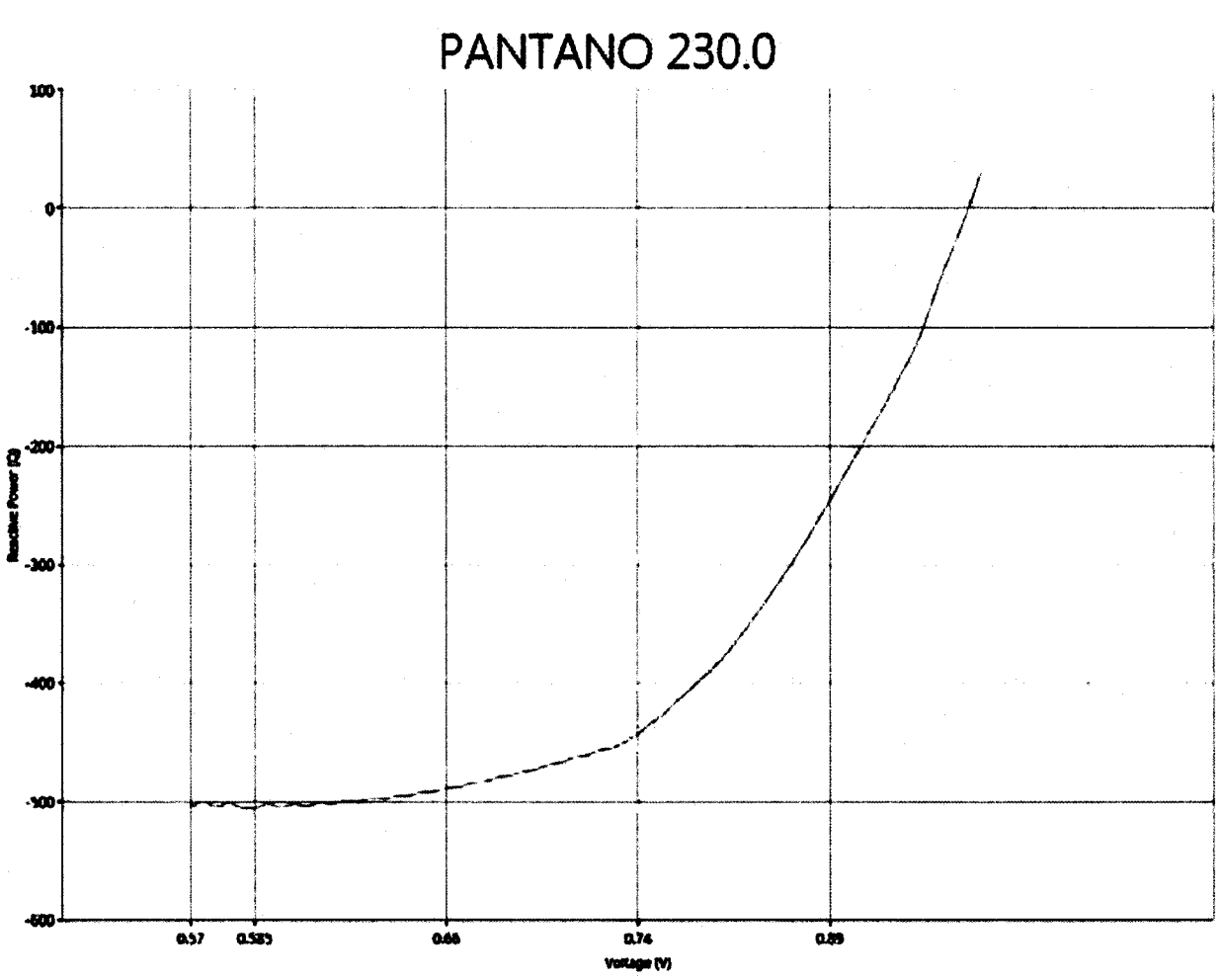
PANTANO 230.0



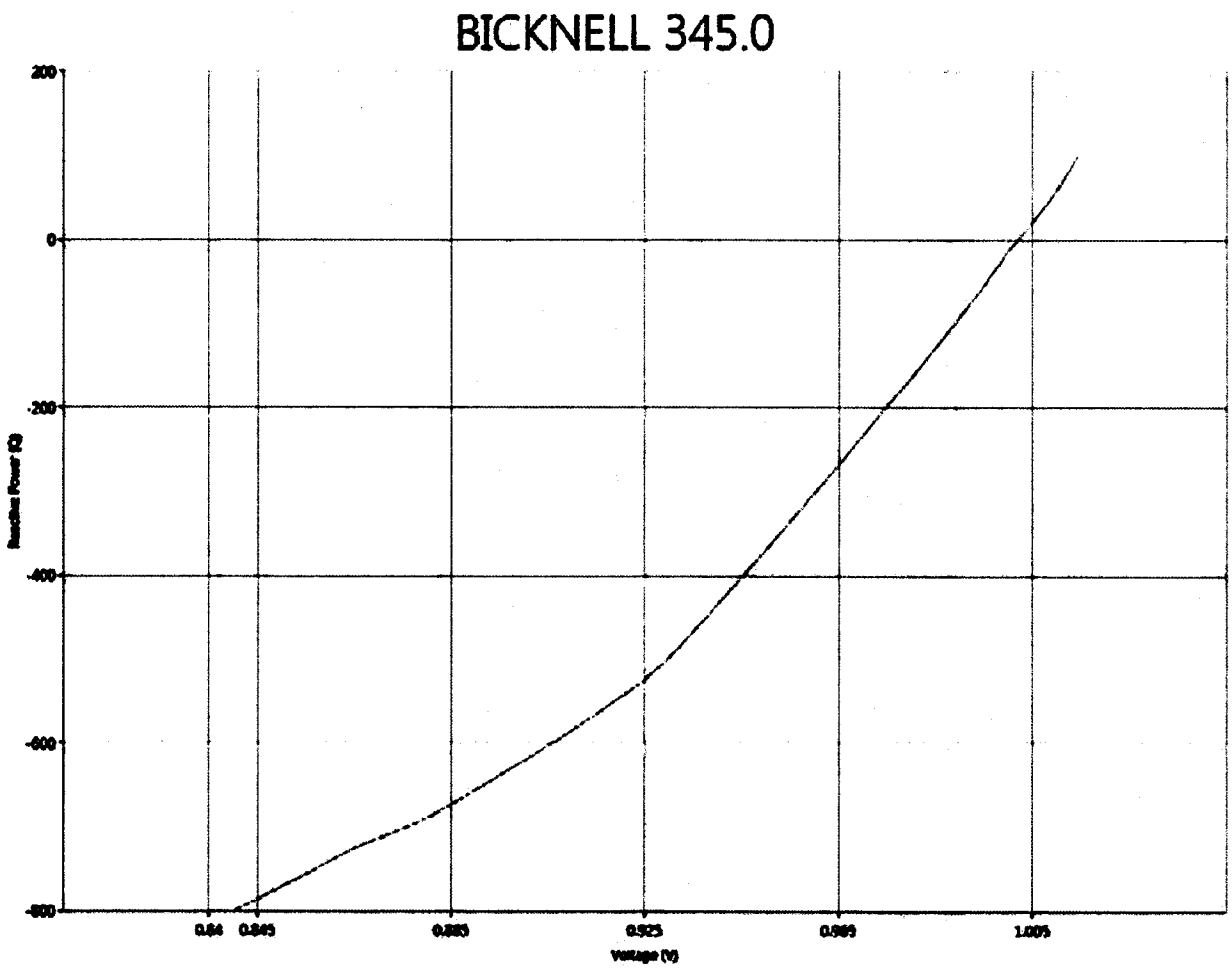
2019HS – Bicknell to Vail 345 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



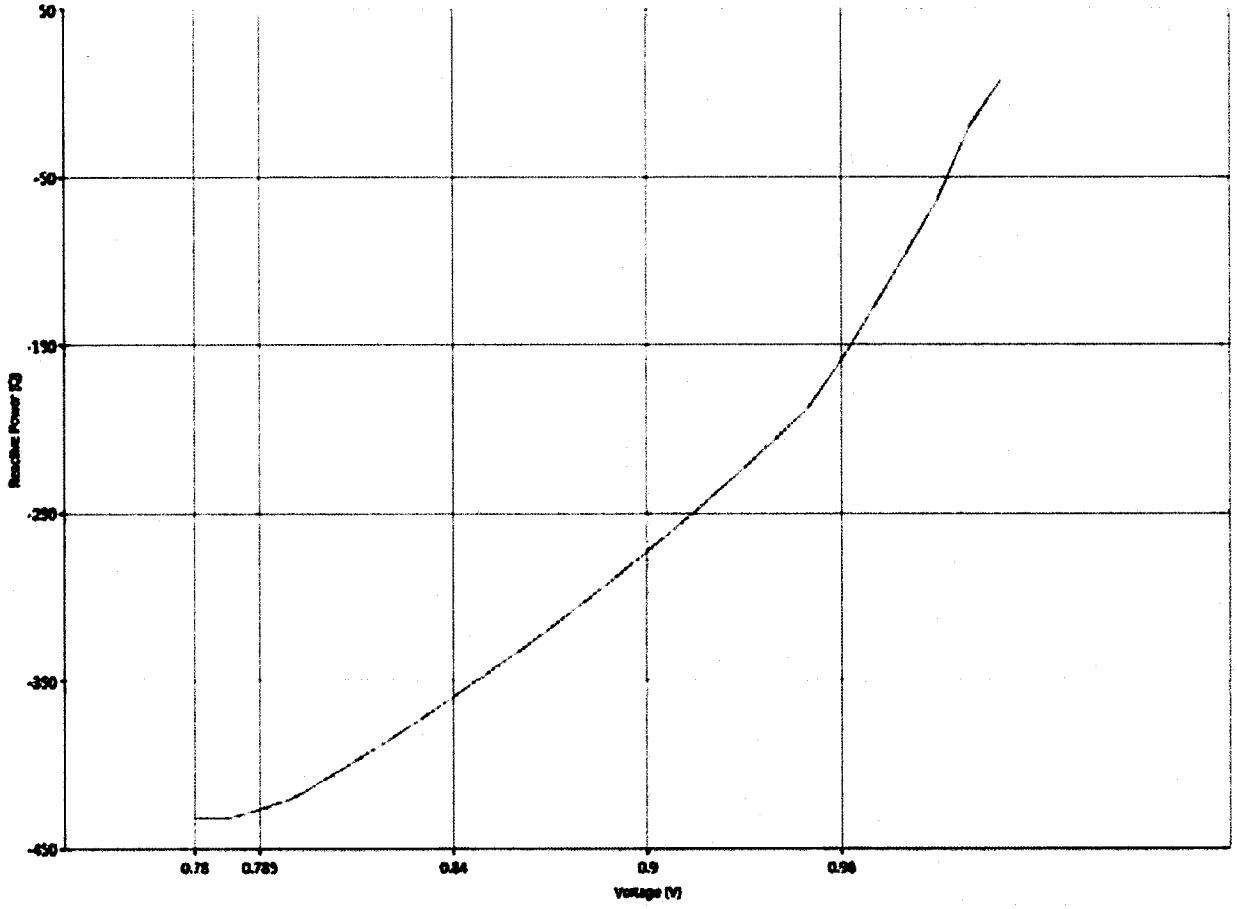

MARANA 115.0
50
-50
-150
-250
-350
-450
0.78
0.783
0.84
0.9
0.96
Voltage (V)

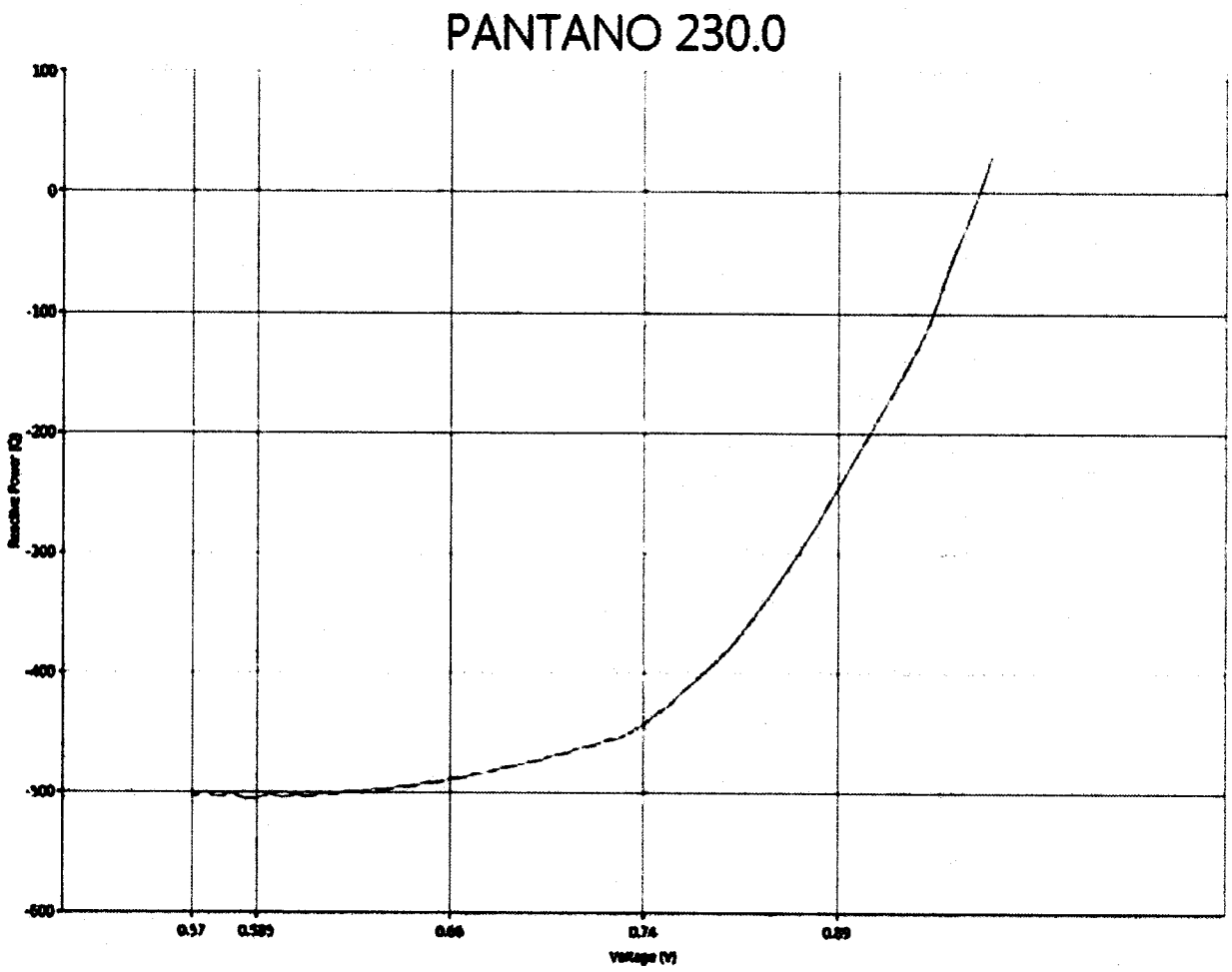

PANTANO 230.0
100
0
-100
-200
-300
-400
-500
Reactive Power (Q)
0.57
0.585
0.66
0.74
0.89
Voltage (V)

2019HS – Saguaro to Marana Tap 115 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

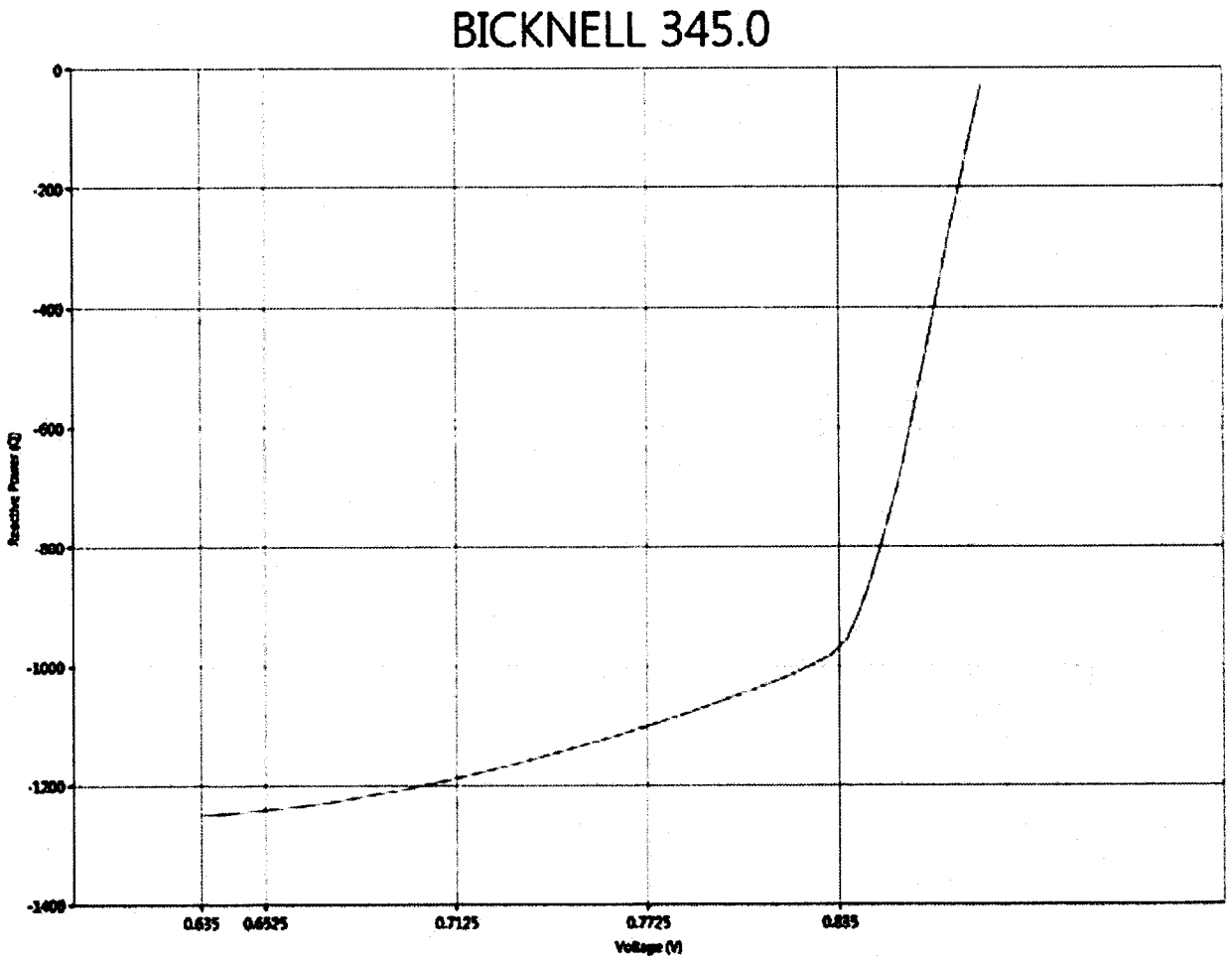


MARANA 115.0

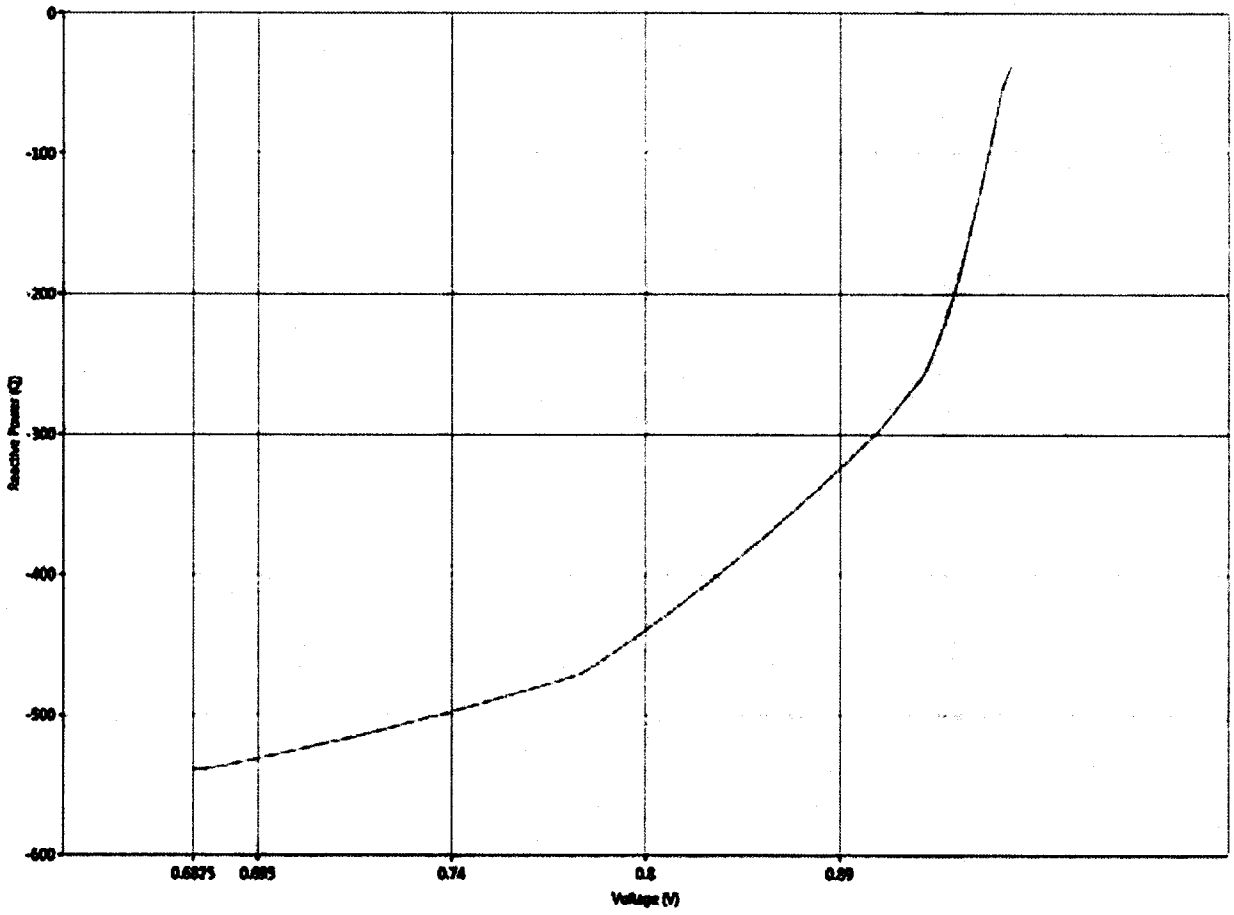

50
-50
-150
-250
-350
-450
Reactive Power (Q)
0.78
0.785
0.84
0.9
0.96
Voltage (V)

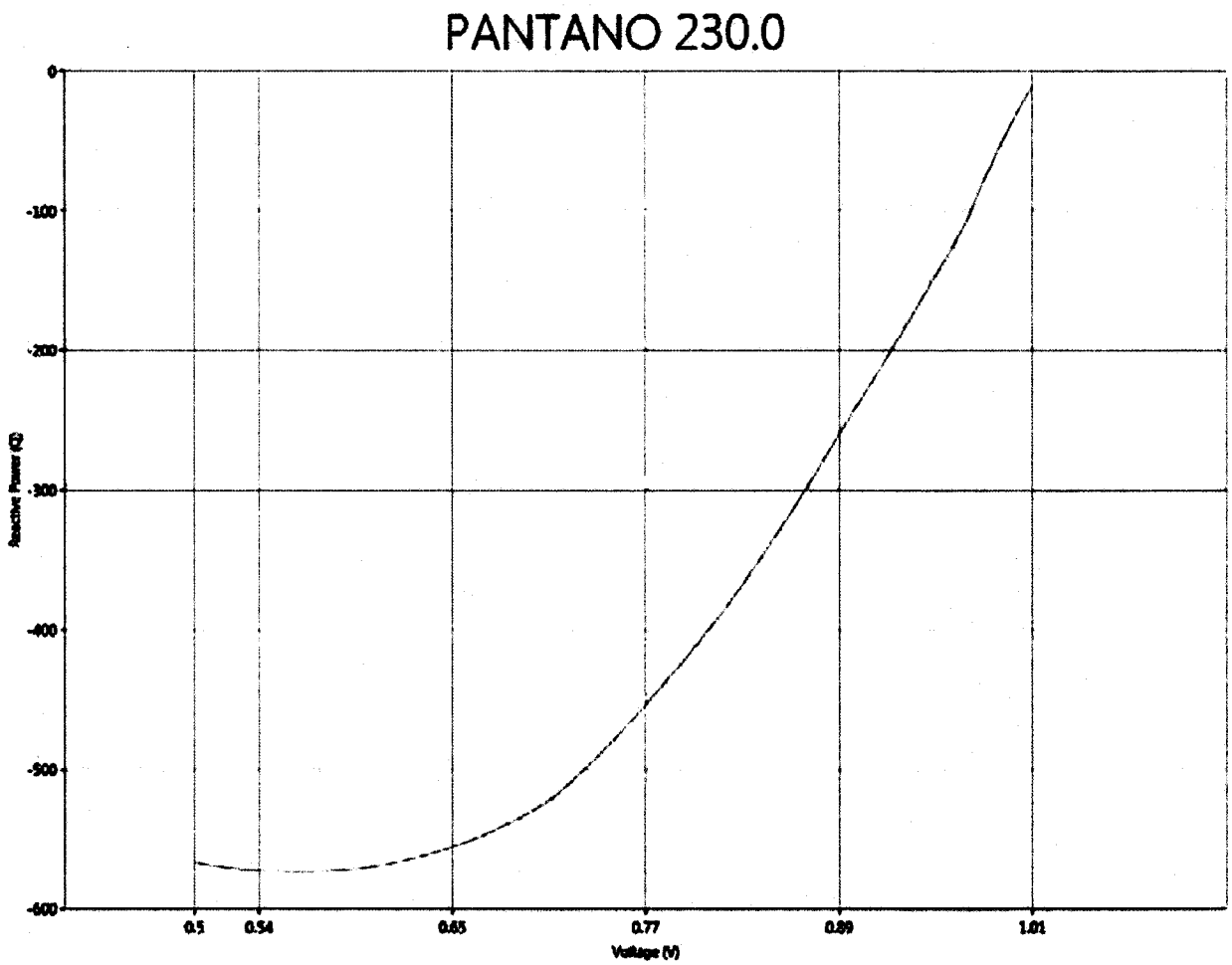

PANTANO 230.0
100
0
-100
-200
-300
-400
-500
-600
0.57
0.589
0.66
0.74
0.89

2019LW – Apache to Butterfield 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

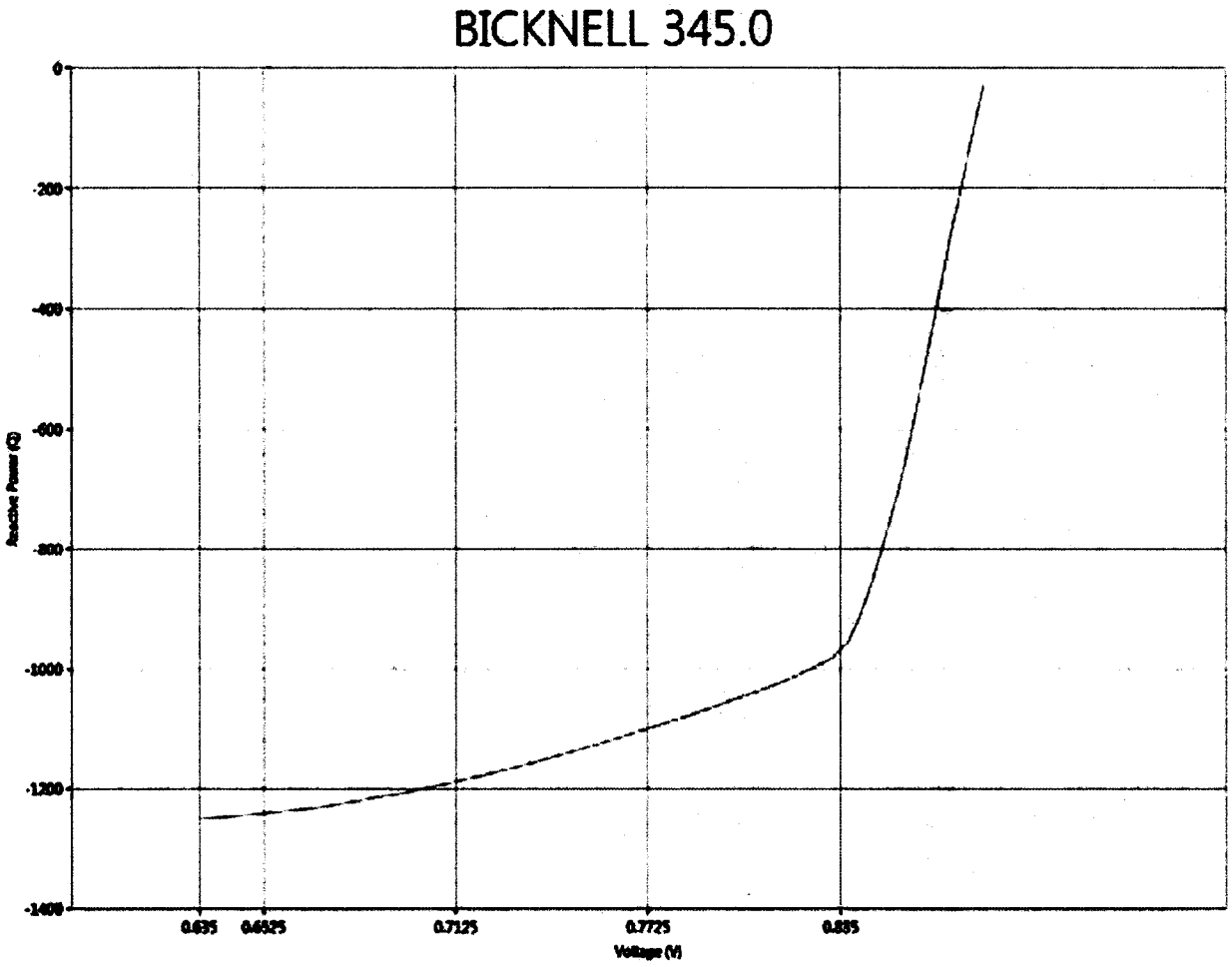


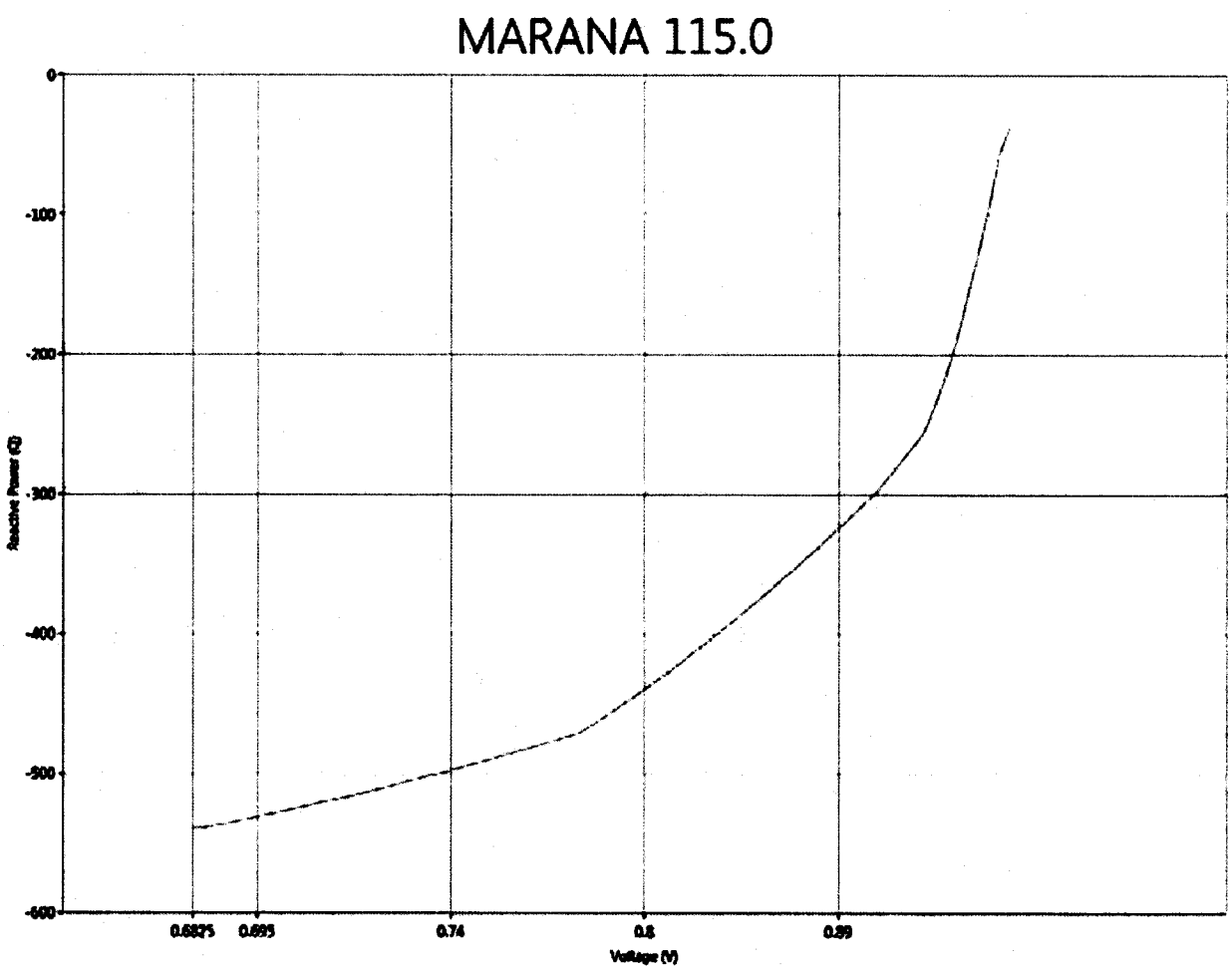
MARANA 115.0

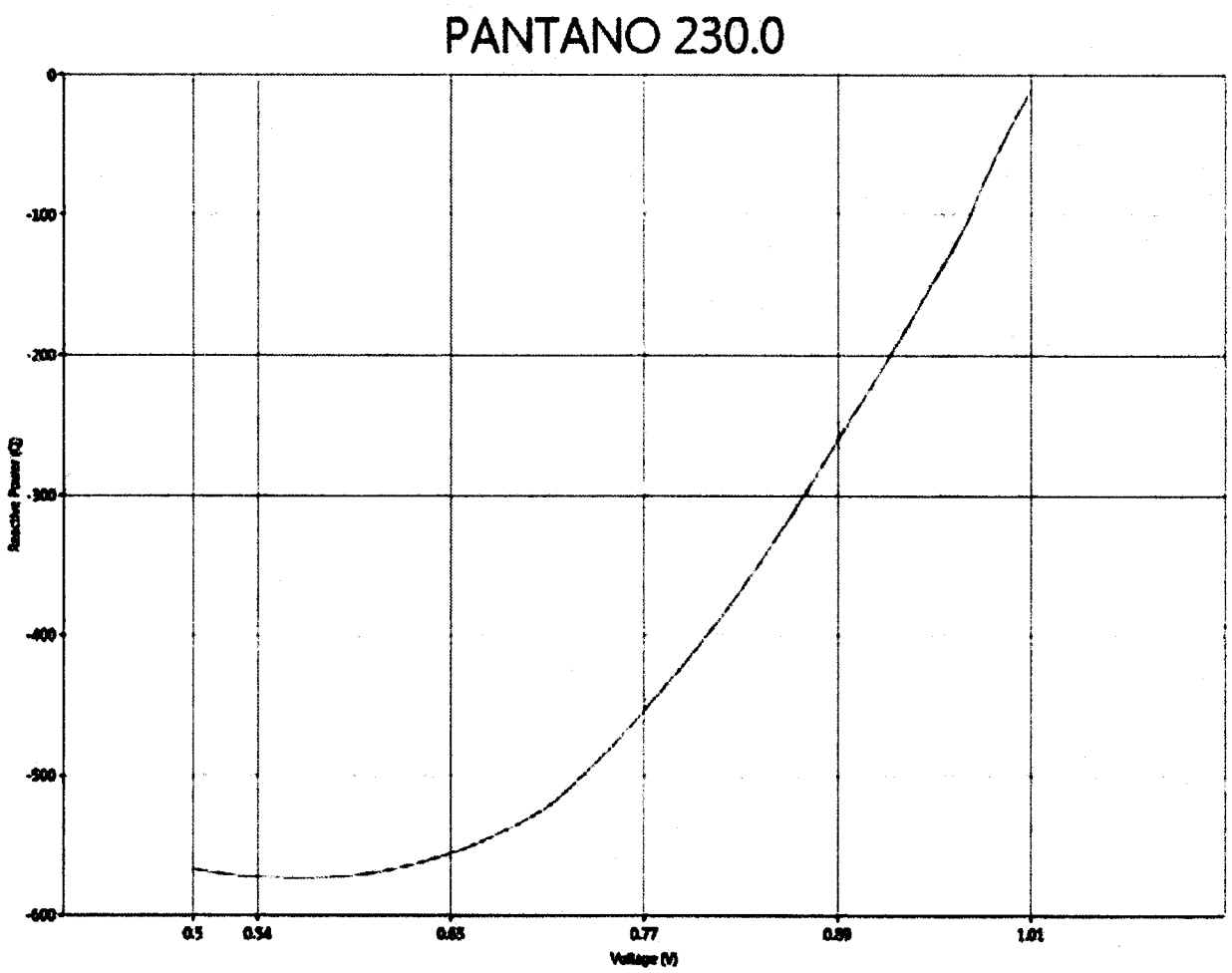

0
-100
-200
-300
-400
-500
-600
Reactive Power (Q)
0.6875
0.695
0.74
0.8
0.89
Voltage (V)


PANTANO 230.0
0
-100
-200
-300
-400
-500
-600
Reactive Power (Q)
0.5
0.54
0.65
0.77
0.89
1.01
Voltage (V)

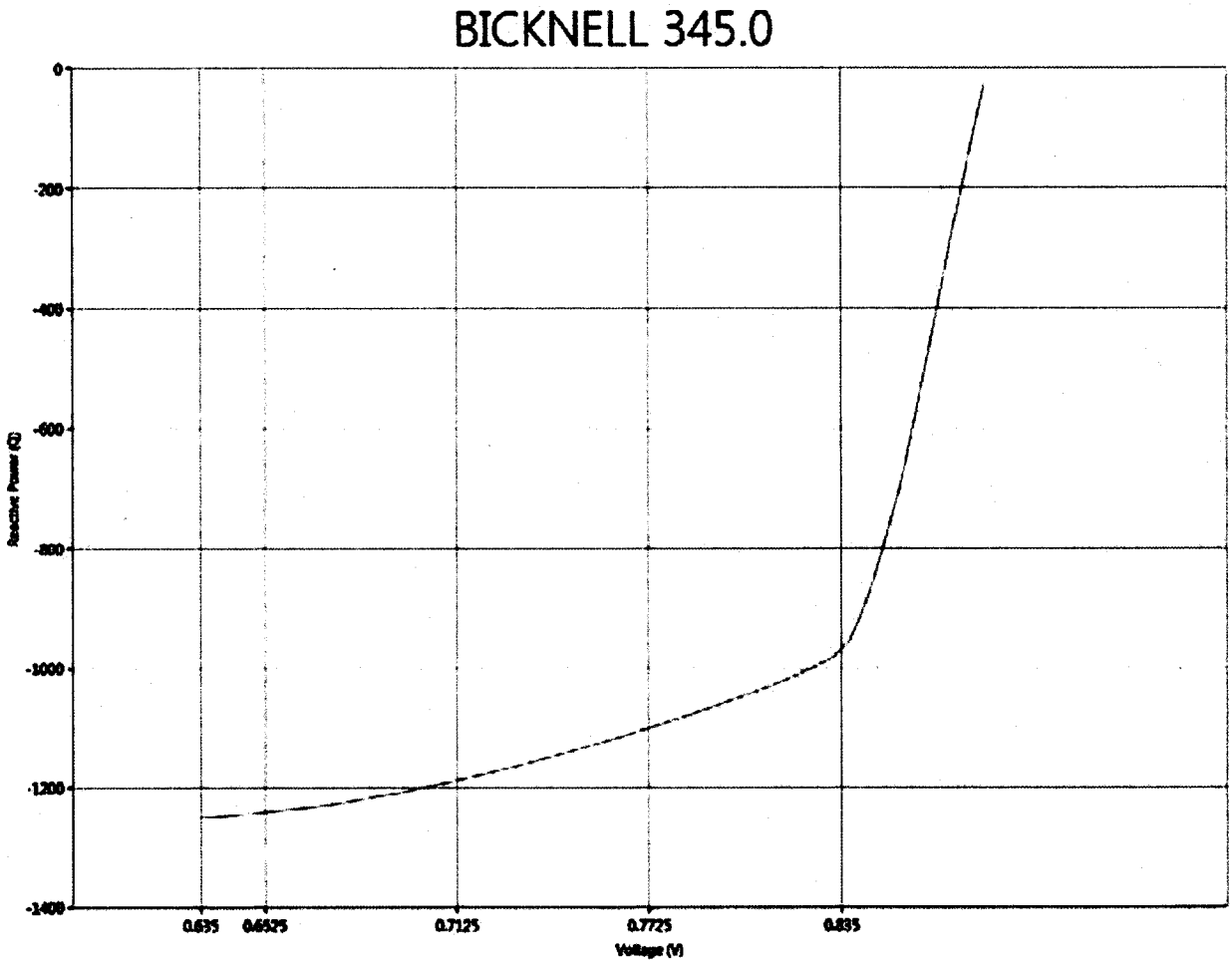
2019LW – Apache to Redtail 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



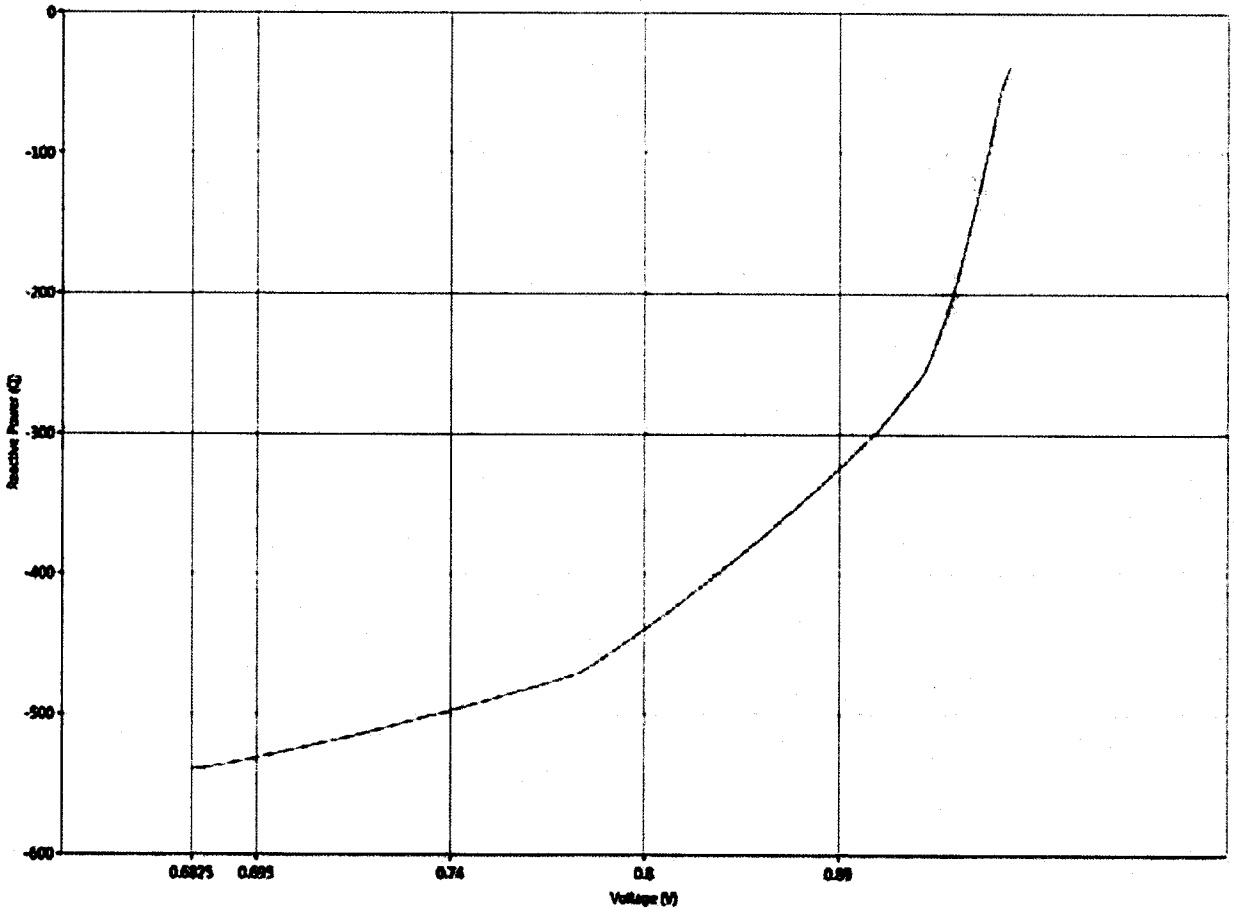

MARANA 115.0
0
-100
-200
-300
-400
-500
-600
Reactive Power (Q)
0.6875
0.695
0.74
0.8
0.89
Voltage (V)


PANTANO 230.0
0
-100
-200
-300
-400
-500
-600
Reactive Power (Q)
0.5
0.54
0.65
0.77
0.89
1.01
Voltage (V)

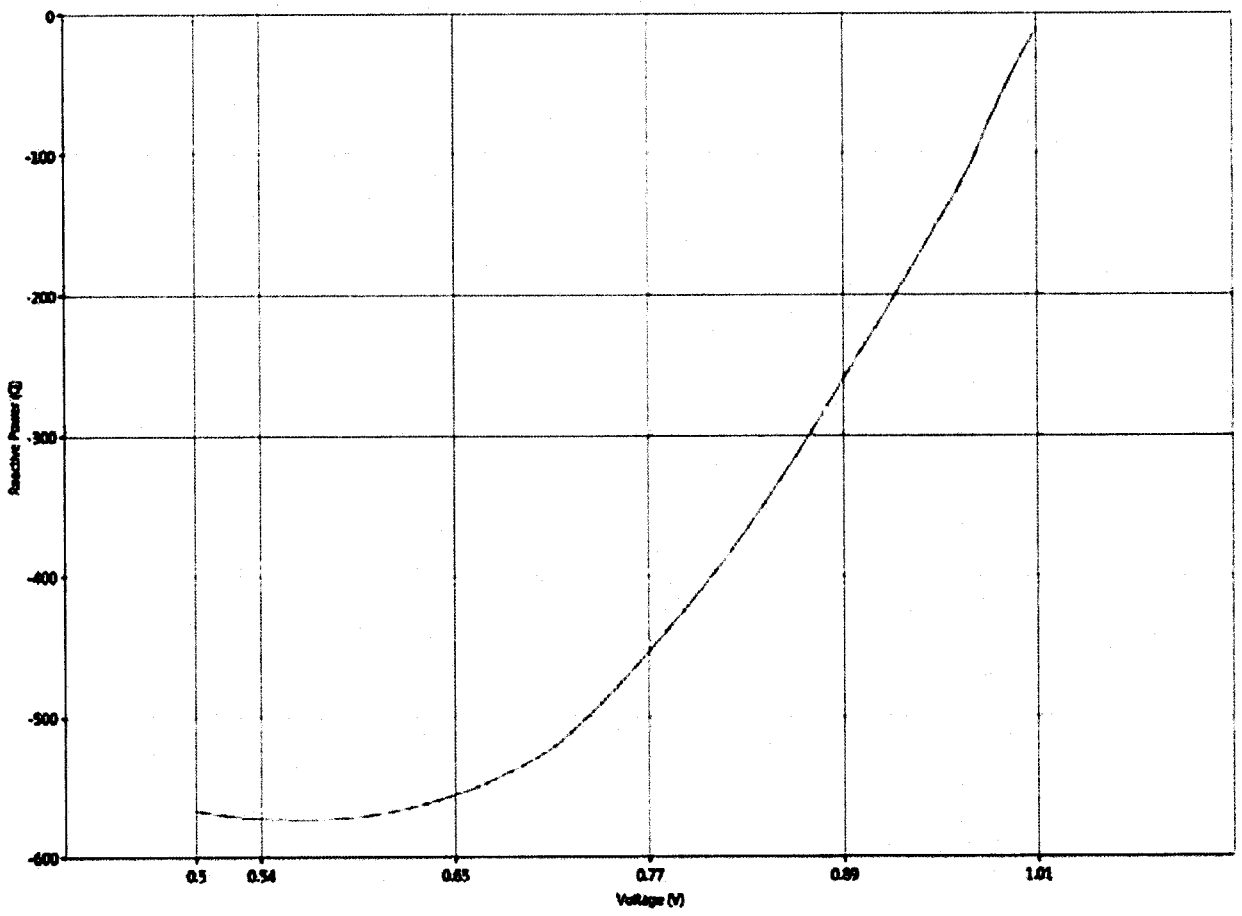
2019LW – Bicknell to Vail 345 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



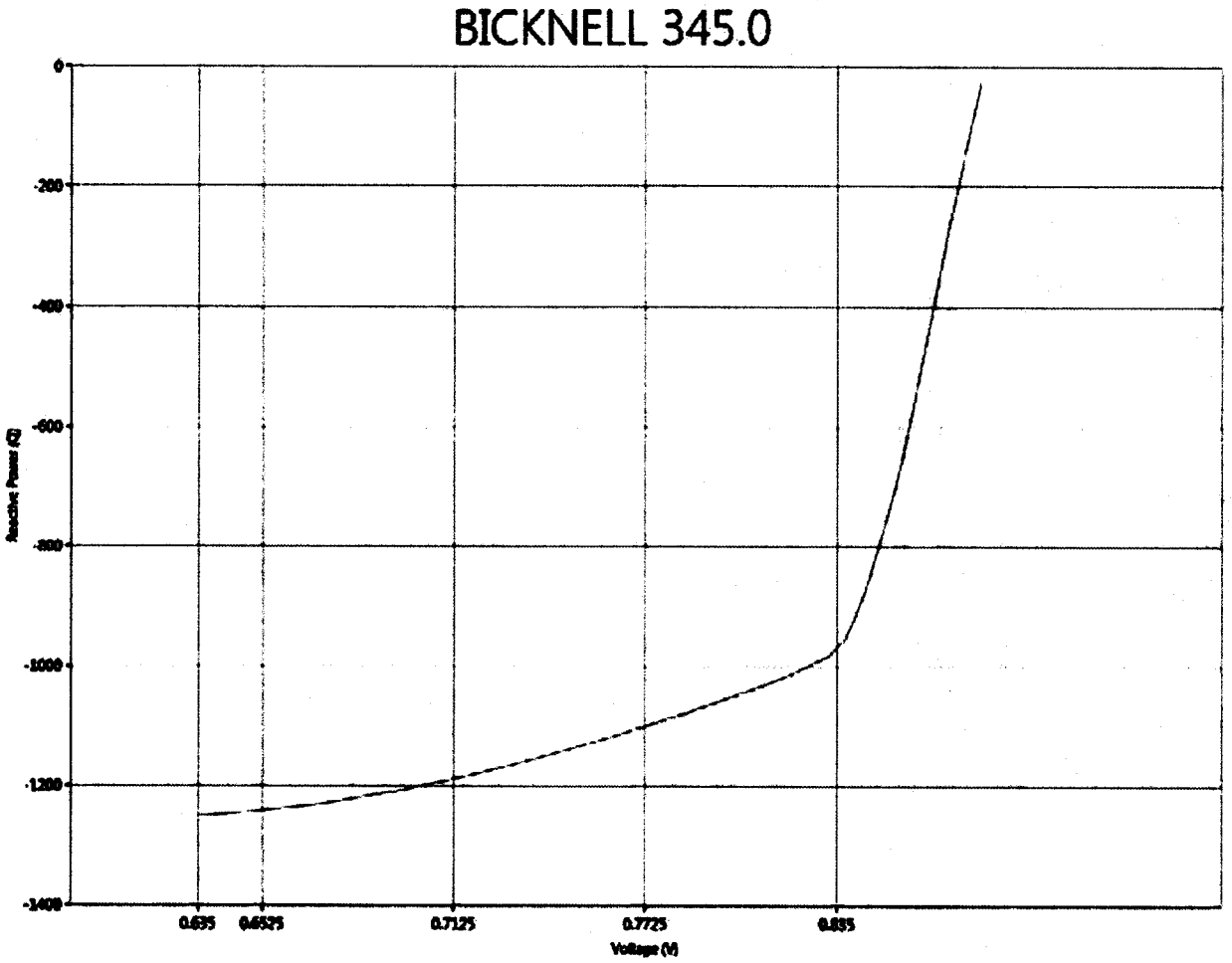
MARANA 115.0


0
-100
-200
-300
-400
-500
-600
Reactive Power (Q)
0.6875
0.695
0.74
0.8
0.89
Voltage (V)

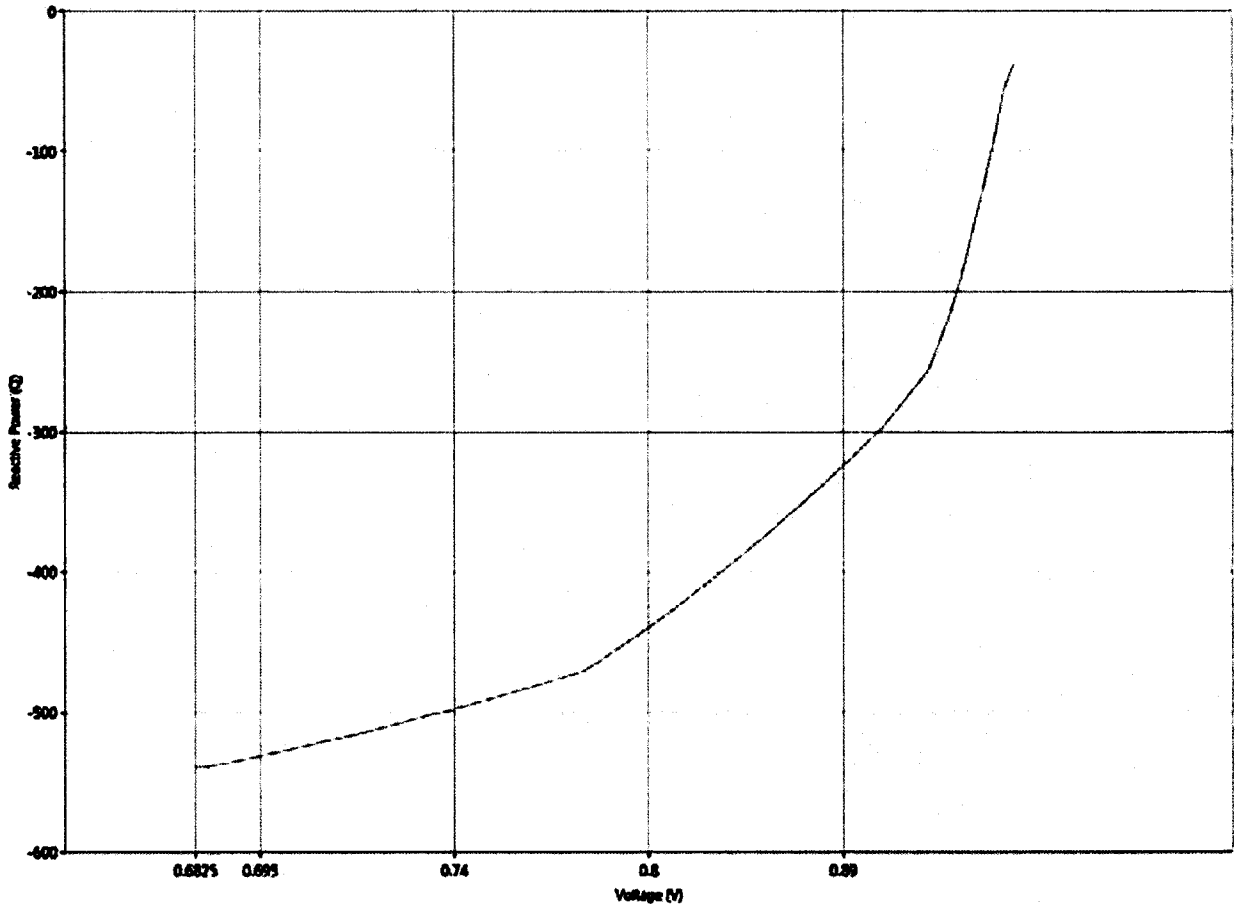
PANTANO 230.0



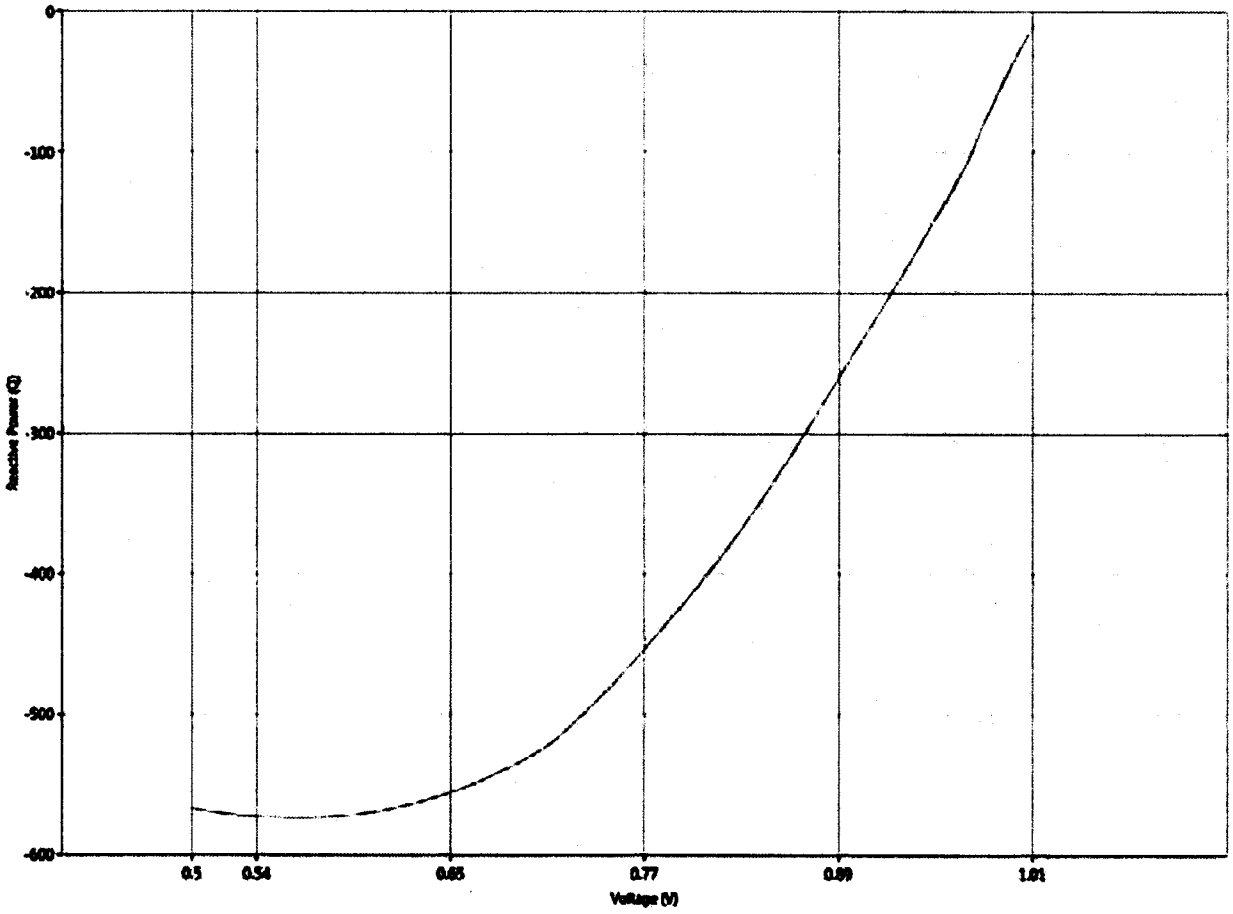
2019LW – Saguaro East to Marana Tap 115 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



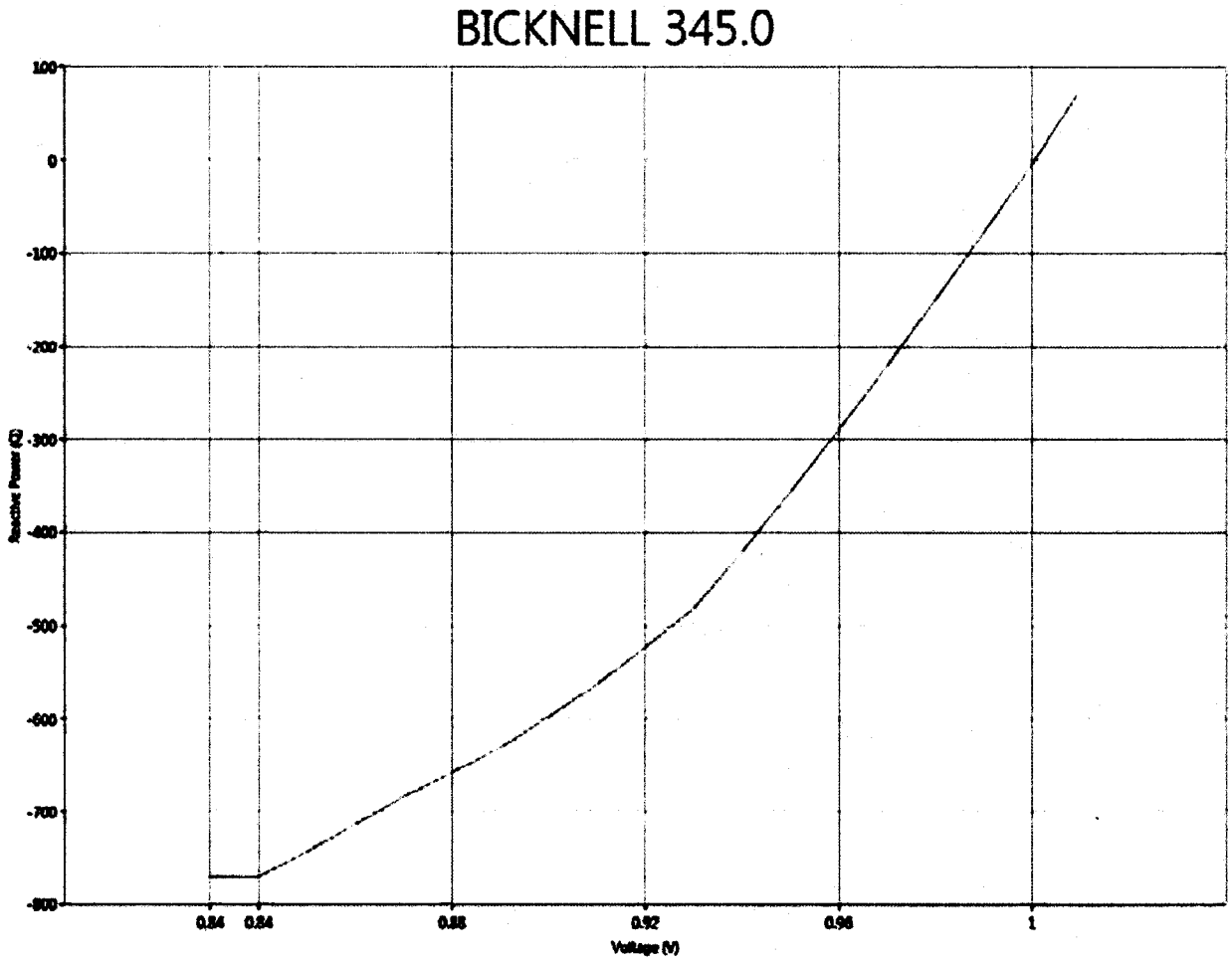
MARANA 115.0


0
-100
-200
-300
-400
-500
-600
Reactive Power (Q)
0.6825
0.695
0.74
0.8
0.89
Voltage (V)

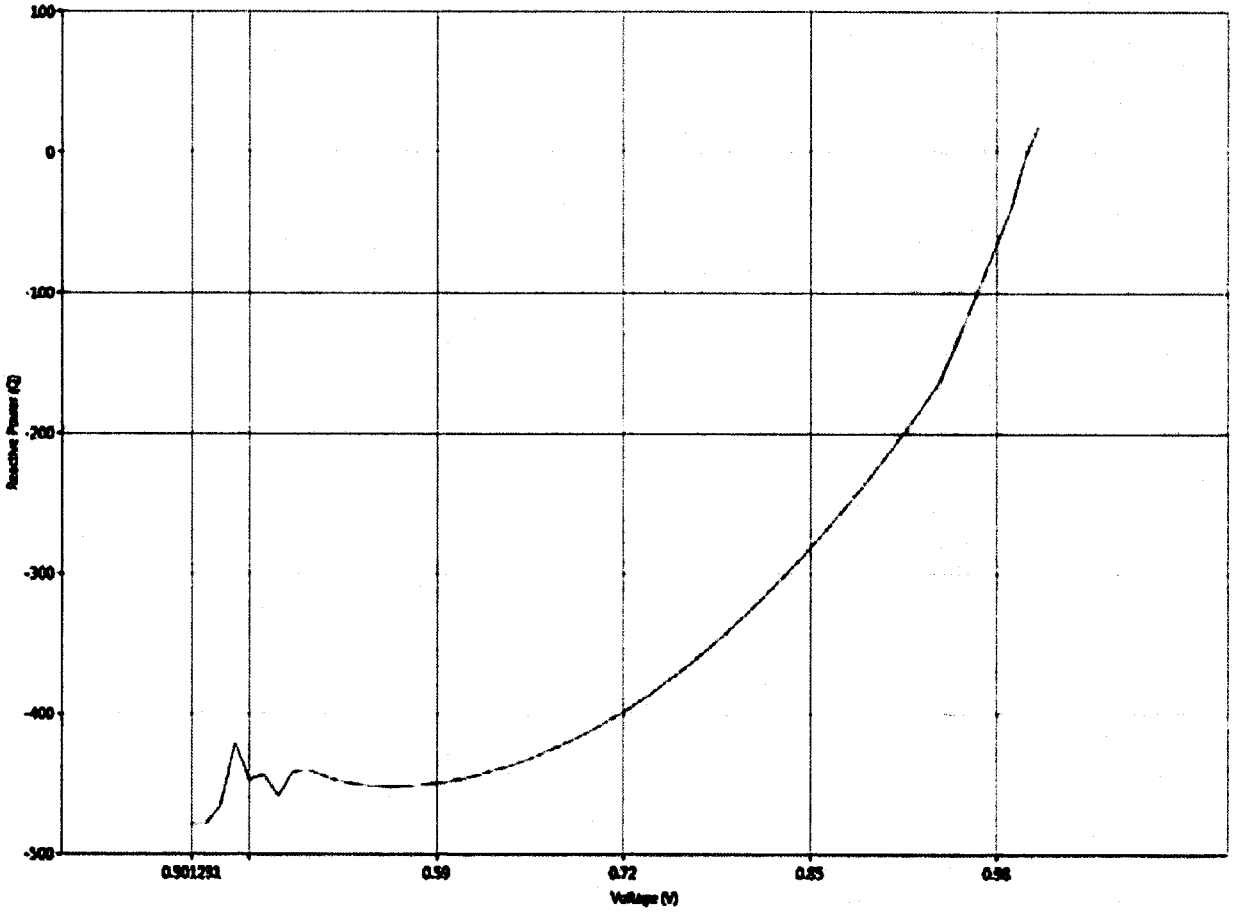
PANTANO 230.0



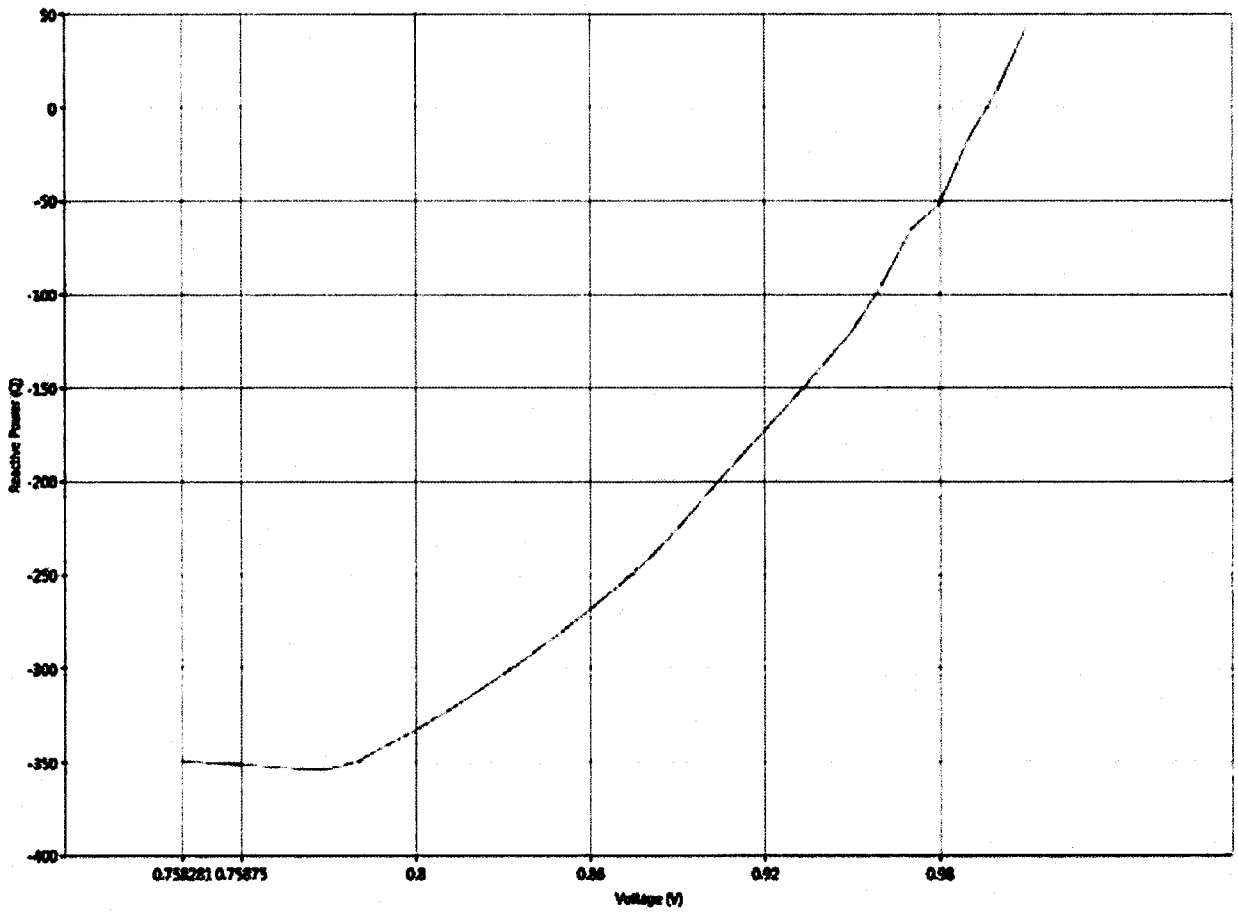
2023HS – Apache to Butterfield 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



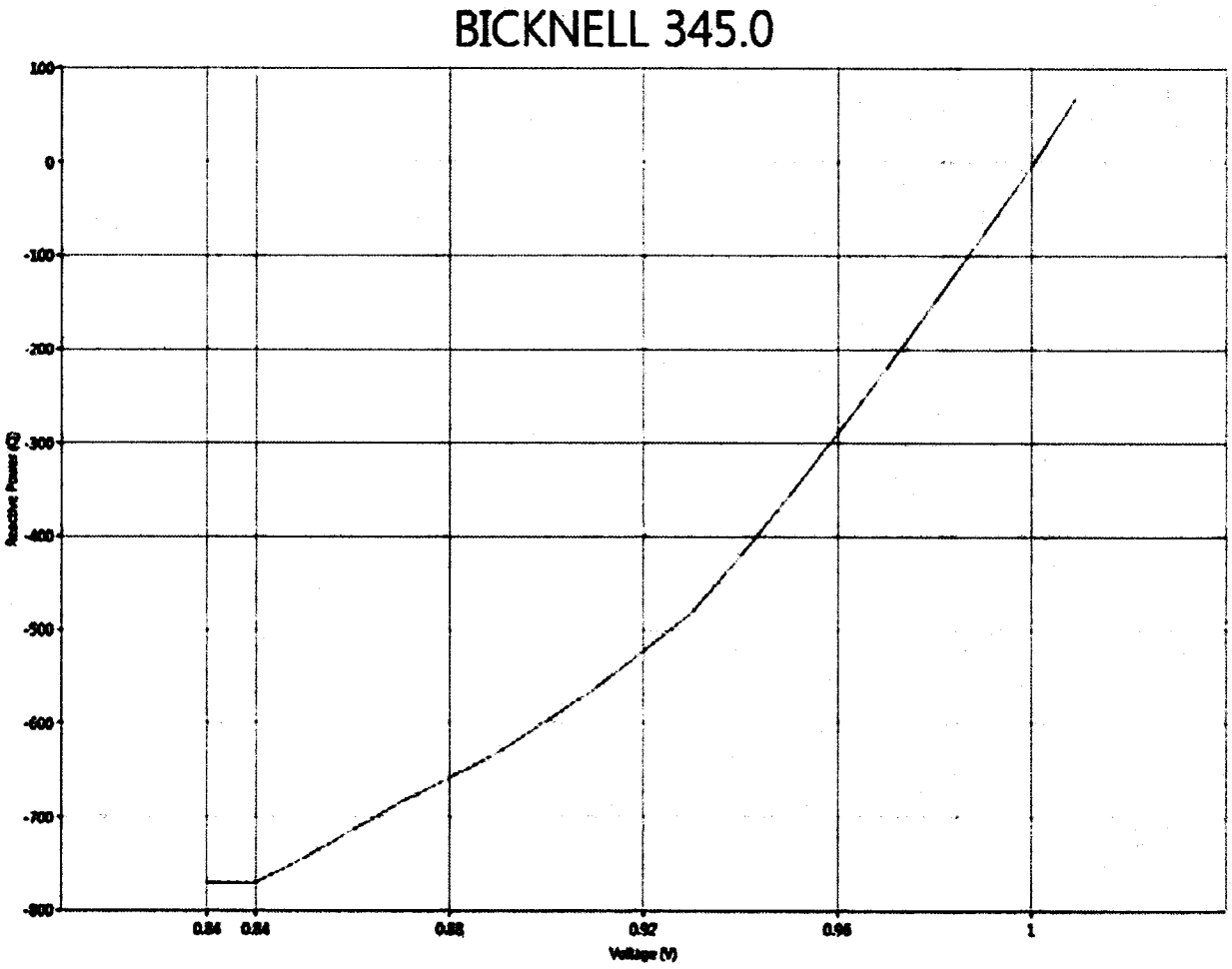
MARANA 115.0



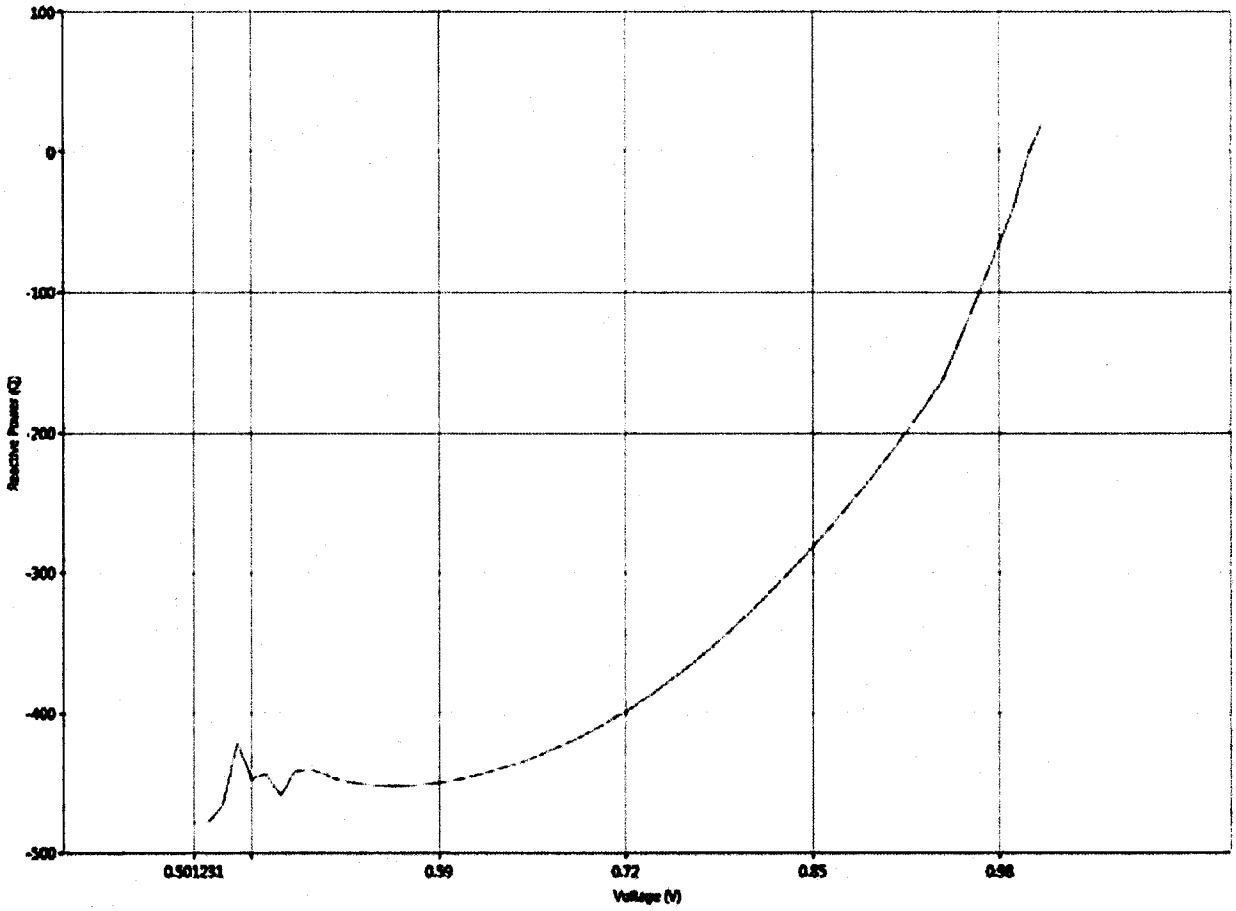
PANTANO 230.0



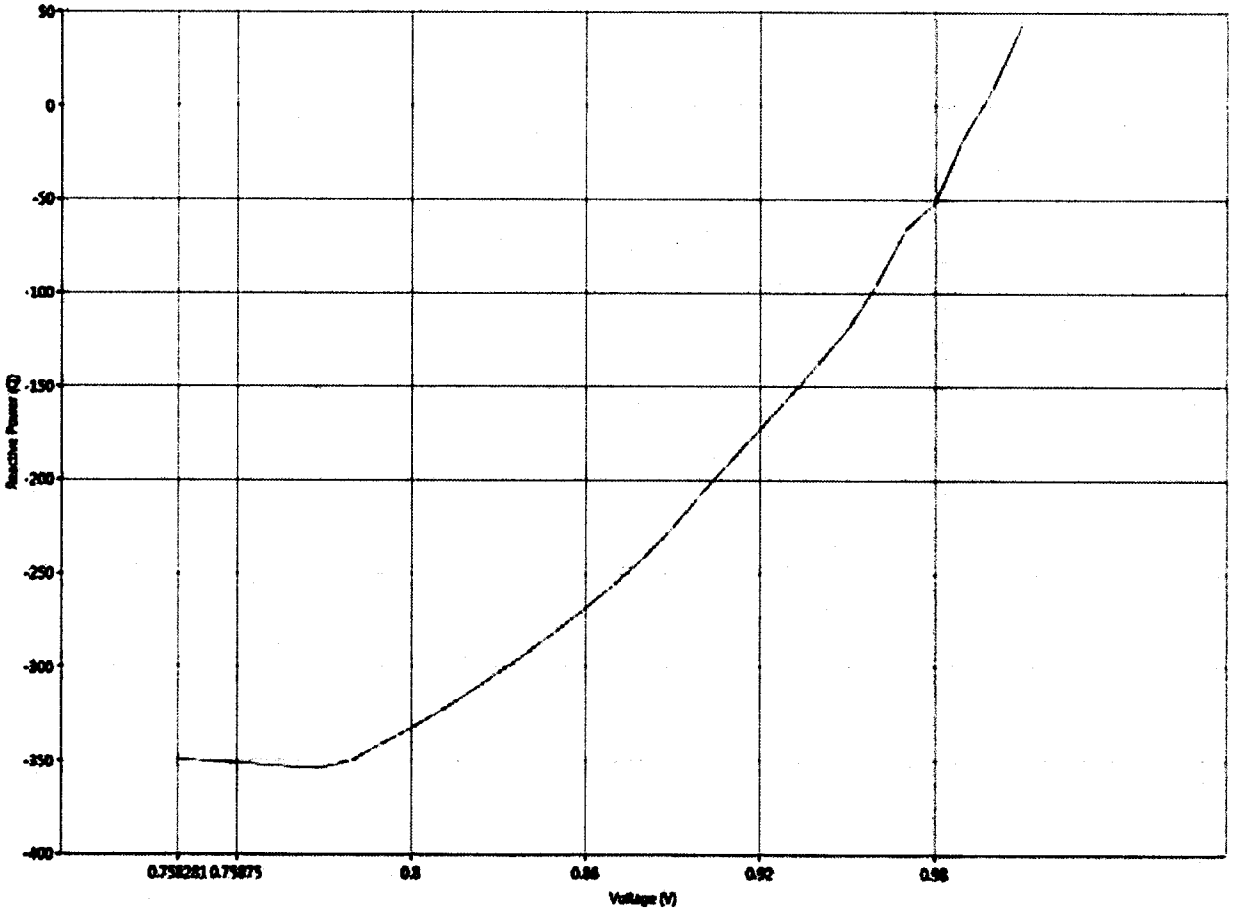
2023HS – Apache to Redtail 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



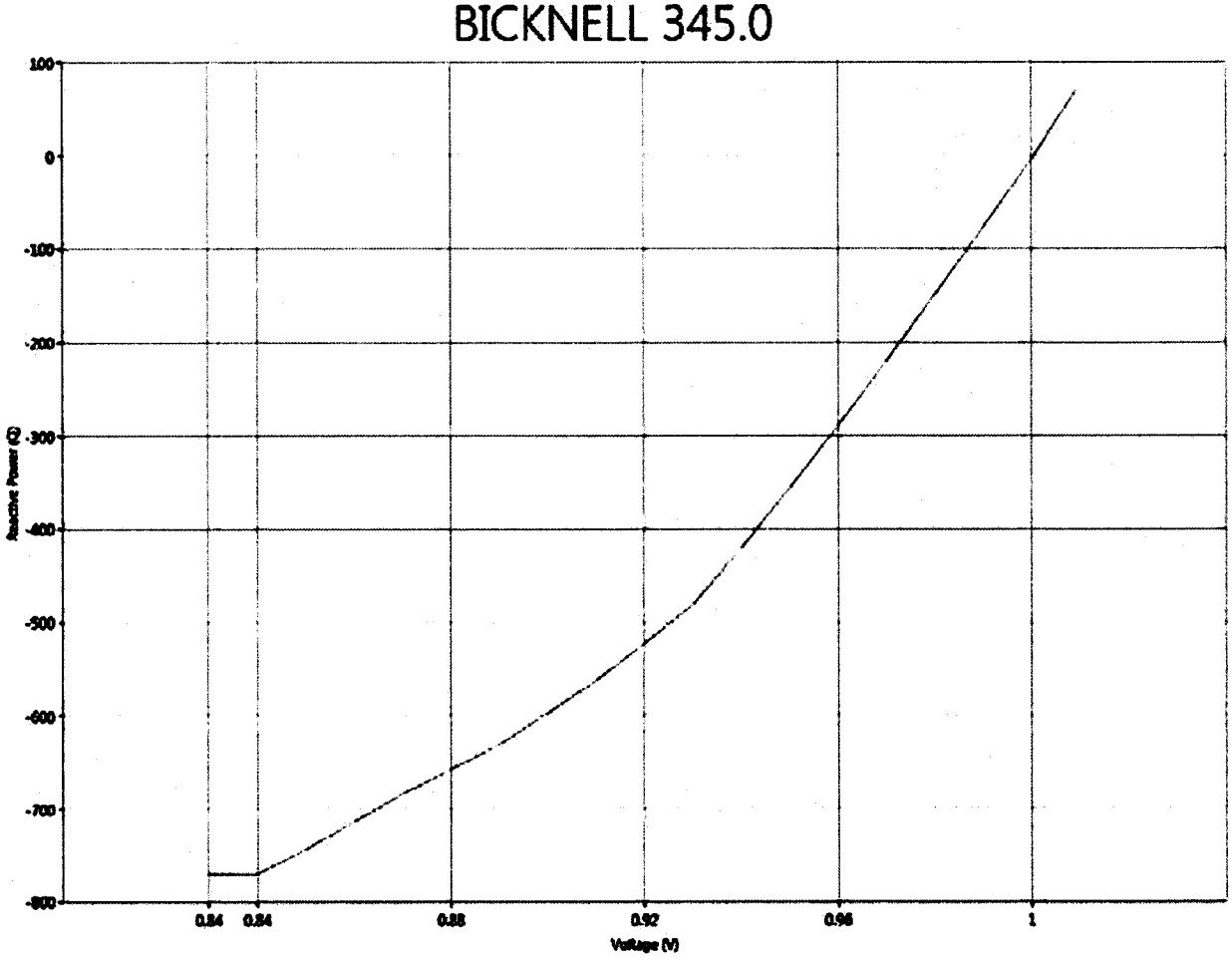
MARANA 115.0


100
0
-100
-200
-300
-400
-500
Reactive Power (Q)
0.501231
0.99
0.72
0.85
0.98
Voltage (V)

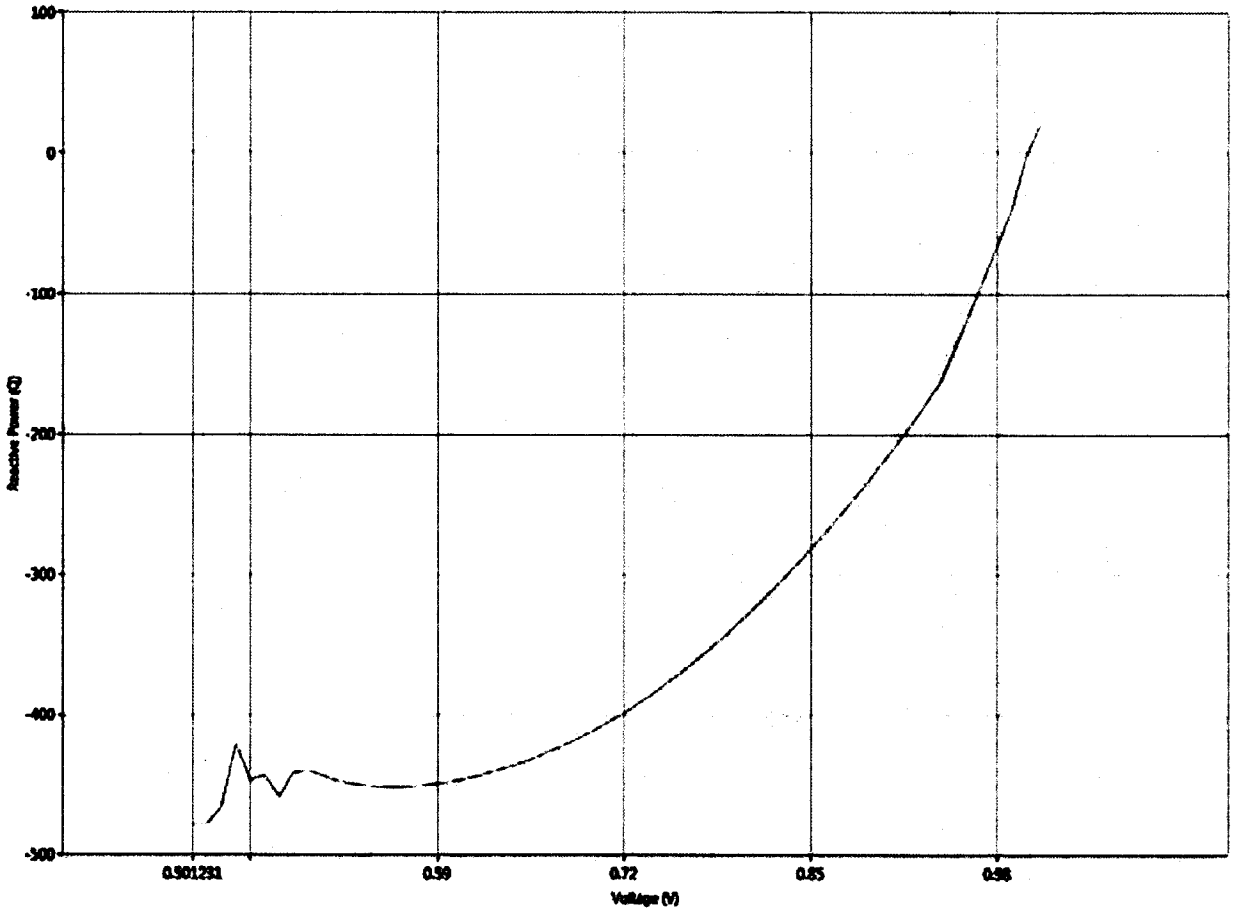
PANTANO 230.0

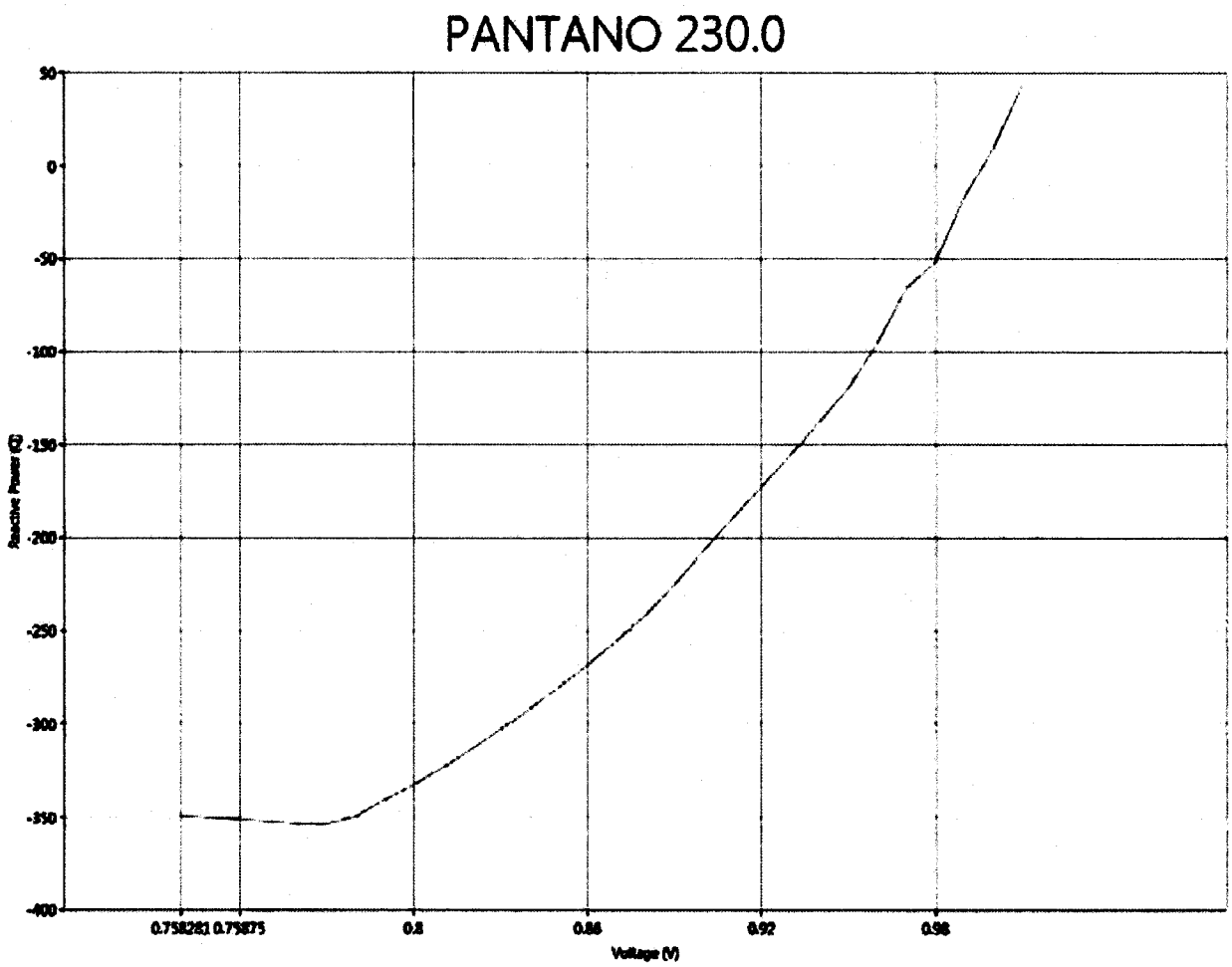


2023HS – Bicknell to Vail 345 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

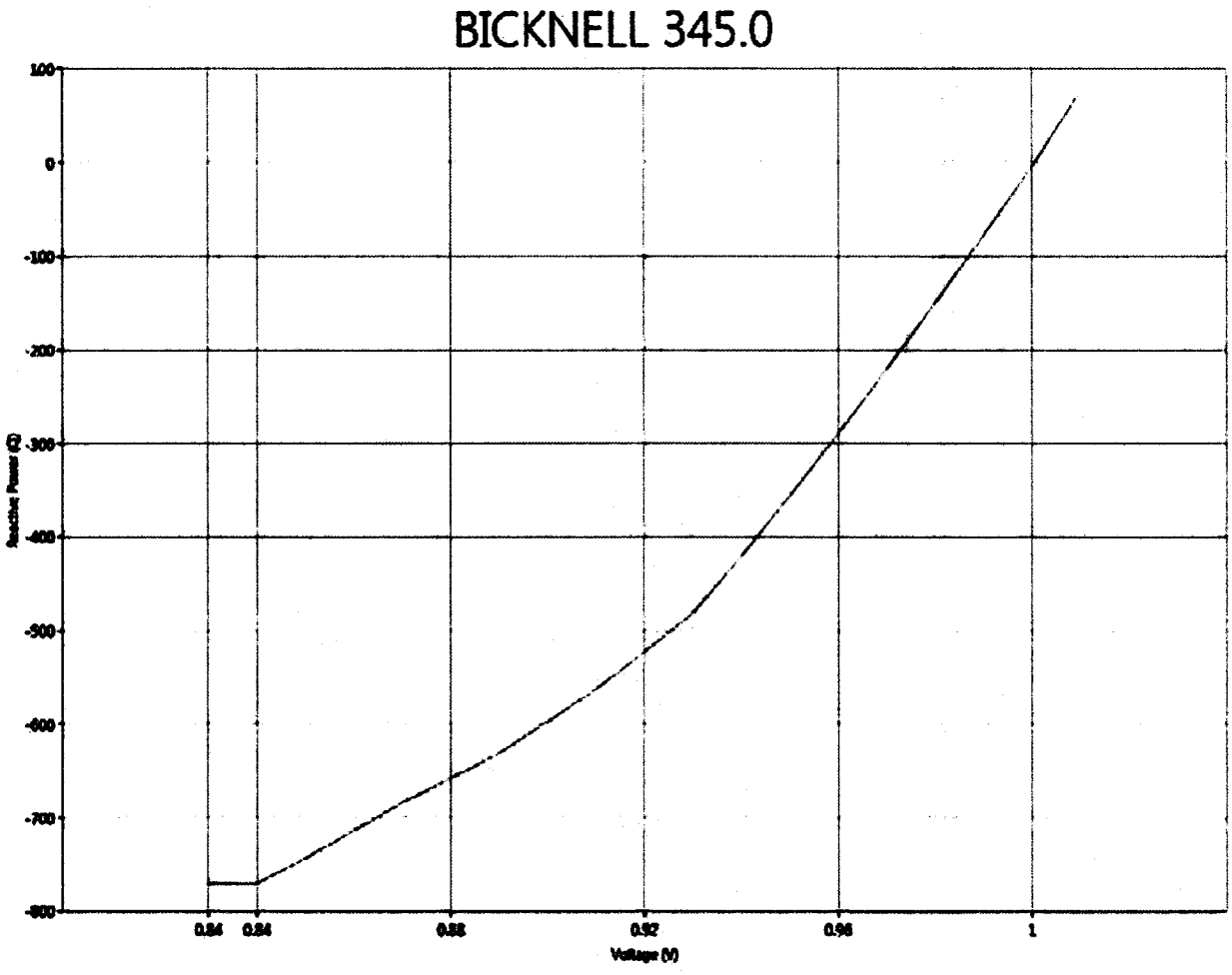


MARANA 115.0

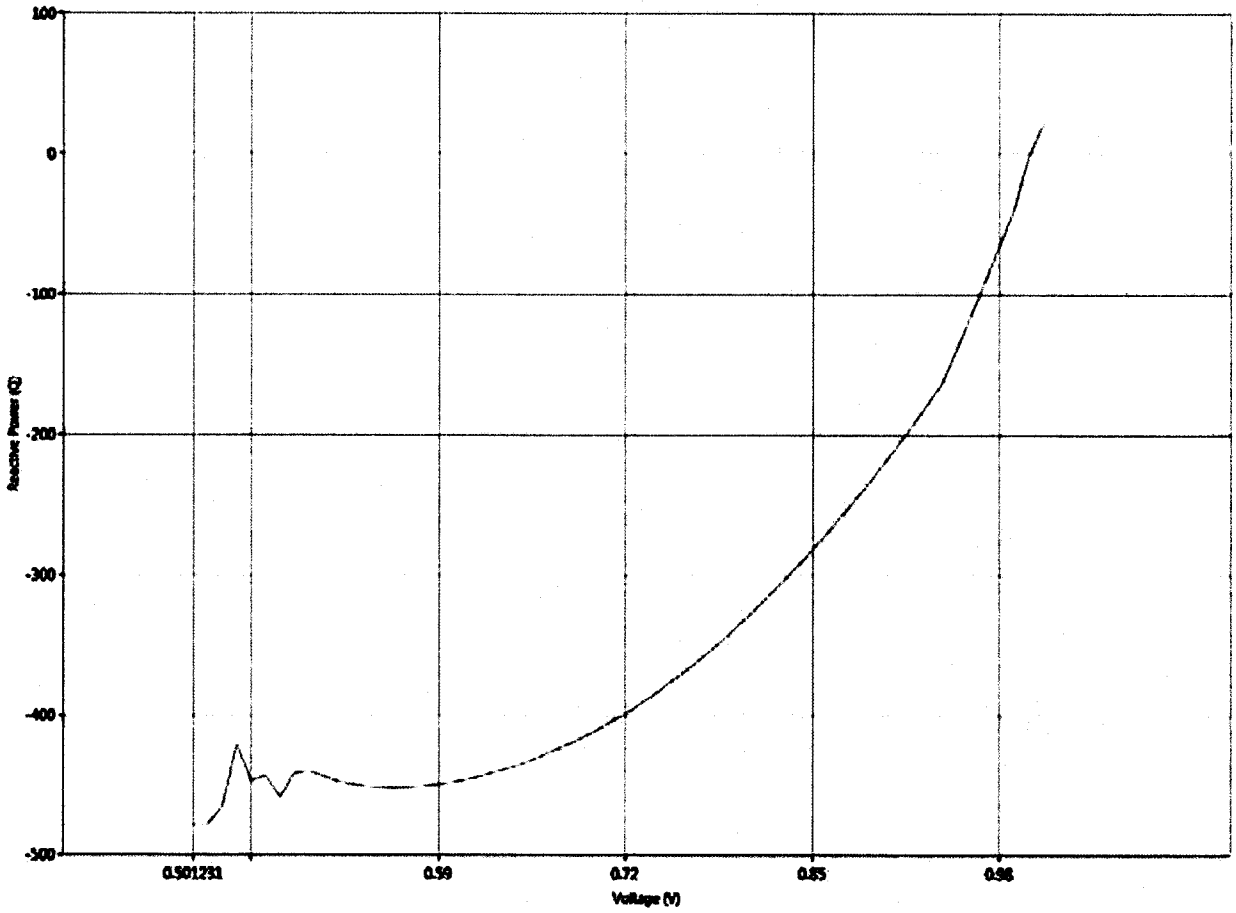

100
0
-100
-200
-300
-400
-500
Reactive Power (Q)
0.901231
0.99
0.72
0.85
0.98
Voltage (V)

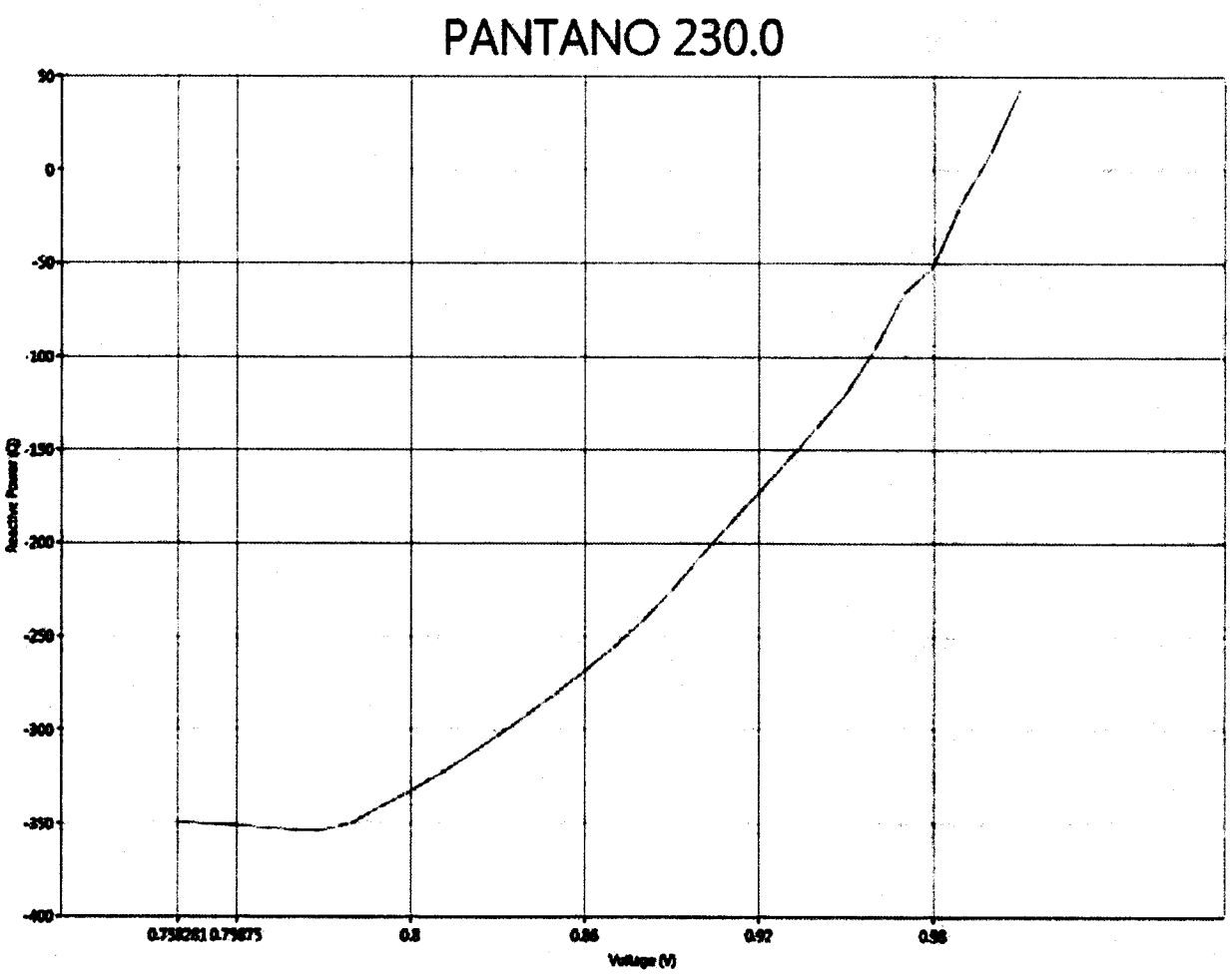

PANTANO 230.0
50
0
-50
-100
-150
-200
-250
-300
-350
-400
Reactive Power (Q)
0.758281
0.75875
0.8
0.86
0.92
0.98
Voltage (V)

2023HS – Saguaro to Marana Tap 115 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

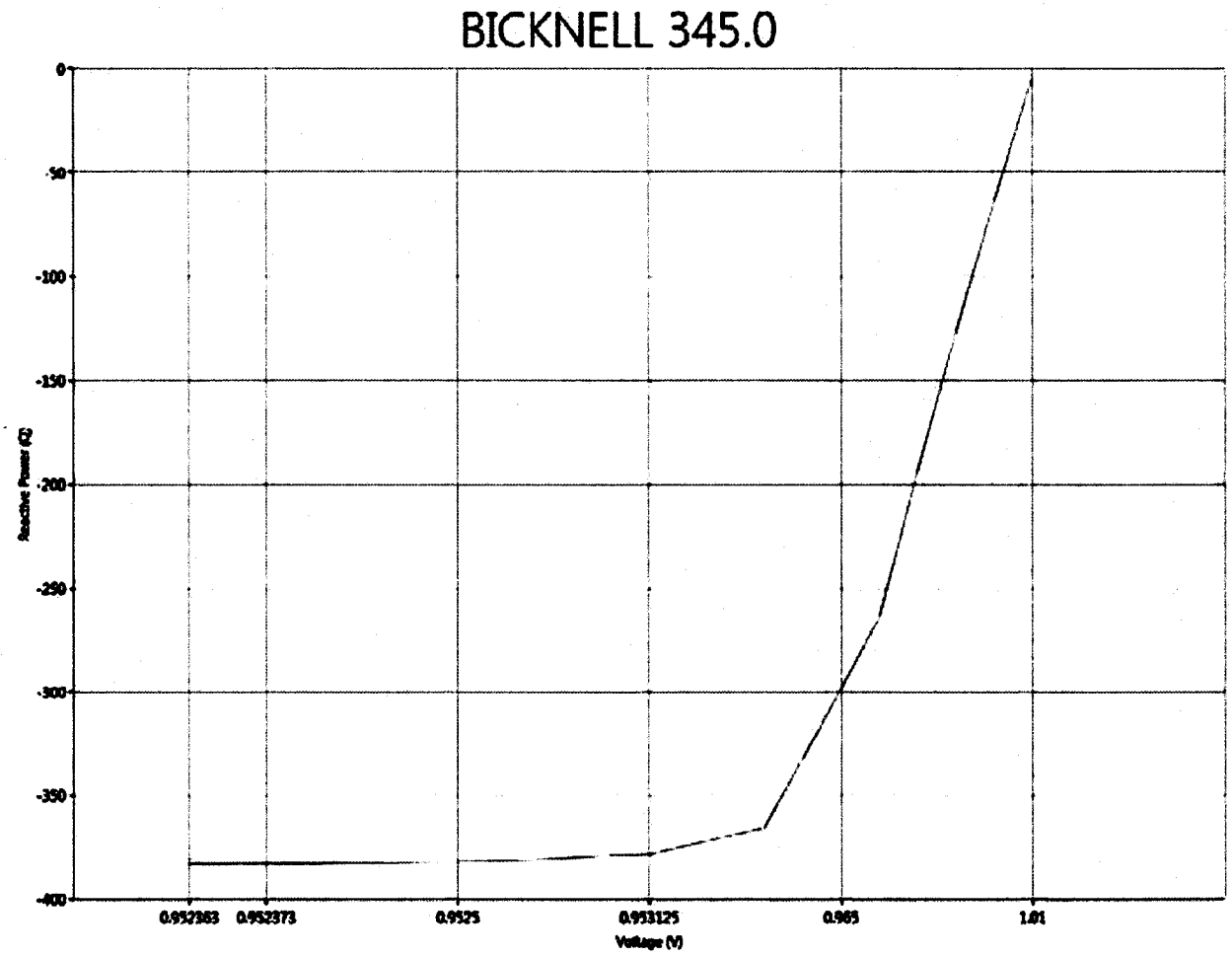


MARANA 115.0

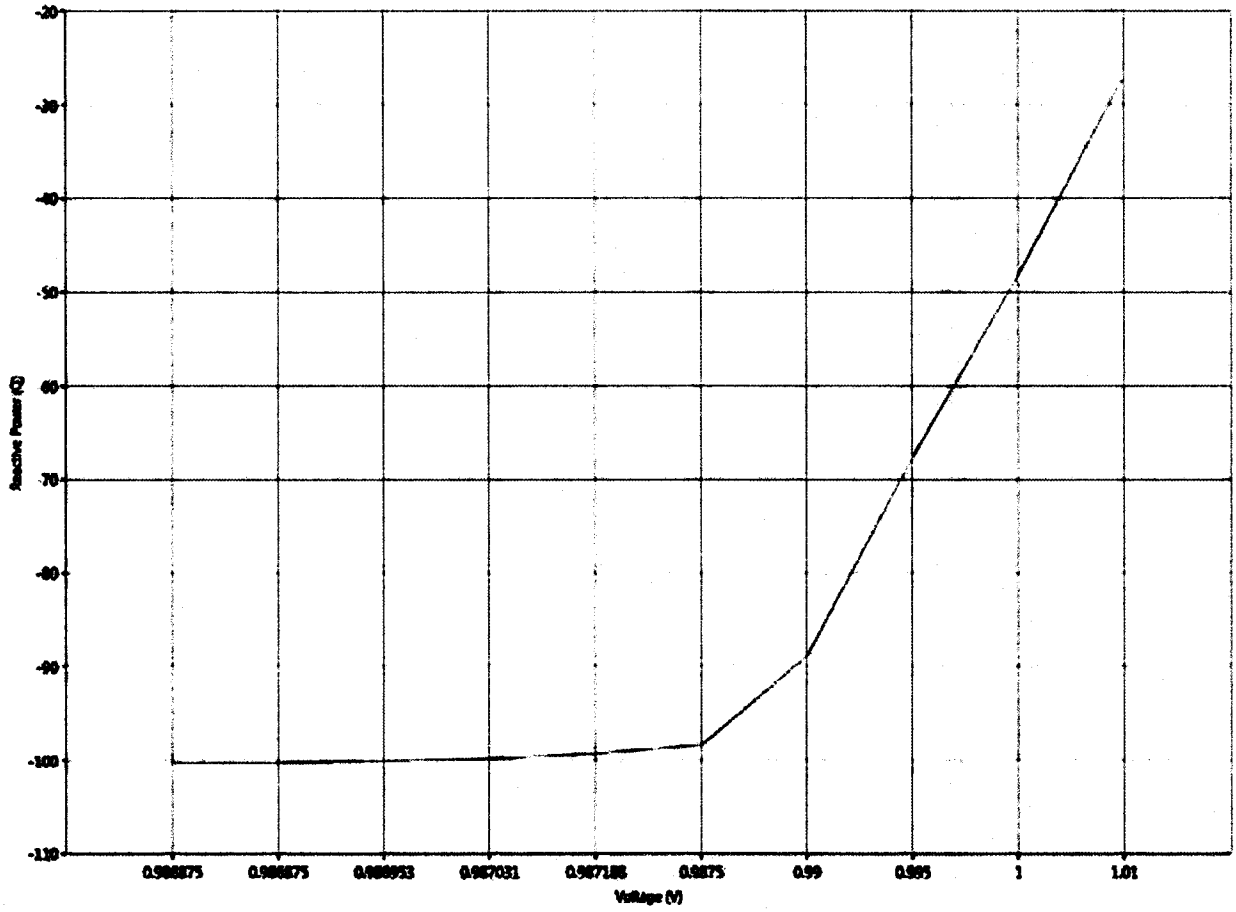

100
0
-100
-200
-300
-400
-500
Reactive Power (Q)
0.501231
0.59
0.72
0.85
0.98
Voltage (V)

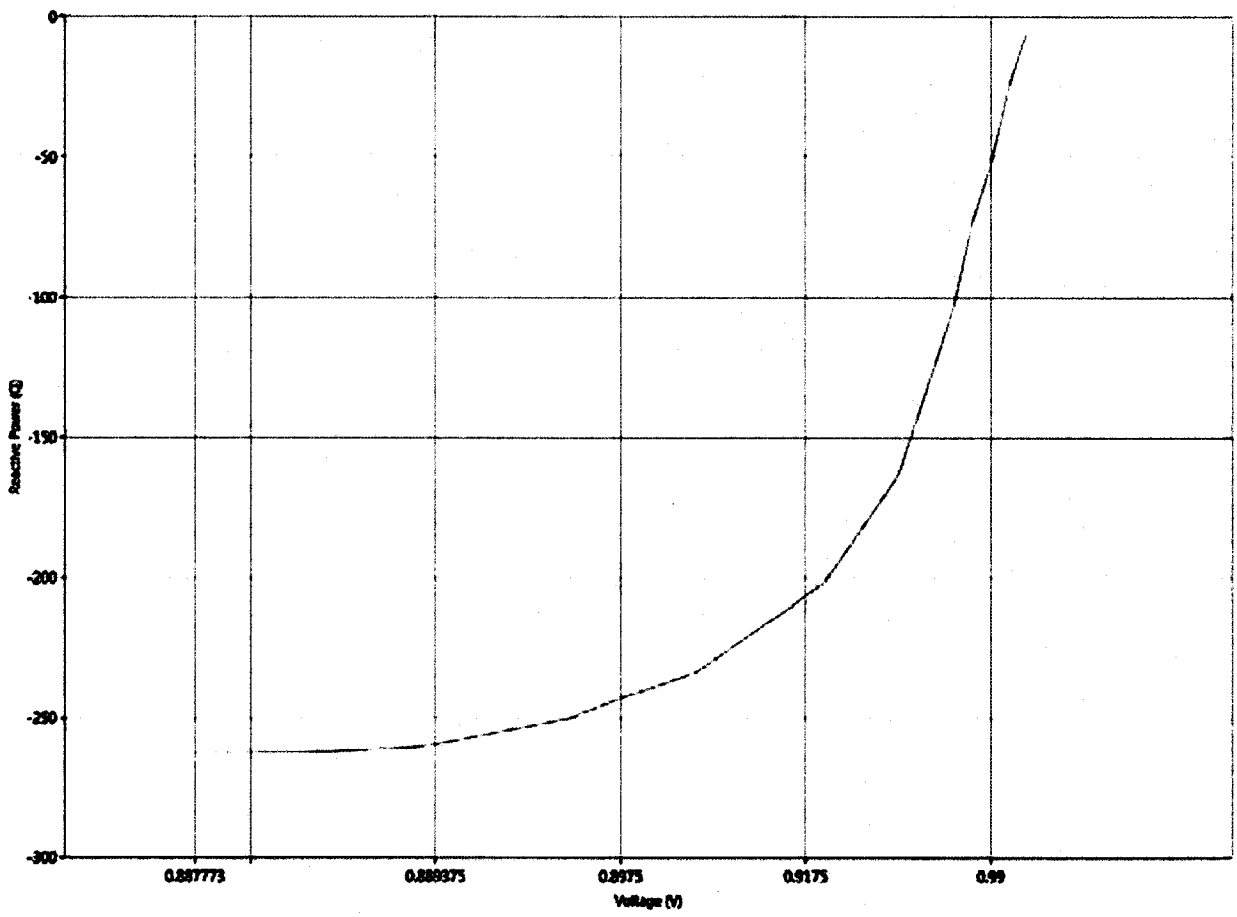

PANTANO 230.0
Reactive Power (Q)
Voltage (V)

2023LW – Apache to Butterfield 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

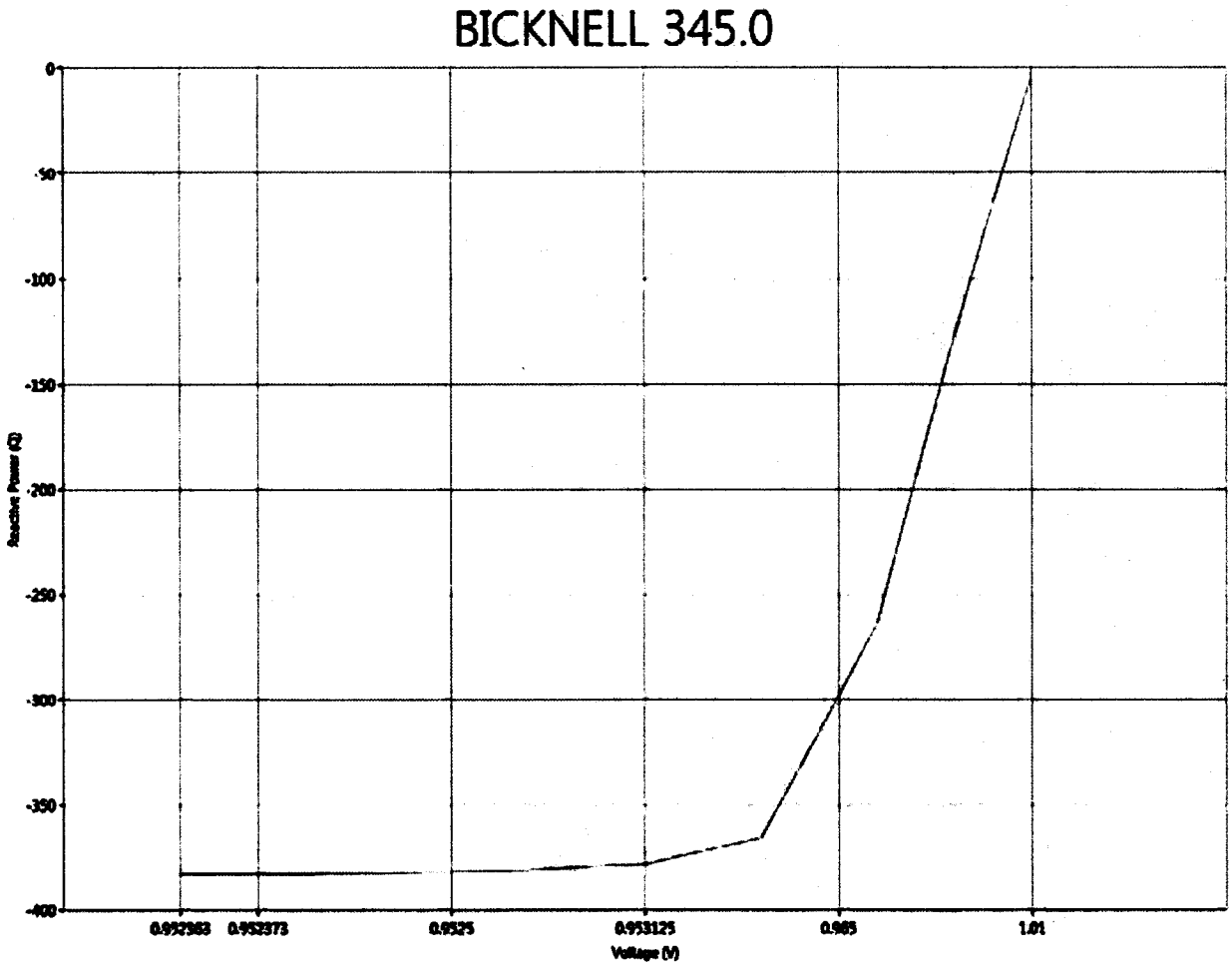


MARANA 115.0

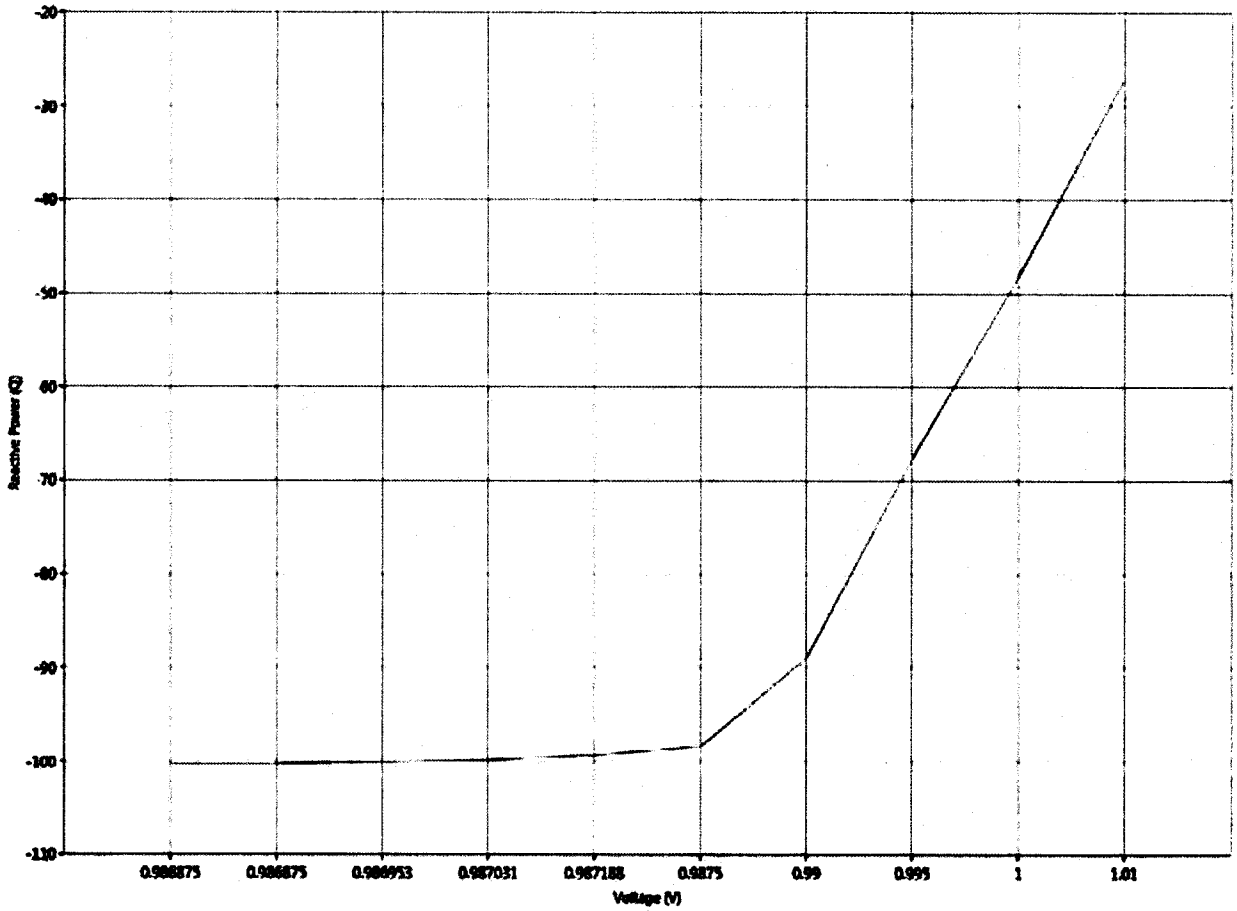

-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
Reactive Power (Q)
0.986875
0.986875
0.986953
0.987031
0.987188
0.9875
0.99
0.995
1
1.01
Voltage (V)

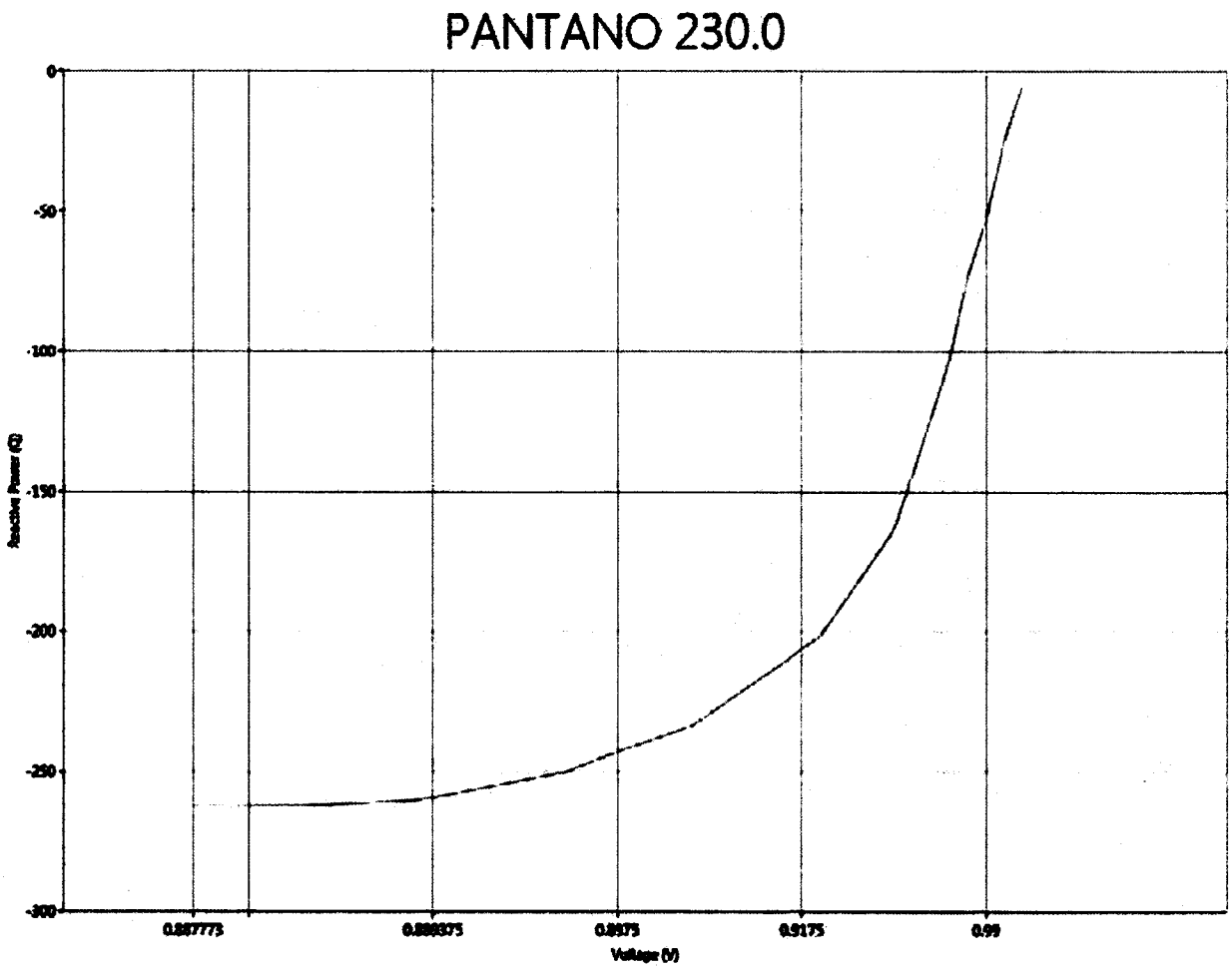

PANTANO 230.0
0
-50
-100
-150
-200
-250
-300
Reactive Power (Q)
0.887773
0.889375
0.8975
0.9175
0.99
Voltage (V)

2023LW – Apache to Redtail 230 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses

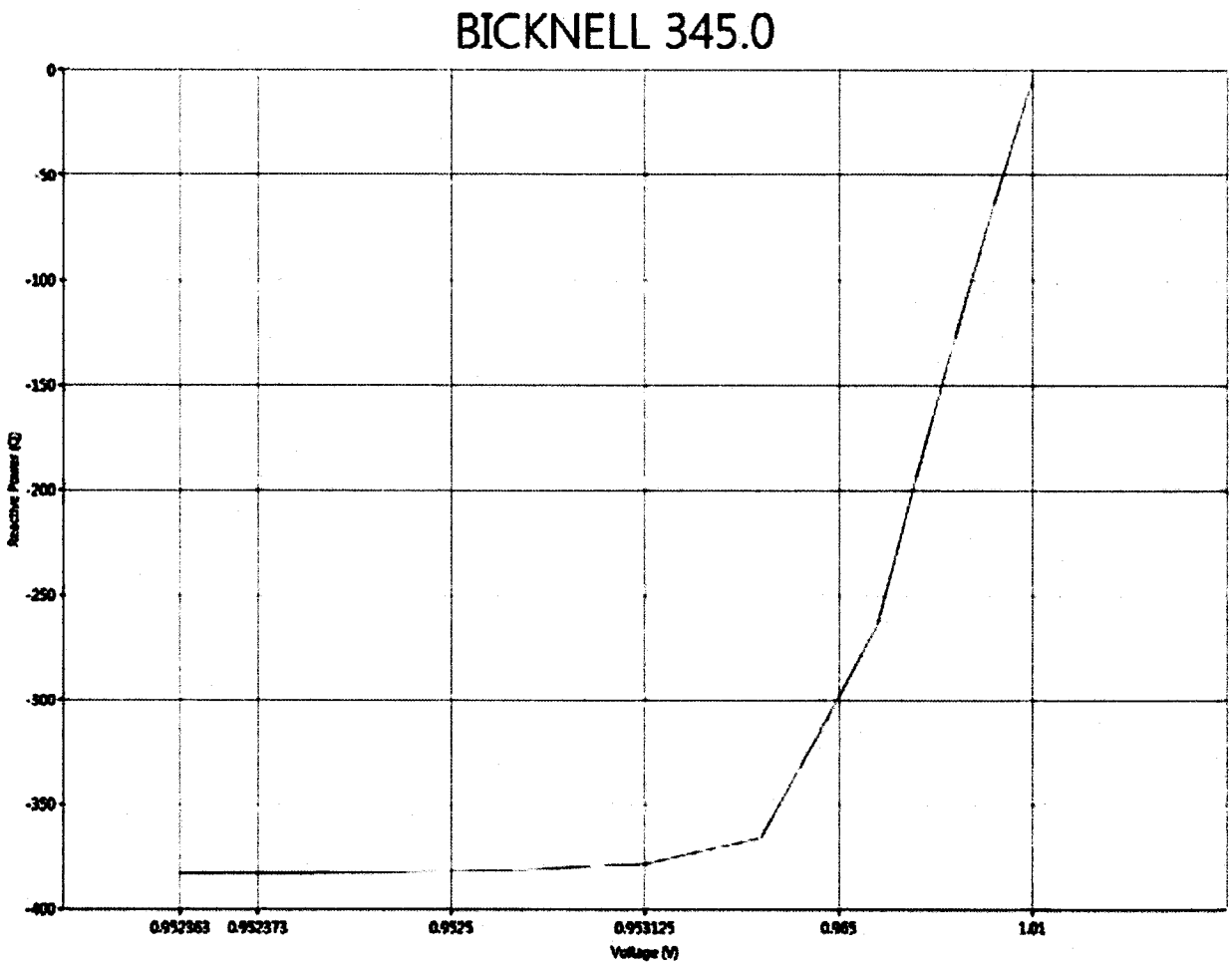


MARANA 115.0

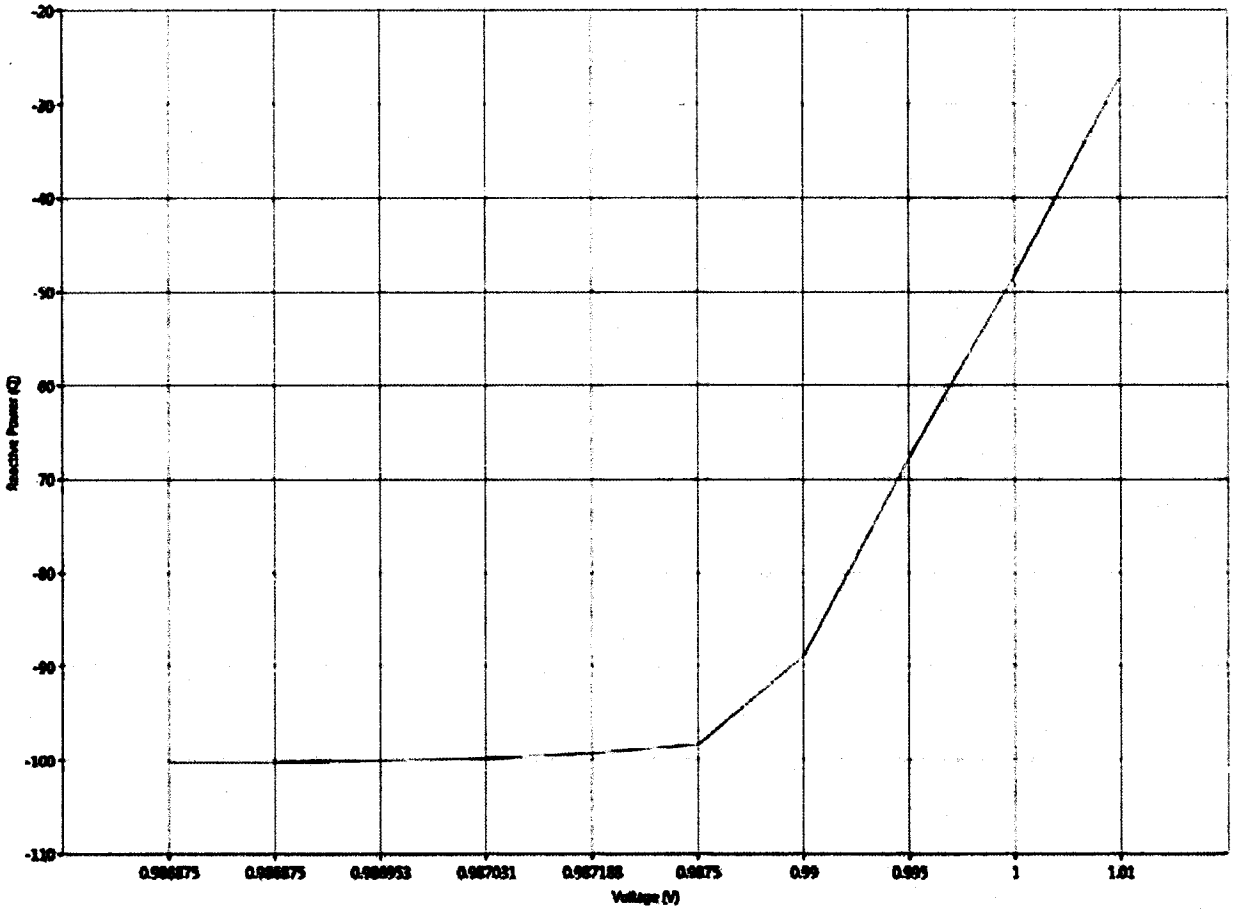

-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
Reactive Power (Q)
0.988875
0.986875
0.986953
0.987031
0.987188
0.9875
0.99
0.995
1
1.01
Voltage (V)


PANTANO 230.0
0
-50
-100
-150
-200
-250
-300
0.887773
0.933375
0.9575
0.9175
0.99
Voltage (V)

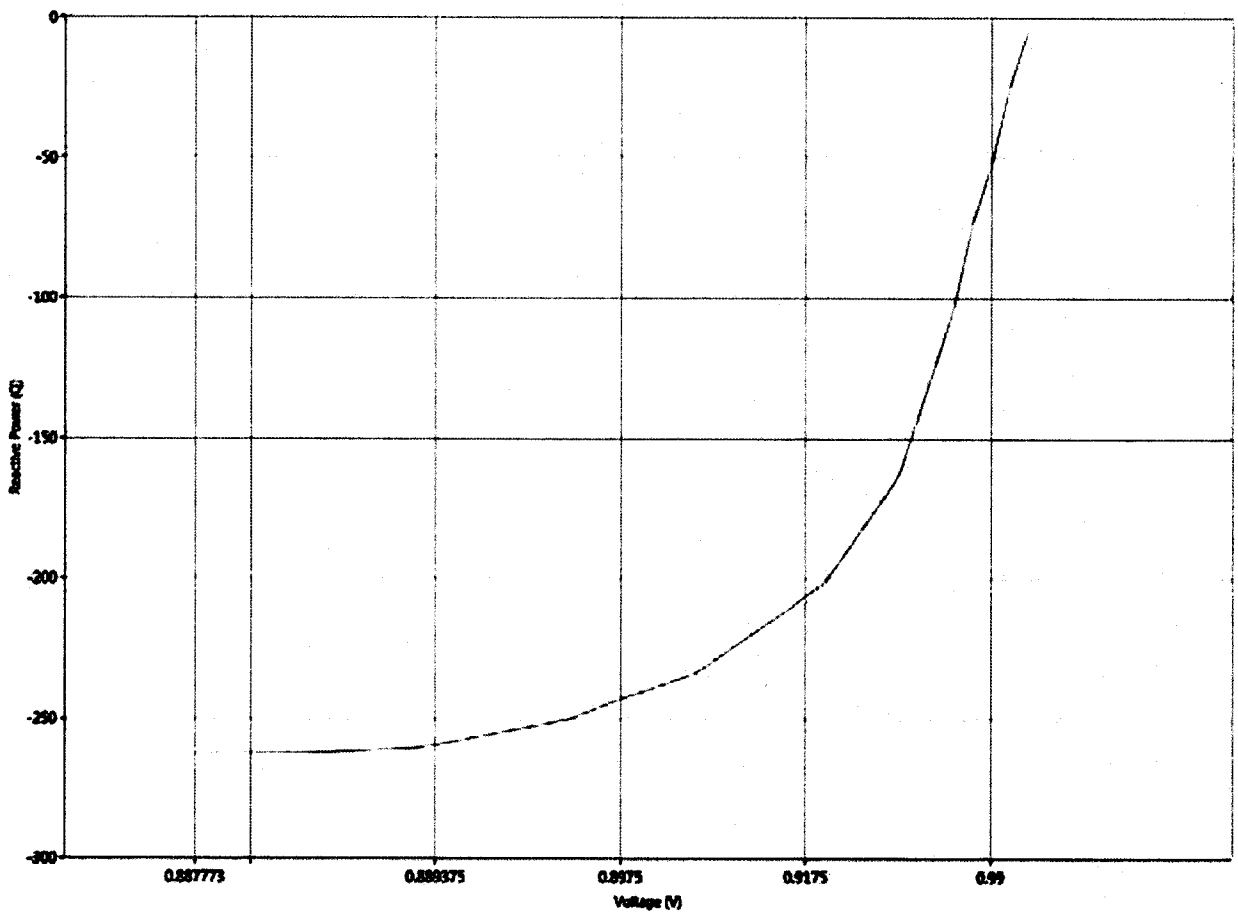
2019LW – Bicknell to Vail 345 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses



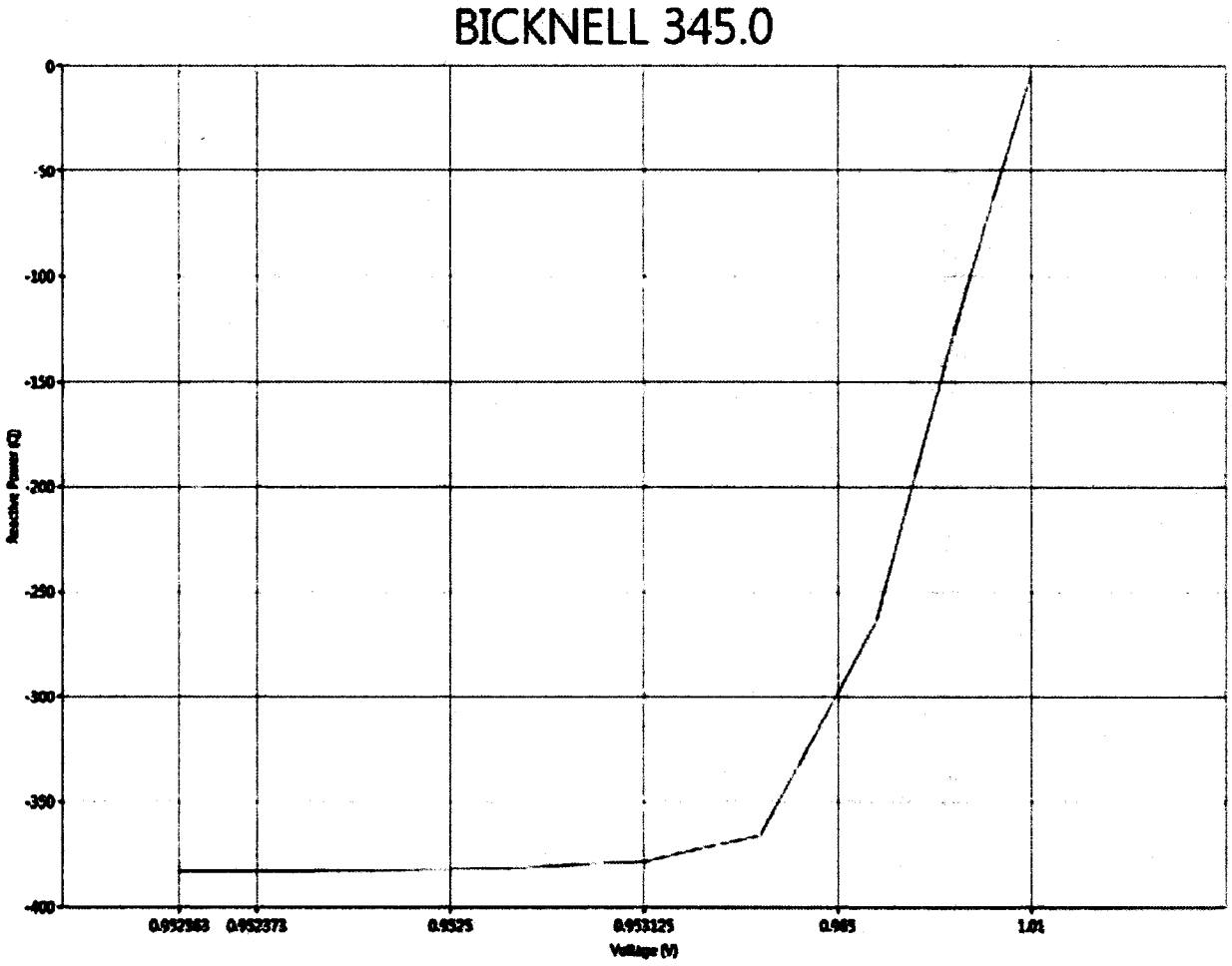
MARANA 115.0

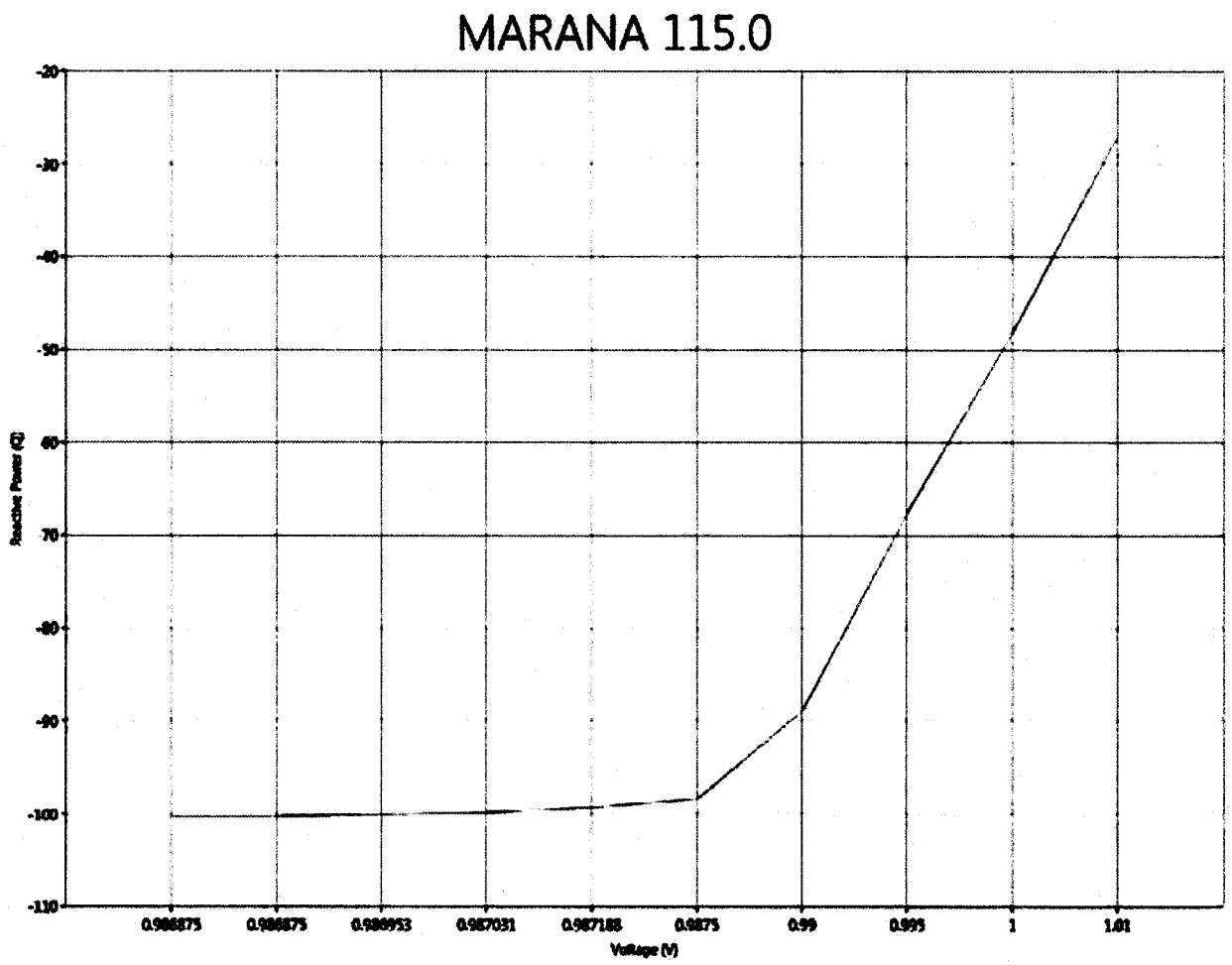

-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
Reactive Power (Q)
0.986875
0.986875
0.986953
0.987031
0.987188
0.9875
0.99
0.995
1
1.01
Voltage (V)

PANTANO 230.0

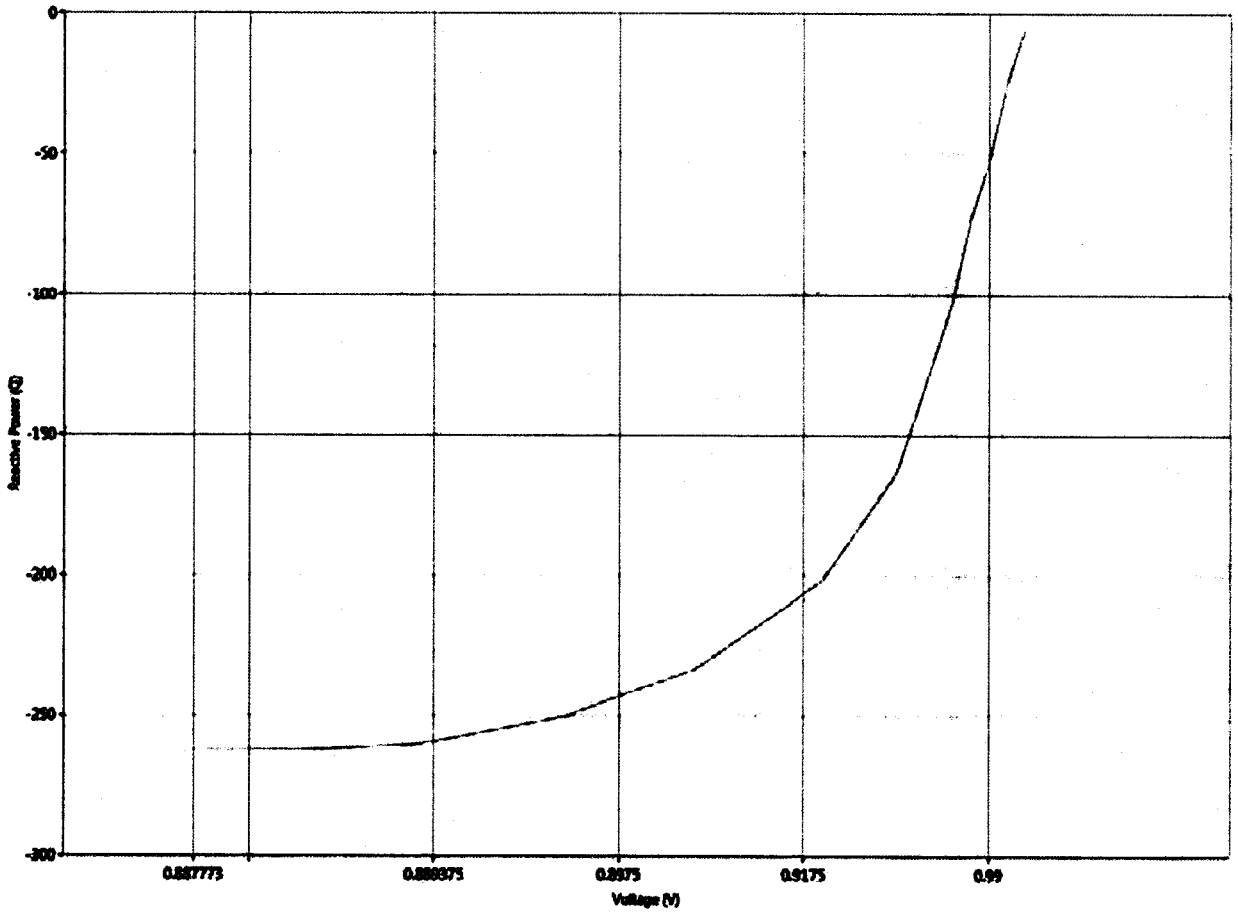


2023LW – Saguaro East to Marana Tap 115 kV Line Outage with plots of Bicknell 345 kV, Marana 115 kV, and Pantano 230 kV buses




MARANA 115.0
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
Reactive Power (Q)
0.986875
0.986875
0.986953
0.987031
0.987188
0.9875
0.99
0.995
1
1.01
Voltage (V)

PANTANO 230.0



APPENDIX E

TRANSIENT STABILITY PLOTS

2014HS Plots:

Apache – Butterfield 230 kV Outage. 242

Apache – Redtail 230 kV Outage 245

Bicknell – Vail 345 kV Outage 248

Saguaro East – Marana 115 kV Outage 251

Apache – Butterfield 230 kV & Saguaro East – Marana 115 kV Outage. 254

Apache – Butterfield 230 kV & Bicknell – Vail 345 kV Outage. 257

2019HS Plots:

Apache – Butterfield 230 kV Outage 260

Apache – Redtail 230 kV Outage 263

Bicknell – Vail 345 kV Outage 266

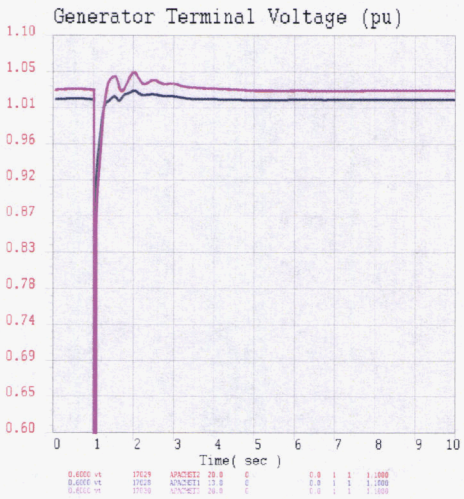
Sagauro East – Marana 115 kV Outage. 269

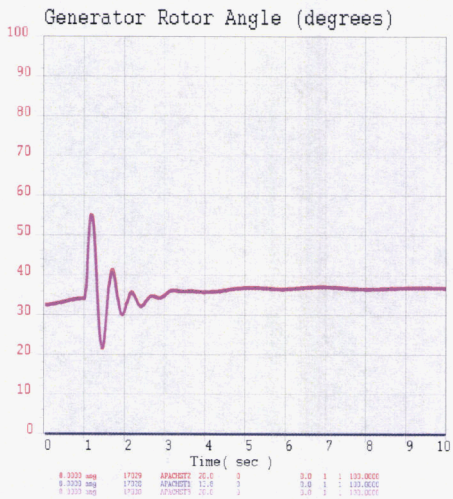
Apache – Butterfield & Saguaro East – Marana 115 kV Outage 272

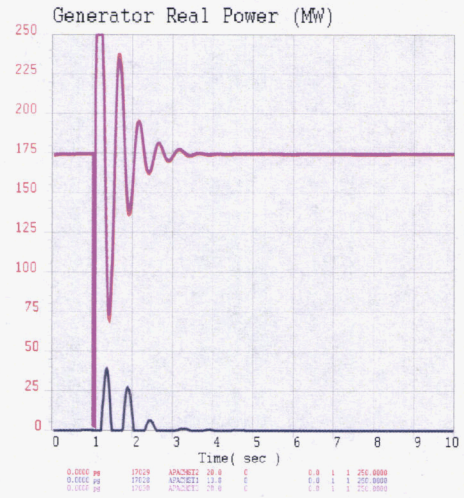
Apache – Butterfield 230 kV & Bicknell – Vail 345 kV Outage 275

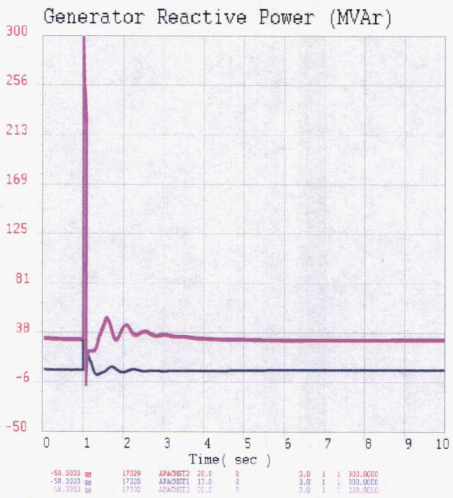
2014HS – Apache to Butterfield 230 kV Line Outage – Apache Generators Output

APACHE GENERATORS OUTPUT





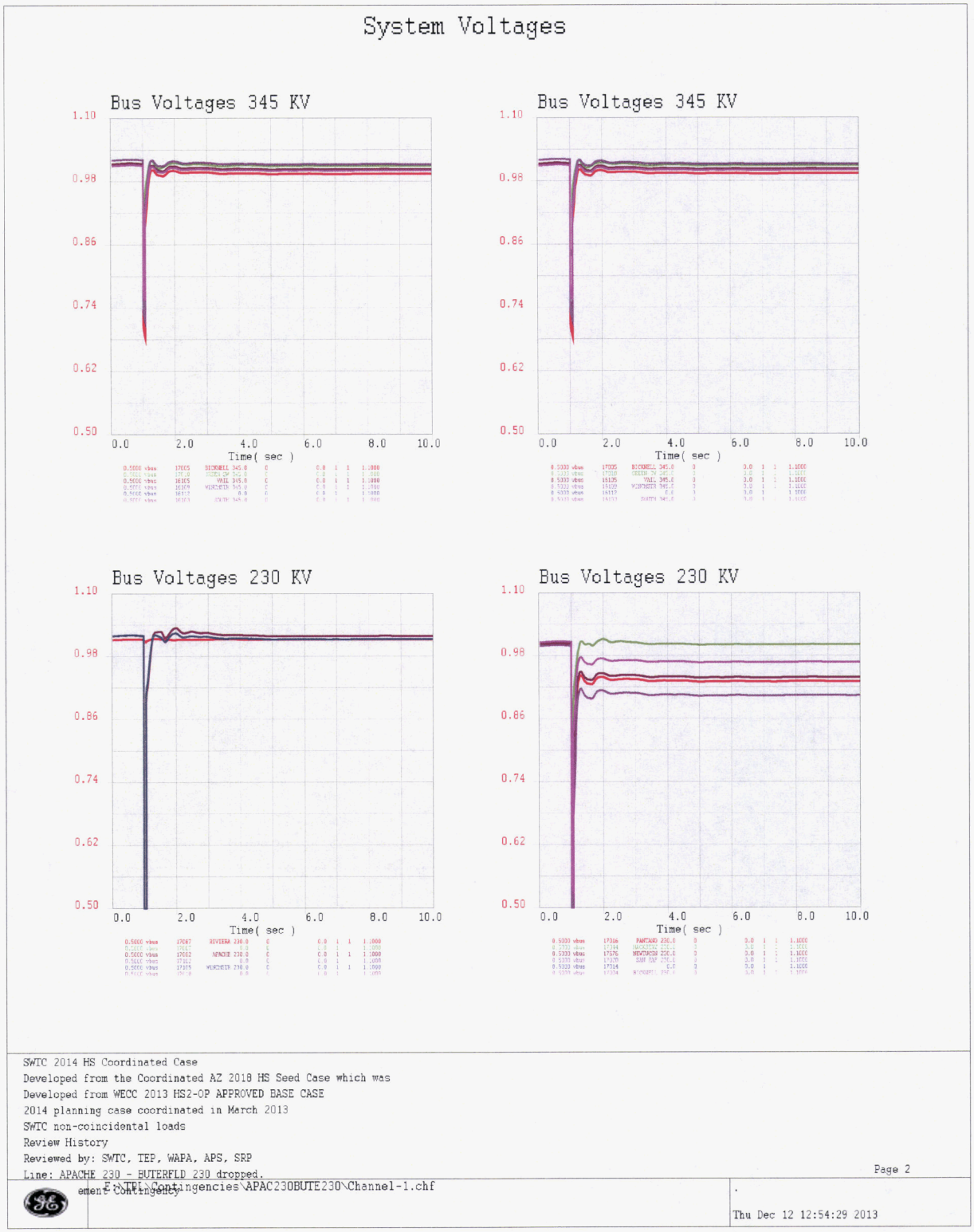




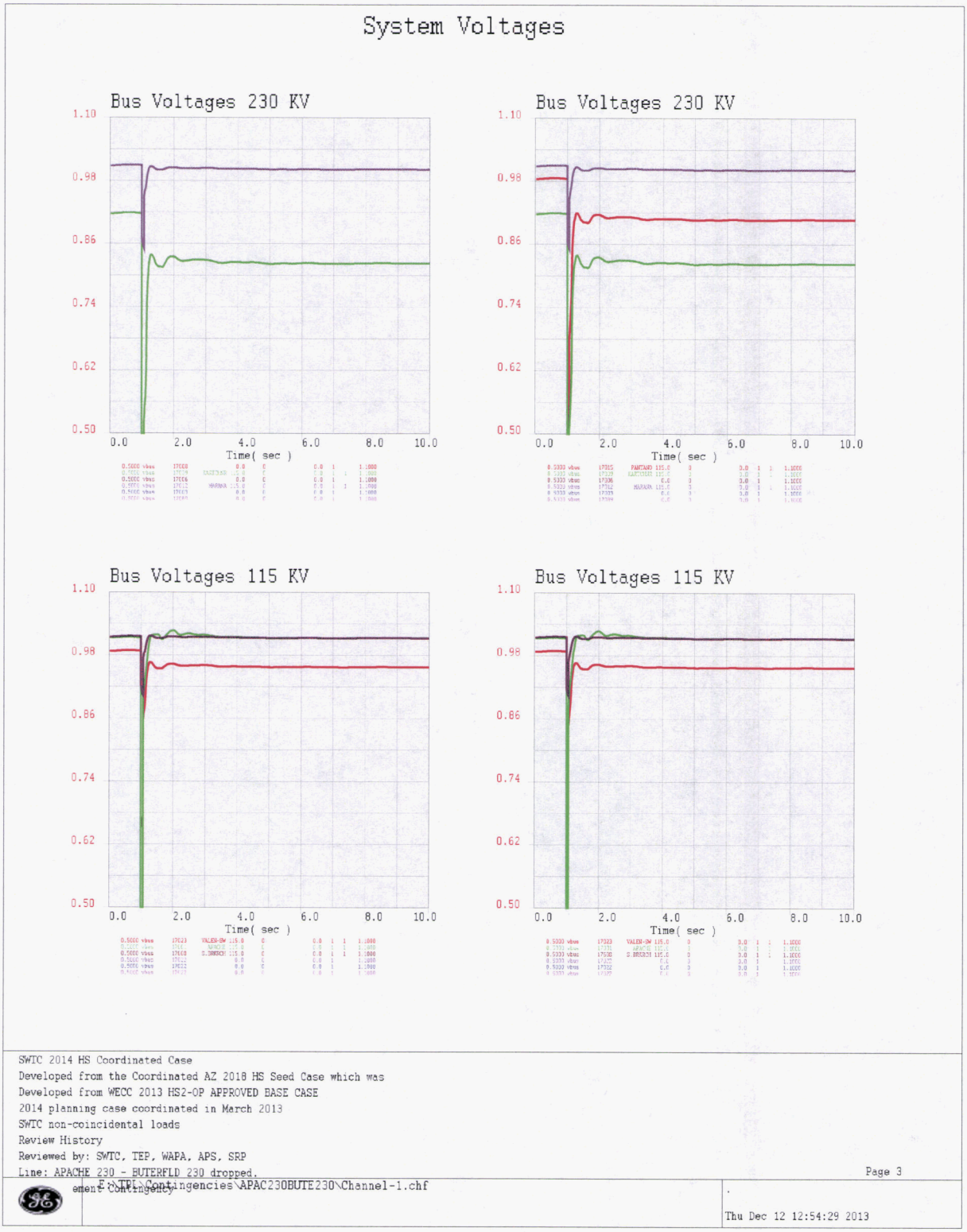
SWTC 2014 HS Coordinated Case
Developed from the Coordinated AZ 2018 HS Seed Case which was
Developed from WECC 2013 HS2-OP APPROVED BASE CASE
2014 planning case coordinated in March 2013
SWTC non-coincidental loads
Review History
Reviewed by: SWTC, TEP, WAPA, APS, SRP
Line: APACHE 230 - BUTERFLD 230 dropped.
E:\TPL Contingencies\APAC230BUTE230\Channel-1.chf
ement Contingency

Page 1

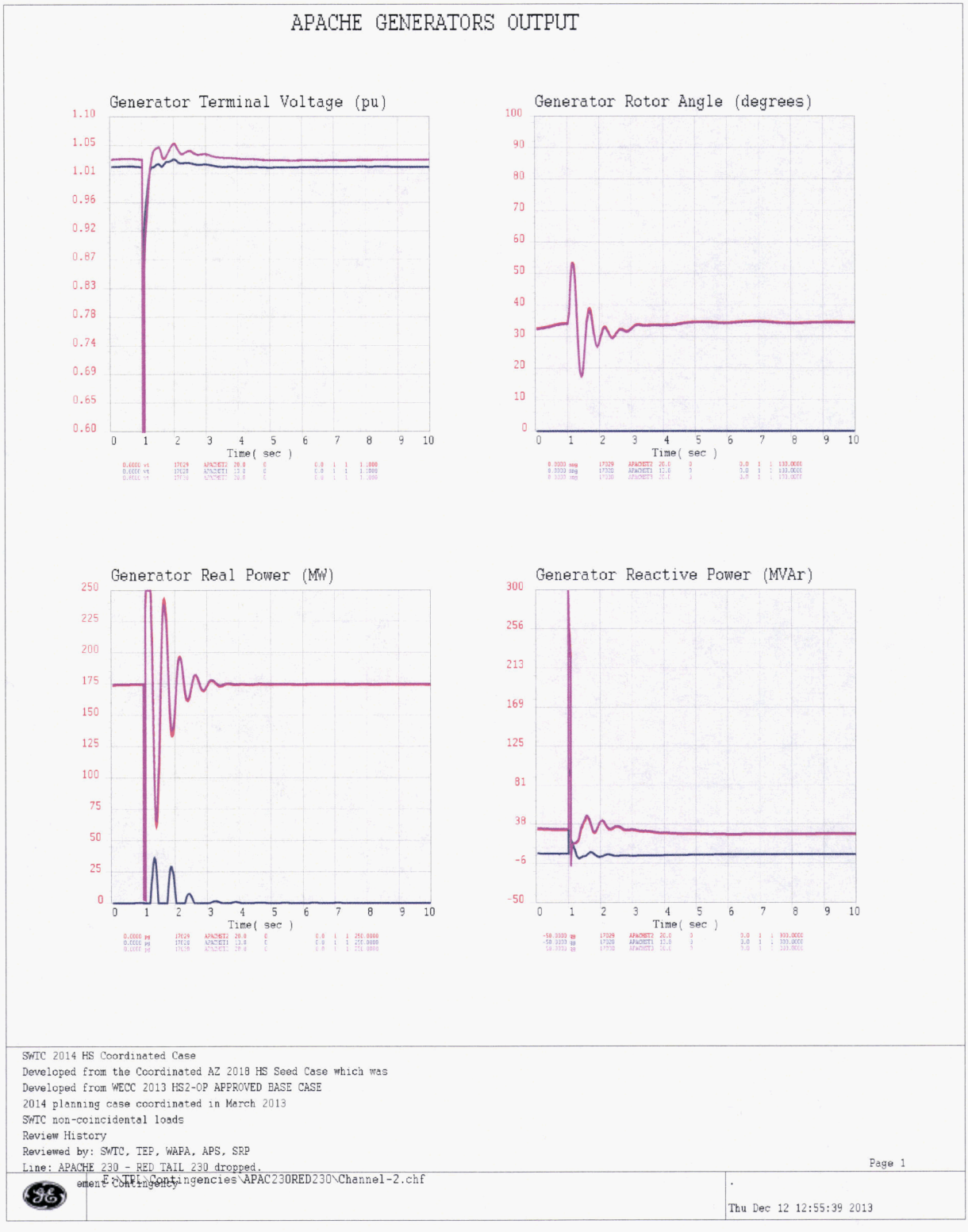
Thu Dec 12 12:54:29 2013

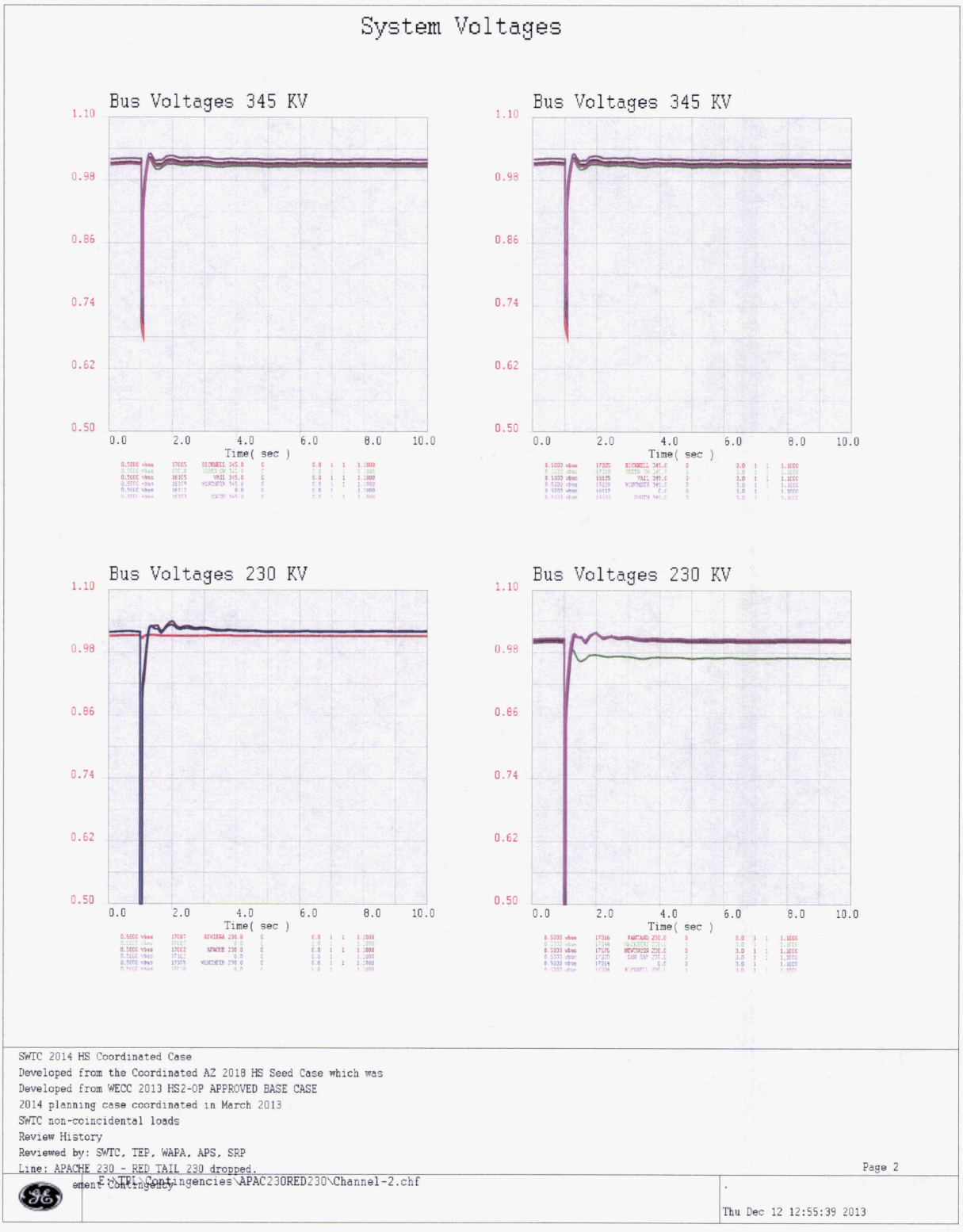

System Voltages
Bus Voltages 345 KV
Bus Voltages 345 KV
Bus Voltages 230 KV
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWTC 2014 HS Coordinated Case
Developed from the Coordinated AZ 2018 HS Seed Case which was
Developed from WECC 2013 HS2-OP APPROVED BASE CASE
2014 planning case coordinated in March 2013
SWTC non-coincidental loads
Review History
Reviewed by: SWTC, TEP, WAPA, APS, SRP
Line: APACHE 230 - BUTERFLD 230 dropped.
Page 2
E:\TEP\Contingencies\APAC230BUTE230\Channel-1.chf
ement Contingency
Thu Dec 12 12:54:29 2013

2014HS – Apache to Butterfield 230 kV Line Outage – 230 kV & 115 kV Bus Voltages

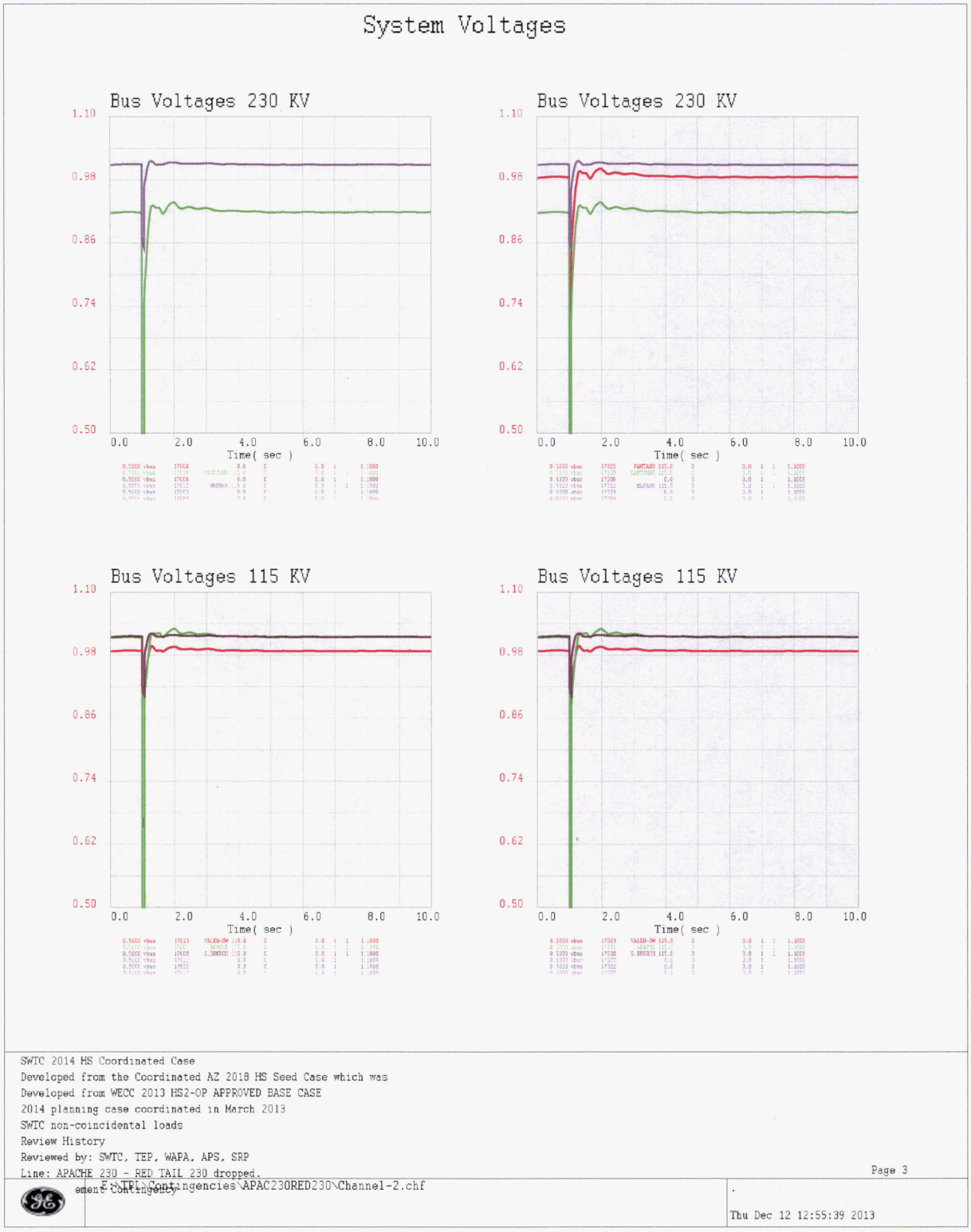


2014HS – Apache to Redtail 230 kV Line Outage – Apache Generators Output



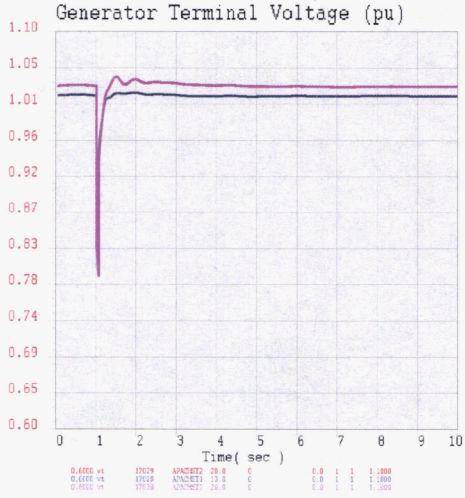

System Voltages
Bus Voltages 345 KV
Bus Voltages 345 KV
Bus Voltages 230 KV
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWTC 2014 HS Coordinated Case
Developed from the Coordinated AZ 2018 HS Seed Case which was
Developed from WECC 2013 HS2-OP APPROVED BASE CASE
2014 planning case coordinated in March 2013
SWTC non-coincidental loads
Review History
Reviewed by: SWTC, TEP, WAPA, APS, SRP
Line: APACHE 230 - RED TAIL 230 dropped.
Page 2
F:\TPL Contingencies\APAC230RED230\Channel-2.chf
ement Contingency
Thu Dec 12 12:55:39 2013

2014HS – Apache to Redtail 230 kV Line Outage – 230 kV & 115 kV Bus Voltages

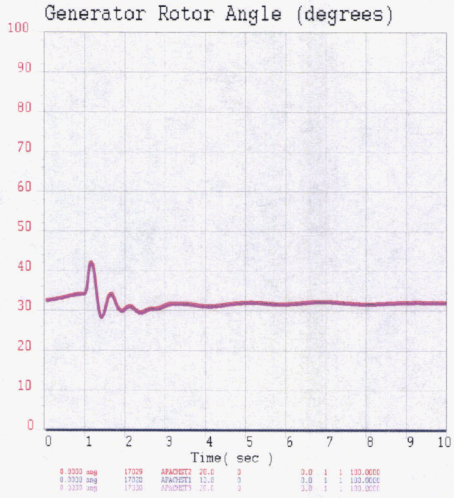


APACHE GENERATORS OUTPUT

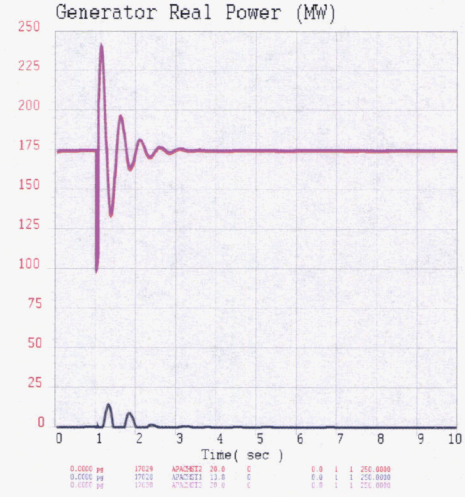
Generator Terminal Voltage (pu)



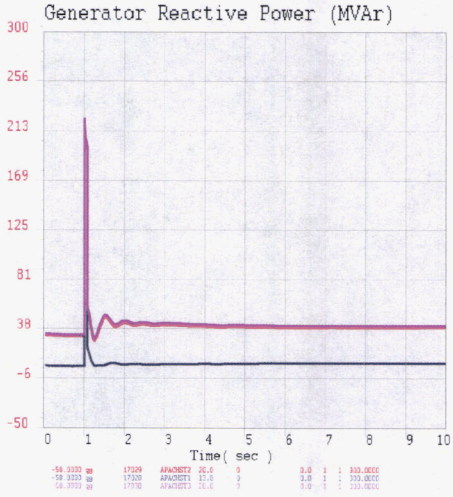
Generator Rotor Angle (degrees)



Generator Real Power (MW)



Generator Reactive Power (MVAr)



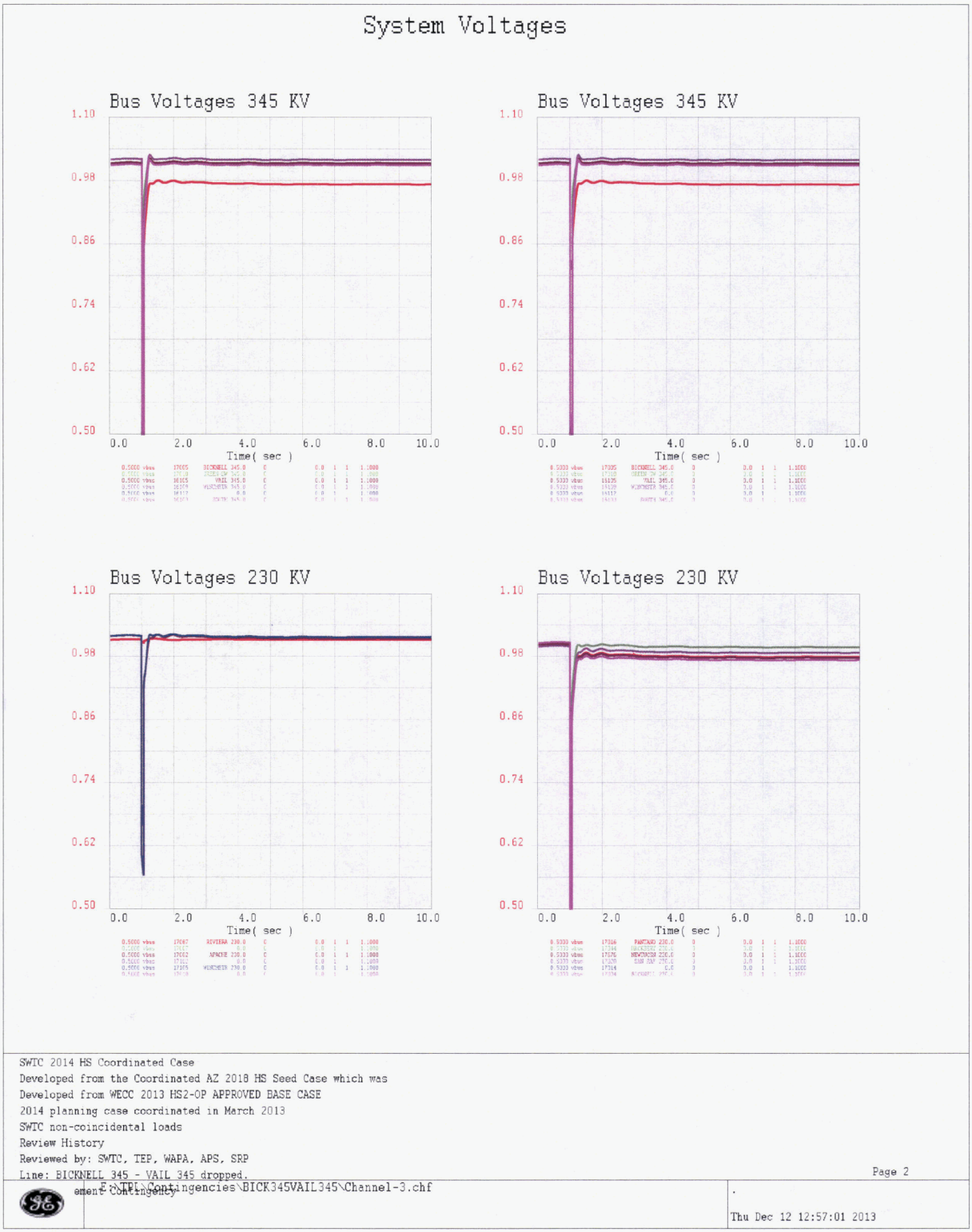
SWTC 2014 HS Coordinated Case
Developed from the Coordinated AZ 2018 HS Seed Case which was
Developed from WECC 2013 HS2-OP APPROVED BASE CASE
2014 planning case coordinated in March 2013
SWTC non-coincidental loads
Review History
Reviewed by: SWTC, TEP, WAPA, APS, SRP
Line: BICKNELL 345 - VAIL 345 dropped.

Page 1

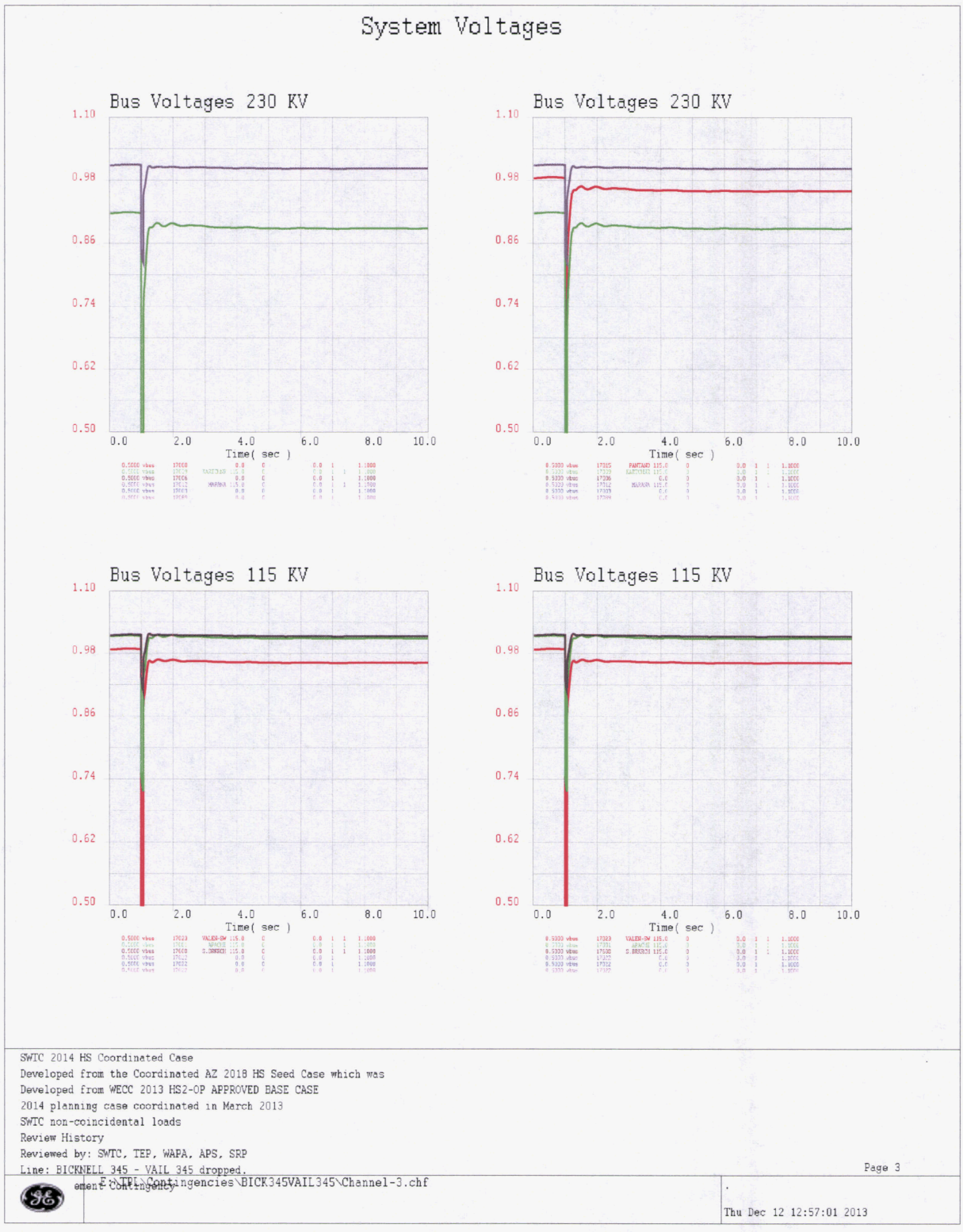
F:\TPL\Contingencies\BICK345VAIL345\Channel-3.chf

ement Contingency

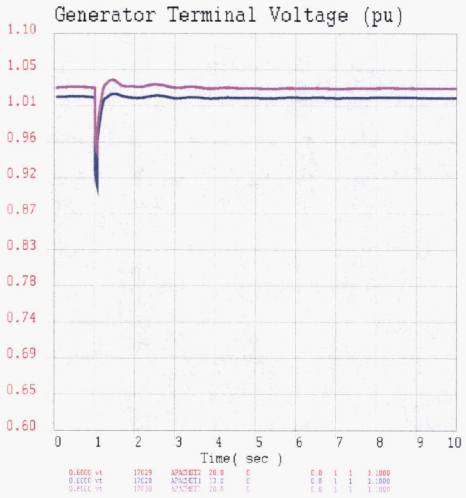
Thu Dec 12 12:57:01 2013

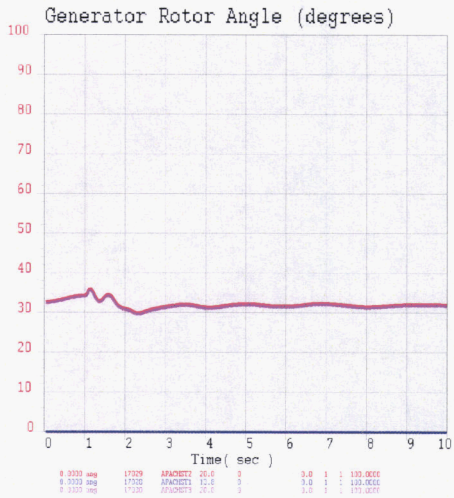

System Voltages
Bus Voltages 345 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 345 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWTC 2014 HS Coordinated Case
Developed from the Coordinated AZ 2018 HS Seed Case which was
Developed from WECC 2013 HS2-OP APPROVED BASE CASE
2014 planning case coordinated in March 2013
SWTC non-coincidental loads
Review History
Reviewed by: SWTC, TEP, WAPA, APS, SRP
Line: BICKNELL 345 - VAIL 345 dropped.
Page 2
E:\TPL\Contingencies\BICK345VAIL345\Channel-3.chf
ement Contingency
.
Thu Dec 12 12:57:01 2013

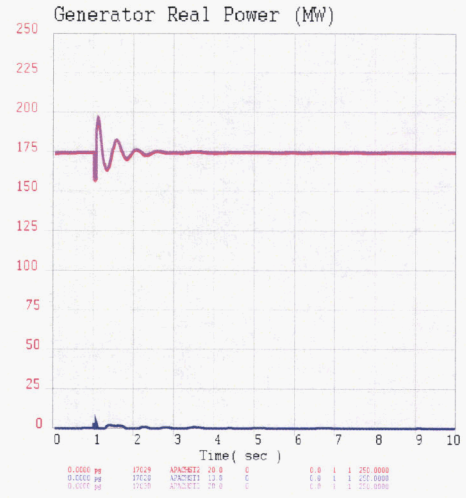
2014HS – Bicknell to Vail 345 kV Line Outage – 230 kV & 115 kV Bus Voltages

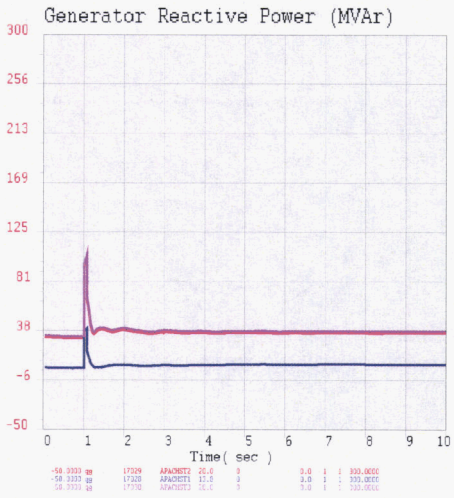


APACHE GENERATORS OUTPUT









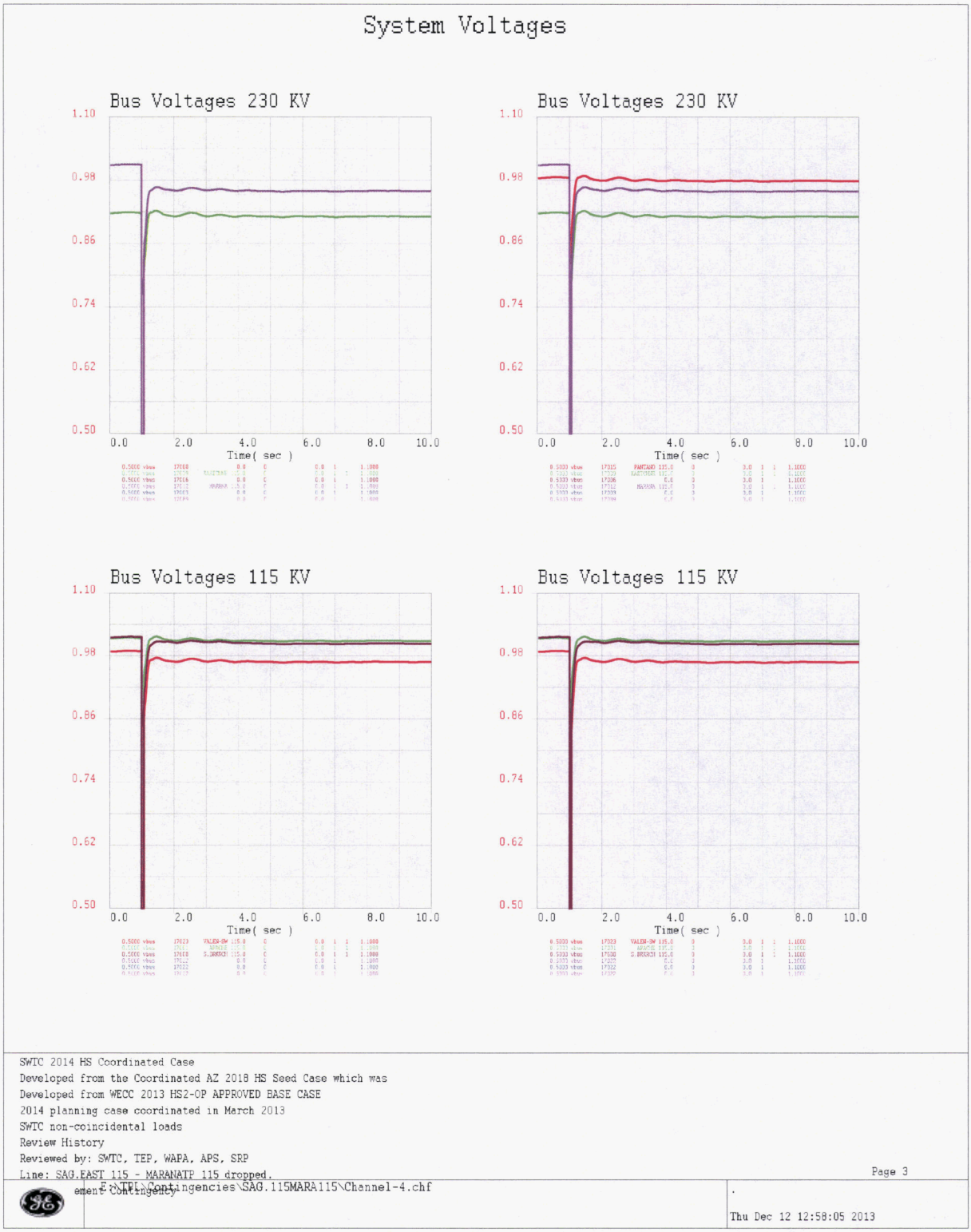
SWTC 2014 HS Coordinated Case
Developed from the Coordinated AZ 2018 HS Seed Case which was
Developed from WECC 2013 HS2-OP APPROVED BASE CASE
2014 planning case coordinated in March 2013
SWTC non-coincidental loads
Review History
Reviewed by: SWTC, TEP, WAPA, APS, SRP
Line: SAG.EAST 115 - MARANATP 115 dropped.

Page 1

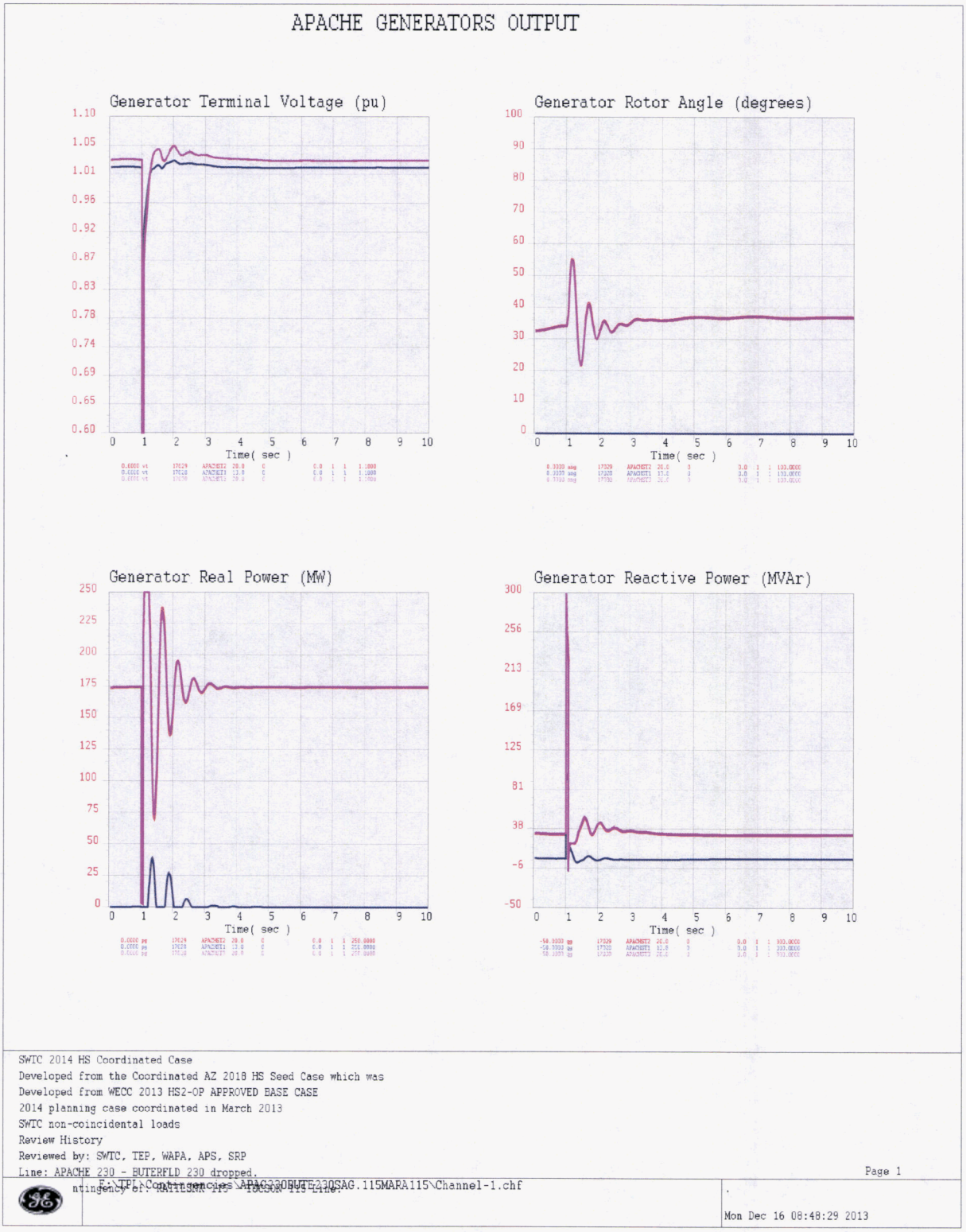
E:\TPL\Contingencies\SAG.115MARA115\Channel-4.chf
ement Contingency

.
Thu Dec 12 12:58:04 2013

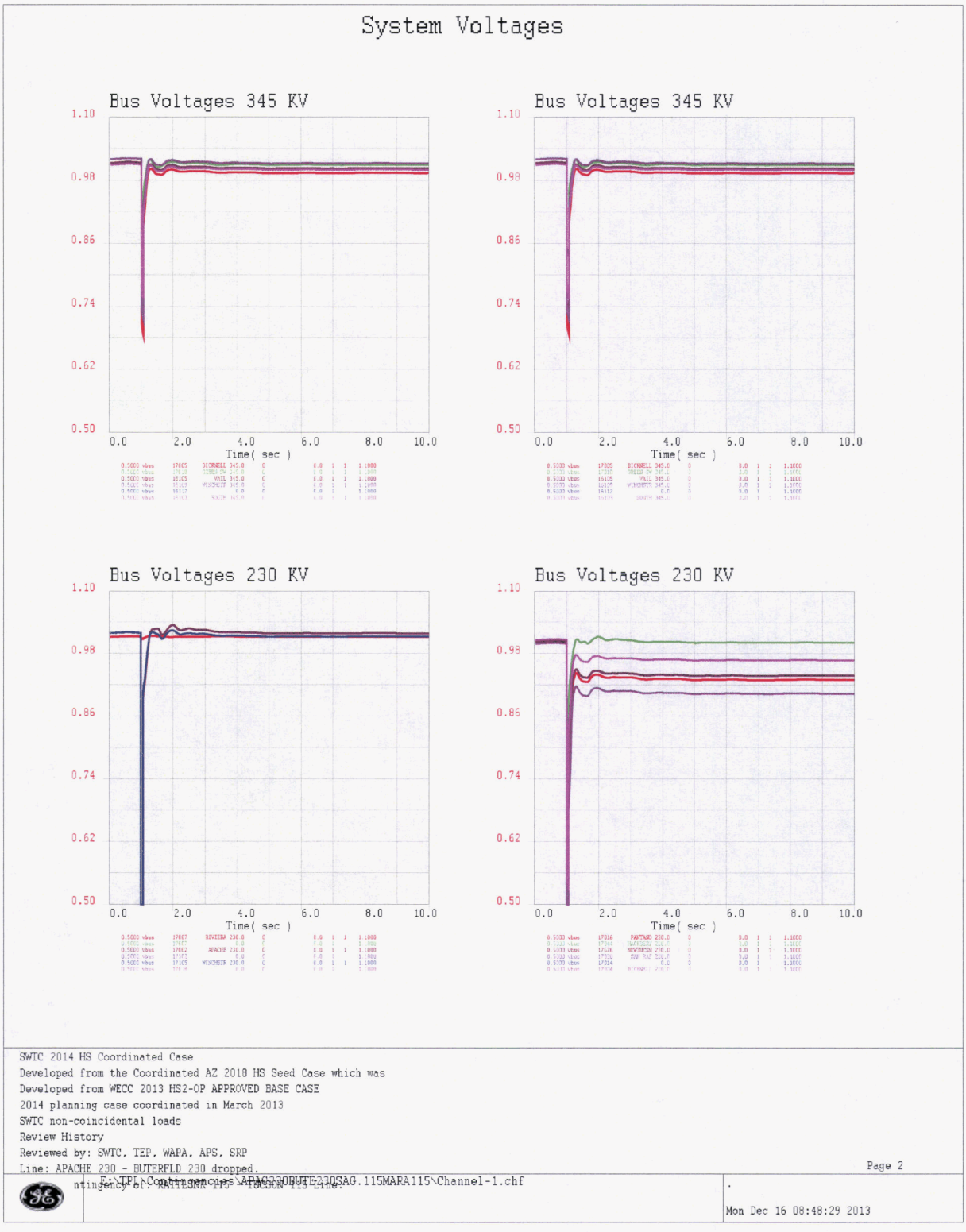
System Voltages
Bus Voltages 345 KV
Bus Voltages 345 KV
Bus Voltages 230 KV
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWTC 2014 HS Coordinated Case
Developed from the Coordinated AZ 2018 HS Seed Case which was
Developed from WECC 2013 HS2-OP APPROVED BASE CASE
2014 planning case coordinated in March 2013
SWTC non-coincidental loads
Review History
Reviewed by: SWTC, TEP, WAPA, APS, SRP
Line: SAG.EAST 115 - MARANATP 115 dropped.
Page 2
F:\TPL\Contingencies\SAG.115MARA115\Channel-4.chf
Thu Dec 12 12:58:05 2013


System Voltages
Bus Voltages 230 KV
Bus Voltages 230 KV
Bus Voltages 115 KV
Bus Voltages 115 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWTC 2014 HS Coordinated Case
Developed from the Coordinated AZ 2018 HS Seed Case which was
Developed from WECC 2013 HS2-OP APPROVED BASE CASE
2014 planning case coordinated in March 2013
SWTC non-coincidental loads
Review History
Reviewed by: SWTC, TEP, WAPA, APS, SRP
Line: SAG.EAST 115 - MARANATP 115 dropped.
Page 3
E:\TEP\Contingencies\SAG.115MARA115\Channel-4.chf
ement Contingency
Thu Dec 12 12:58:05 2013

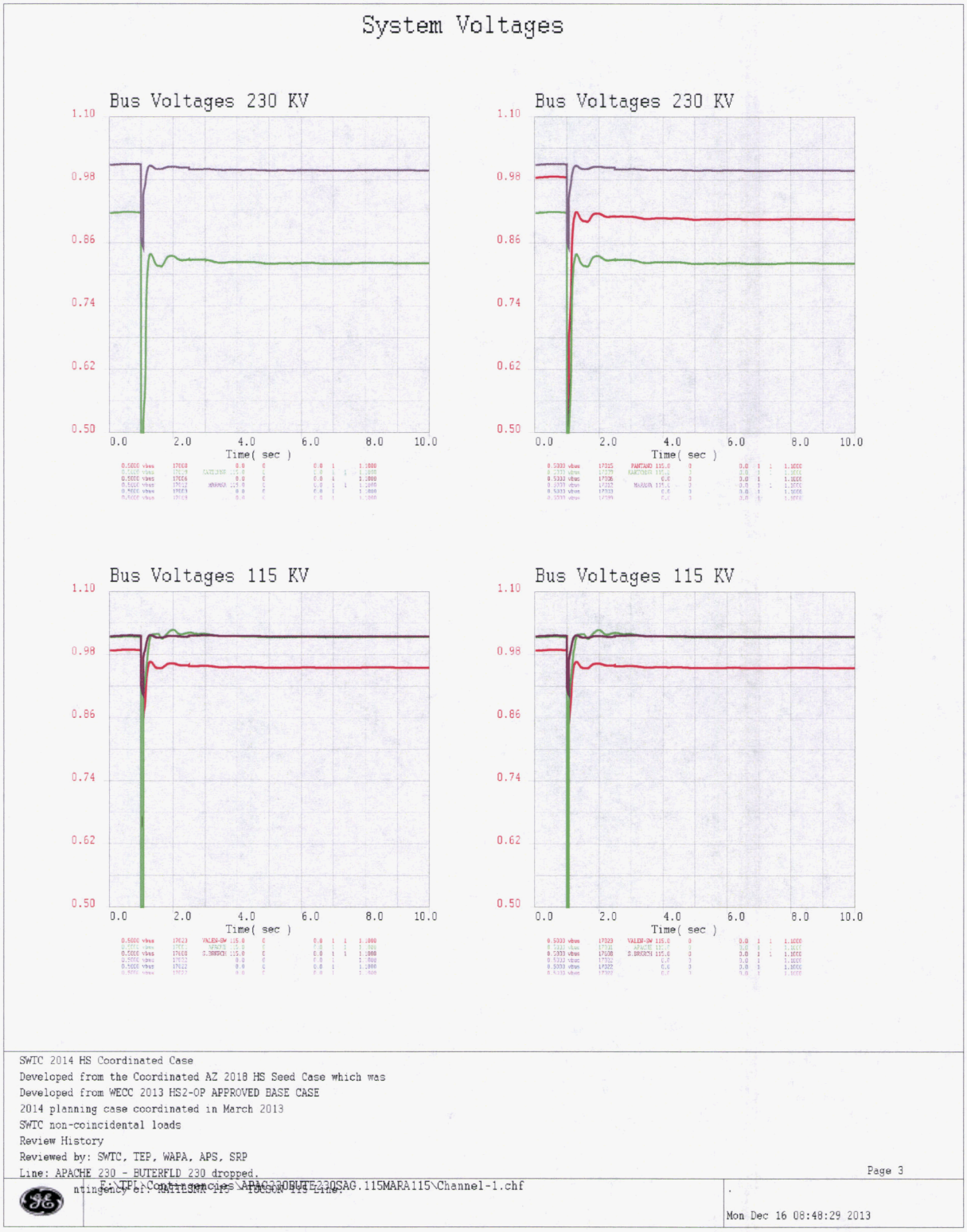
2014HS – Apache to Butterfield 230 kV & Saguaro East to Marana 115 kV Line Outages – Apache Generators Output



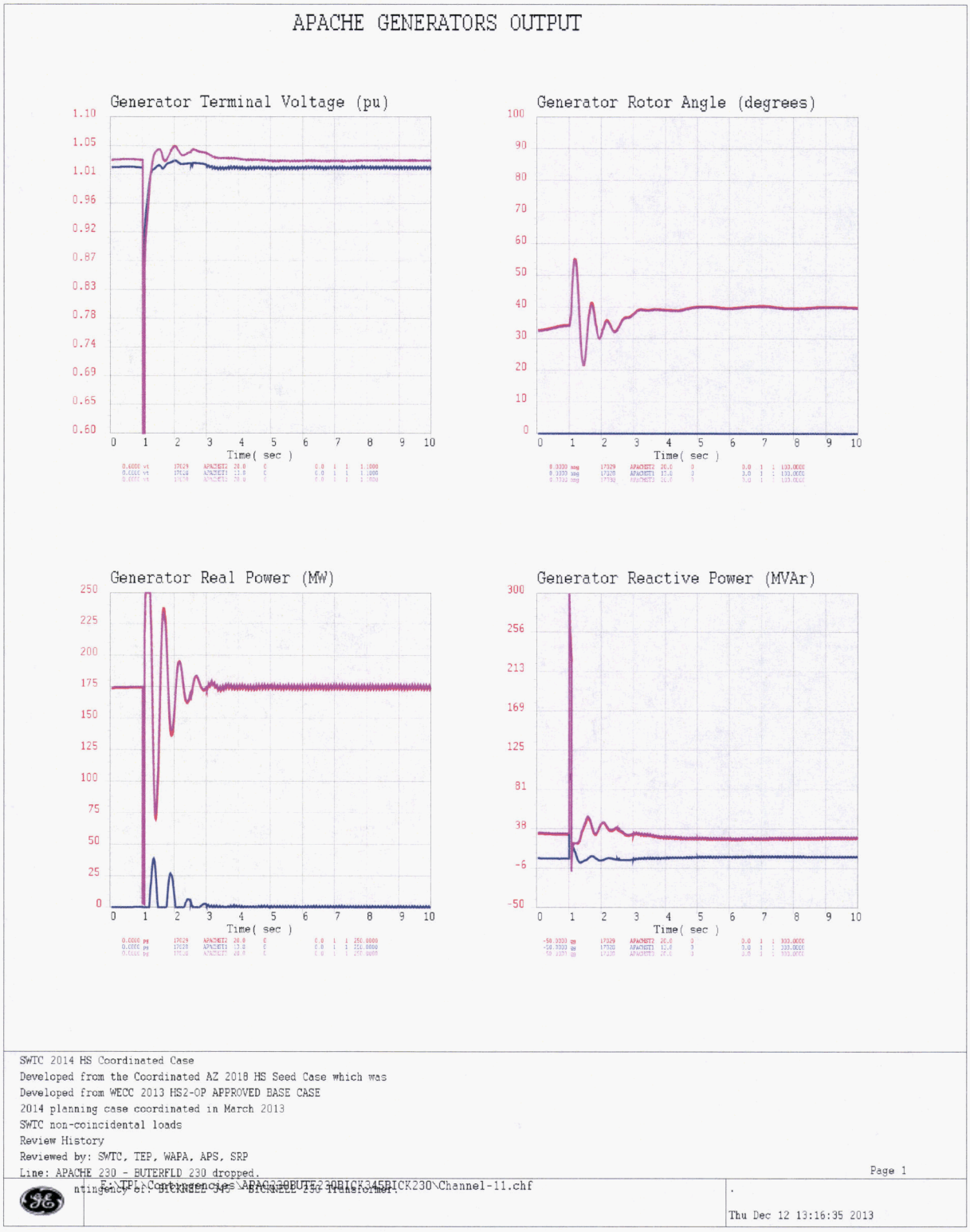
2014HS – Apache to Butterfield 230 kV & Saguaro East to Marana 115 kV Line Outages – 345 kV & 230 kV Bus Voltages



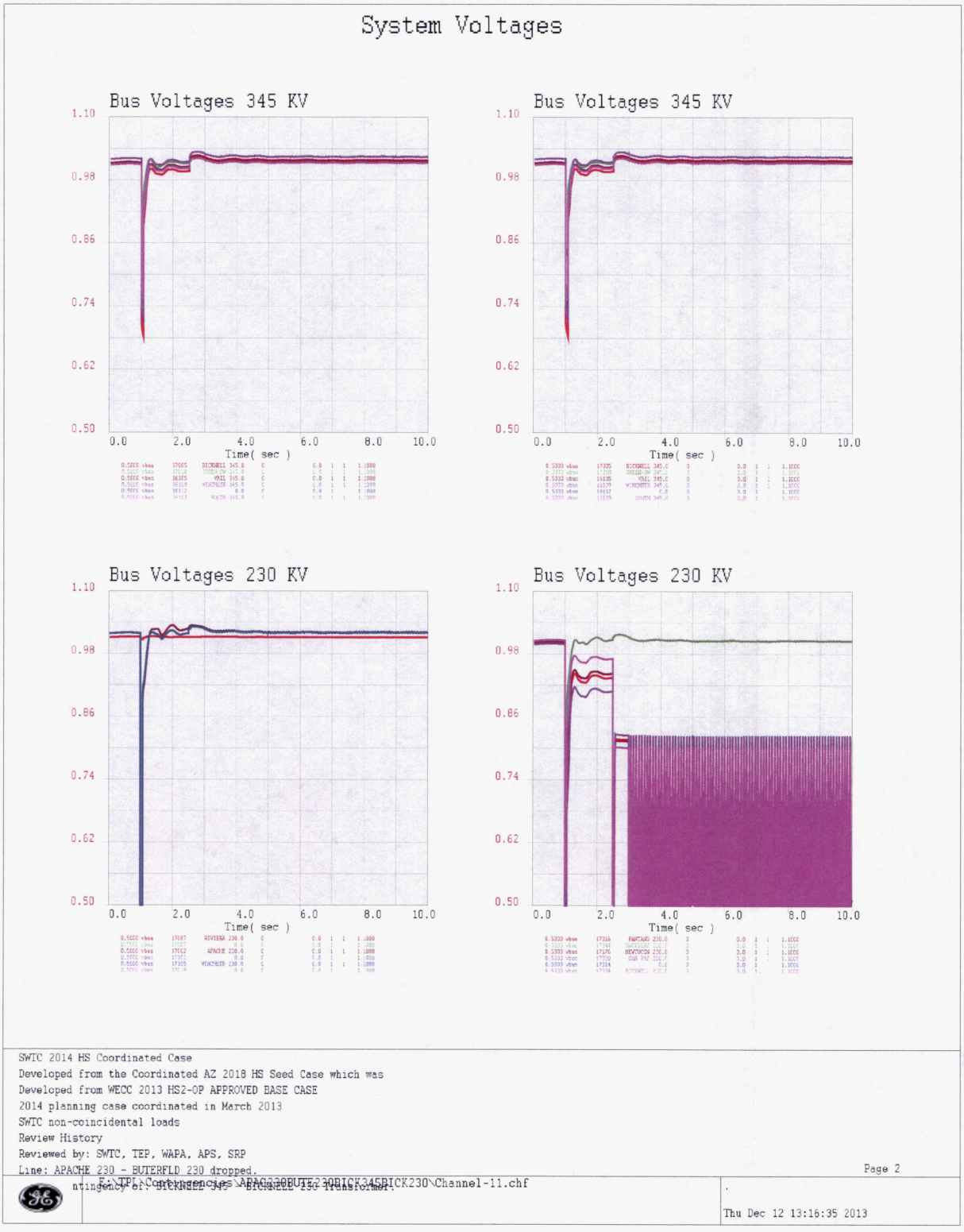
2014HS – Apache to Butterfield 230 kV & Saguaro East to Marana 115 kV Line Outages – 230 kV & 115 kV Bus Voltages



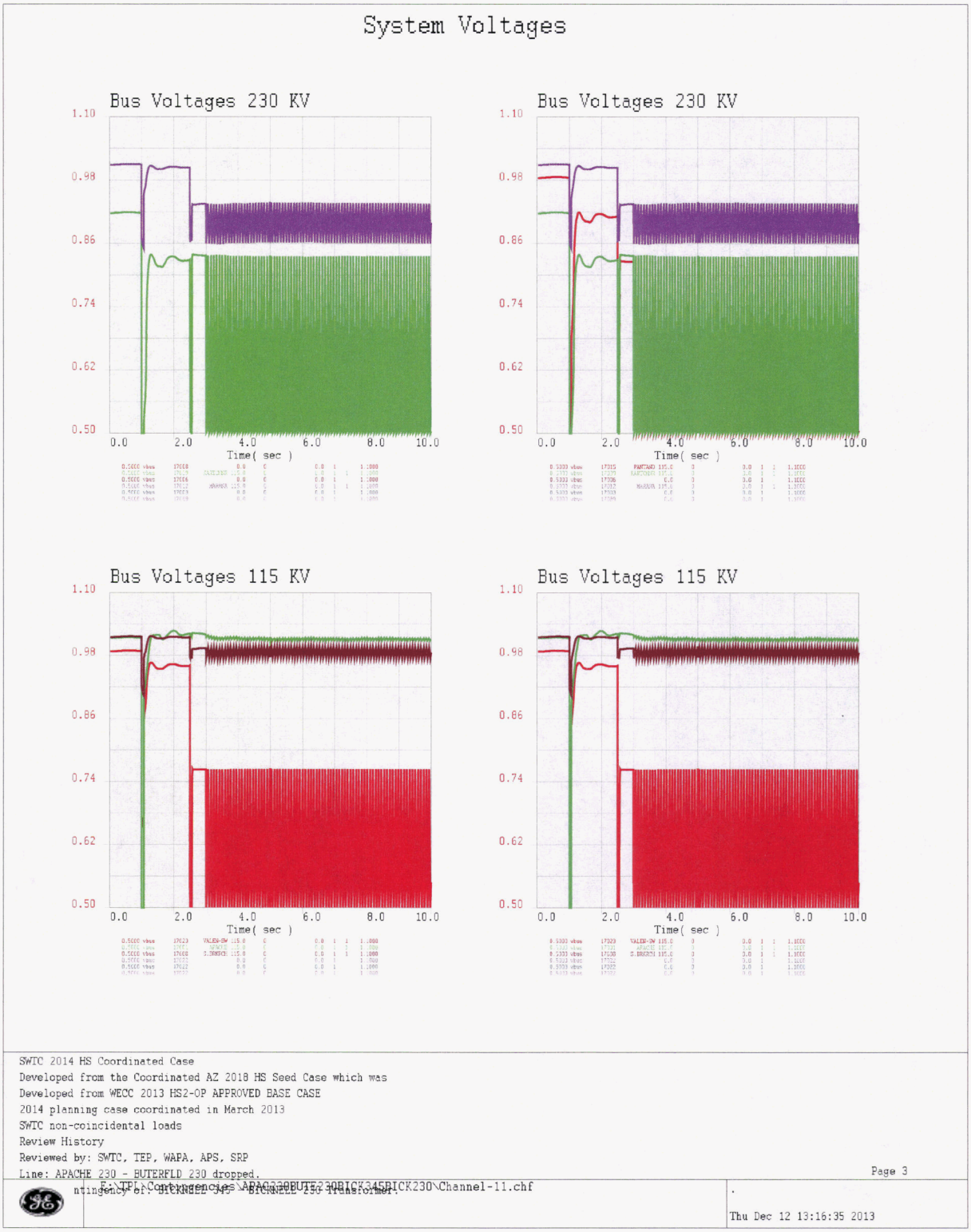
2014HS – Apache to Butterfield 230 kV & Bicknell to Vail 345 kV Line Outages – Apache Generators Output



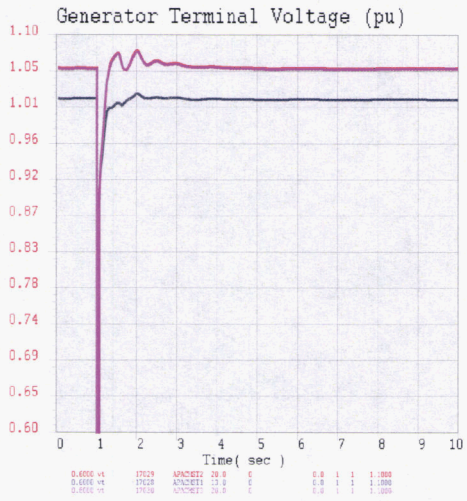
2014HS – Apache to Butterfield 230 kV & Bicknell to Vail 345 kV Line Outages – 345 kV & 230 kV Bus Voltages

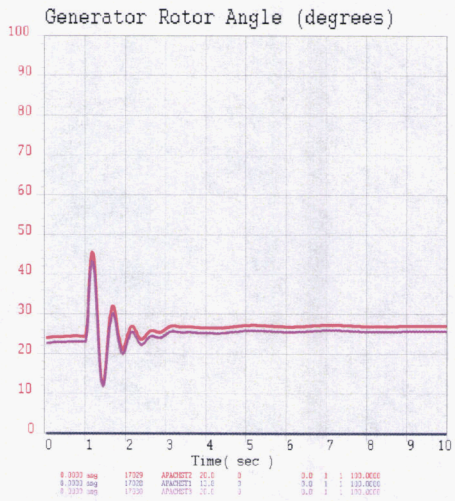


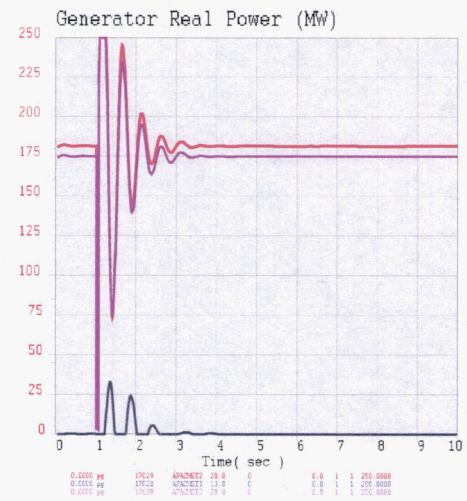
2014HS – Apache to Butterfield 230 kV & Bicknell to Vail 345 kV Line Outages – 230 kV & 115 kV Bus Voltages

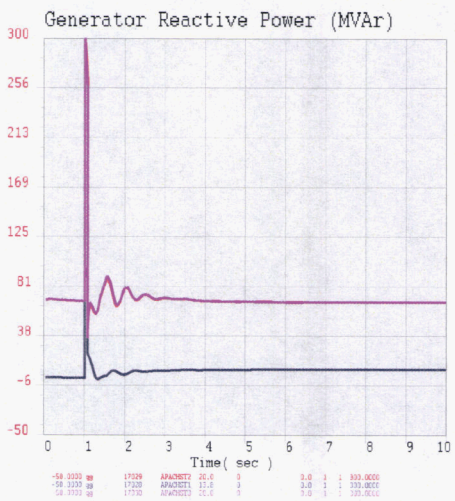


APACHE GENERATORS OUTPUT







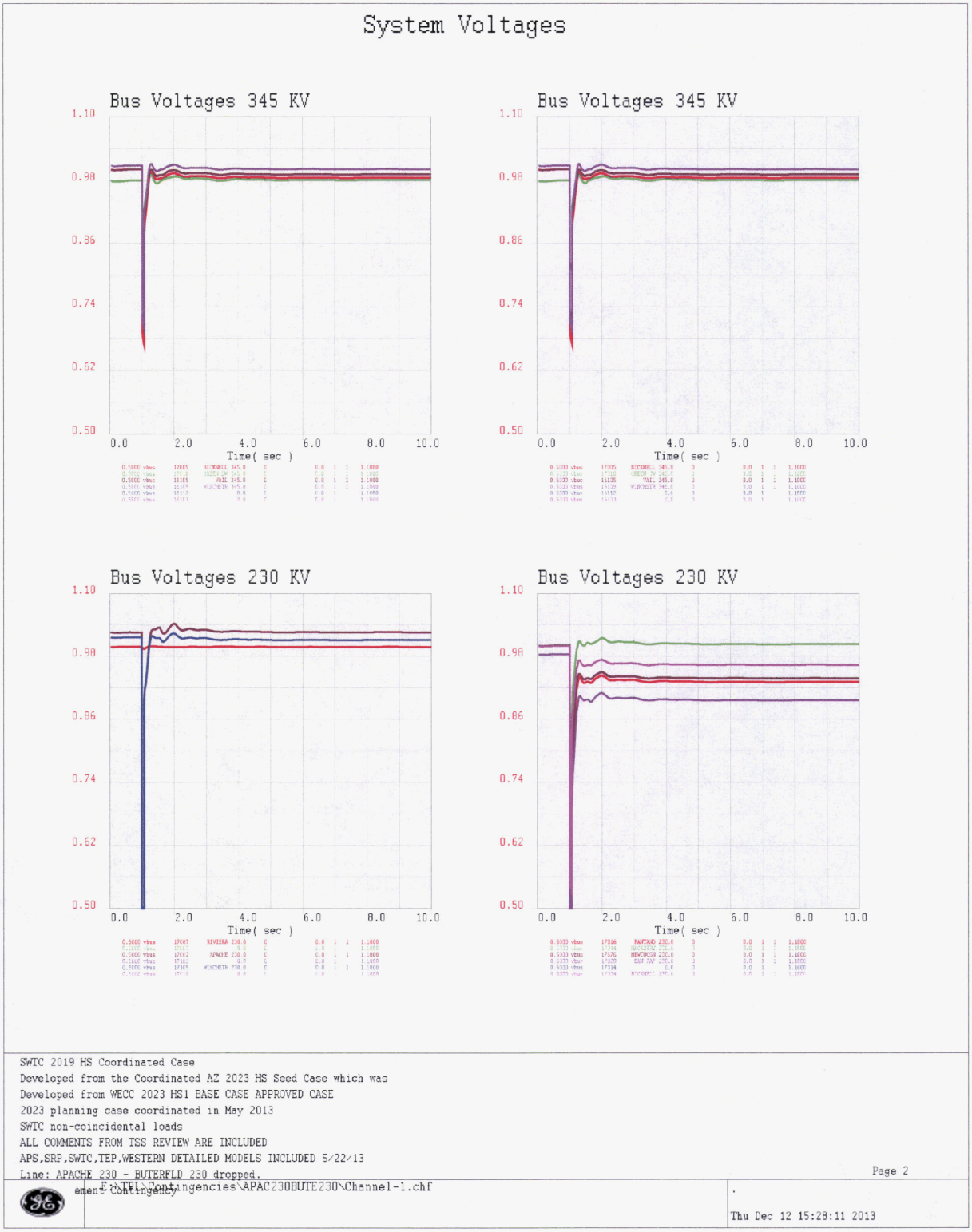


SWTC 2019 HS Coordinated Case
Developed from the Coordinated AZ 2023 HS Seed Case which was
Developed from WECC 2023 HS1 BASE CASE APPROVED CASE
2023 planning case coordinated in May 2013
SWTC non-coincidental loads
ALL COMMENTS FROM TSS REVIEW ARE INCLUDED
APS,SRP,SWTC,TEP,WESTERN DETAILED MODELS INCLUDED 5/22/13
Line: APACHE 230 - BUTERFLD 230 dropped.

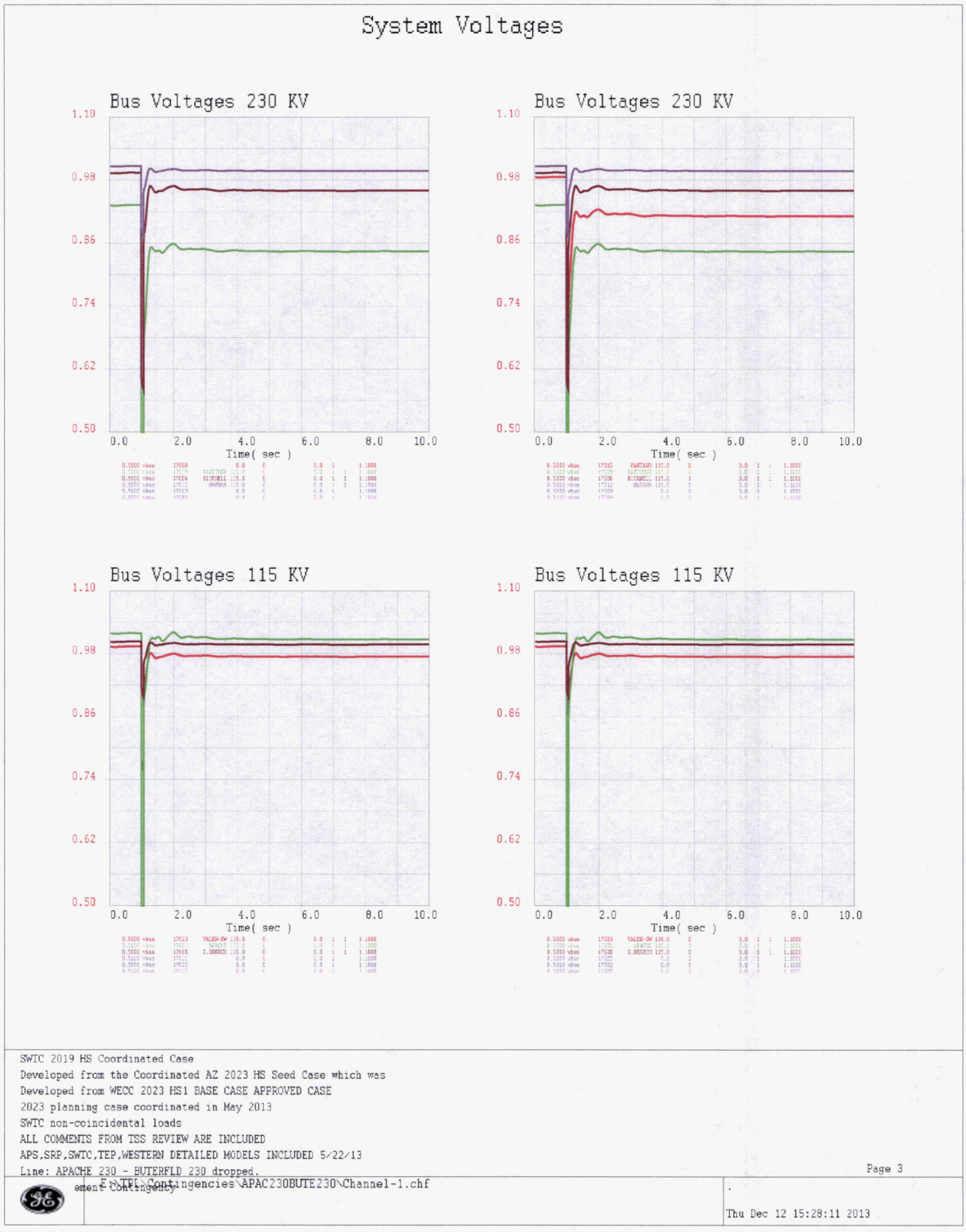
Page 1

F:\TPL\Contingencies\APAC230BUTE230\Channel-1.chf
ement Contingency

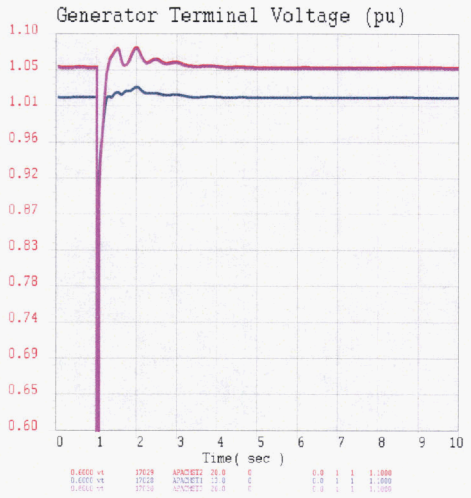
Thu Dec 12 15:28:11 2013

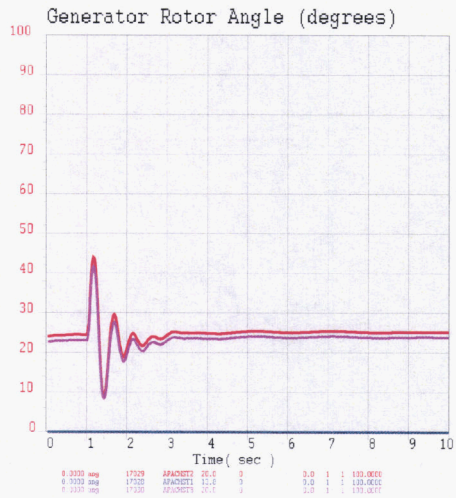

System Voltages
Bus Voltages 345 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 345 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWIC 2019 HS Coordinated Case
Developed from the Coordinated AZ 2023 HS Seed Case which was
Developed from WECC 2023 HS1 BASE CASE APPROVED CASE
2023 planning case coordinated in May 2013
SWIC non-coincidental loads
ALL COMMENTS FROM TSS REVIEW ARE INCLUDED
APS,SRP,SWIC,TEP,WESTERN DETAILED MODELS INCLUDED 5/22/13
Line: APACHE 230 - BUTERFLD 230 dropped.
Page 2
ement Contingency
P:\TEP\Contingencies\APAC230BUTE230\Channel-1.chf
Thu Dec 12 15:28:11 2013

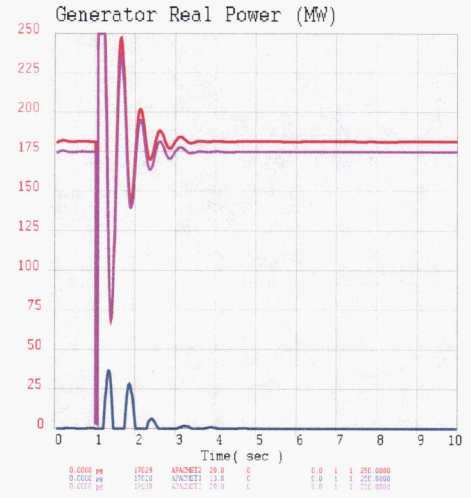
2019HS – Apache to Butterfield 230 kV Line Outage – 230 kV & 115 kV Bus Voltages

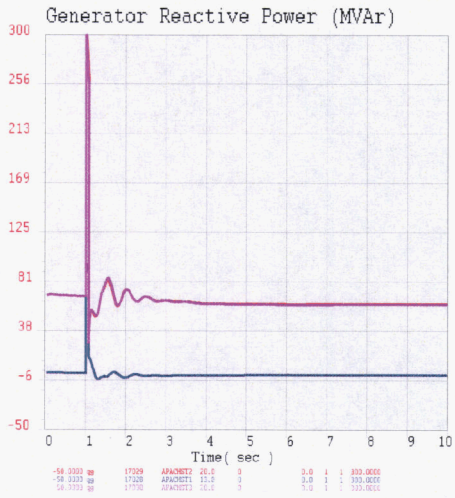


APACHE GENERATORS OUTPUT









SWTC 2019 HS Coordinated Case
Developed from the Coordinated AZ 2023 HS Seed Case which was
Developed from WECC 2023 HS1 BASE CASE APPROVED CASE
2023 planning case coordinated in May 2013
SWTC non-coincidental loads
ALL COMMENTS FROM TSS REVIEW ARE INCLUDED
APS,SRP,SWTC,TEP,WESTERN DETAILED MODELS INCLUDED 5/22/13
Line: APACHE 230 - RED TAIL 230 dropped.

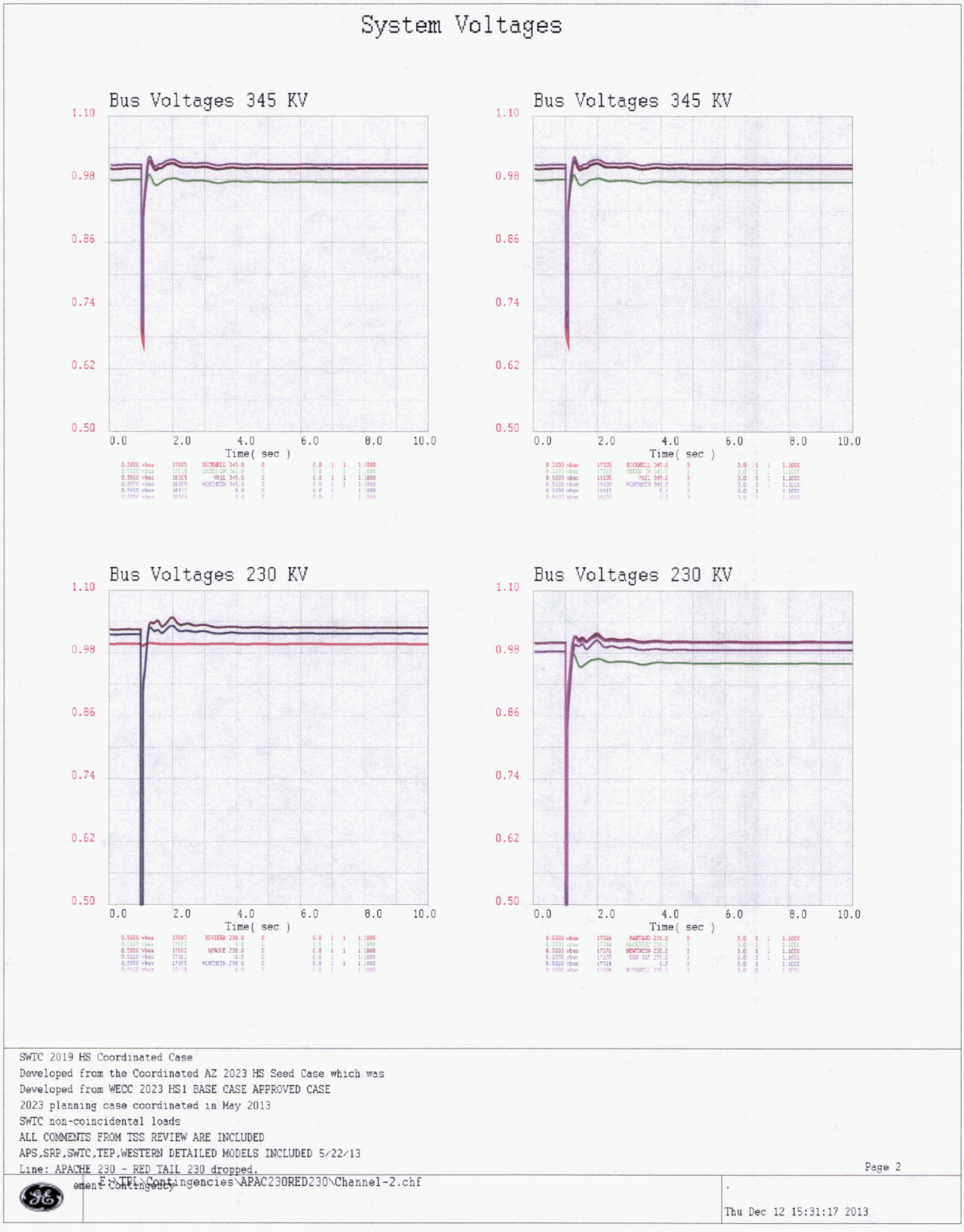
Page 1

emen~ Contingency E:\TPL\Contingencies\APAC230RED230\Channel-2.chf

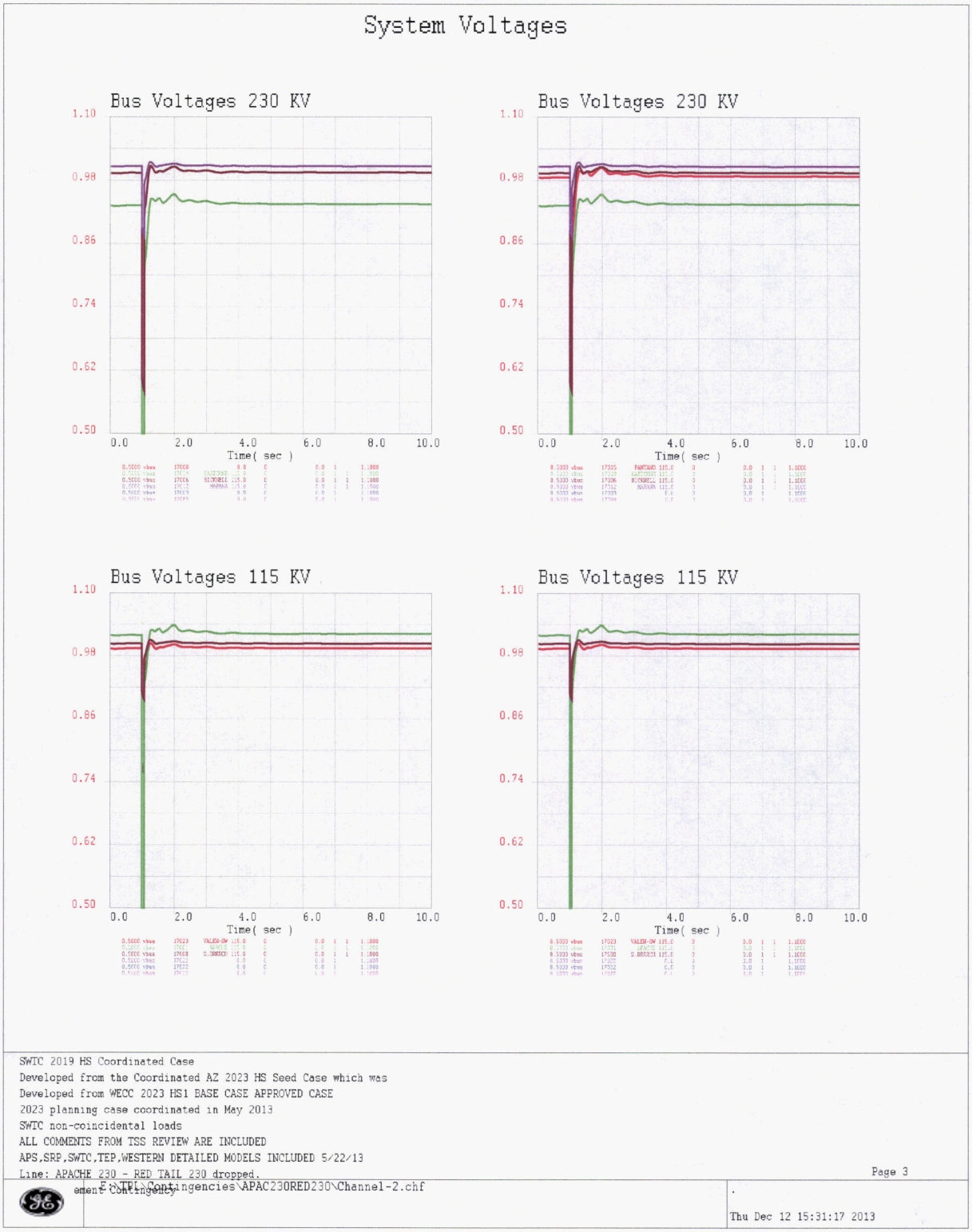
.

Thu Dec 12 15:31:17 2013

2019HS – Apache to Redtail 230 kV Line Outage – 345 kV & 230 kV Bus Voltages

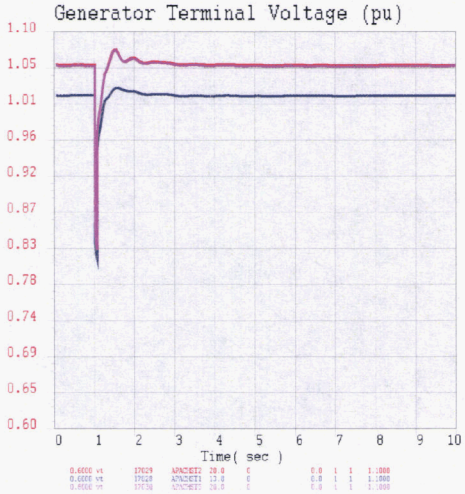


2019HS – Apache to Redtail 230 kV Line Outage – 230 kV & 115 kV Bus Voltages

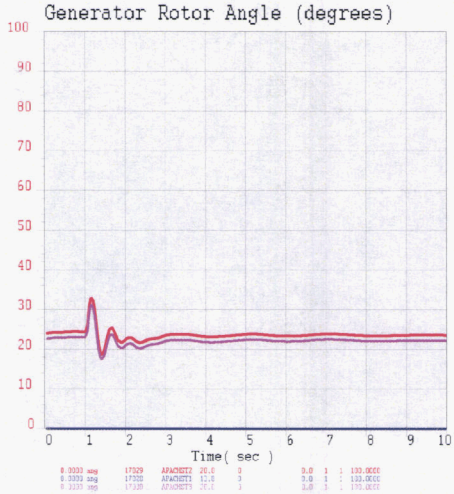


APACHE GENERATORS OUTPUT

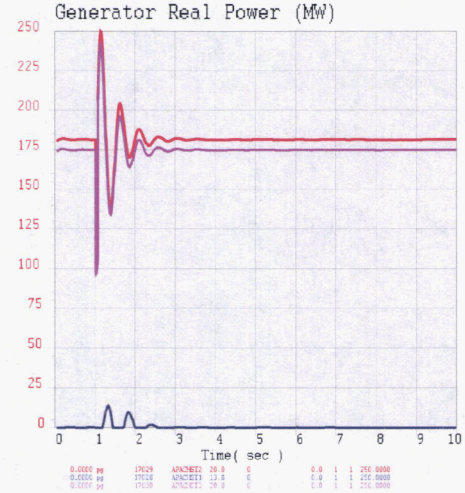
Generator Terminal Voltage (pu)



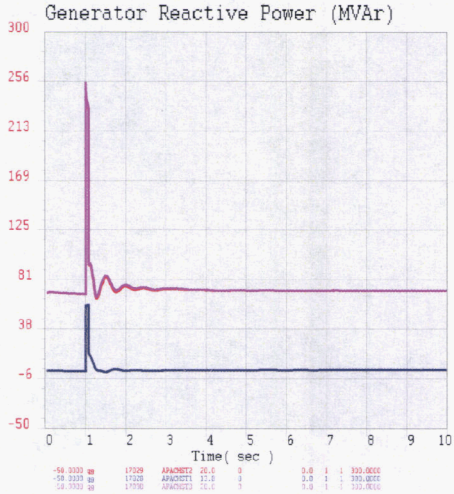
Generator Rotor Angle (degrees)



Generator Real Power (MW)



Generator Reactive Power (MVAr)



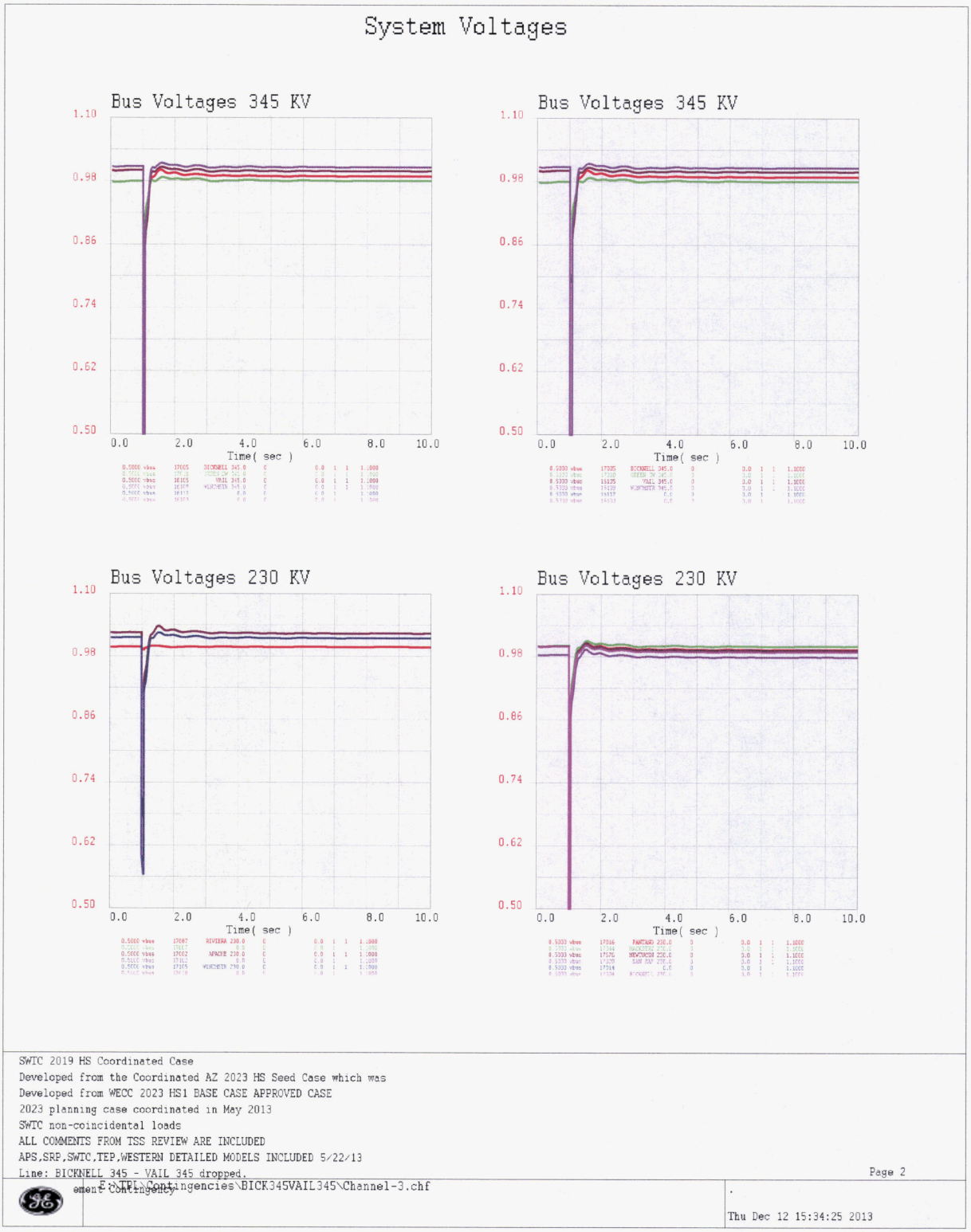
SWTC 2019 HS Coordinated Case
Developed from the Coordinated AZ 2023 HS Seed Case which was
Developed from WECC 2023 HS1 BASE CASE APPROVED CASE
2023 planning case coordinated in May 2013
SWTC non-coincidental loads
ALL COMMENTS FROM TSS REVIEW ARE INCLUDED
APS,SRP,SWTC,TEP,WESTERN DETAILED MODELS INCLUDED 5/22/13
Line: BICKNELL 345 - VAIL 345 dropped.

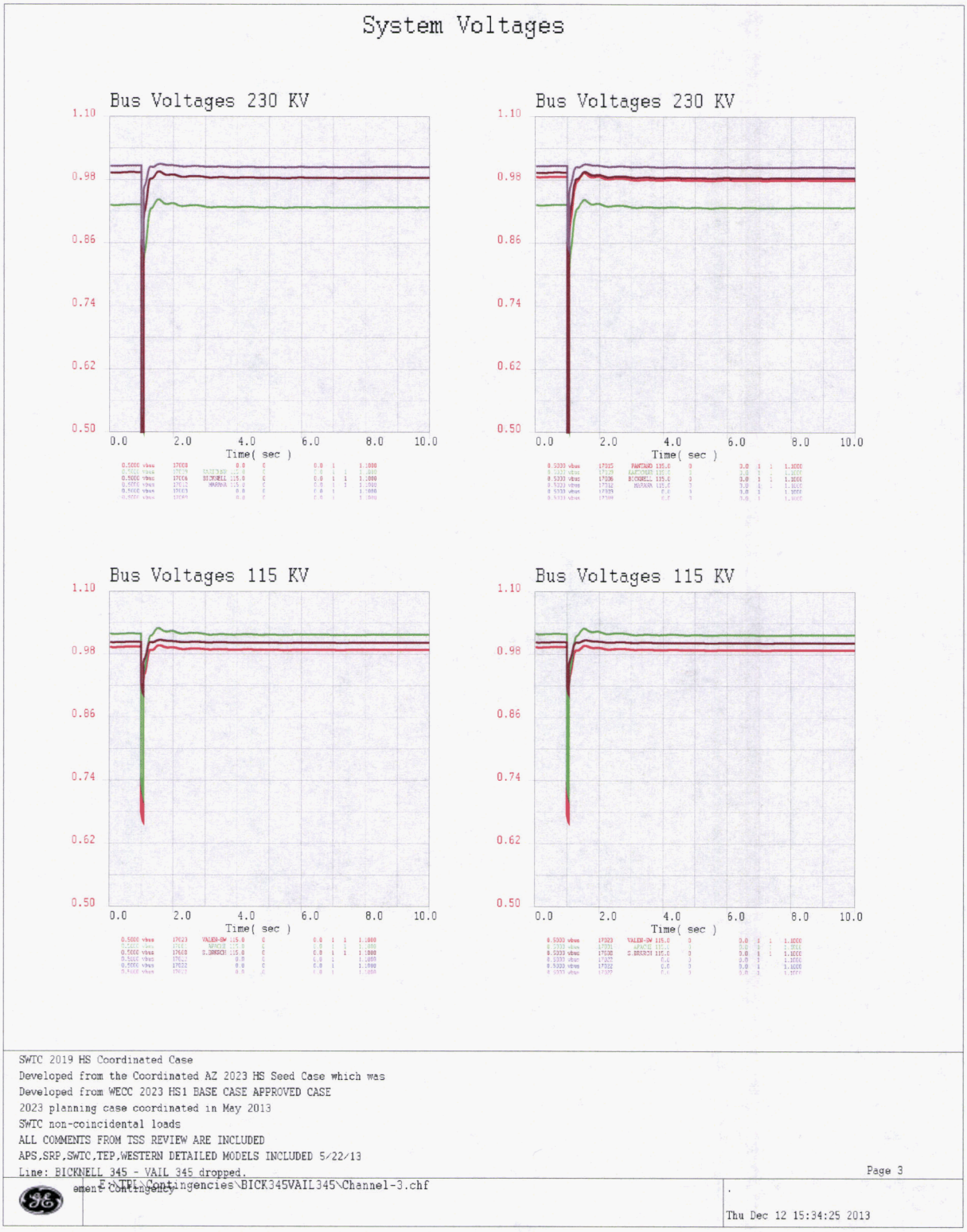
Page 1

ement Contingency

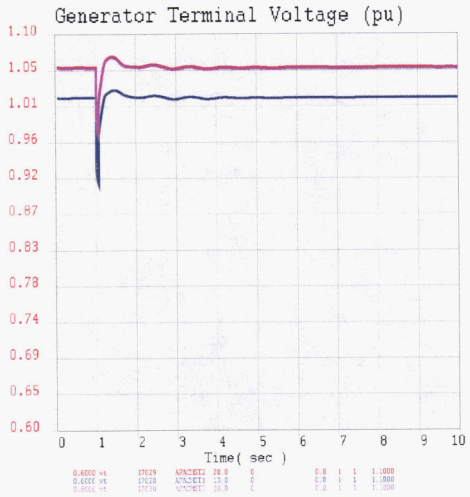
F:\TPL\Contingencies\BICK345VAIL345\Channel-3.chf

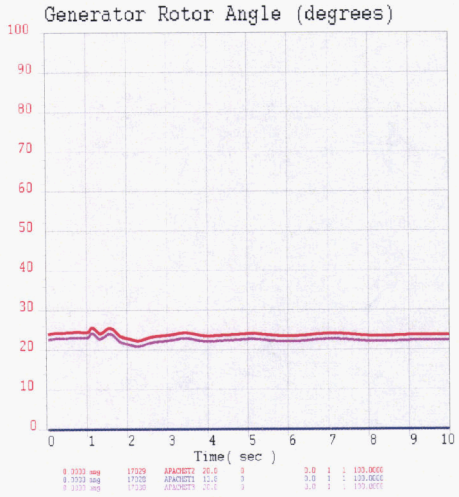
Thu Dec 12 15:34:25 2013

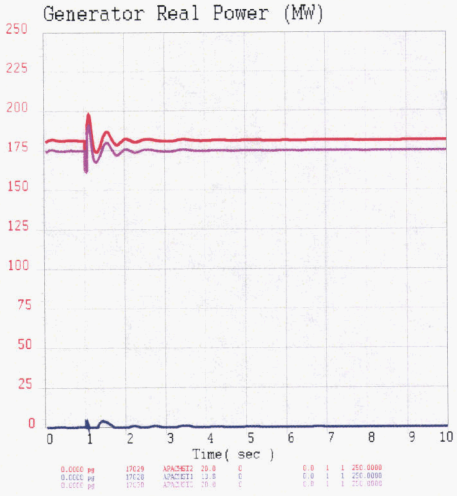

System Voltages
Bus Voltages 345 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 345 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWTC 2019 HS Coordinated Case
Developed from the Coordinated AZ 2023 HS Seed Case which was
Developed from WECC 2023 HS1 BASE CASE APPROVED CASE
2023 planning case coordinated in May 2013
SWTC non-coincidental loads
ALL COMMENTS FROM TSS REVIEW ARE INCLUDED
APS,SRP,SWTC,TEP,WESTERN DETAILED MODELS INCLUDED 5/22/13
Line: BICKNELL 345 - VAIL 345 dropped.
Page 2
E:\TPL\Contingencies\BICK345VAIL345\Channel-3.chf
ement Contingency
.
Thu Dec 12 15:34:25 2013

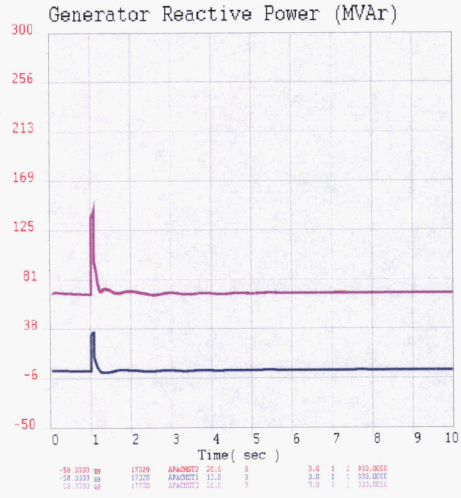

System Voltages
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 115 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
Bus Voltages 115 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWTC 2019 HS Coordinated Case
Developed from the Coordinated AZ 2023 HS Seed Case which was
Developed from WECC 2023 HS1 BASE CASE APPROVED CASE
2023 planning case coordinated in May 2013
SWTC non-coincidental loads
ALL COMMENTS FROM TSS REVIEW ARE INCLUDED
APS,SRP,SWTC,TEP,WESTERN DETAILED MODELS INCLUDED 5/22/13
Line: BICKNELL 345 - VAIL 345 dropped.
Page 3
F:\TPL\Contingencies\BICK345VAIL345\Channel-3.chf
Thu Dec 12 15:34:25 2013

APACHE GENERATORS OUTPUT







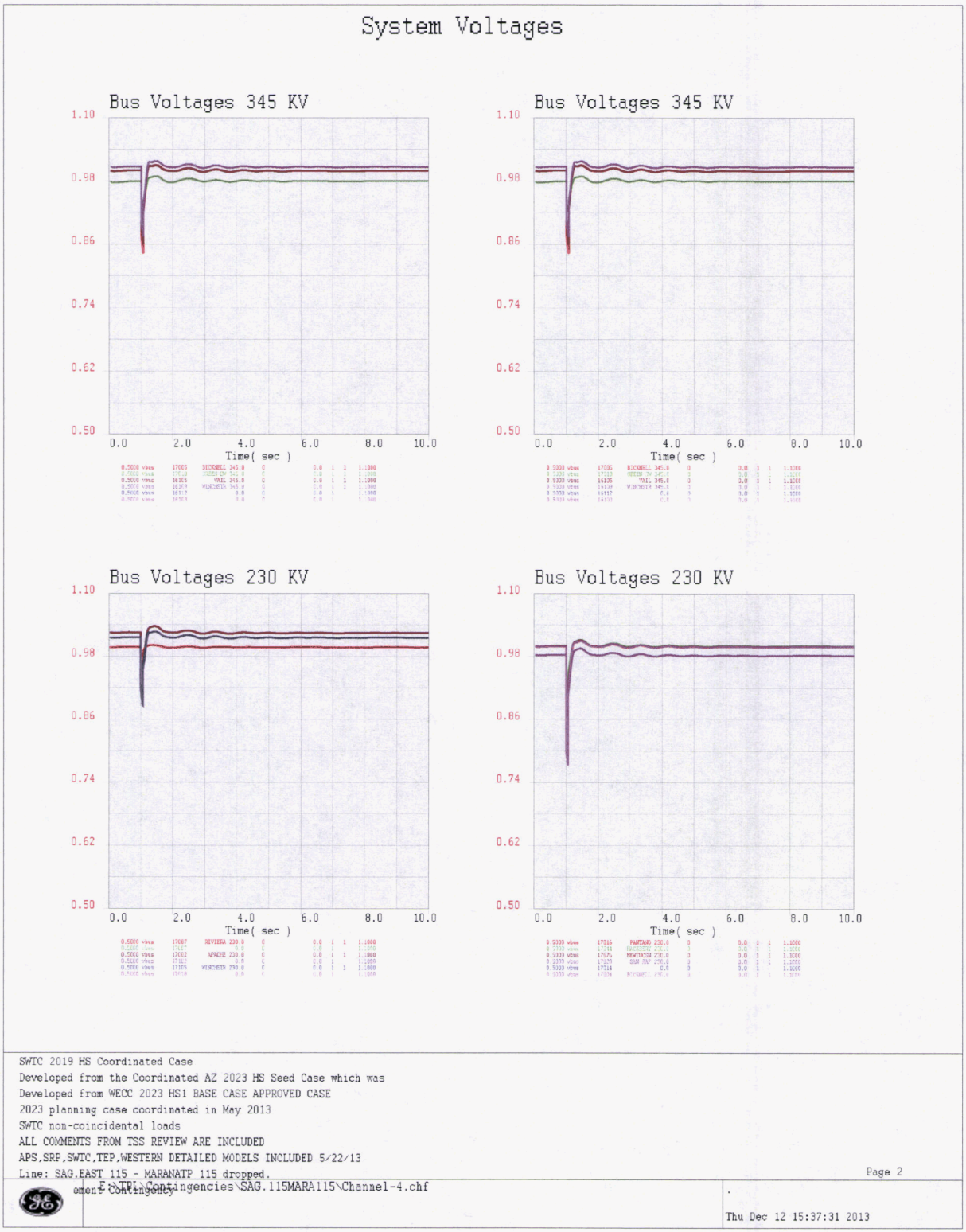


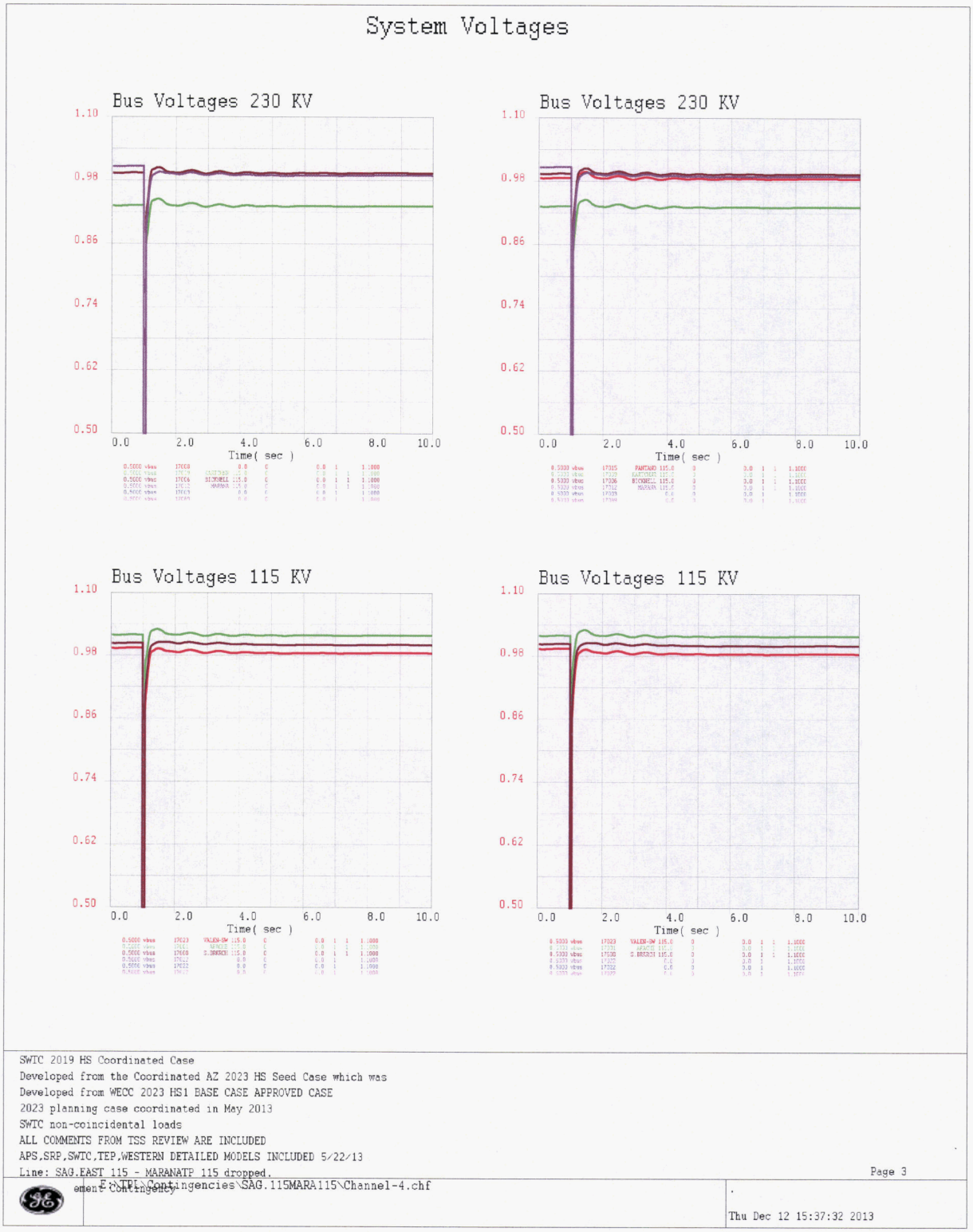
SWIC 2019 HS Coordinated Case
Developed from the Coordinated AZ 2023 HS Seed Case which was
Developed from WECC 2023 HS1 BASE CASE APPROVED CASE
2023 planning case coordinated in May 2013
SWIC non-coincidental loads
ALL COMMENTS FROM TSS REVIEW ARE INCLUDED
APS,SRP,SWTC,TEP,WESTERN DETAILED MODELS INCLUDED 5/22/13
Line: SAG.EAST 115 - MARANATP 115 dropped.
ement contingency

Page 1

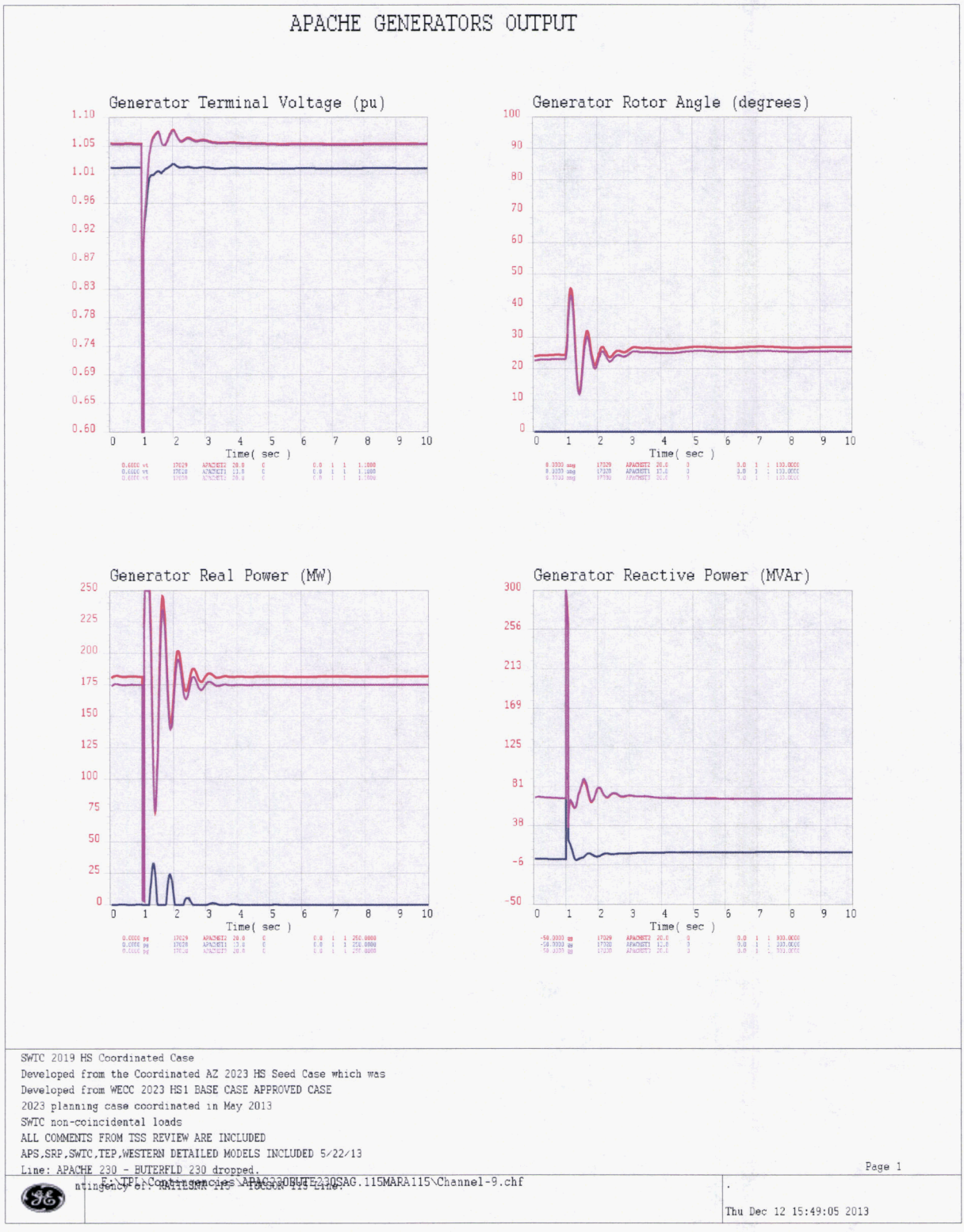
E:\TPL\Contingencies\SAG.115MARA115\Channel-4.chf

Thu Dec 12 15:37:31 2013

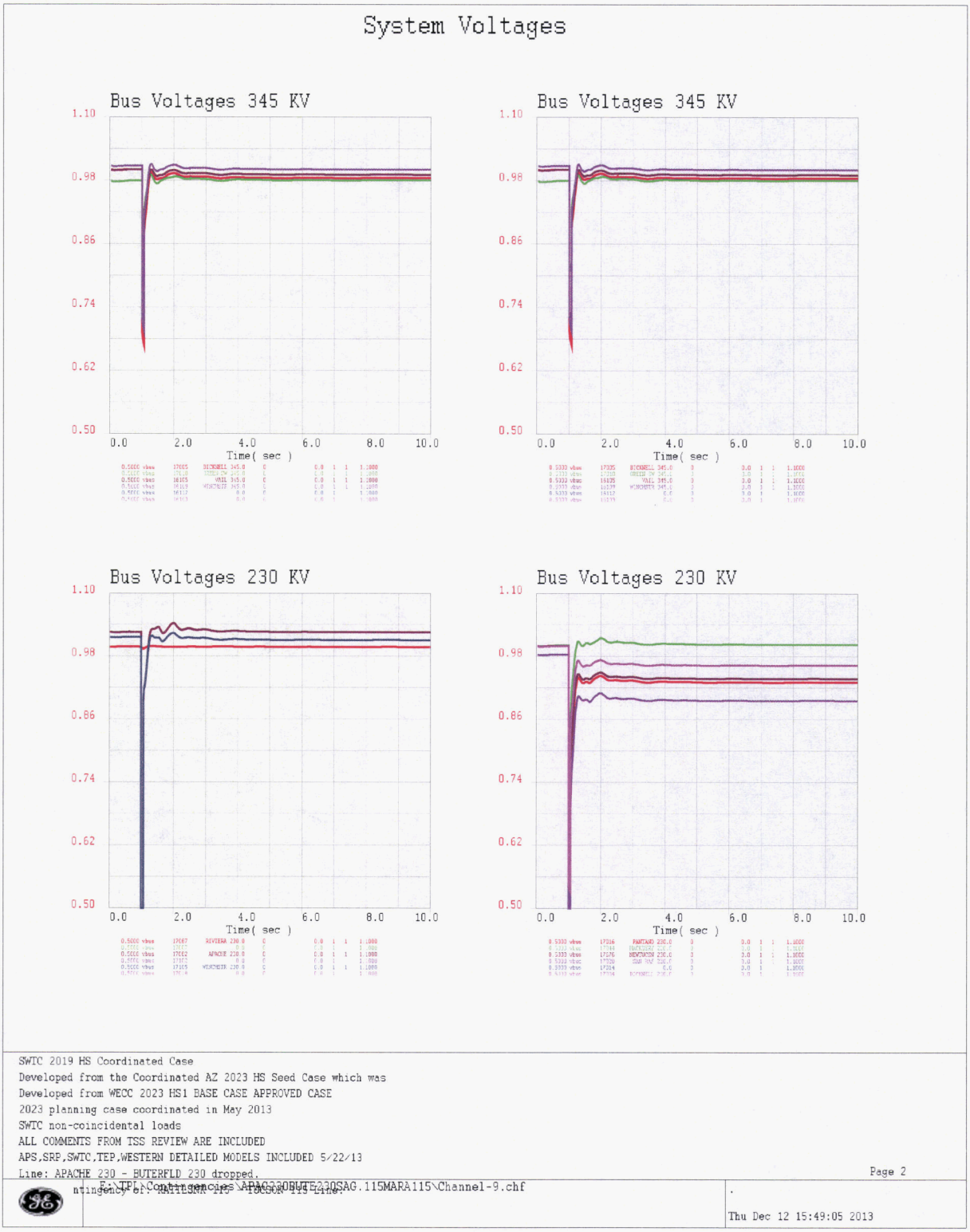

System Voltages
Bus Voltages 345 KV
Bus Voltages 345 KV
Bus Voltages 230 KV
Bus Voltages 230 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWTC 2019 HS Coordinated Case
Developed from the Coordinated AZ 2023 HS Seed Case which was
Developed from WECC 2023 HS1 BASE CASE APPROVED CASE
2023 planning case coordinated in May 2013
SWTC non-coincidental loads
ALL COMMENTS FROM TSS REVIEW ARE INCLUDED
APS,SRP,SWTC,TEP,WESTERN DETAILED MODELS INCLUDED 5/22/13
Line: SAG.EAST 115 - MARANATP 115 dropped.
Page 2
F:\TPL\Contingencies\SAG.115MARA115\Channel-4.chf
ement Contingency
Thu Dec 12 15:37:31 2013


System Voltages
Bus Voltages 230 KV
Bus Voltages 230 KV
Bus Voltages 115 KV
Bus Voltages 115 KV
1.10
0.98
0.86
0.74
0.62
0.50
0.0
2.0
4.0
6.0
8.0
10.0
Time(sec)
SWTC 2019 HS Coordinated Case
Developed from the Coordinated AZ 2023 HS Seed Case which was
Developed from WECC 2023 HS1 BASE CASE APPROVED CASE
2023 planning case coordinated in May 2013
SWTC non-coincidental loads
ALL COMMENTS FROM TSS REVIEW ARE INCLUDED
APS,SRP,SWTC,TEP,WESTERN DETAILED MODELS INCLUDED 5/22/13
Line: SAG.EAST 115 - MARANATP 115 dropped.
Page 3
E:\TPL\Contingencies\SAG.115MARA115\Channel-4.chf
ement Contingency
Thu Dec 12 15:37:32 2013

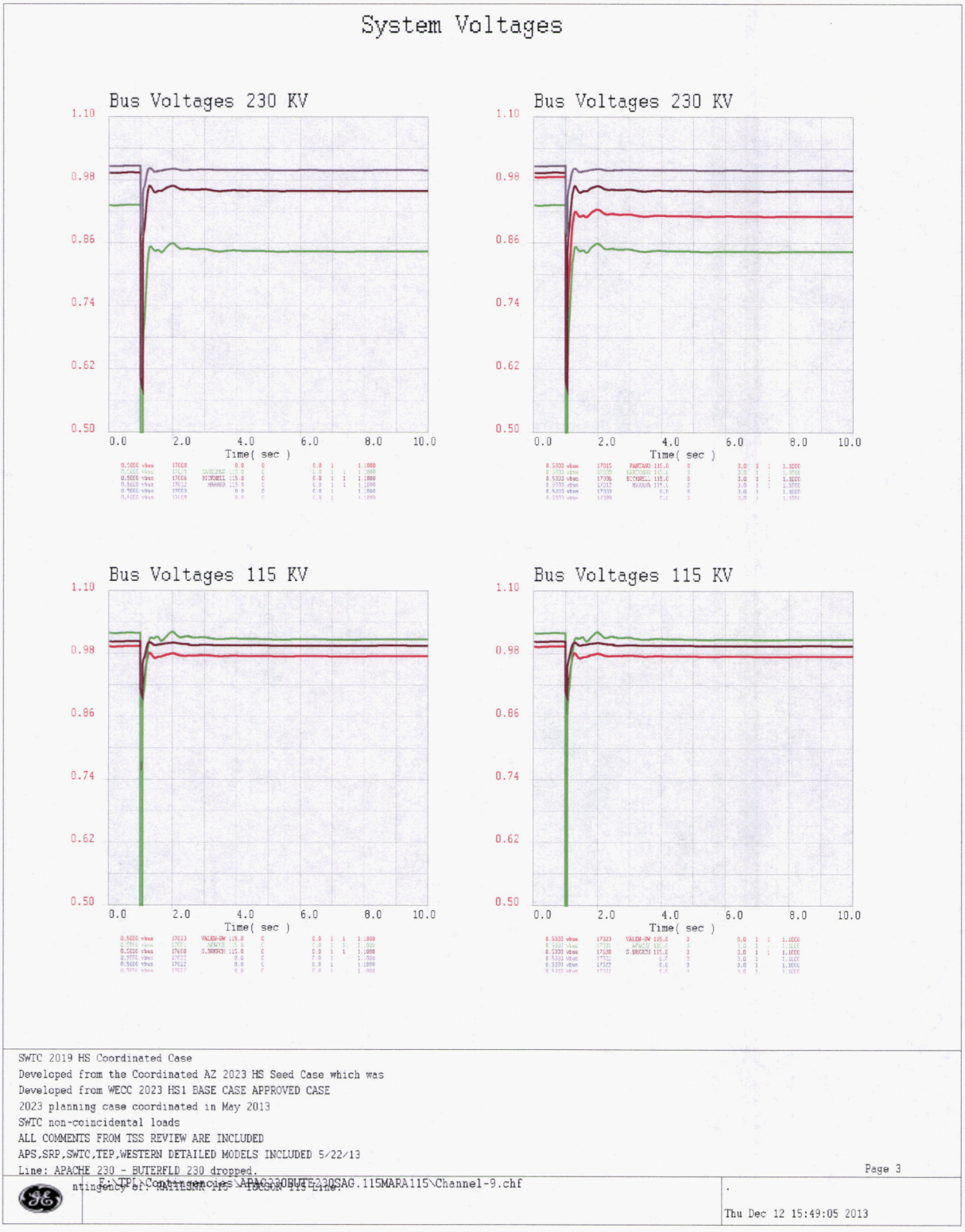
2019HS – Apache to Butterfield 230 kV & Saguaro East to Marana 115 kV Line Outages – Apache Generators Output



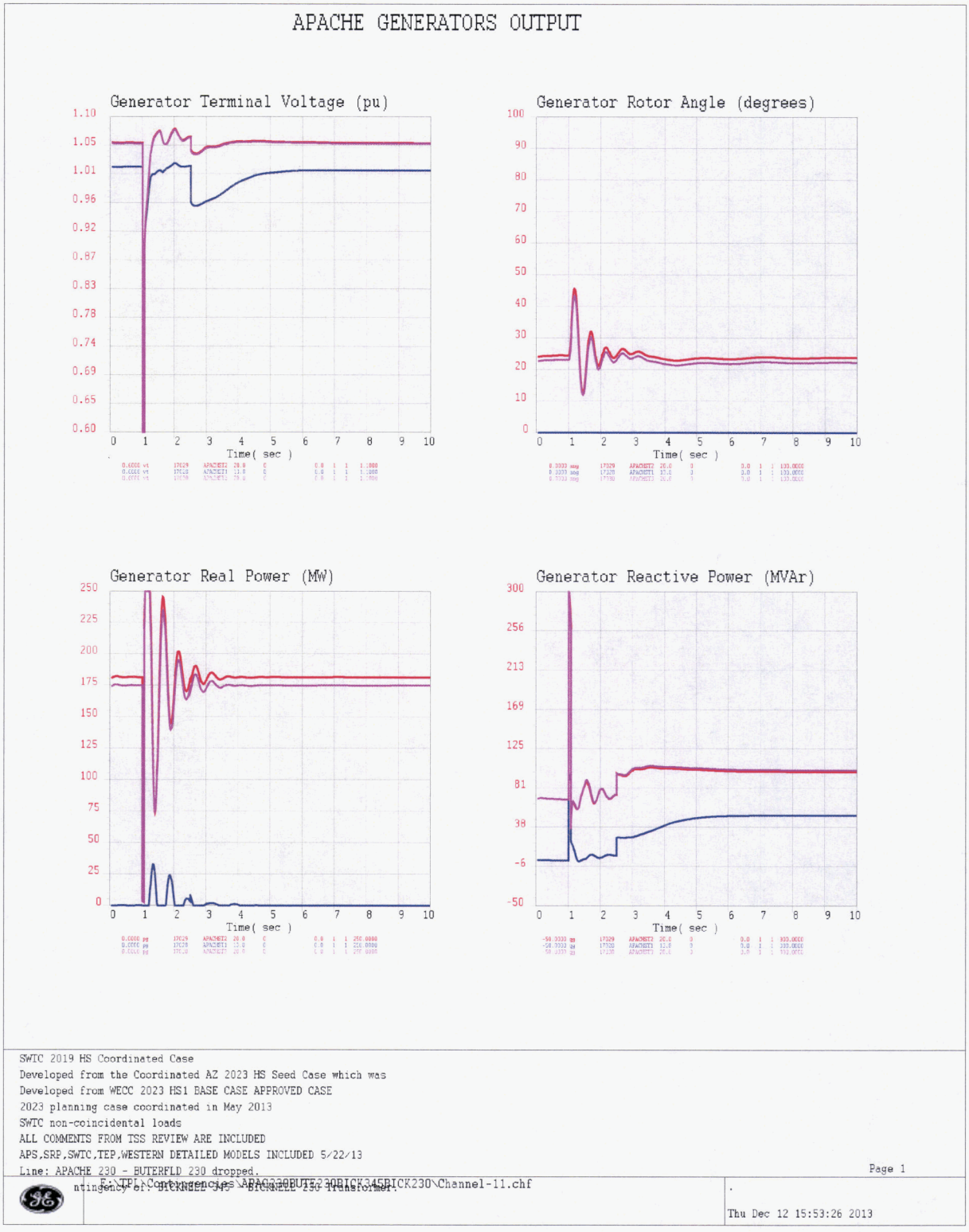
2019HS – Apache to Butterfield 230 kV & Saguaro East to Marana 115 kV Line Outages – 345 kV & 230 kV Bus Voltages



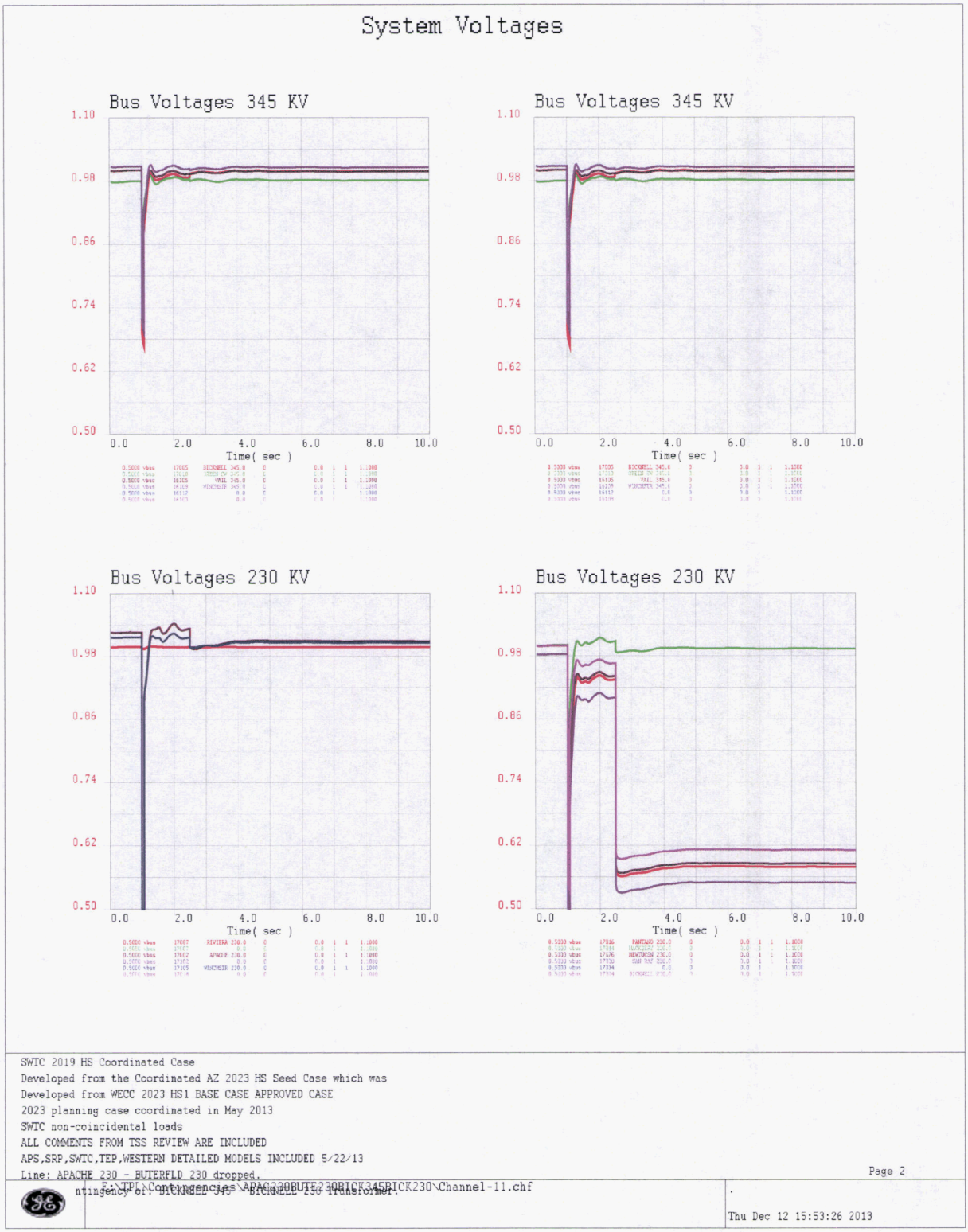
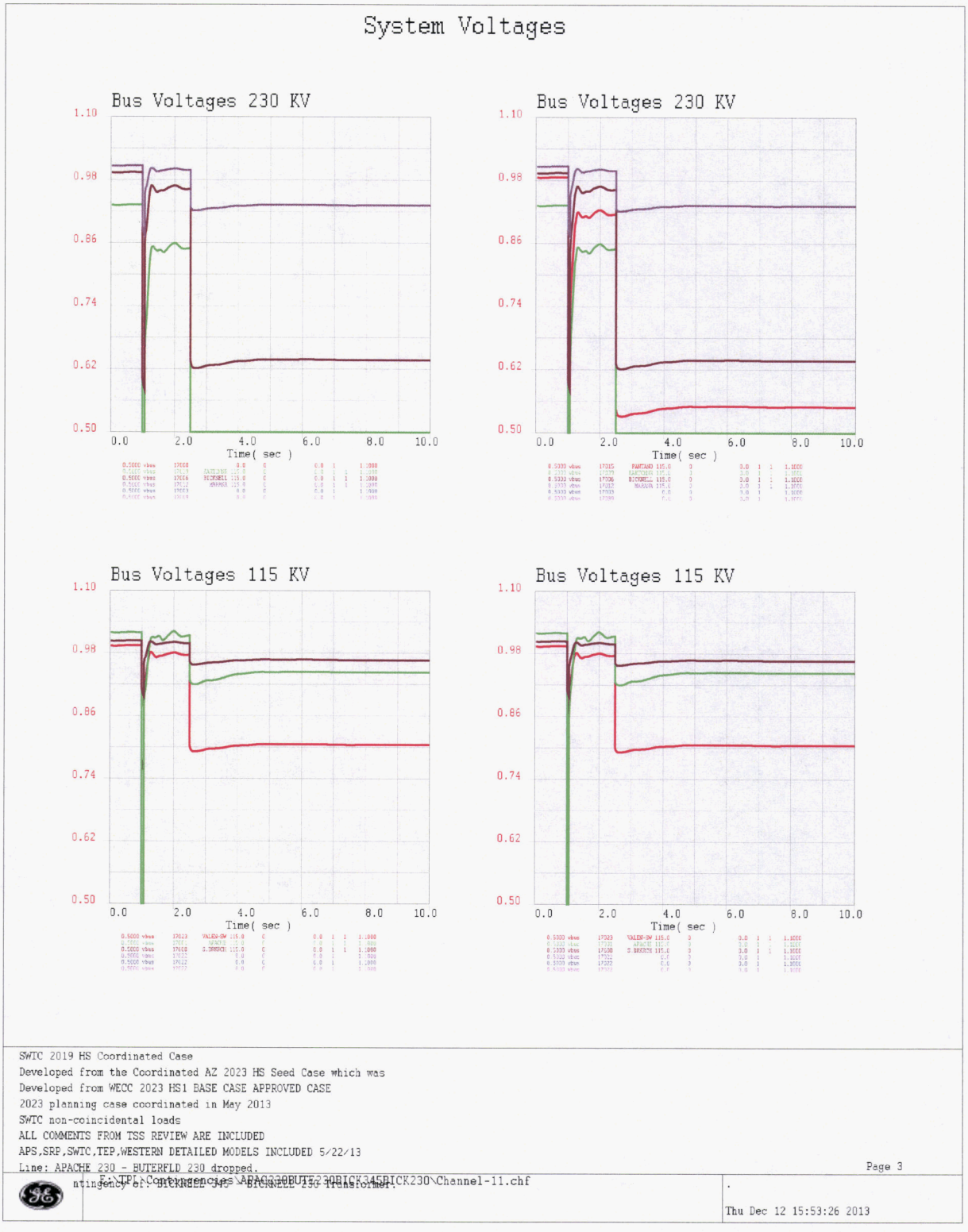
2019HS – Apache to Butterfield 230 kV & Saguaro East to Marana 115 kV Line Outages – 230 kV & 115 kV Bus Voltages



2019HS – Apache to Butterfield 230 kV & Bicknell to Vail 345 kV Line Outages – Apache Generators Output



2019HS – Apache to Butterfield 230 kV & Bicknell to Vail 345 kV Line Outages – 345 kV & 230 kV Bus Voltages



2019HS – Apache to Butterfield 230 kV & Bicknell to Vail 345 kV Line Outages – 230 kV & 115 kV Bus Voltages