Interconnection System Impact Study Report
Request # GI-2016-3
Final Report

600 MW Wind Generating Facility
Missile Site 345 kV Substation, Colorado

Public Service Company of Colorado
Transmission Planning
August 19, 2016

Executive Summary

Public Service Company of Colorado (PSCo) received an Interconnection Request (IR) on February 12, 2016 which was assigned GI-2016-3 queue position. GI-2016-3 is a wind generating facility rated at 600 MW gross electrical output that will be located in Elbert, Lincoln and Kit Carson Counties in Colorado. The point of interconnection (POI) requested for GI-2016-3 is the 345 kV bus within the PSCo Missile Site Substation.

The proposed 600 MW generating facility will consist of 300 wind turbine generators (WTG), where each WTG is rated 2.0 MW and is equipped with a 0.69/34.5 kV step-up transformer. Preliminary information on the wind generating facility's layout suggests that the 300 WTG's will be grouped into three 34.5 kV collector systems, each consisting of 100 WTG's (200 MW). Each 34.5 kV collector system will connect to a 34.5/345 kV main step-up transformer (MST). The three MST's will be connected to the POI using a customer-owned 345 kV radial transmission line (i.e. gen-tie) that is approximately 90 miles long.

The commercial operation date (COD) requested for the generating facility is December 31, 2018 and the requested back-feed date is August 1, 2018. The IR indicated that this Feasibility Study should include studies for both Network Resource Interconnection Service (NRIS) and Energy Resource Interconnection Service (ERIS).

The main purpose of this System Impact Study is to determine the steady state and dynamic system impacts of interconnecting 600 MW of generation at the Missile Site 345 kV POI for delivery to PSCo network loads. Towards this purpose, the study also identifies the transmission improvements needed to enable delivery of the rated 600 MW output of GI-2016-3 to the PSCo network load for NRIS.

The System Impact Study consisted of steady state (power flow), short-circuit and transient stability analyses. The power flow analysis was expanded from what was performed in the Feasibility Study. In addition to evaluating 2021 heavy summer (2021HS) conditions, analyses were performed using 2017 light spring (2017LS), and 2026 heavy summer (2026 HS) base cases. For the 2021HS and 2017LS conditions, three power flow models were created. For the 2026HS condition, two power flow

models were created. The three cases for the 2021 and 2017 conditions included a Benchmark Case, which models the planned transmission system topology before the proposed generator interconnection, one Study Case that includes the 600 MW generation under study, and another Study Case that also includes the network upgrades identified to qualify the generation as NRIS. The two power flow models created for the 2026HS condition excluded the Study Case with 600 MW generation without network upgrades because the planned network upgrades are scheduled to be in-service before 2026.

The power flow analysis results provided in Table A.1 identified the following thermal constraints for the additional 600 MW injection:

(a) The 345/230 kV transformation capacity at Smoky Hill substation due to single contingency outage of any one of the two 345/230 kV auto-transformers;
(b) The Missile Site – Daniels Park 230 kV line for the single contingency outage of Missile Site – Smoky Hill 345kV line;
(c) The Clark – Jordan 230 kV underground line for several single contingencies, with the worst overload resulting from the single contingency outage of the Smoky Hill – Tollgate – Leetsdale 230 kV line; and
(d) The Beaver Creek 115/230 kV auto-transformer for an outage of the Beaver Creek 115 kV bus tie.

As the owner of Beaver Creek 115/230 kV auto-transformer, Tri-State Generation and Transmission (Tri-State) has been designated as an affected party for this interconnection study.

The Pawnee – Daniels Park 345 kV project[1] is a PSCo planned project for which the Colorado Public Utility Commission (CPUC) has approved a Certificate of Public Convenience and Necessity (CPCN) that includes an in-service date of May 2022[2]. Therefore, this System Impact Study evaluated the effectiveness of Pawnee – Daniels Park 345 kV (P-DP) project in mitigating the thermal overloads due to the proposed 600 MW interconnection. Mitigation of all four thermal overloads due to the aggregate impact of transmission improvements comprising the P–DP project is evident from the power flow analysis results provided in Table A.2.

The Pawnee – Daniels Park (P-DP) project alleviates the 345/230 kV transformation capacity constraint at Smoky Hill because it includes installing a 345/230 kV, 560 MVA auto-transformer at a new Harvest Mile Substation, which is electrically the same as adding a third auto-transformer at Smoky Hill. Further, the Smoky Hill (Harvest Mile) – Daniels Park 345 kV line comprised in the P–DP project helps eliminate the thermal overload on the Clark – Jordan 230 kV line by redirecting a significant amount of power into Daniels Park from Smoky Hill. Also, the Missile Site – Daniels Park 345 kV line within the P–DP project provides a new parallel path from Missile Site to Daniels Park.

[1] More information at: http://www.transmission.xcelenergy.com/Projects/Colorado
[2] Public Service has filed a Petition for Variance with the CPUC in Proceeding 16V-0314E to revise the in-service date of P-DP to October 2019.

The P-DP project also alleviates potential overloading of Tri-State's Beaver Creek 230/115 kV transformer.

In both the 2021 and 2026 Study Cases which include the 600 MW generation and the P-DP project in service, the Greenwood – Leetsdale 230 kV line could experience post-contingency overload due to the forced outage of Smoky Hill – Leetsdale 230kV line. However, since the existing line rating is limited by substation terminal equipment which would be replaced as normal course of business to achieve a higher facility rating, it is not identified as a network upgrade. Therefore, the P–DP project is adequate for mitigating all thermal constraints attributed to GI-2016-3 and is recommended as the network upgrade for delivery of 600 MW rated output to PSCo network load.

The short circuit analysis results based on the 2017-18 transmission topology did not identify the need for any additional network upgrades for the proposed GI-2016-3 interconnection.

The transient stability analysis was performed using a 2020 heavy summer (2020HS) case and did not identify any unacceptable/degraded stability performance due to the proposed GI-2016-3 interconnection. Both angular stability as well as LVRT (Low Voltage Ride-Through) performance was acceptable for all normally cleared three-phase fault disturbances at the Missile Site 345 kV bus as well as a close in fault at Ault on the Craig-Ault 345 kV line. Also, stability performance was acceptable following the loss of over 500 MW of conventional generation at Pawnee Substation. Therefore, no additional network upgrades are required based on the transient stability analysis.

Based on the noted results, this System Impact Study concludes that the GI-2016-3 interconnection would not achieve 600 MW NRIS[3] until the Pawnee – Daniels Park 345 kV Project is placed in service. As noted in the 2016 Project update[4], the in-service date for Smoky Hills – Daniels Park portion of the project is intended to be advanced to October 2019 and a Petition for Variance was submitted to the Colorado Public Utilities Commission (CPUC Proceeding No. 16V-0314E) to modify their previous decision. This petition has since been merged with the Rush Creek Wind Project in CPUC Proceeding No. 16A-0117E/16V-0314E.

Prior to the Pawnee – Daniels Park 345 kV project being in-service, GI-2016-3 may be interconnected as ERIS[5] to deliver its output using the existing firm or non-firm transmission capacity on an "as available" basis.

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[3] Network Resource Interconnection Service allows the Interconnection Customer 's Large Generating Facility to be designated as a Network Resource, up to the Large Generating Facility's full output, on the same basis as existing Network Resources interconnected to Transmission Provider's Transmission System, and to be studied as a Network Resource on the assumption that such a designation will occur. (*section 3.2.2 of Attachment N in Xcel Energy OATT*)

[4] More information at:
http://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/Files/PDF/Projects/CO/Pawnee-Daniels/CO-Transmission-Pawnee-Daniels-March-2016-Project-Update.pdf

[5] Energy Resource Interconnection Service allows Interconnection Customer to connect the Large Generating Facility to the Transmission System and be eligible to deliver the Large Generating Facility's output using the existing firm or non-firm capacity of the Transmission System on an "as available" basis. Energy Resource Interconnection Service

Therefore, for GI-2016-3 interconnection:

NRIS (before network upgrades) = 0 MW
NRIS (after network upgrades) = 600 MW
ERIS (before network upgrades) = 0 to 600 MW on “as-available” basis

Cost estimates for the Transmission Provider Interconnection Facilities are provided in Tables 1 and 2, and the cost estimates for the Pawnee – Daniels Park 345 kV project are provided in Table 3 – Network Upgrades for Delivery. The estimated total cost for the required Interconnection Facilities is **$6.579M** (of which $3.552M is Interconnection Customer Funded and $3.027M is PSCo Transmission Provider Funded) and the estimated total cost for the Network Upgrades is **$178.3M.**
The CPCN (Certificate of Public Convenience and Necessity) for Pawnee – Daniels Park 345kV Project has been granted by the CPUC and the estimated total cost for this (PSCo Transmission Provider Funded) Network Upgrade has also been approved by the CPUC.

Total Estimated Cost for Interconnecting GI-2016-3 as NRIS = ~$184.9M

Total Estimated Cost for Interconnecting GI-2016-3 as ERIS = ~$6.6M

does not in and of itself convey any right to deliver electricity to any specific customer or Point of Delivery. (*section 3.2.1 of Attachment N in Xcel Energy OATT*)

Power Flow N-1 Contingency Analysis

The 2021HS, 2017LS, and 2026 HS base cases were updated to dispatch the existing and planned generation within the Pawnee and Missile Site "generation pockets" (i.e. aggregate of generation in the local area) at their respective highest coincident output deemed appropriate for the planning of adequate transmission capacity. This was done in accordance with the generation dispatch assumptions practiced by PSCo Transmission Planning function to study the feasibility and system impact of generator interconnection requests as a Transmission Provider. Accordingly, the existing, planned and proposed generating plants at Pawnee and Missile Site stations were dispatched as noted below.

Pawnee local "generation pocket"

- ✓ Pawnee Fossil Fuel generation = 100% of rated capacity = 536 MW
- ✓ Manchief Gas generation = 90% of rated capacity = 252 MW
- ✓ Peetz Logan Wind generation = 40% of rated capacity = 230 MW

Aggregate Generation Dispatched at Pawnee in all Cases = 1018 MW

Missile Site local "generation pocket"

- ✓ Cedar Point (Missile Site 230kV) = 80% of rated capacity = 200 MW
- ✓ Limon I, II, III (Missile Site 345kV) = 80% of rated capacity = 480 MW
- ✓ GI-2016-3 (Missile Site 345kV) = 100% of rated capacity = 600 MW

Aggregate Generation Dispatched at Missile Site in Benchmark Case = 680 MW

Aggregate Generation Dispatched at Missile Site in Study Case(s) = 1280 MW

The GI-2016-3 *Benchmark Cases* were derived from the 2021HS, 2017LS, and 2026 HS base cases by changing the generation dispatch at Pawnee and Missile Site as noted above. Also, transmission facilities comprising the Pawnee – Daniels Park project modeled in the 2021HS case were removed in the Benchmark Case. Generation at Blue Spruce, Rocky Mountain Energy Center (RMEC), and Comanche was used to balance the PSCo area generation with the increased injection at Pawnee and Missile Site substations.

Two GI-2016-3 *Study Cases* were created from the 2021HS and 2017LS cases -- without and with the network upgrades. The GI-2016-3 *Study Case without network upgrades* was created by adding the GI-2016-3 generating plant at Missile Site 345kV bus into the Benchmark Case and dispatching it at 600 MW rated output. The GI-2016-3 *Study Case with network upgrades* was created by adding the Pawnee – Daniels Park Project's transmission facilities to the previous case. A *Study Case with network upgrades* was also created from the 2026HS case.

PSCo adheres to all applicable NERC Standards & WECC Criteria for Bulk Electric System (BES) acceptable performance, as well as its internal transmission planning criteria for all studies. During system intact (N-0) conditions, PSCo's steady-state performance criteria require the transmission bus voltages remain within 0.95 – 1.05 per unit of nominal and the power flows stay below the applicable normal ratings of the transmission facilities. Following a single contingency, the steady state bus voltages must remain within 0.90 – 1.05 per unit of nominal, and the power flows must continue to stay below the applicable normal facility ratings. For N-1 post-contingency system conditions, the applicable normal rating is the seasonal continuous rating of the transmission facility – but PSCo allows use of eight-hour facility rating for transformers for which it is available. Further, PSCo does not rely on 30-minute emergency ratings of transmission facilities for meeting N-1 system performance in planning studies.

Based on the results of the steady-state power flow analyses on the Benchmark and Study Cases provided in Table A.1 in the Appendix, it is evident that injecting 600 MW at the Missile Site 345 kV bus results in heavy N-1 thermal overloads on the Smoky Hill 345/230 kV auto-transformers, the Missile Site – Daniels Park 230 kV line, the Clark – Jordan 230 kV underground line, and the Beaver Creek 230/115 kV transformer. Without any transmission improvements (i.e. network upgrades) to mitigate these four thermal constraints – that is, by only utilizing the existing capability of PSCo's transmission system – the GI-2016-3 interconnection qualifies for NRIS at 0 MW and for ERIS within the 0–600 MW output range by using the "as available" firm or non-firm capacity of the existing transmission system. The power flow results provided in Table A.2 in the Appendix demonstrate that the GI-2016-3 interconnection will achieve NRIS for its rated 600 MW output after the network upgrades are constructed (i.e. Pawnee – Daniels Park 345kV Project is in service).

Therefore, for GI-2016-3 interconnection:

NRIS (before network upgrades) = 0 MW
NRIS (after network upgrades) = 600 MW
ERIS (before network upgrades) = 0 to 600 MW on "as-available" basis

Voltage Regulation and Reactive Power Capability

Interconnection Customers are required to interconnect their Large Generating Facilities with Public Service of Colorado's (PSCo) Transmission System in accordance with the *Xcel Energy Interconnection Guidelines for Transmission Interconnected Producer-Owned Generation Greater Than 20 MW* (available at: http://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/Files/PDF/Interconnection/Interconnections-POL-TransmissionInterconnectionGuidelineGreat20MW.pdf).
In addition, wind generating plant interconnections must also fulfill the performance requirements specified in FERC Order 661-A. Accordingly, the following voltage regulation and reactive power capability requirements at the POI are applicable to this interconnection request:

- To ensure reliable operation, all Generating Facilities interconnected to the PSCo transmission system are expected to adhere to the *Rocky Mountain Area Voltage Coordination Guidelines (RMAVCG)*. Accordingly, since the POI for this interconnection request is located within Northeast Colorado - Region 7 defined in the *RMAVCG*; the applicable ideal transmission system voltage profile range is 1.02 – 1.03 per unit at regulated buses and 1.0 – 1.03 per unit at non-regulated buses.
- Xcel Energy's OATT requires all Interconnection Customers to have the reactive capability to achieve +/– 0.95 power factor at the POI, with the maximum reactive capability (corresponding to rated output) available at all output levels. Furthermore, Xcel Energy requires all Generating Facilities to have dynamic voltage control capability and maintain the POI voltage specified by the Transmission Operator as long as the generating plant is on-line, producing power and it is not called upon to operate outside its 0.95 lag – 0.95 lead power factor range capability at the POI.
- It is the responsibility of the Interconnection Customer to determine the type (switched shunt capacitors and/or switched shunt reactors, etc.), the size (MVAR), and the locations (34.5 kV or 345 kV bus) of any additional static reactive power compensation needed within the generating plant in order to have adequate reactive capability to meet the +/– 0.95 power factor and the 1.02 – 1.03 per unit voltage range standards at the POI. Further, for wind generating plants to meet the LVRT (Low Voltage Ride Through) performance requirements specified in FERC Order 661-A, an appropriately sized and located dynamic reactive power device (DVAR, SVC, etc.) may also need to be installed within the generating plant.
- The Interconnection Customer is required to demonstrate to the satisfaction of PSCo Transmission Operations prior to the commercial in-service date of the generating plant that it can safely and reliably operate within the required power factor and voltage ranges (noted above).

Transient Stability Analysis

The transient stability analysis was performed using benchmark and study dynamics cases derived from the WECC 2020 Heavy Summer (2020HS) dynamics case created for use with the Siemens PTI PSSE software program. The benchmark dynamics case was updated to match the generation dispatch in the Pawnee and Missile Site area similar to the power flow cases discussed previously. The study dynamics case was developed by adding the GI-2016-3 generating facility and the transmission facilities comprising the Pawnee – Daniels Park project. Finally, the user model supplied by Vestas for its V110 VCSS 2.0MW wind turbine generators proposed to be installed in the GI-2016-3 generating facility was integrated into the study dynamics case.

The transient stability analysis consisted of simulating disturbances at the POI as well as at two generating stations in northern Colorado. Eight normally cleared three-phase fault disturbances were simulated for the benchmark and study dynamics cases, as noted below:

A. NERC Category P1 (single contingency) Disturbances
(Three-phase, close-in fault at bus designated by asterisk (*) with normal clearing of 6 cycles)

1. Missile Site* – Pawnee #1 345 kV Line
2. Missile Site* – Smoky Hill 345 kV Line
3. Missile Site* – Daniels Park 345 kV Line[6]
4. Missile Site 345*/230 kV transformer
5. Craig – Ault* 345 kV Line
6. Pawnee 22*/230 kV step-up transformer w/ tripping of Pawnee unit

B. NERC Category P7 (common structure double contingency) Disturbances
(Three-phase, close-in fault at bus designated by asterisk (*) with normal clearing of 6 cycles)

7. Pawnee – Missile Site* #1 & #2 345 kV double circuit tower line[6]
8. Missile Site* – Smoky Hill and Missile Site* – Daniels Park 345 kV double circuit tower line[6]

The results noted in Appendix B demonstrate that no unacceptable/degraded stability performance occurs due to the proposed GI-2016-3 interconnection. Since none of the normally cleared three-phase fault disturbances at Missile Site resulted in tripping of the Vestas V110 VCSS 2.0MW wind turbine generators proposed for the GI-2016-3 generating facility, it is concluded that angular stability as well as LVRT (Low Voltage Ride-Through) performance of GI-2016-3 is acceptable. Further, loss of a major transmission path from Craig as well as loss of a significant synchronous generator at Pawnee did not result in any angular or voltage stability issues on the transmission system. Detailed stability plots are provided in Appendix C.

Short Circuit Analysis

The short circuit study results show that no circuit breakers in the Missile Site station (or any adjoining station) will be over-dutied by interconnecting the proposed GI-2016-3 wind generation facility.

GI-2016-3 Impact on Short Circuit Levels and Breaker Duty Margins at Missile Site 345 kV POI

System Condition	Three-Phase (3-Ph) Fault Level (Amps)	Single-Line-to-Ground (SLG) Fault Level (Amps)	Breaker Duty Margin for 3-Ph Fault	Breaker Duty Margin for SLG Fault
Before GI-2016-3 Y2017-18	10,910	10,151	82.7 %	83.9 %
After GI-2016-3 Y2017-18	11,967	11,208	81.0 %	82.2 %

[6] Performed only for cases with the Pawnee-Daniels Park 345 kV project included.

Costs Estimates and Assumptions

Scoping level cost estimates (+/- 30% accuracy) for the Transmission Provider Interconnection Facilities and Network Upgrades for Delivery were developed by PSCo Engineering.

Tables 1–3 below list the transmission improvements needed to accommodate the interconnection and delivery of GI-2016-3 generation output as NRIS. The estimated total cost for the Interconnection Facilities is **$6.579M** (of which $3.552M is Interconnection Customer Funded and $3.027M is PSCo Transmission Provider Funded) and for the Network Upgrades for Delivery is **$178.3M**. The CPCN (Certificate of Public Convenience and Necessity) for Pawnee – Daniels Park 345kV Project has been granted by the CPUC and the estimated total cost for this (PSCo Transmission Provider Funded) Network Upgrade has also been approved by the CPUC. The cost estimates are subject to change upon a more detailed and refined design.

Figure 1 below is the one-line drawing of the Missile Site Substation 345 kV switchyard. The drawing depicts the POI and the PCO delineating the Transmission Provider's and Interconnection Customer's Interconnection Facilities for the proposed GI-2016-3 interconnection. Additional transmission facilities comprising the Network Upgrades at Missile Site Substation required for GI-2016-3 are also shown.

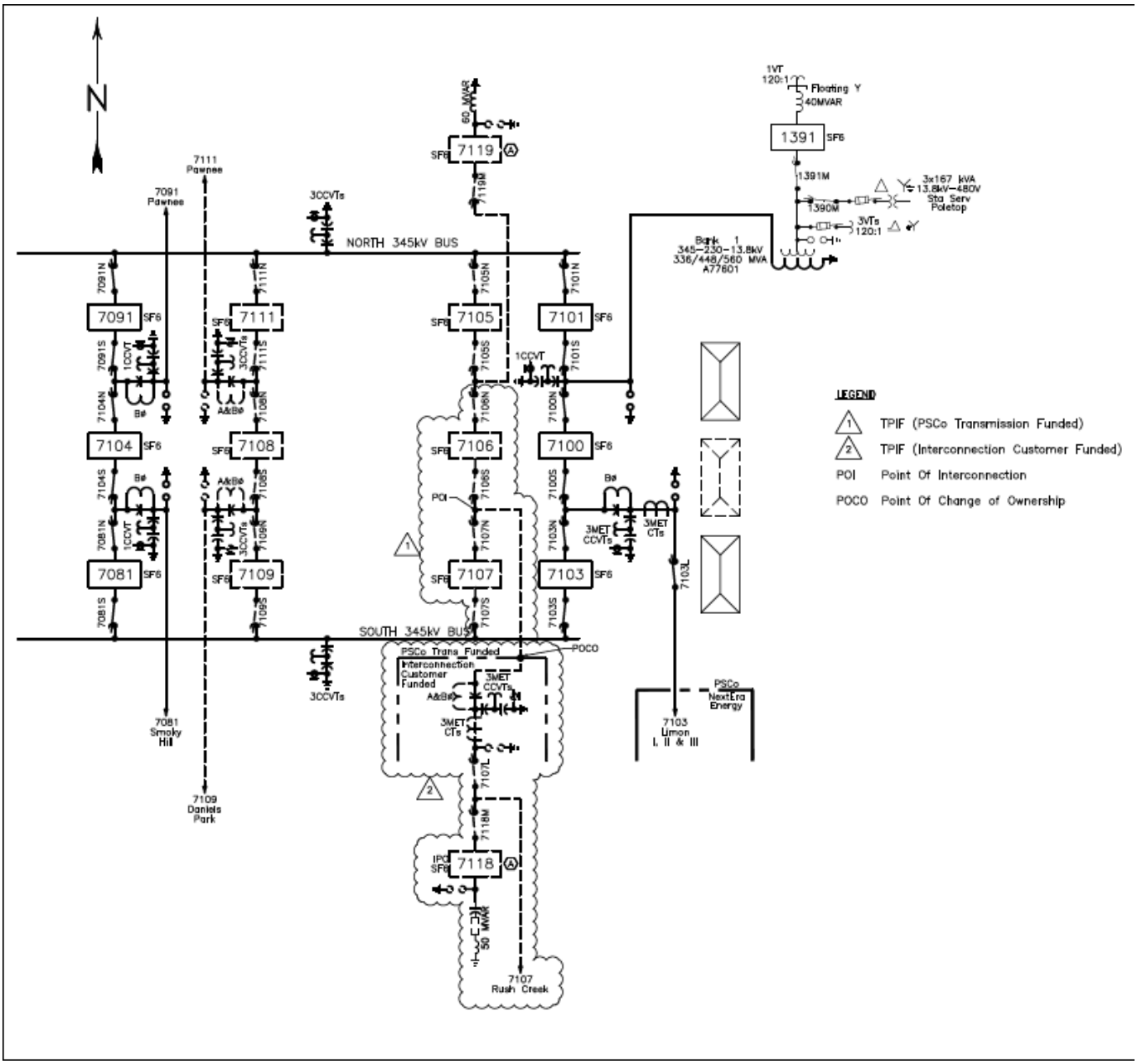

Figure 1 GI-2016-3 Interconnection to 345kV Bus in Missile Site Substation

Table 1: PSCo Owned; Interconnection Customer Funded Interconnection Facilities

Element	Description	Cost Estimate (Millions)
PSCo's Missile Site 345 kV Transmission Substation	Interconnect Customer to the 345kV bus at the Missile Site Substation. The new equipment includes: • One 345kV, 3000 amp IPO circuit breaker • One 345kV, 75MVAR shunt capacitor bank • Two 345kV, 3000 amp gang switches • Three 345kV CT metering units • Three 345kV PT metering units • Six 345kV lightning arresters • Primary metering for Load Frequency/Automated Generation Control • Power Quality Metering • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated transmission line communications, fiber, relaying and testing	**$3.357**
	Transmission line tap from Customer's last line structure outside of PSCo's yard into new bay position (assumed 300' span, conductor, hardware and labor).	**$0.075**
Customer's 345 kV Substation	Load Frequency/Automated Generation Control (LF/AGC) RTU and associated equipment.	**$0.120**
	Total Cost Estimate for PSCo-Owned, Customer-Funded Interconnection Facilities	**$3.552**
Time Frame	**Site, design, procure and construct**	**24 Months**

Table 2: PSCo Owned; PSCo Transmission Provider Funded Interconnection Facilities

Element	Description	Cost Estimate (Millions)
PSCo's Missile Site 345 kV Transmission Substation	Interconnect Customer to the bus at the Missile Site Substation. The new equipment includes: • Three 345kV, 3000 amp circuit breakers • Six 345kV, 3000 amp gang switches • Associated station controls, communications, supervisory and SCADA equipment • Associated electrical equipment, bus, wiring and grounding • Associated foundations and structures • Associated equipment and system testing	**$3.027**
	Total Cost Estimate for PSCo-Owned, PSCo-Funded Interconnection Facilities	**$3.027**
Time Frame	**Site, design, procure and construct**	**24 months**

Cost Estimate Assumptions for Interconnection Facilities (Tables 1 & 2)

- Scoping level project cost estimates for Interconnection Facilities (+/- 30% accuracy) were developed by PSCo Engineering.
- Estimates are based on 2016 dollars (appropriate contingency and escalation included).
- Labor is estimated for straight time only – no overtime included.
- AFUDC has been excluded.
- Lead times for materials were considered for the schedule.
- The estimated time to site, design, procure and construct the Interconnection Facilities is approximately 24 months after authorization to proceed has been obtained.
- A CPCN will not be required and no new substation land will need to be acquired for the construction of Interconnection Facilities.

Table 3: PSCo Network Upgrades for Delivery

Transmission Facilities	
Pawnee – Daniels Park Project Cost Estimate (Millions)	**$178.3**
Time Frame to site, design, procure and construct	**Fall 2019**

Notes:

- The CPCN for Pawnee – Daniels Park Project was approved by the CPUC on November 25, 2014 (Proceeding No. 14A-0287E).
- In the decision approving the CPCN, the CPUC stated that construction could not begin until 2020. This resulted in an estimated in-service date of 2022.
- On April 2016, PSCo filed a Petition for Variance, requesting an in-service date of October 2019.
- Cost Estimates are unchanged from what were provided in the CPCN.

Appendix A – Power Flow N-1 Contingency Analysis Results

2021 Heavy Summer Case

High Coincidence Generation Dispatch at Pawnee & Missile Site:

Pawnee 230kV (100% Coal + 90% Gas + 40% Wind) = 1018 MW;

Missile Site 345kV Wind = 480 MW (80%); Missile Site 230kV Wind = 200 MW (80%)

600 MW output from GI-2016-3 is dispatched to sink at Spruce (268 MW), RMEC (147 MW) & Comanche (185 MW)

Table A.1 – Differential Impact[7] of GI-2016-3 on Facility Loadings Without Network Upgrades

				Branch N-1 Loading Before 600 MW GI		Branch N-1 Loading After 600 MW GI			
Monitored Facility (Line or Transformer)	Type	Owner	Summer Normal (Continuous / 8-hour) Facility Rating in MVA	Flow in MVA	Flow in % of Summer Normal Rating	Flow in MVA	Flow in % of Summer Normal Rating	Differential Impact of GI-2016-3	N-1 Contingency Outage
Smoky Hill 230/345 kV # T4/T5	Xfmr	PSCo	644	637.5	99.0%	897.0	139.3%	+40.3%	Smoky Hill 230/345 kV # T5/T4
Missile Site – Daniels Park 230kV	Line	PSCo	741	595.0	80.5%	806.0	111.4%	+30.9%	Missile Site – Smoky Hill 345 kV
Clark – Jordan 230 kV	Line	PSCo	331	300.0	91.0%	338	103.1%	+12.1%	Smoky Hill – Leetsdale 230 kV
Beaver Creek 115/230 kV	Xfmr	TSGT	224	220	97.0%	240	107.1%	+10.1%	Beaver Creek PSCo – Beaver Creek WAPA 115 kV bus tie

[7] **Due to proposed 600 MW generation increase at Missile Site 345 kV Station**

Table A.2 – After GI-2016-3 With Pawnee – Daniels Park 345kV Project (Network Upgrades) In-Service

				Branch N-1 Loading After 600 MW GI			
Monitored Facility (Line or Transformer)	**Type**	**Owner**	**Summer Normal (Continuous / 8-hour) Facility Rating in MVA**	**Flow in MVA**	**Flow in % of Summer Normal Rating**	**% Flow Reduction**	**N-1 Contingency Outage**
Smoky Hill 230/345 kV # T4/T5	Xfmr	PSCo	644	392.9	61.0%	–78.3%	Smoky Hill 230/345 kV # T5/T4
Missile Site – Daniels Park 230kV	Line	PSCo	741	485.0	66.0%	–45.4%	Missile Site – Smoky Hill 345 kV
Clark – Jordan 230 kV	Line	PSCo	331	229.0	69.0%	–34.1%	Smoky Hill – Leetsdale 230 kV
Beaver Creek 115/230 kV	Xfmr	TSGT	224	219	97.0%	–10.1%	Beaver Creek PSCo – Beaver Creek WAPA 115 kV bus tie

Appendix B – Transient Stability Analysis Results

Stability Disturbances							
#	Fault Location	Fault Type	Facility Tripped	Clearing Time (cycles)	Stability Performance	Post-Fault Voltage Recovery	Angular Stability
1	Missile Site 345 kV	3ph	Missile Site – Pawnee 345kV Line	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
2	Missile Site 345 kV	3ph	Missile Site – Smoky Hill 345kV Line	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
3	Missile Site 345 kV	3ph	Missile Site – Daniels Park 345kV Line	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
4	Missile Site 345 kV	3ph	Missile Site 345/230 kV Auto-Transformer	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
5	Craig 345 kV	3ph	Craig – Ault 345kV Line	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
6.	Pawnee 22 kV	3ph	Pawnee Generator	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
7.	Missile Site 345 kV	3ph	Pawnee – Missile Site #1 and #2 345 kV double circuit tower line (DCTL)	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping
8.	Missile Site 345 kV	3ph	Missile Site – Smoky Hill and Missile Site – Daniels Park 345 kV double circuit tower line (DCTL)	Primary (6.0)	Acceptable	Maximum transient voltage dips within WECC criteria	No generator tripped & positive damping

Appendix C – Transient Stability Analysis Plots

SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_P-M.out

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BM: P-MS #1 345 KV

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CHNL# 440: [VOLT 70107 [CHEROKEE 230.00]]
1.0500 0.70000

CHNL# 863: [VOLT 70599 [SMOKYHIL 345.00]]
1.0500 0.70000

CHNL# 862: [VOLT 70598 [PAWNEE 345.00]]
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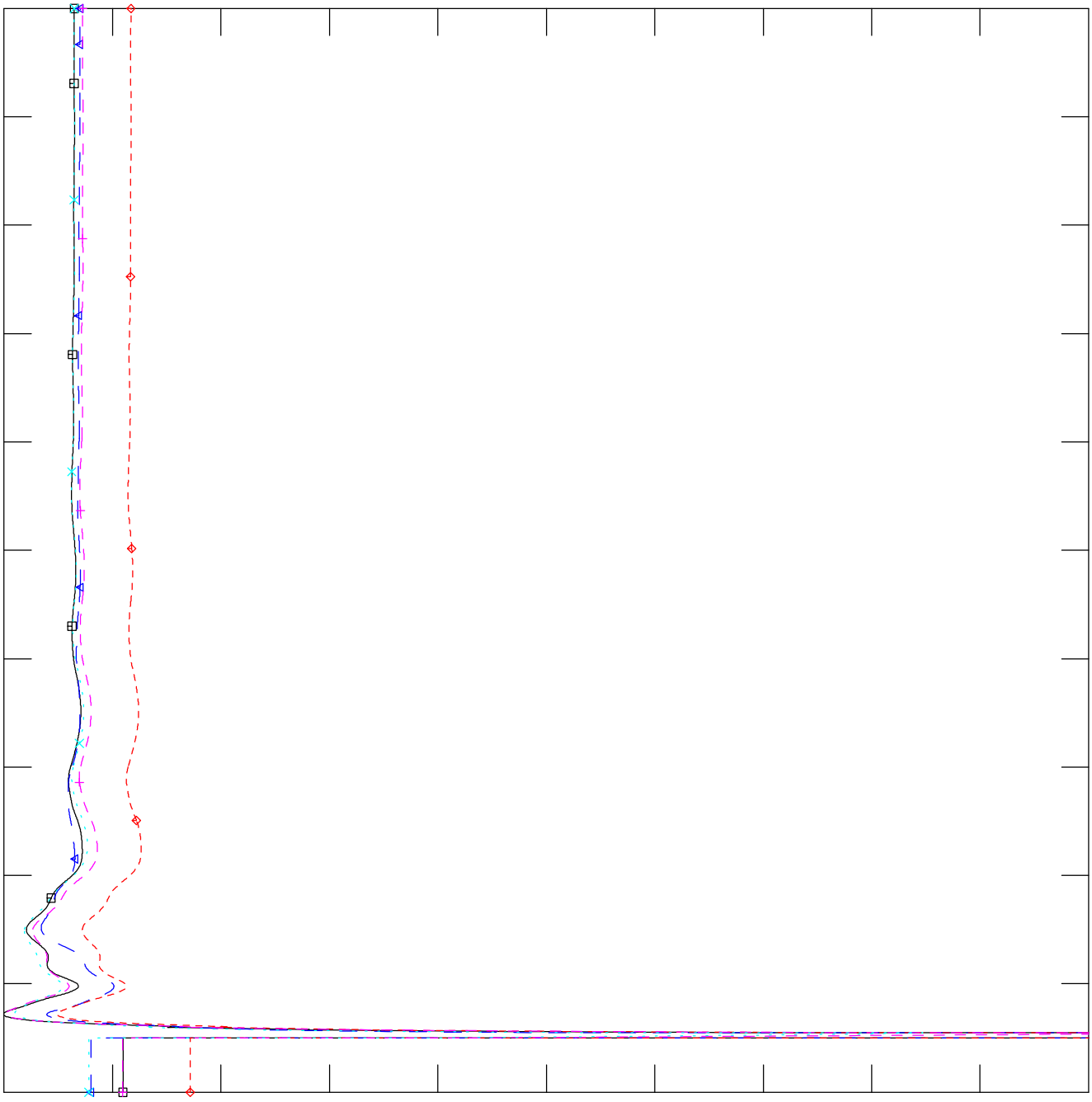

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

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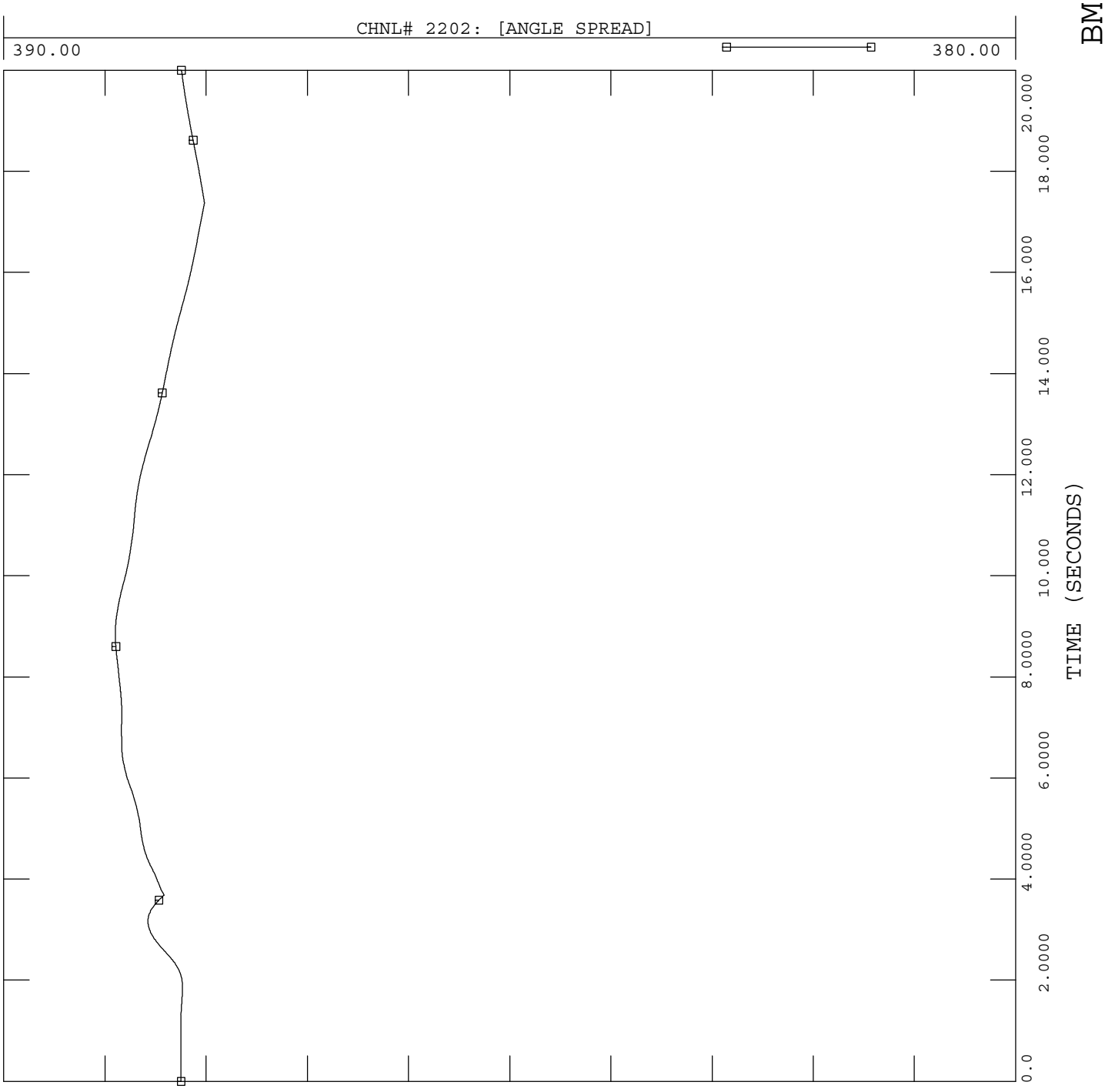
WED, AUG 17 2016 15:16

BM: P-MS #1 345 KV



SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_P-M.out

WED, AUG 17 2016 15:17

BM: P-MS #1 345 KV

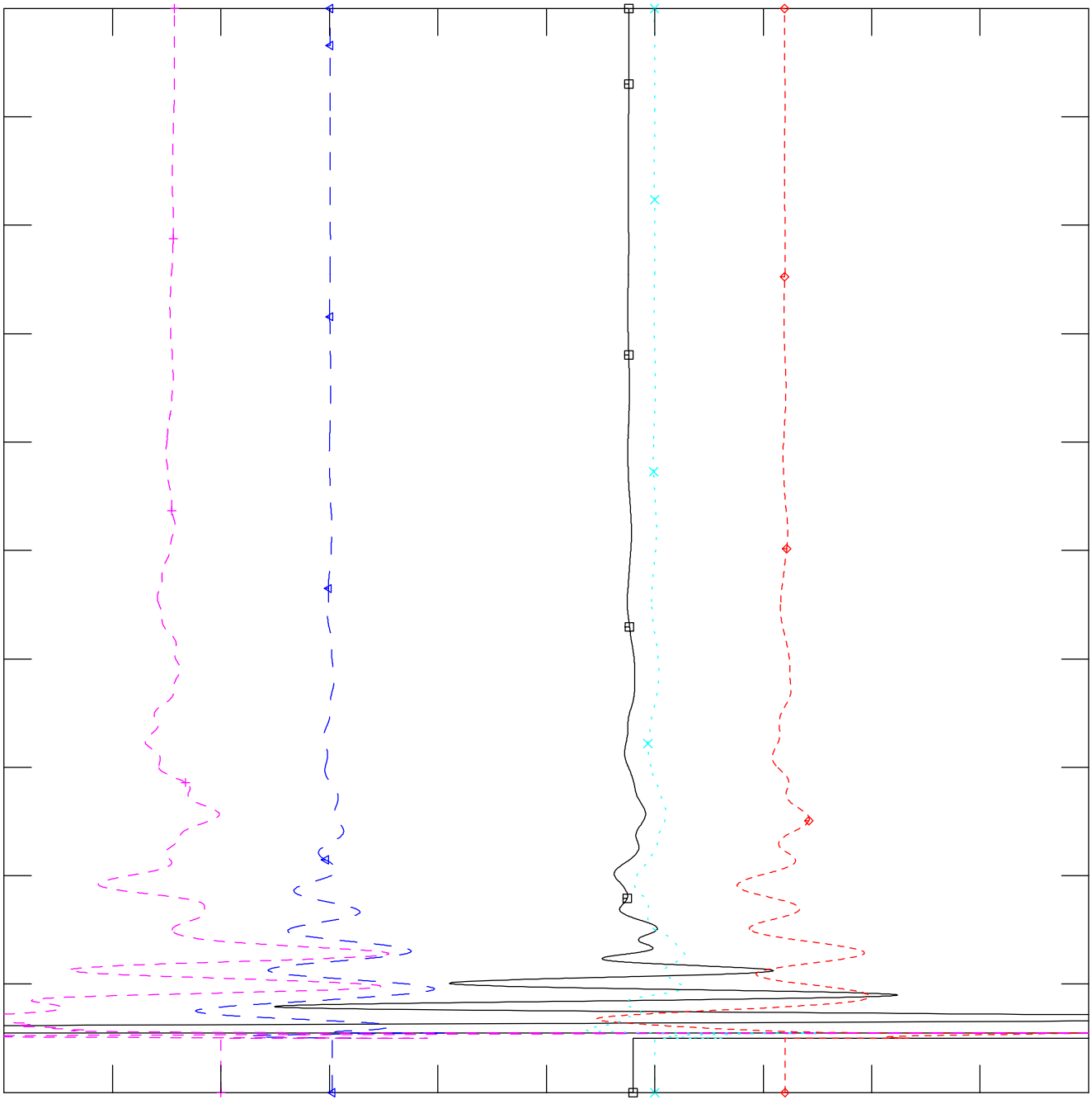
CHNL# 145: [POWR 70409[ST.VRAIN 22.000]G1]
4.5000 2.0000

CHNL# 206: [POWR 70593[SPNDLE1 18.000]G1]
1.3500 1.1000

CHNL# 205: [POWR 70591[RMEC3 23.000]G3]
5.0000 2.5000

CHNL# 128: [POWR 70145[CHEROKEE5 18.000]G5]
2.5000 0.0

CHNL# 133: [POWR 70310[PAWNEE 22.000]C1]
6.5000 4.0000



SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_P-M.out

WED, AUG 17 2016 15:17

ST: P-MS #1 345 KV

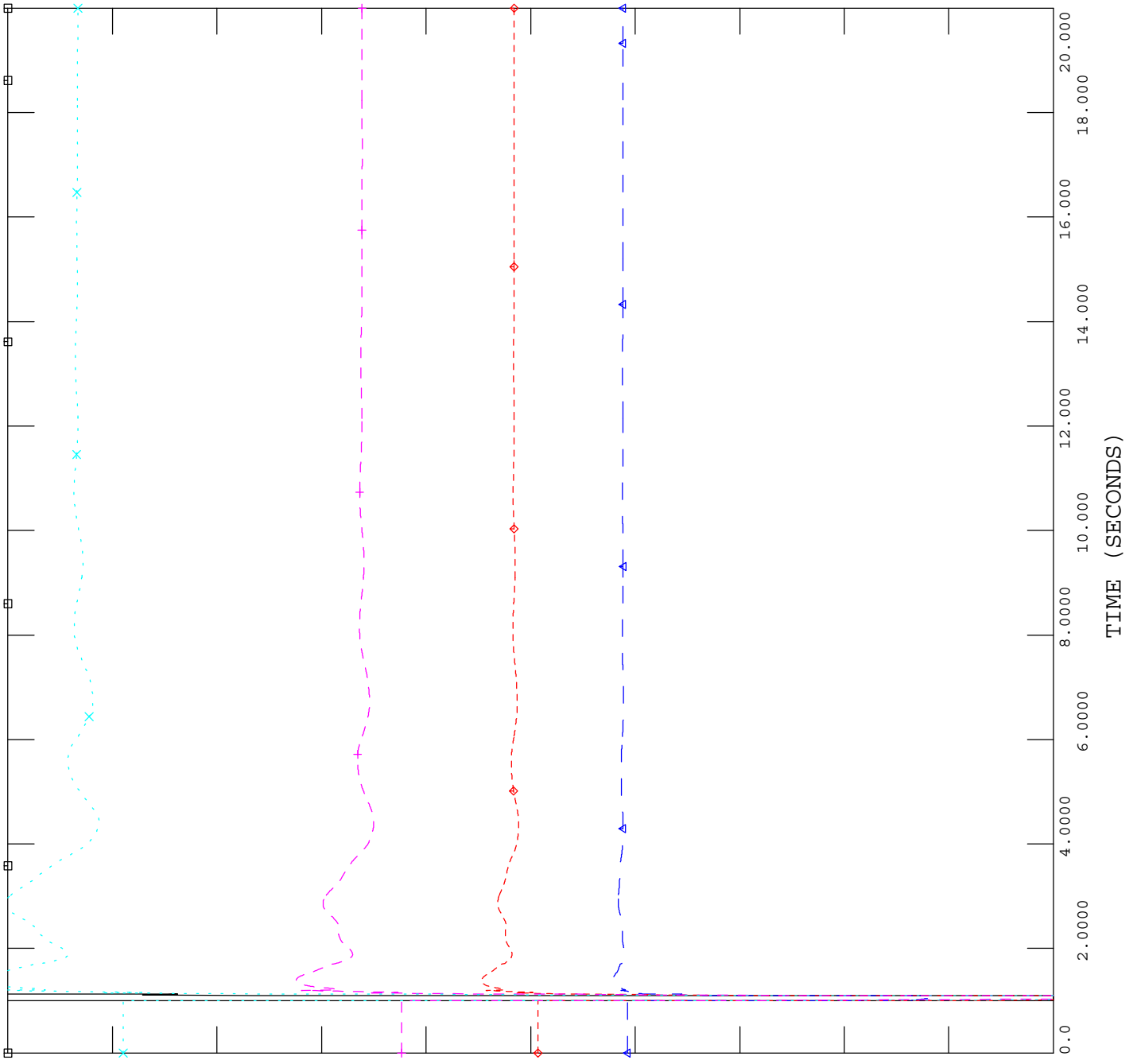
CHNL# 843: [VOLT 70590 [RMEC 230.00]]
1.0500 0.80000

CHNL# 431: [VOLT 70107 [CHEROKEE 230.00]]
1.2000 0.70000

CHNL# 851: [VOLT 70599 [SMOKYHIL 345.00]]
1.5000 0.50000

CHNL# 850: [VOLT 70598 [PAWNEE 345.00]]
2.5000 0.0

CHNL# 865: [VOLT 70624 [MIS_SITE 345.00]]
1.0000 0.0



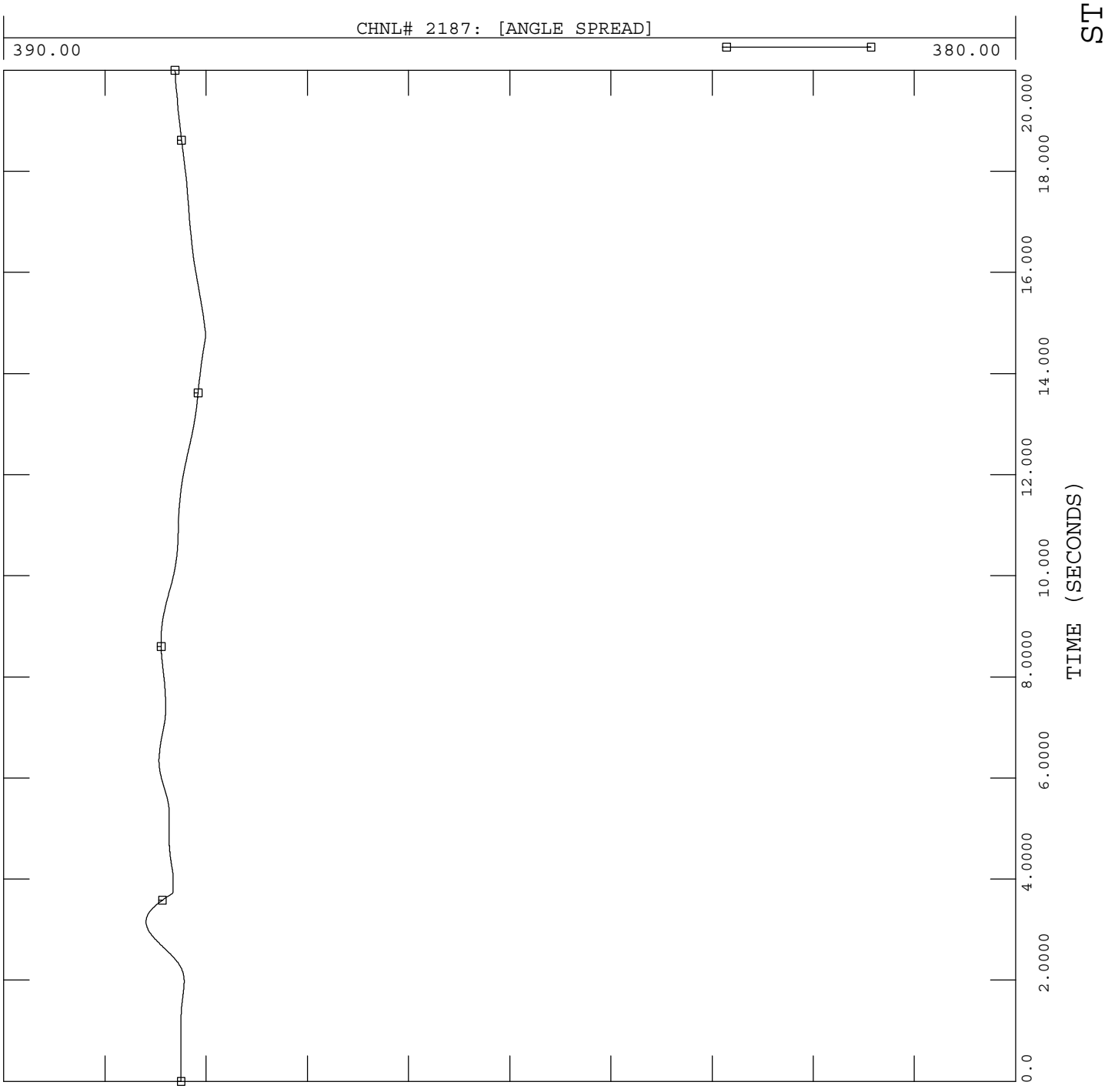
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_P-M.out

WED, AUG 17 2016 15:18

ST: P-MS #1 345 KV



SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_P-M.out

WED, AUG 17 2016 15:18

ST: P-MS #1 345 KV

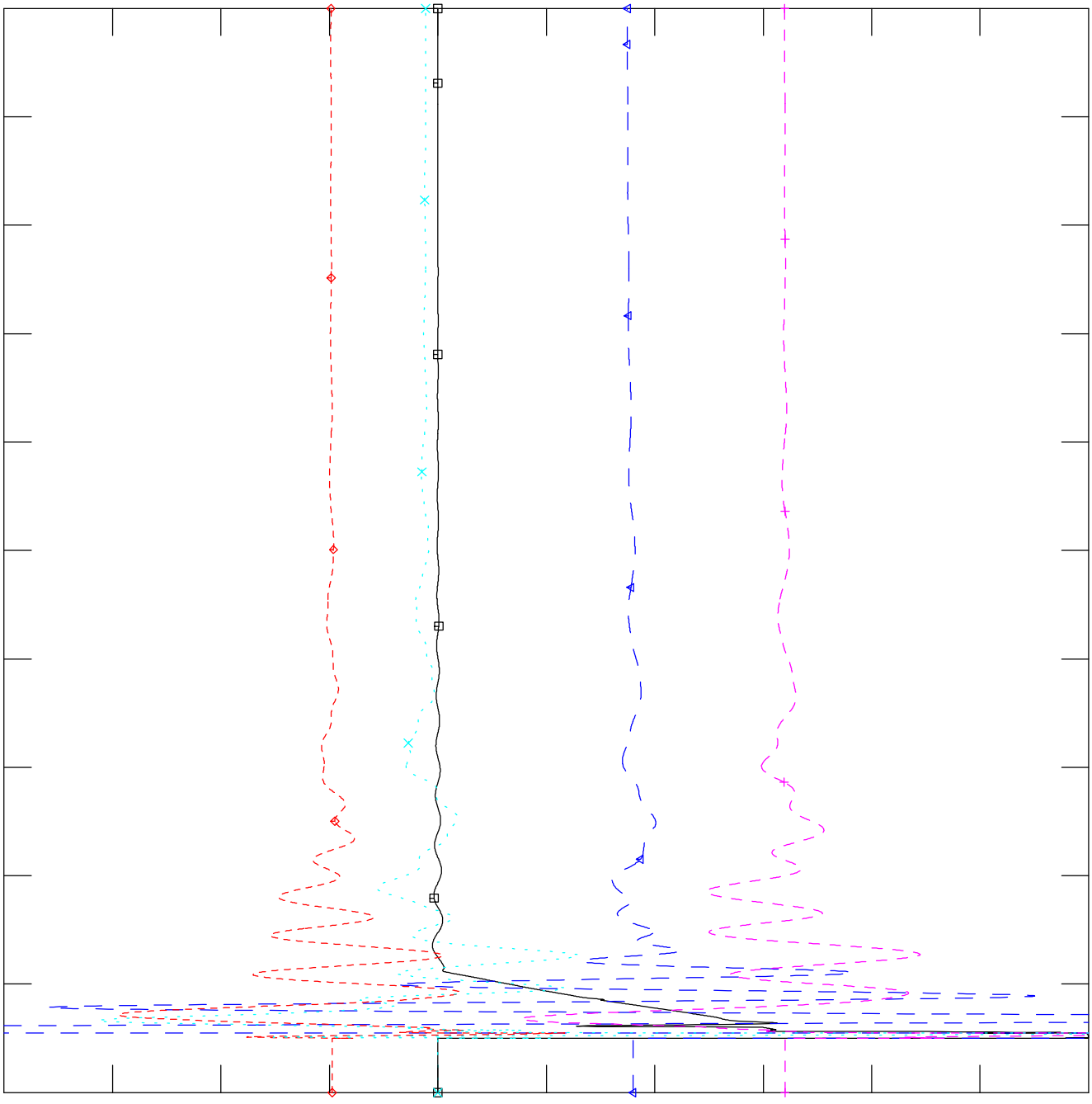
CHNL# 199: [POWR 70593[SPNDLE1 18.000]G1]
1.5000 1.0000

CHNL# 198: [POWR 70591[RMEC3 23.000]G3]
5.0000 2.5000

CHNL# 125: [POWR 70145[CHEROKEE5 18.000]G5]
2.5000 0.0

CHNL# 130: [POWR 70310[PAWNEE 22.000]C1]
6.5000 4.0000

CHNL# 236: [POWR970624[GI-2016-3 0.6900]W1]
10.000 0.0



SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_M-S.out

WED, AUG 17 2016 15:04
BM: MS-SH 345 KV

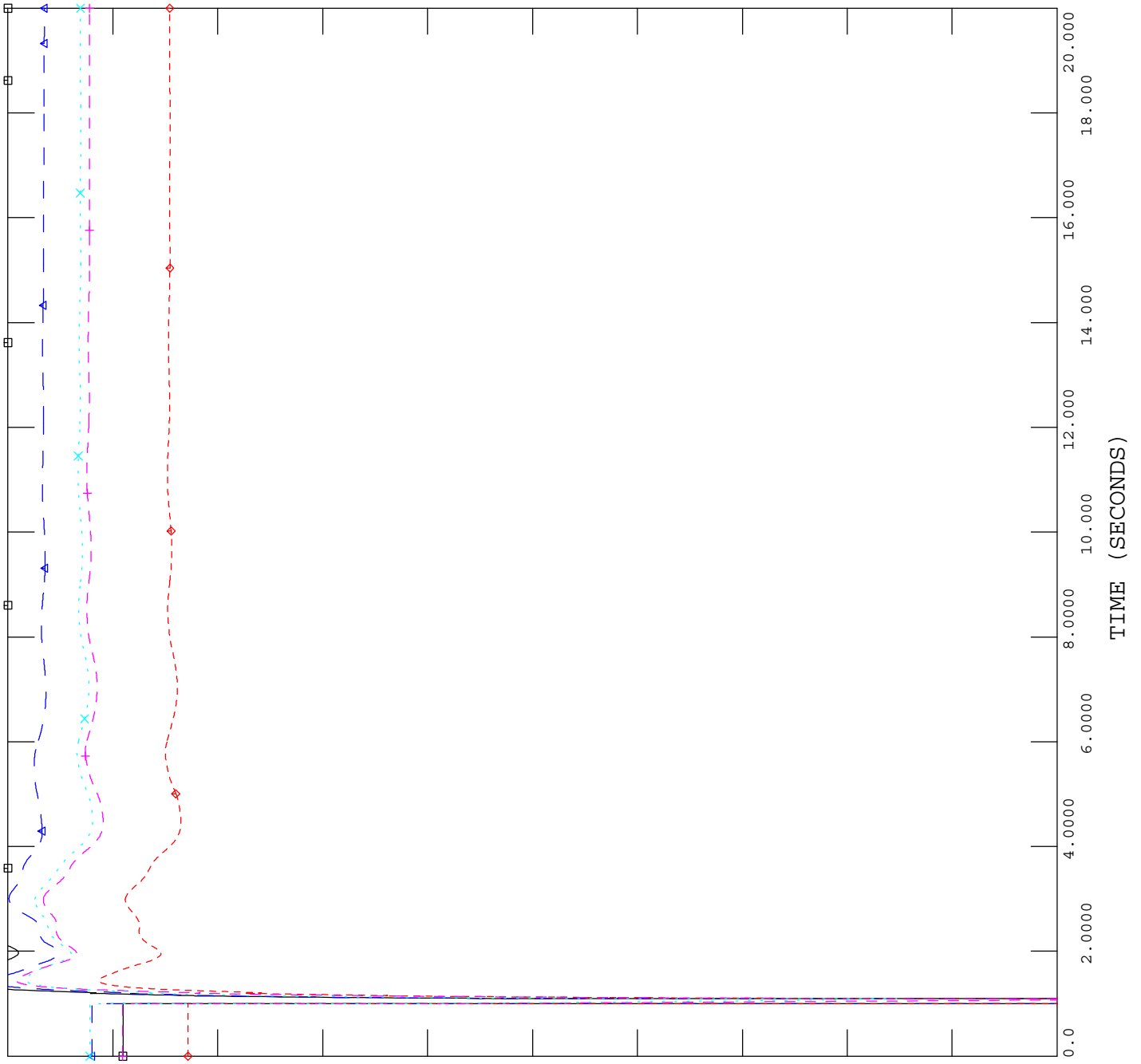
CHNL# 856: [VOLT 70590 [RMEC 230.00]]
1.0500 0.70000

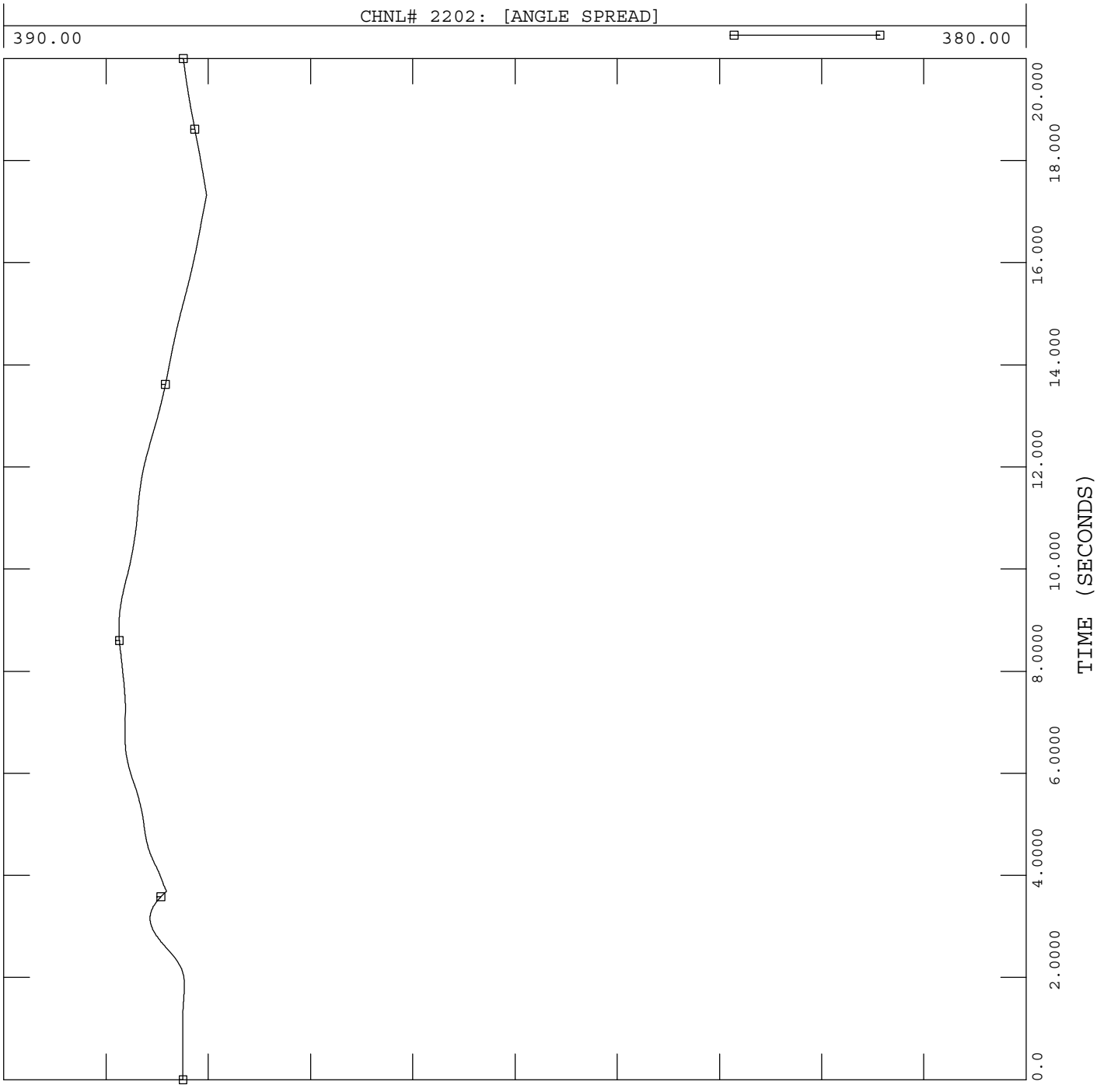
CHNL# 440: [VOLT 70107 [CHEROKEE 230.00]]
1.0500 0.70000

CHNL# 863: [VOLT 70599 [SMOKYHIL 345.00]]
1.0500 0.70000

CHNL# 862: [VOLT 70598 [PAWNEE 345.00]]
1.0500 0.70000

CHNL# 877: [VOLT 70624 [MIS_SITE 345.00]]
1.0500 0.70000



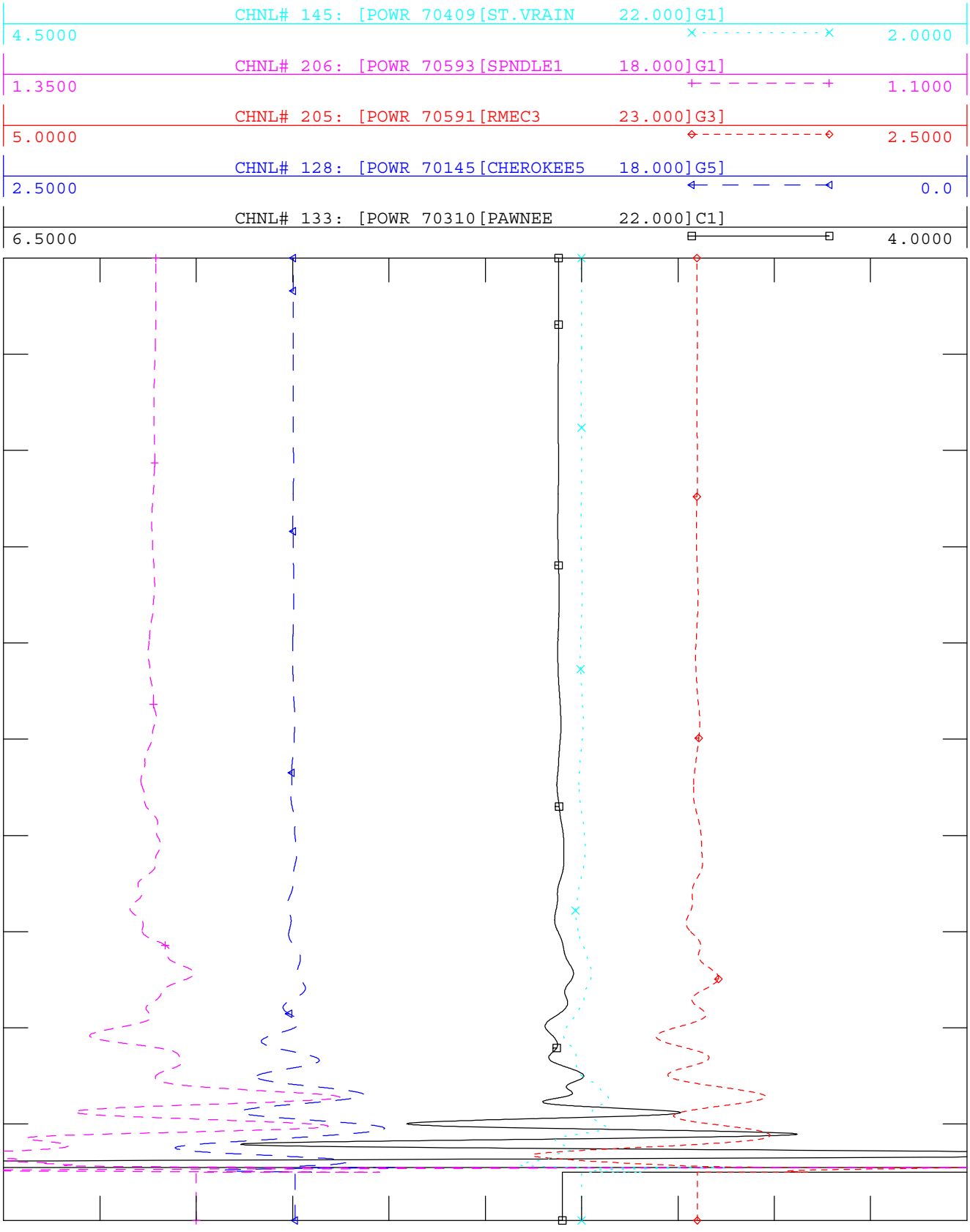

CHNL# 2202: [ANGLE SPREAD]
390.00
380.00
20.000
18.000
16.000
14.000
12.000
10.000
8.0000
6.0000
4.0000
2.0000
0.0
TIME (SECONDS)

SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_M-S.out

WED, AUG 17 2016 15:05
BM: MS-SH 345 KV



SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_M-S.out

WED, AUG 17 2016 15:06
ST_MS-SH 345 KV

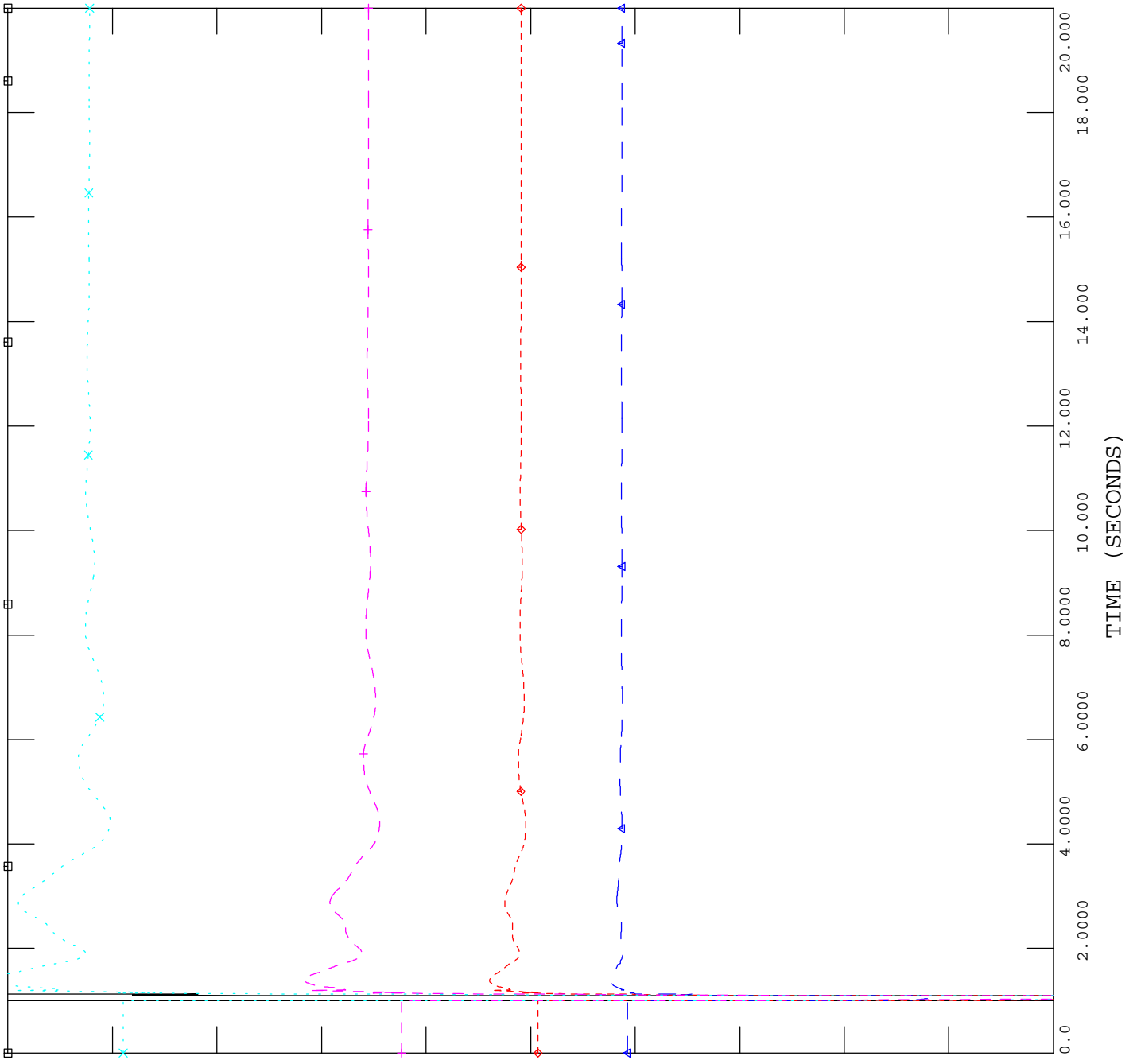
CHNL# 843: [VOLT 70590 [RMEC 230.00]]
1.0500 0.80000

CHNL# 431: [VOLT 70107 [CHEROKEE 230.00]]
1.2000 0.70000

CHNL# 851: [VOLT 70599 [SMOKYHIL 345.00]]
1.5000 0.50000

CHNL# 850: [VOLT 70598 [PAWNEE 345.00]]
2.5000 0.0

CHNL# 865: [VOLT 70624 [MIS_SITE 345.00]]
1.0000 0.0

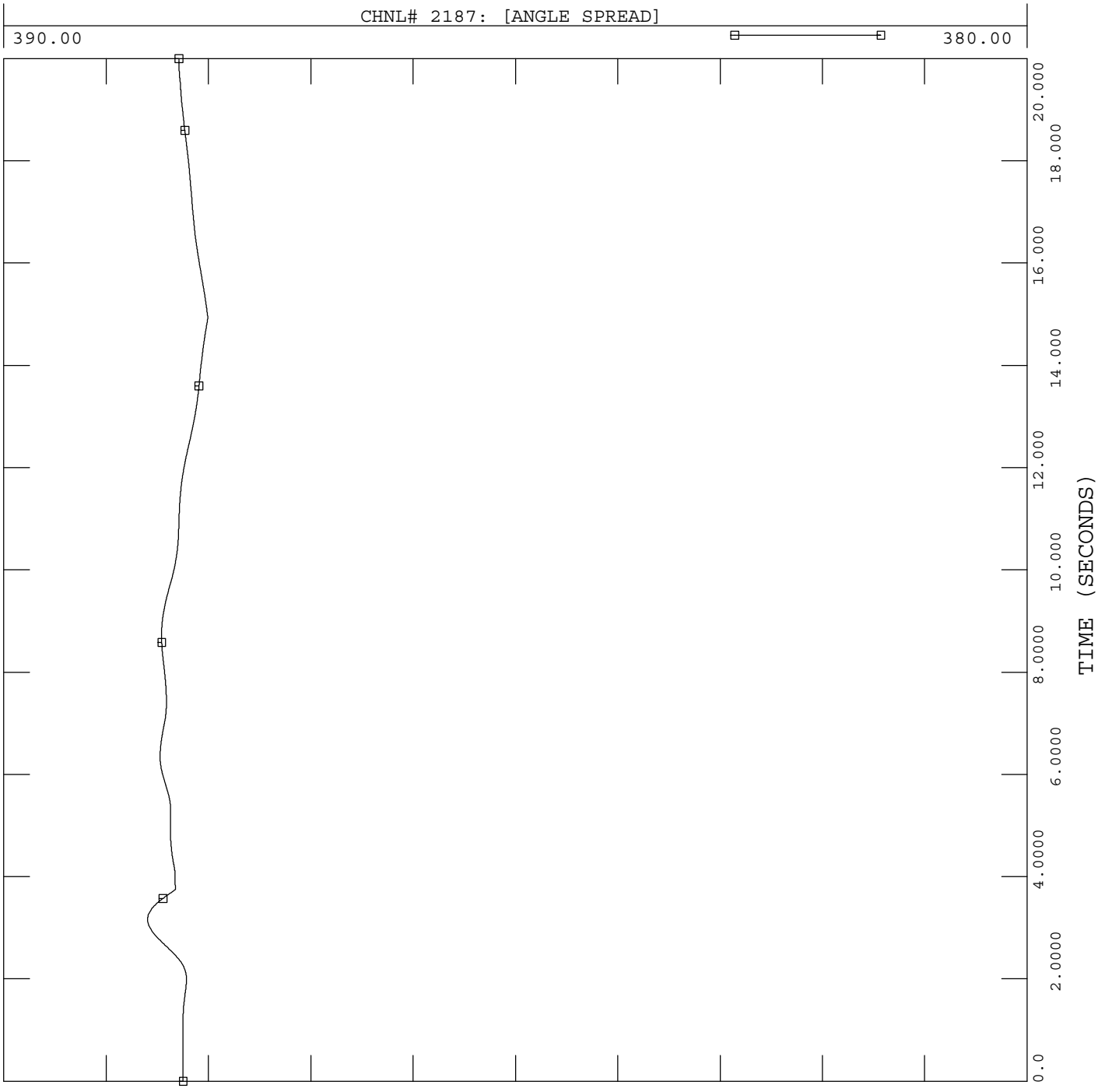


SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_M-S.out

WED, AUG 17 2016 15:07
ST: MS-SH 345 KV



SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_M-S.out

WED, AUG 17 2016 15:07
ST: MS-SH 345 KV

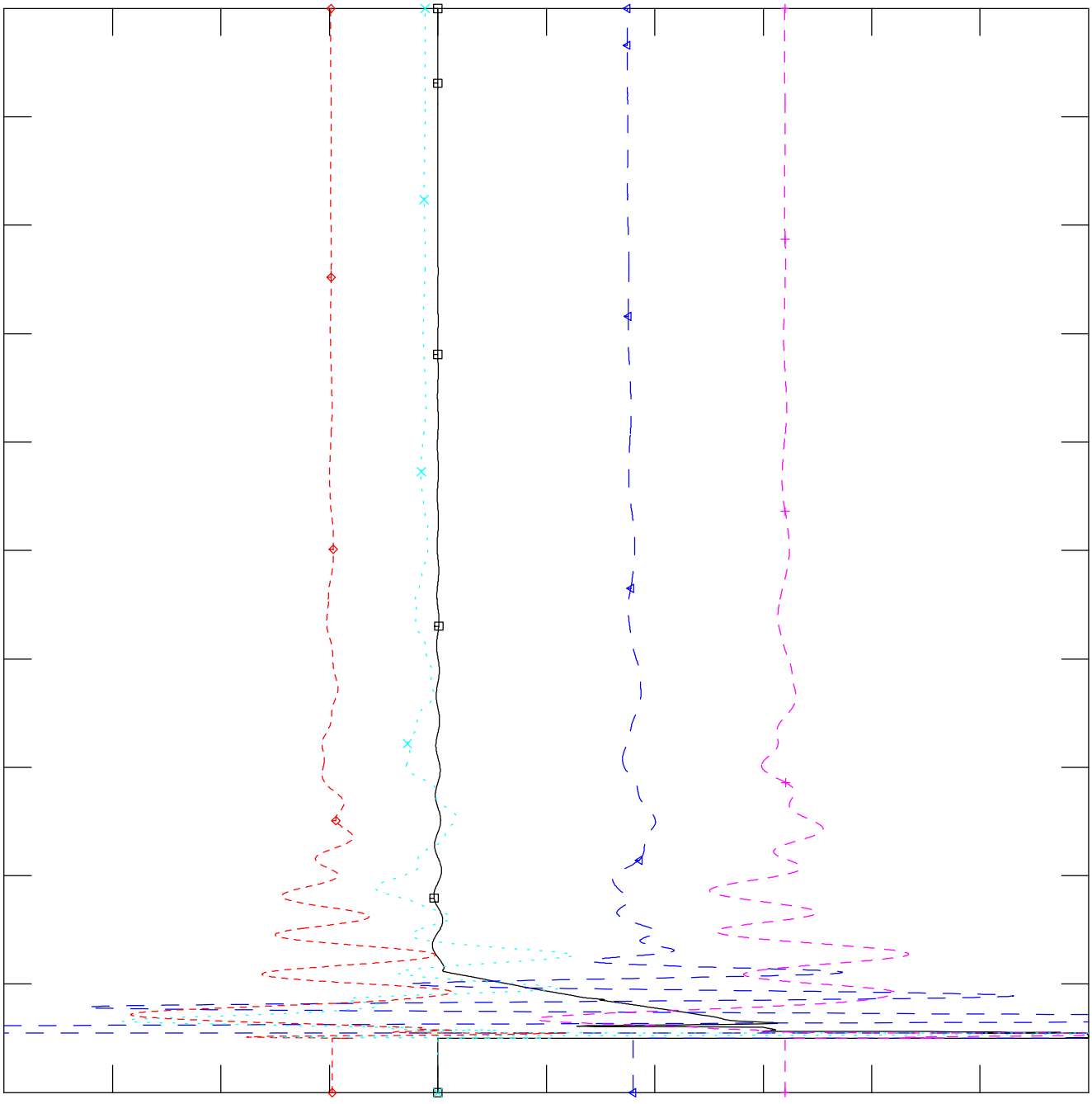
CHNL# 199: [POWR 70593[SPNDLE1 18.000]G1]
1.5000 1.0000

CHNL# 198: [POWR 70591[RMEC3 23.000]G3]
5.0000 2.5000

CHNL# 125: [POWR 70145[CHEROKEE5 18.000]G5]
2.5000 0.0

CHNL# 130: [POWR 70310[PAWNEE 22.000]C1]
6.5000 4.0000

CHNL# 236: [POWR970624[GI-2016-3 0.6900]W1]
10.000 0.0



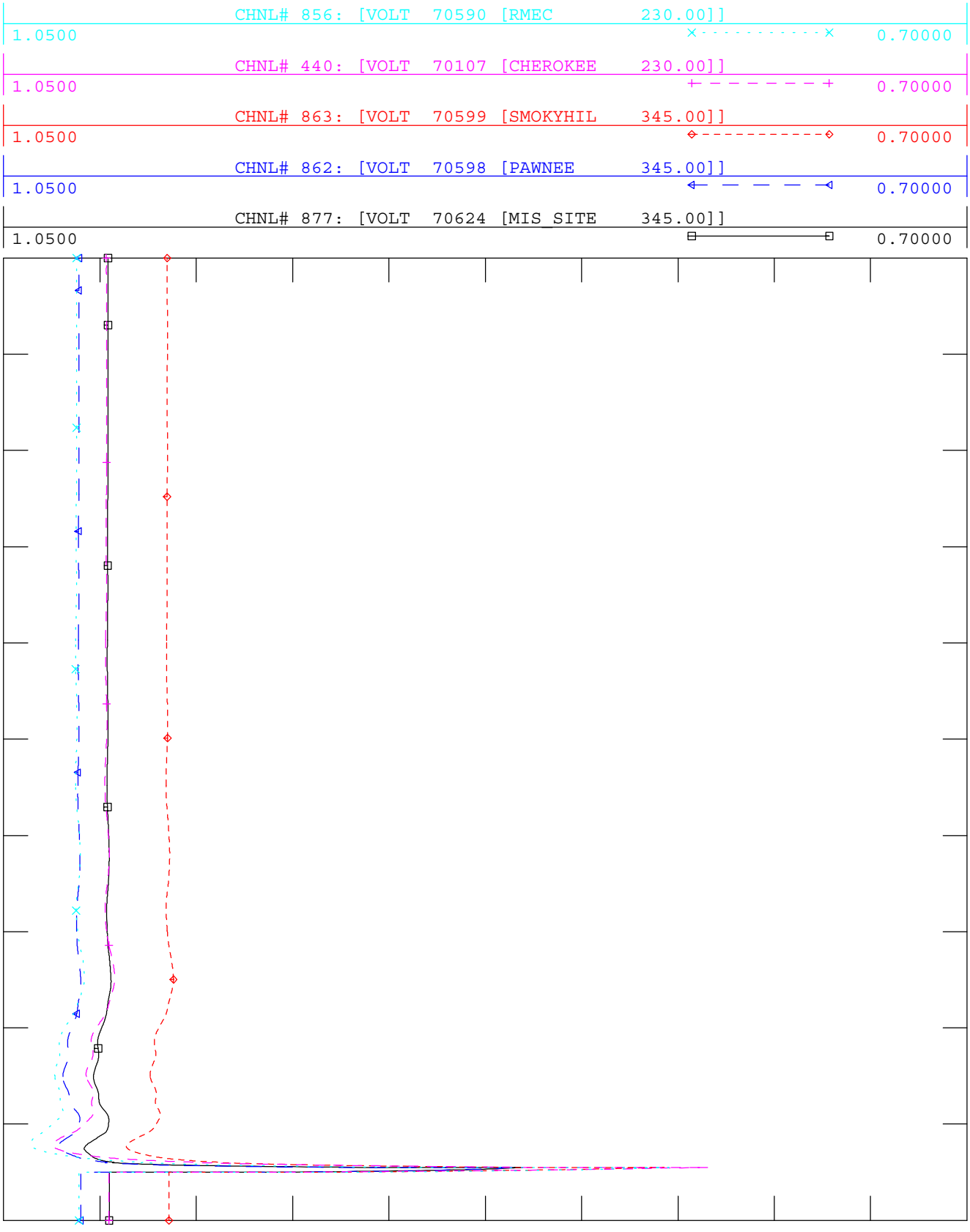
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_C-A.out

WED, AUG 17 2016 15:01

BM: CRAIG-AULT 345 KV



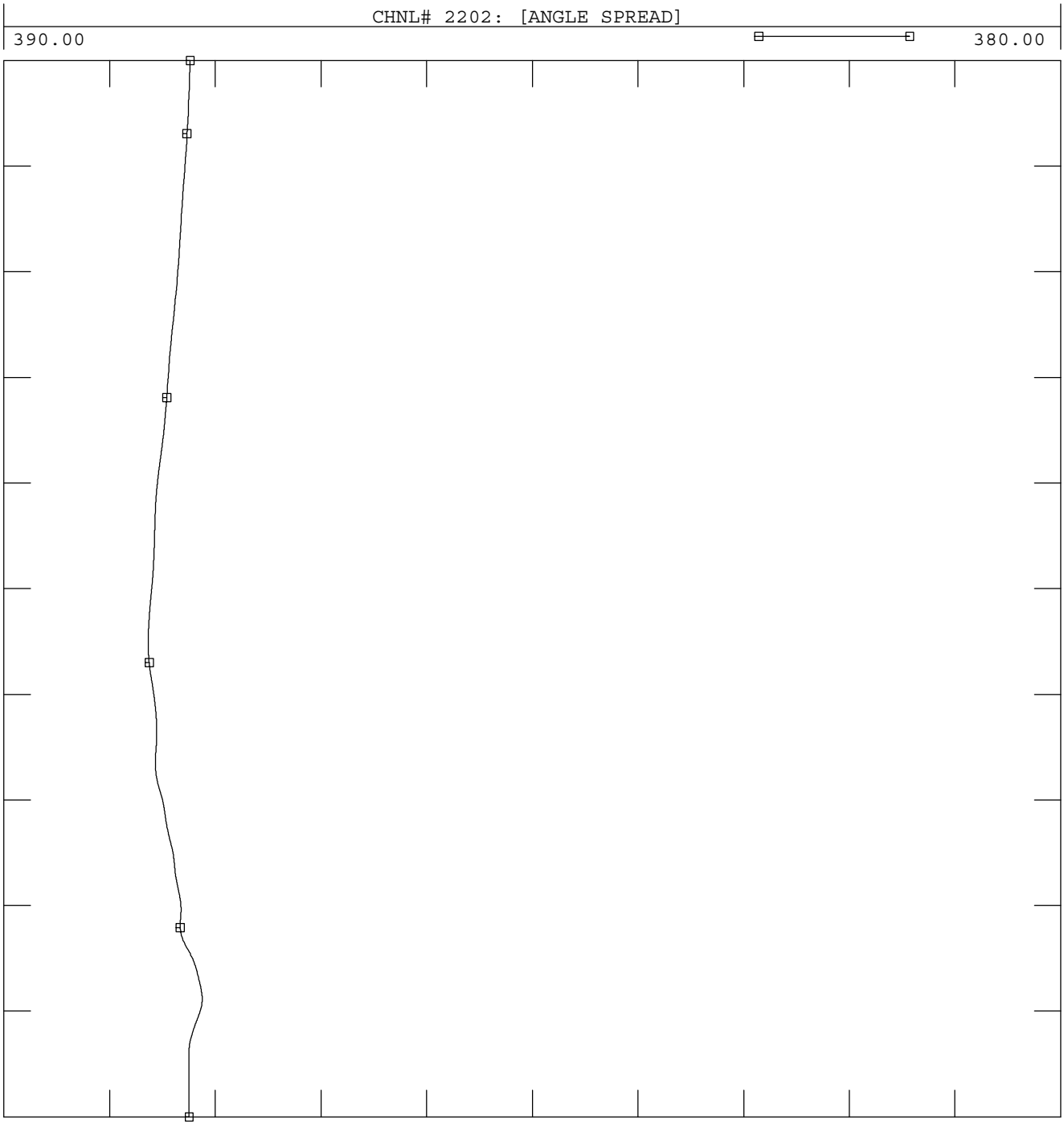
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_C-A.out

WED, AUG 17 2016 15:01

BM: CRAIG-AULT 345 KV



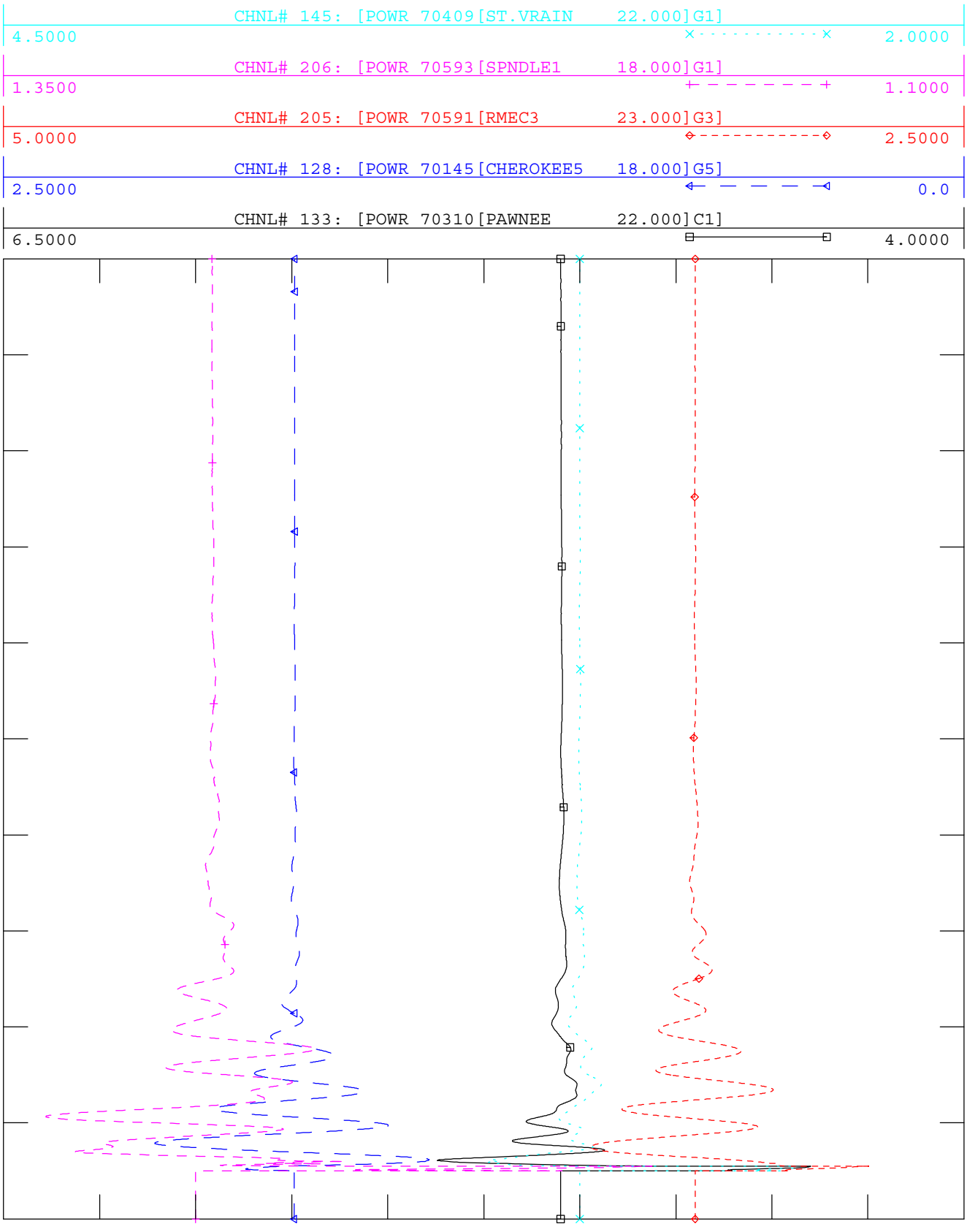
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_C-A.out

WED, AUG 17 2016 15:02

BM: CRAIG-AULT 345 KV



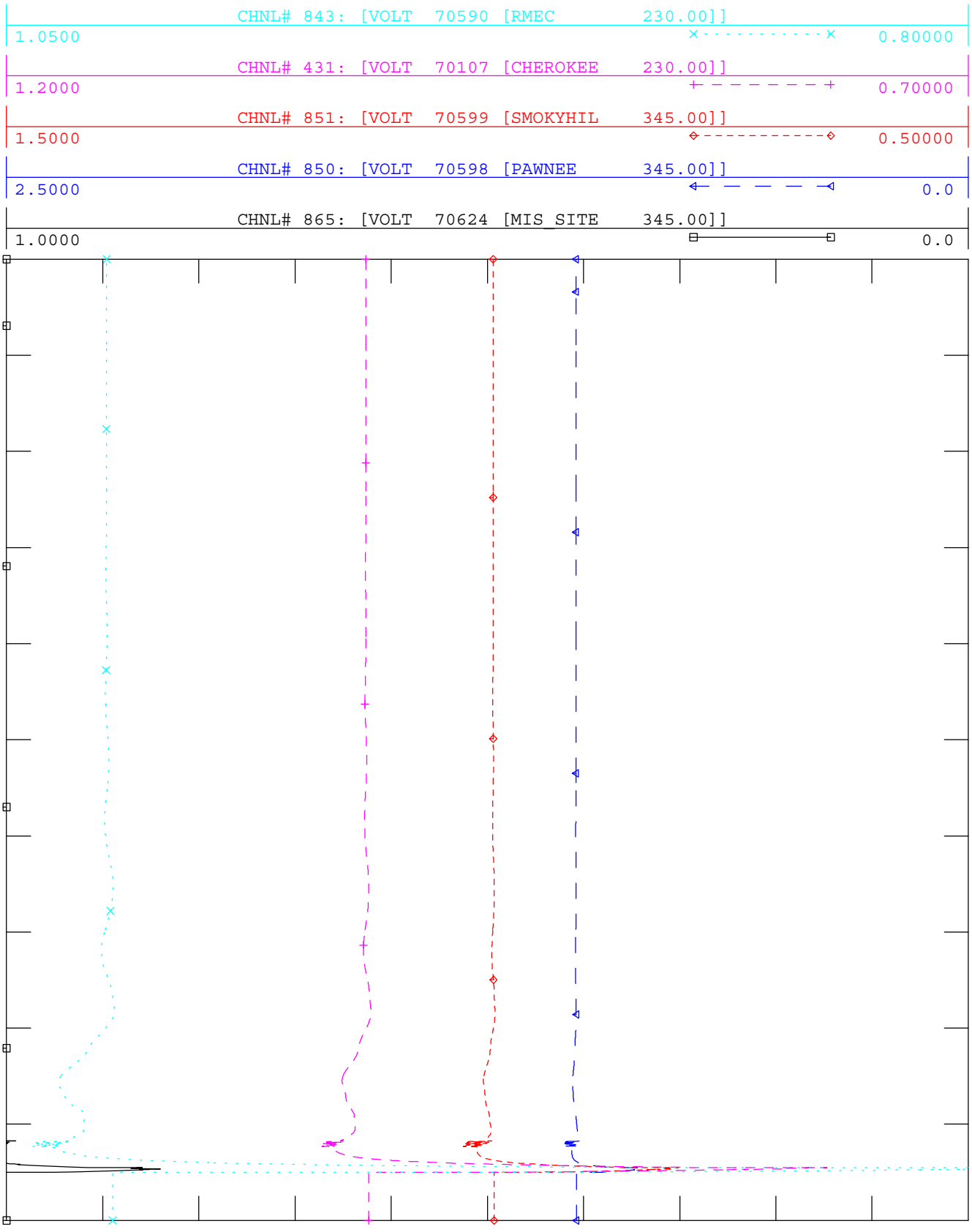
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_C-A.out

WED, AUG 17 2016 15:03

ST: CRAIG-AULT 345 KV

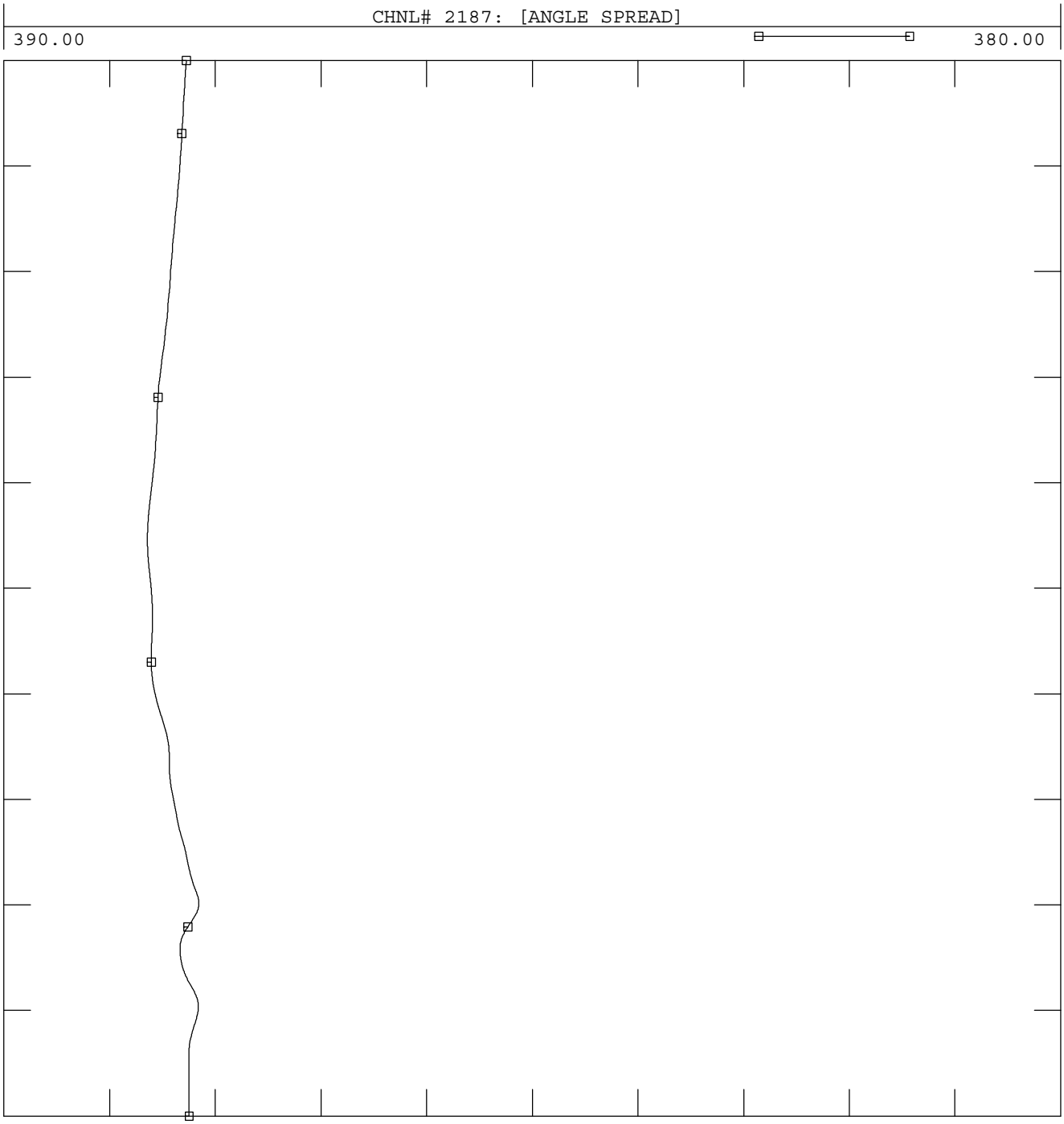


WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_C-A.out

WED, AUG 17 2016 15:03

ST: CRAIG-AULT 345 KV



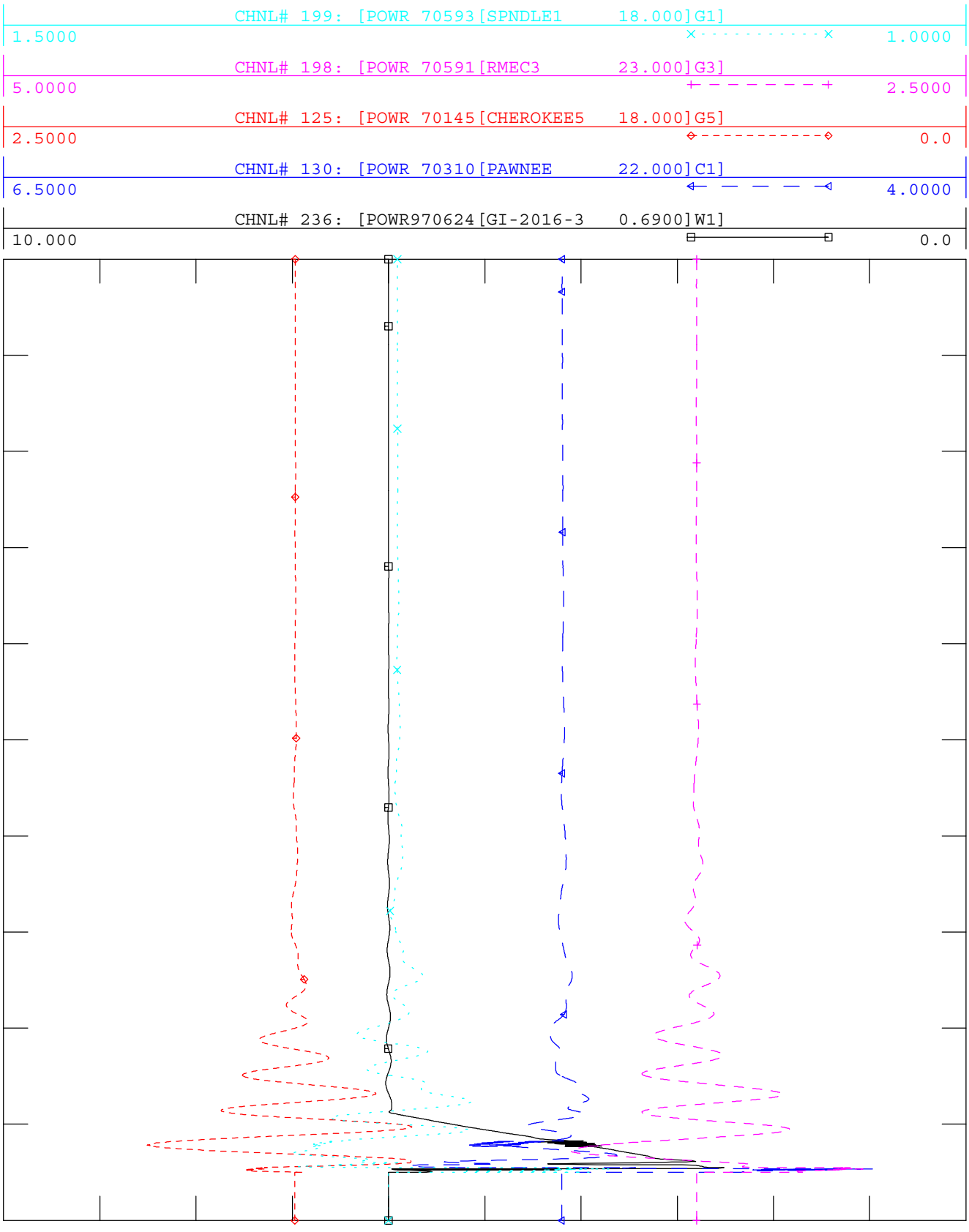
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_C-A.out

WED, AUG 17 2016 15:03

ST: CRAIG-AULT 345 KV



SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_Mtran.out

WED, AUG 17 2016 15:07

BM: MISSILE SITE 230/345

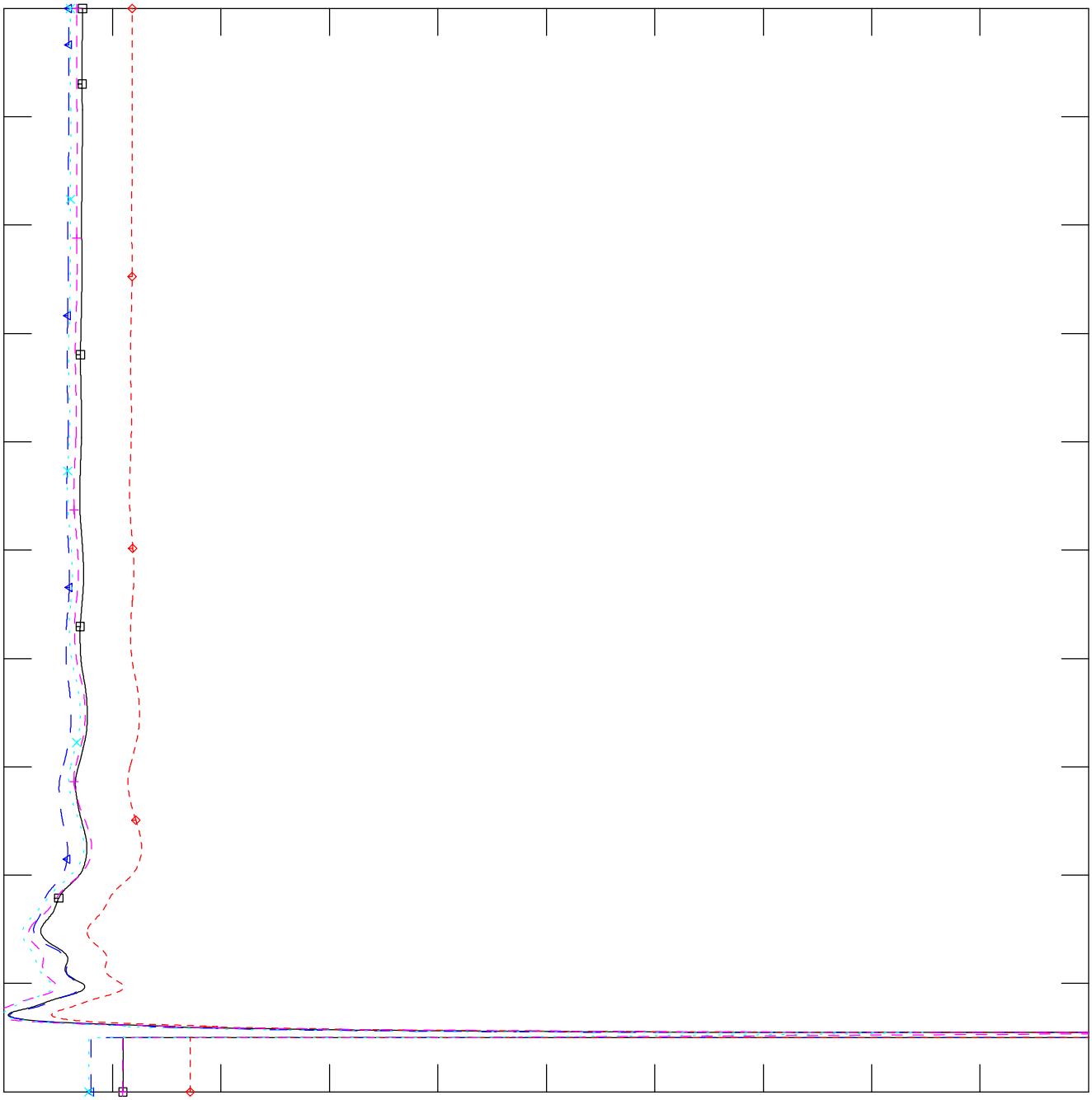
CHNL# 856: [VOLT 70590 [RMEC 230.00]]
1.0500 0.70000

CHNL# 440: [VOLT 70107 [CHEROKEE 230.00]]
1.0500 0.70000

CHNL# 863: [VOLT 70599 [SMOKYHIL 345.00]]
1.0500 0.70000

CHNL# 862: [VOLT 70598 [PAWNEE 345.00]]
1.0500 0.70000

CHNL# 877: [VOLT 70624 [MIS_SITE 345.00]]
1.0500 0.70000



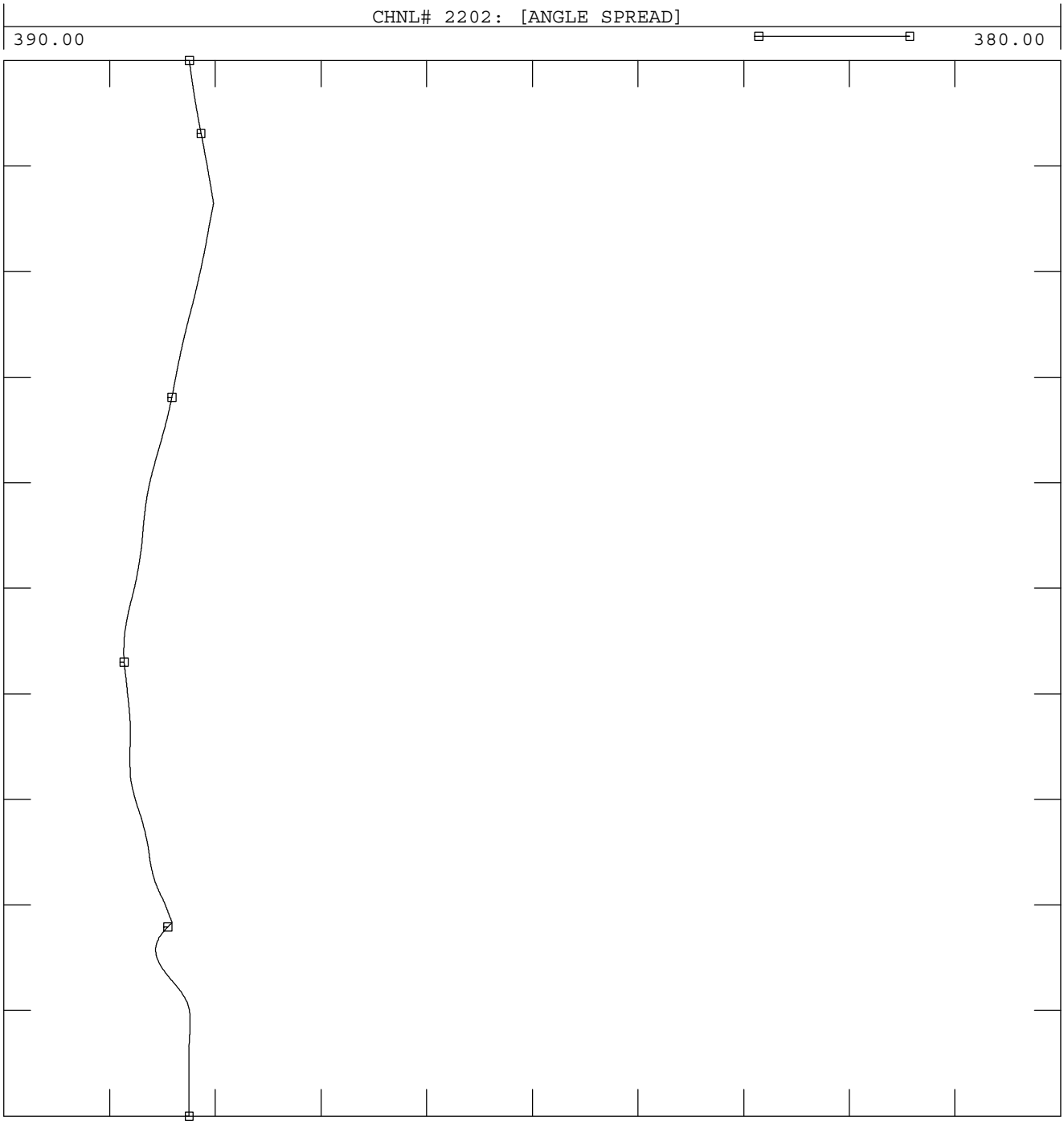
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_Mtran.out

WED, AUG 17 2016 15:08

BM: MISSILE SITE 230/345



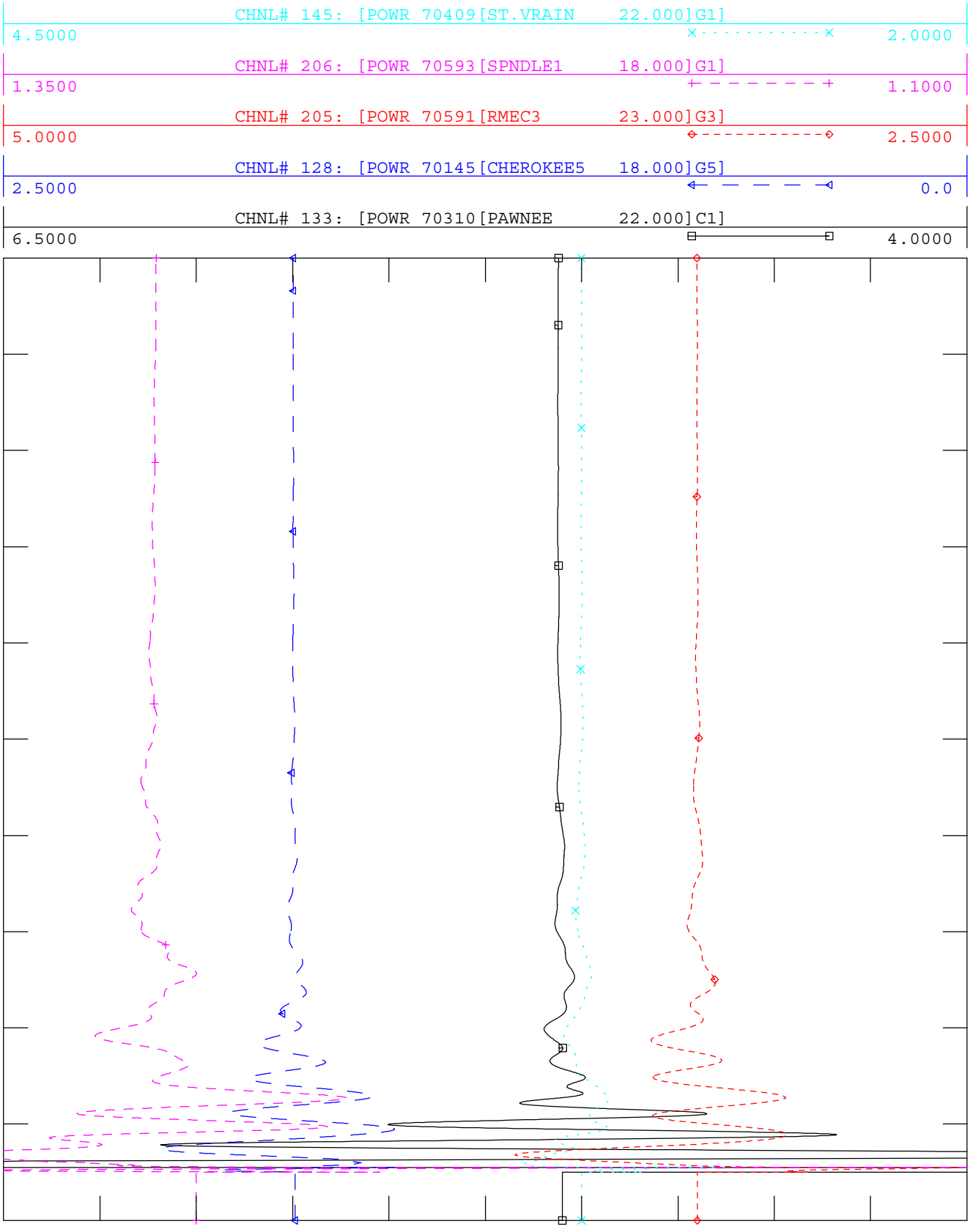
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_Mtran.out

WED, AUG 17 2016 15:09

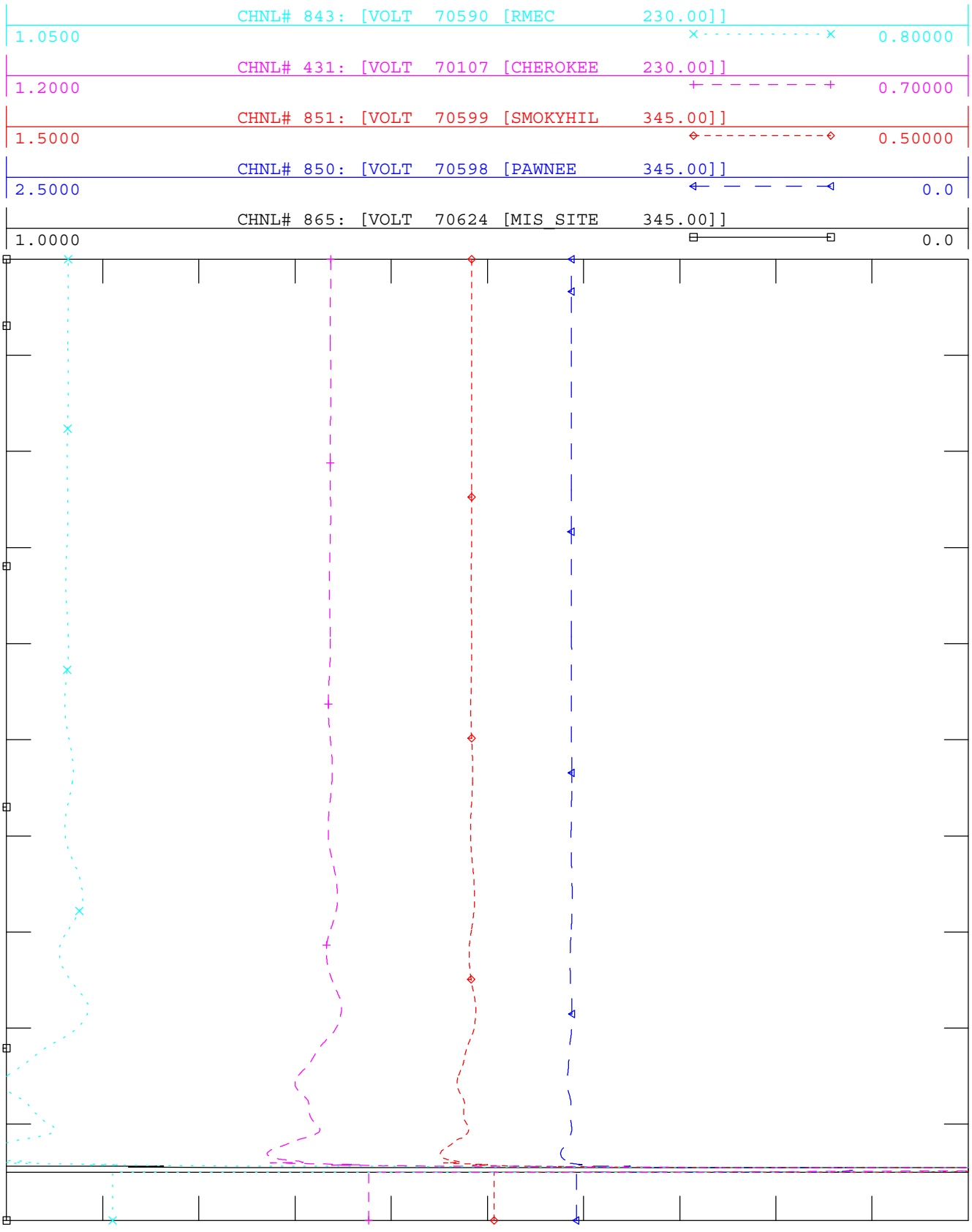
BM: MISSILE SITE 230/345



SIEMENS POWER TECHNOLOGIES INTERNATIONAL

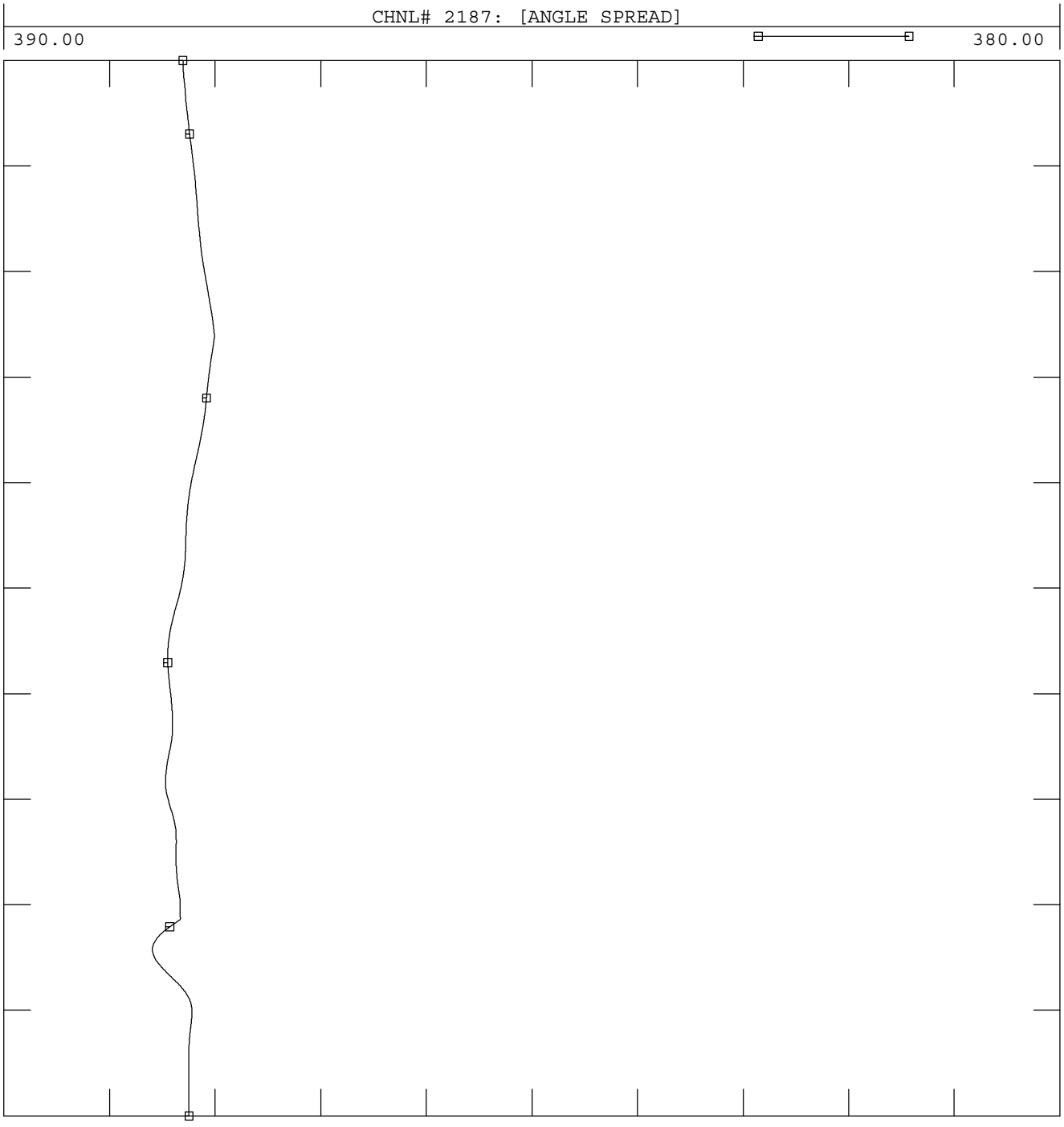
WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_Mtran.out



WED, AUG 17 2016 15:09

ST: MISSILE SITE 230/345


CHNL# 2187: [ANGLE SPREAD]
390.00
380.00
20.000
18.000
16.000
14.000
12.000
10.000
8.0000
6.0000
4.0000
2.0000
0.0
TIME (SECONDS)

SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_Mtran.out

WED, AUG 17 2016 15:10

ST: MISSILE SITE 230/345

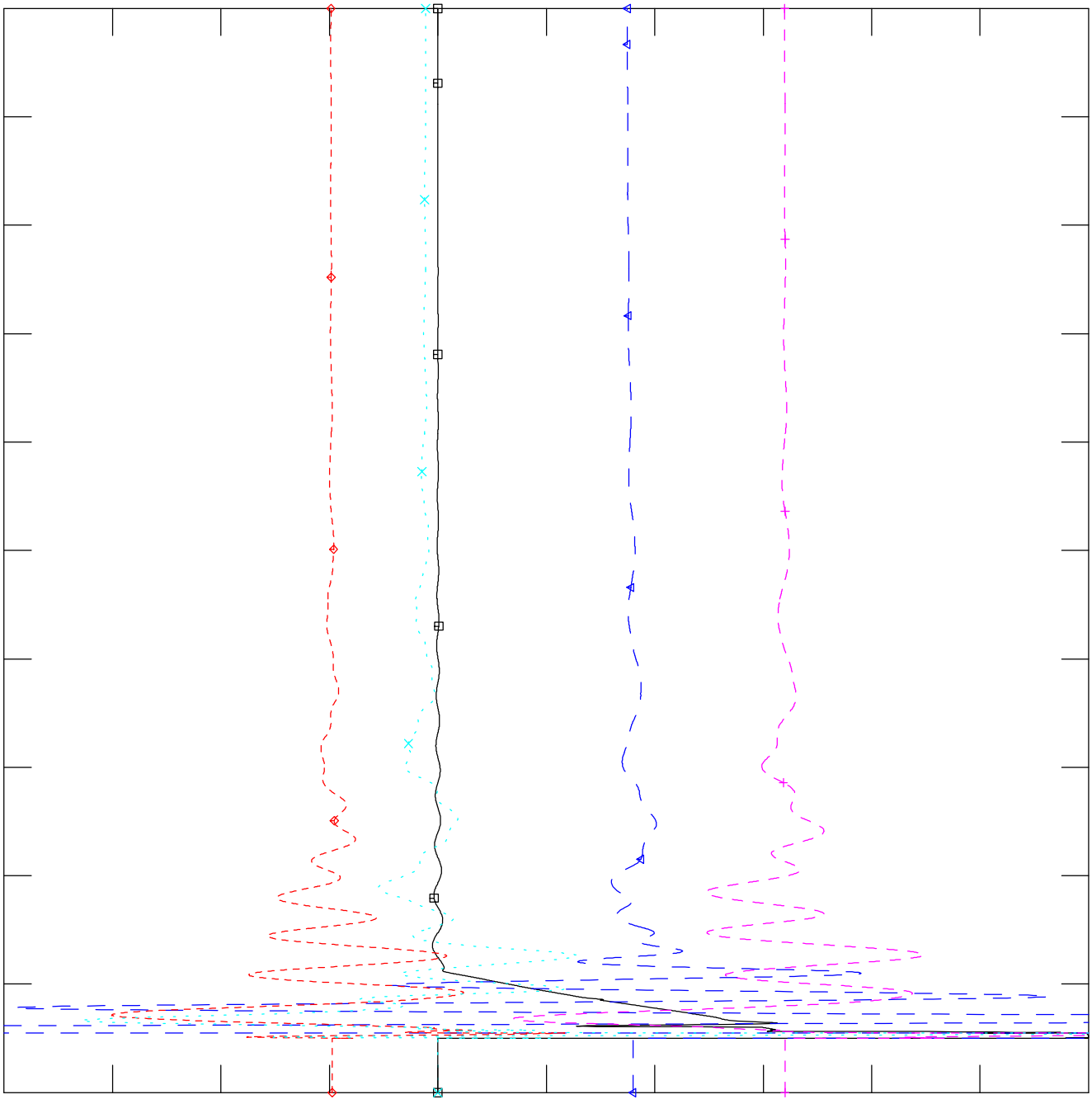
CHNL# 199: [POWR 70593[SPNDLE1 18.000]G1]
1.5000 1.0000

CHNL# 198: [POWR 70591[RMEC3 23.000]G3]
5.0000 2.5000

CHNL# 125: [POWR 70145[CHEROKEE5 18.000]G5]
2.5000 0.0

CHNL# 130: [POWR 70310[PAWNEE 22.000]C1]
6.5000 4.0000

CHNL# 236: [POWR970624[GI-2016-3 0.6900]W1]
10.000 0.0



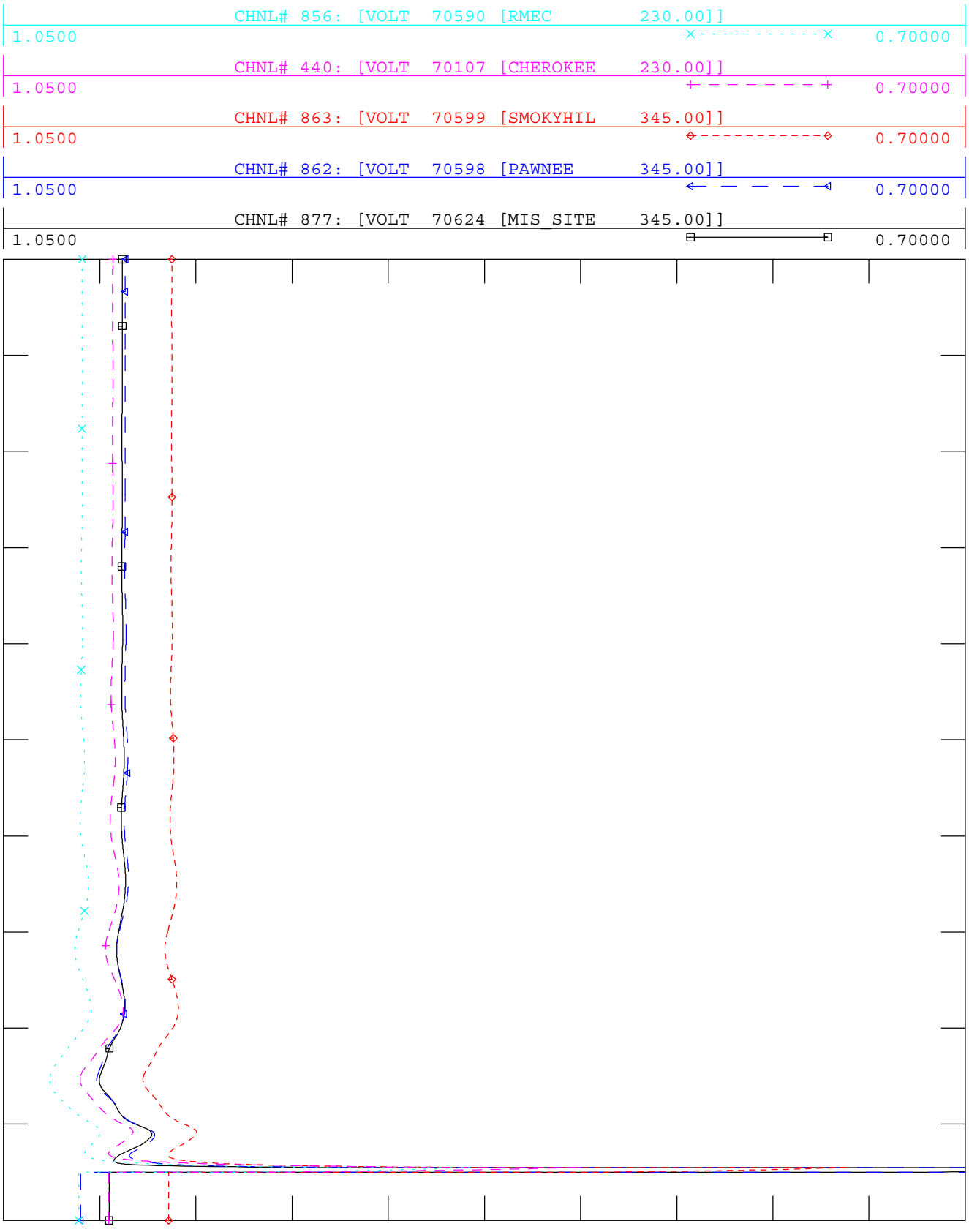
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

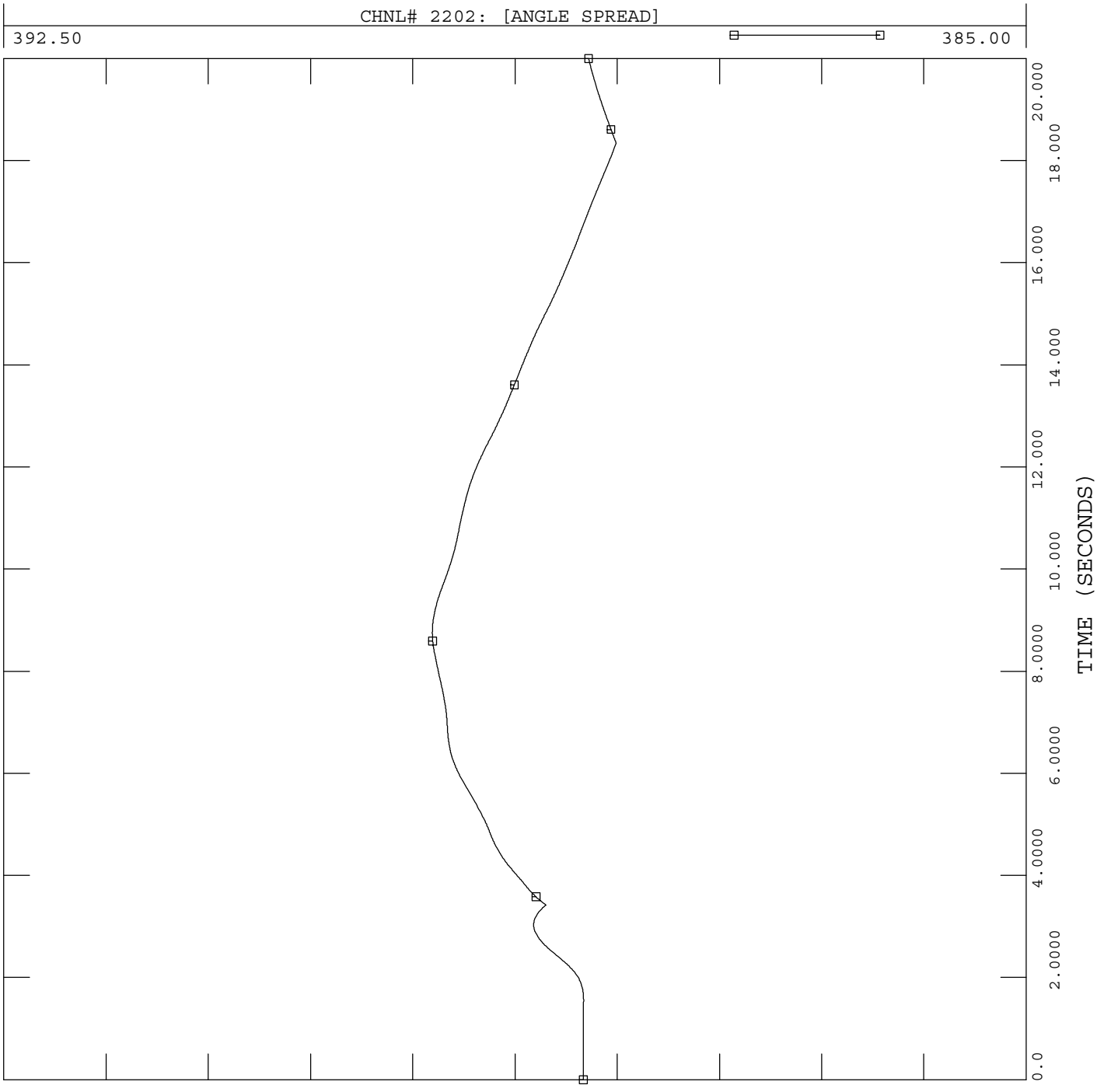
WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_PawneeGen.out

WED, AUG 17 2016 15:42

BM: PAWNEE UNIT




CHNL# 2202: [ANGLE SPREAD]
392.50
385.00
20.000
18.000
16.000
14.000
12.000
10.000
8.0000
6.0000
4.0000
2.0000
0.0
TIME (SECONDS)

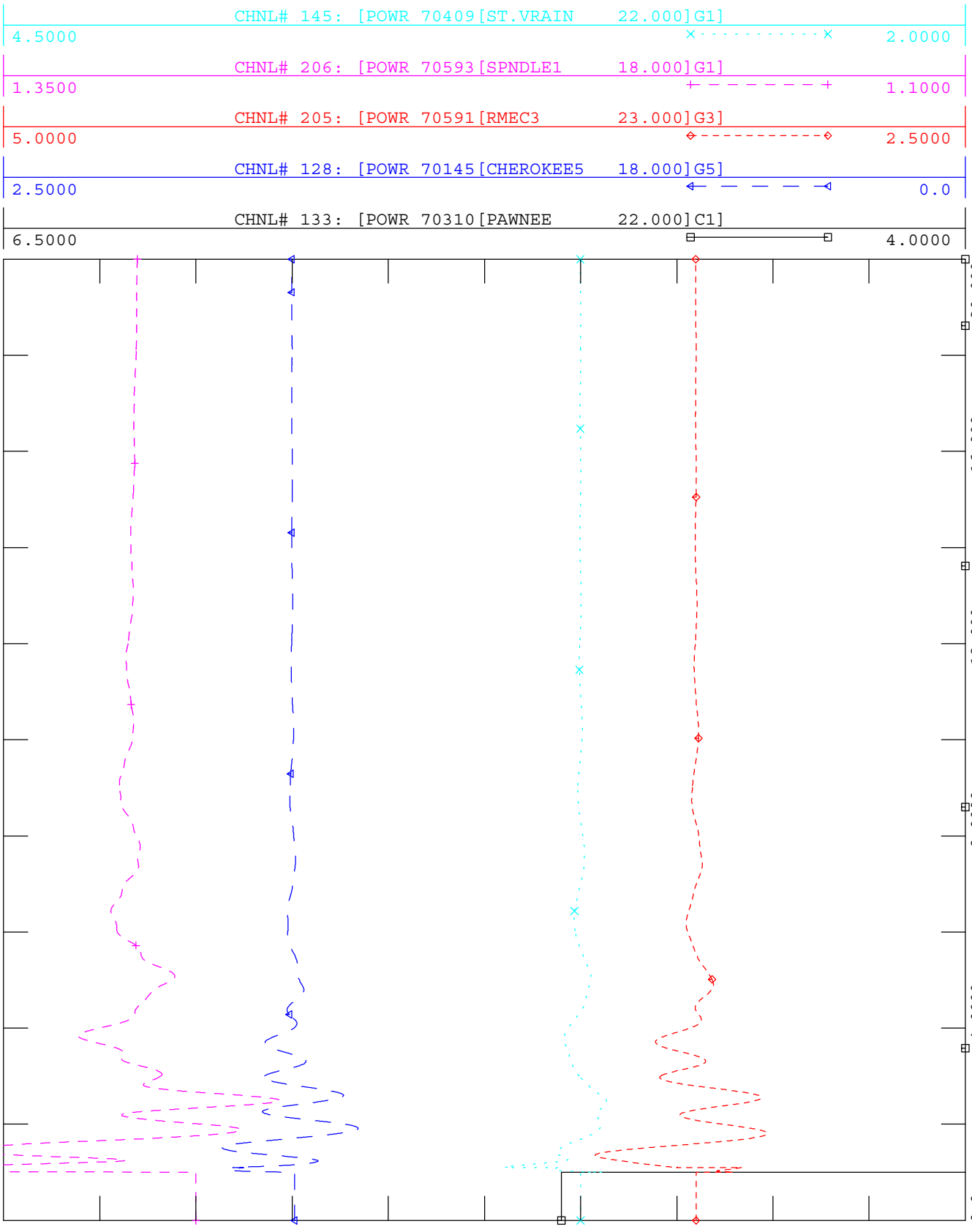
SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_BM_PawneeGen.out

WED, AUG 17 2016 15:43

BM: PAWNEE UNIT

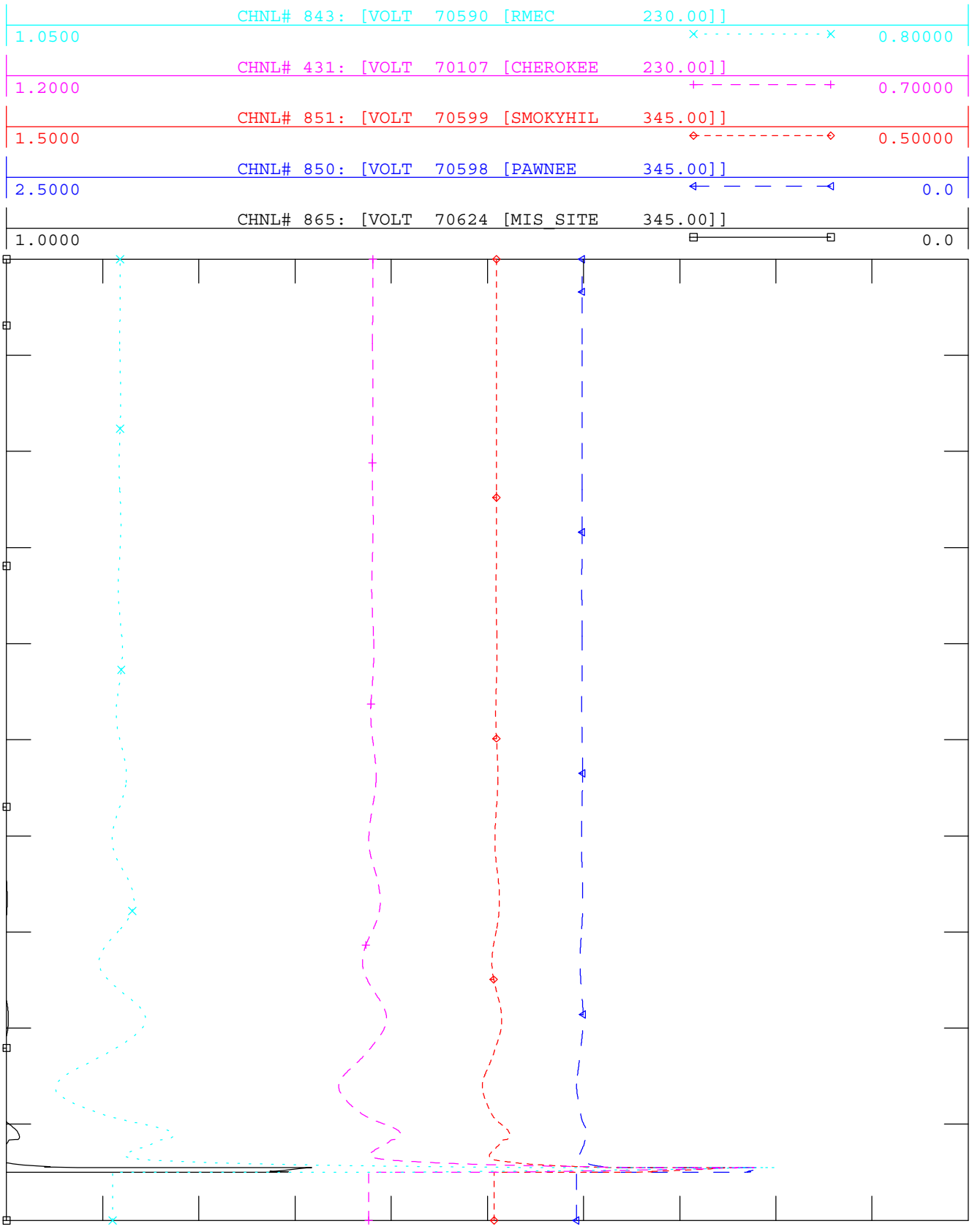


SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_PawneeGen.out

WED, AUG 17 2016 15:14
ST: PAWNEE UNIT

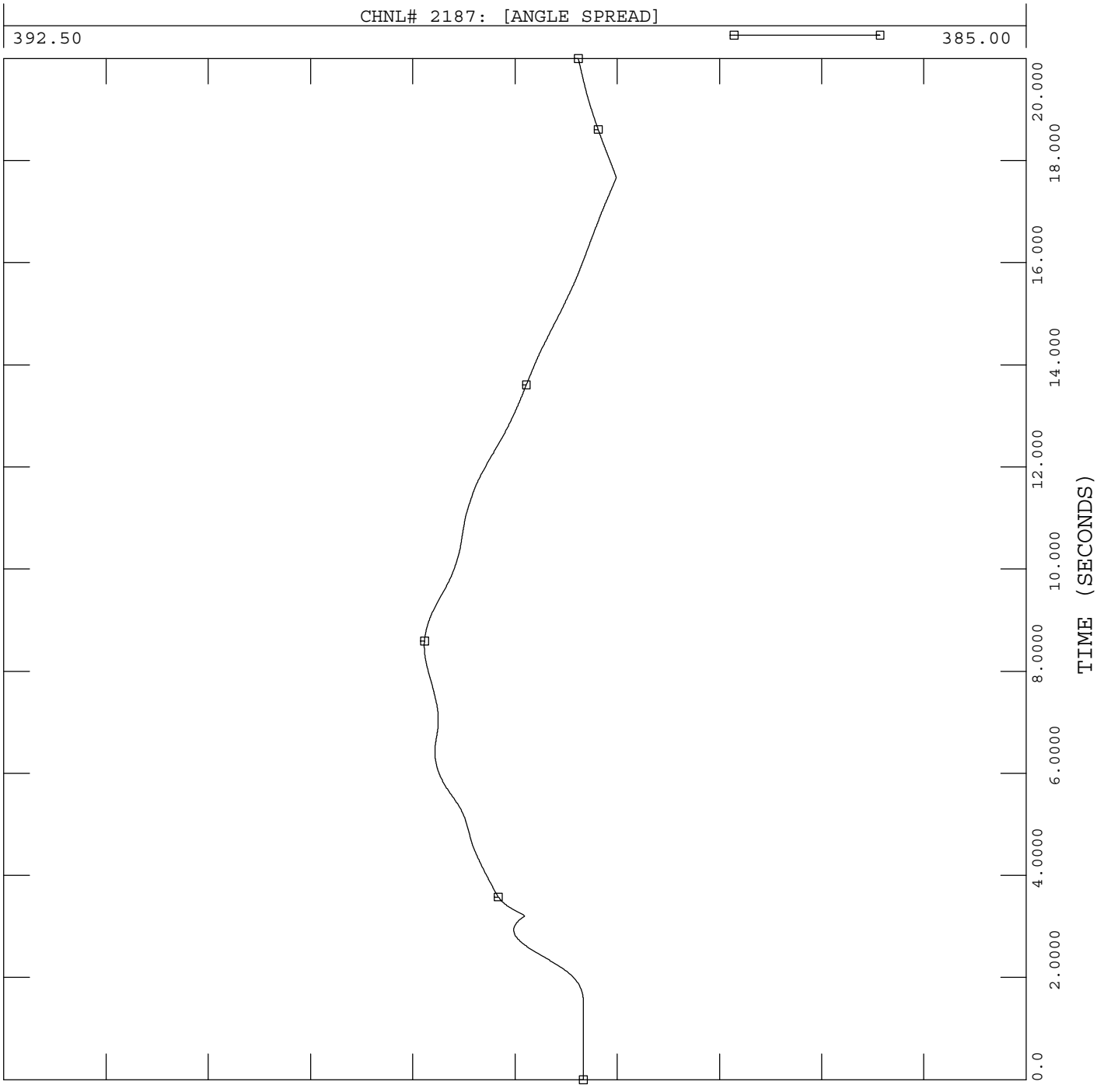


SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_PawneeGen.out

WED, AUG 17 2016 15:14
ST: PAWNEE UNIT

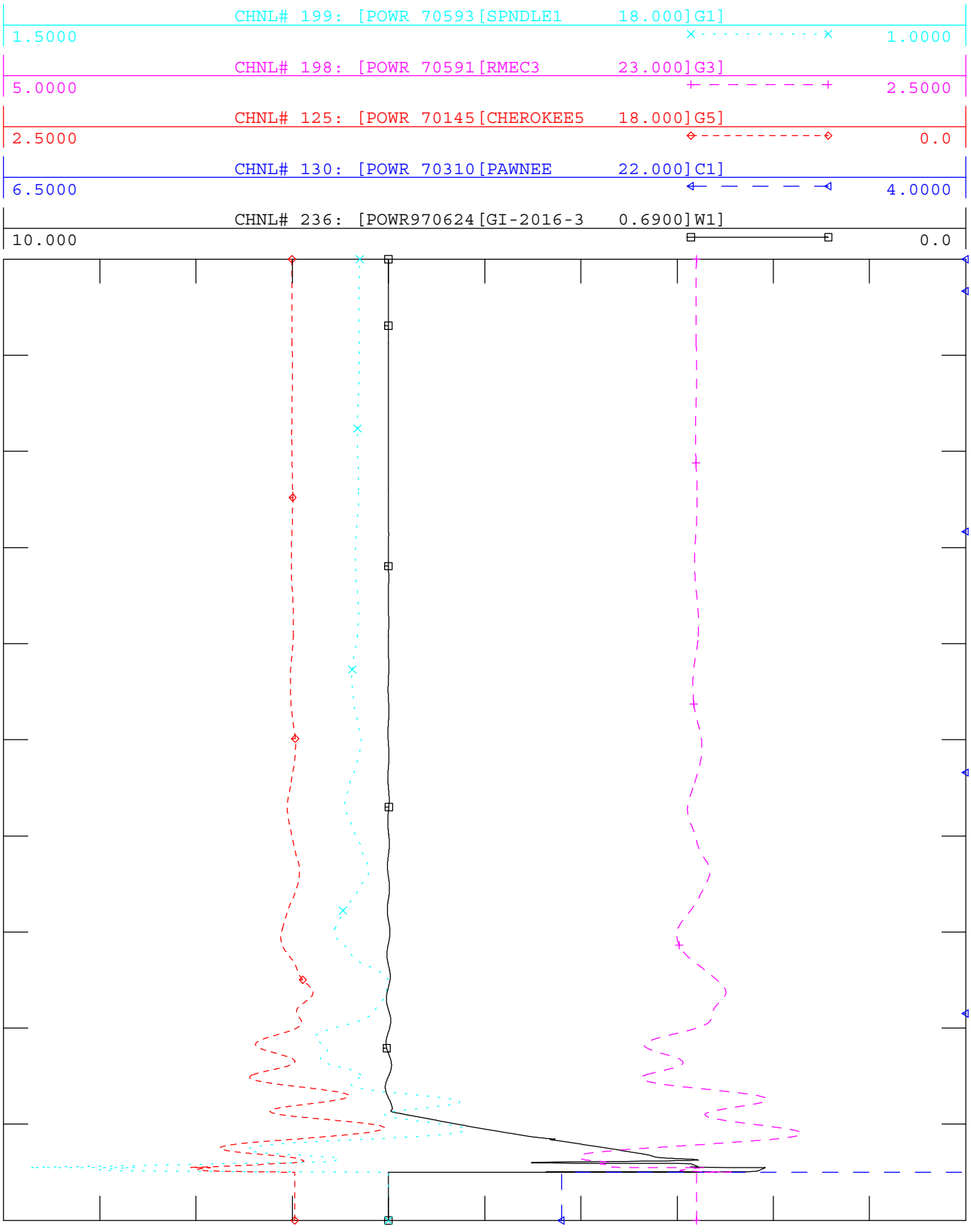


SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_PawneeGen.out

WED, AUG 17 2016 15:14
ST: PAWNEE UNIT



SIEMENS POWER TECHNOLOGIES INTERNATIONAL

WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_M-D.out

WED, AUG 17 2016 15:19
ST: MS-DP 345 KV

CHNL# 843: [VOLT 70590 [RMEC 230.00]]
1.0500 0.80000

CHNL# 431: [VOLT 70107 [CHEROKEE 230.00]]
1.2000 0.70000

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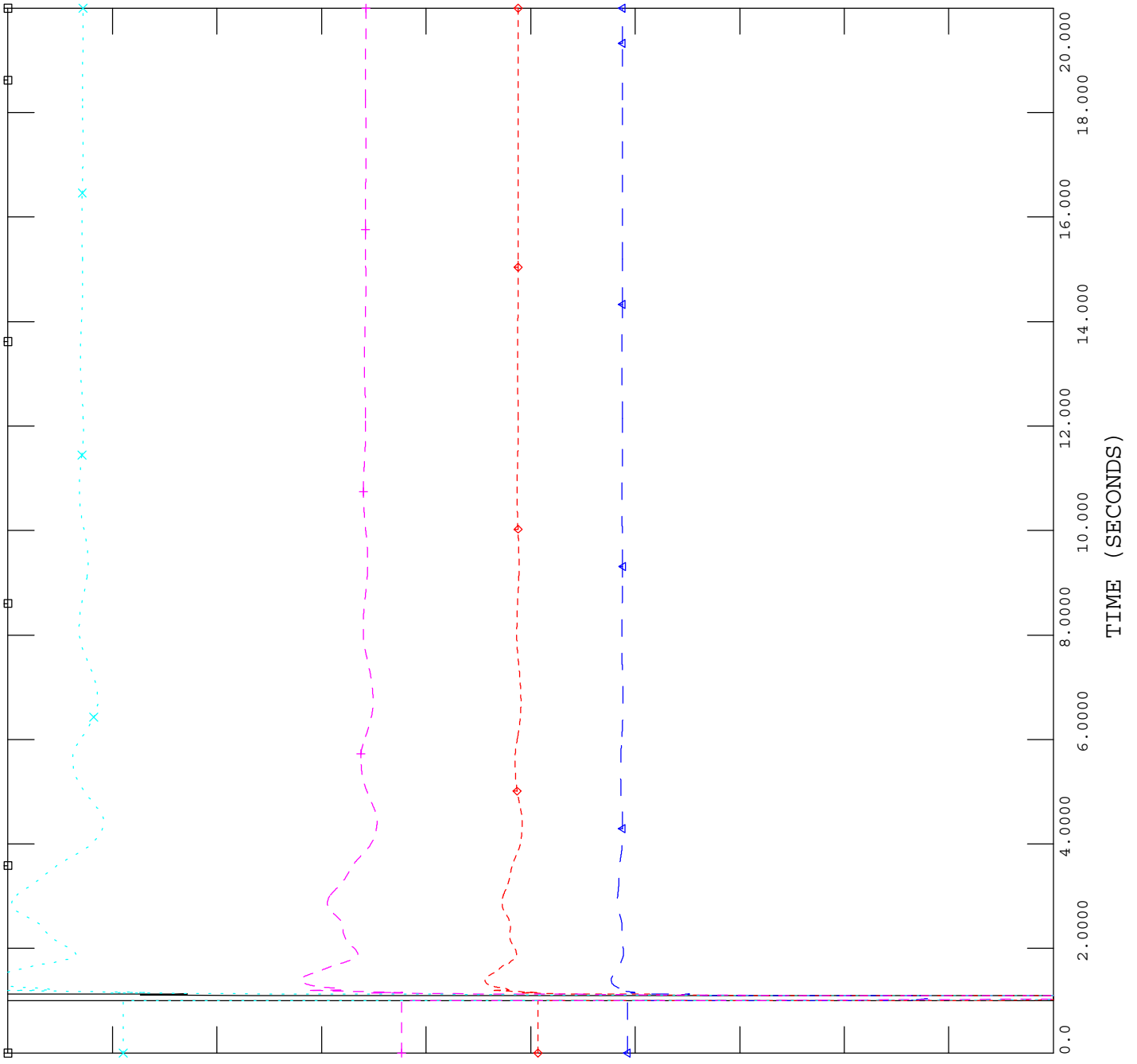

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WESTERN ELECTRICITY COORDINATING COUNCIL
2020 HEAVY SUMMER 2 PLANNING CASE SEPTEMBER 23, 2014

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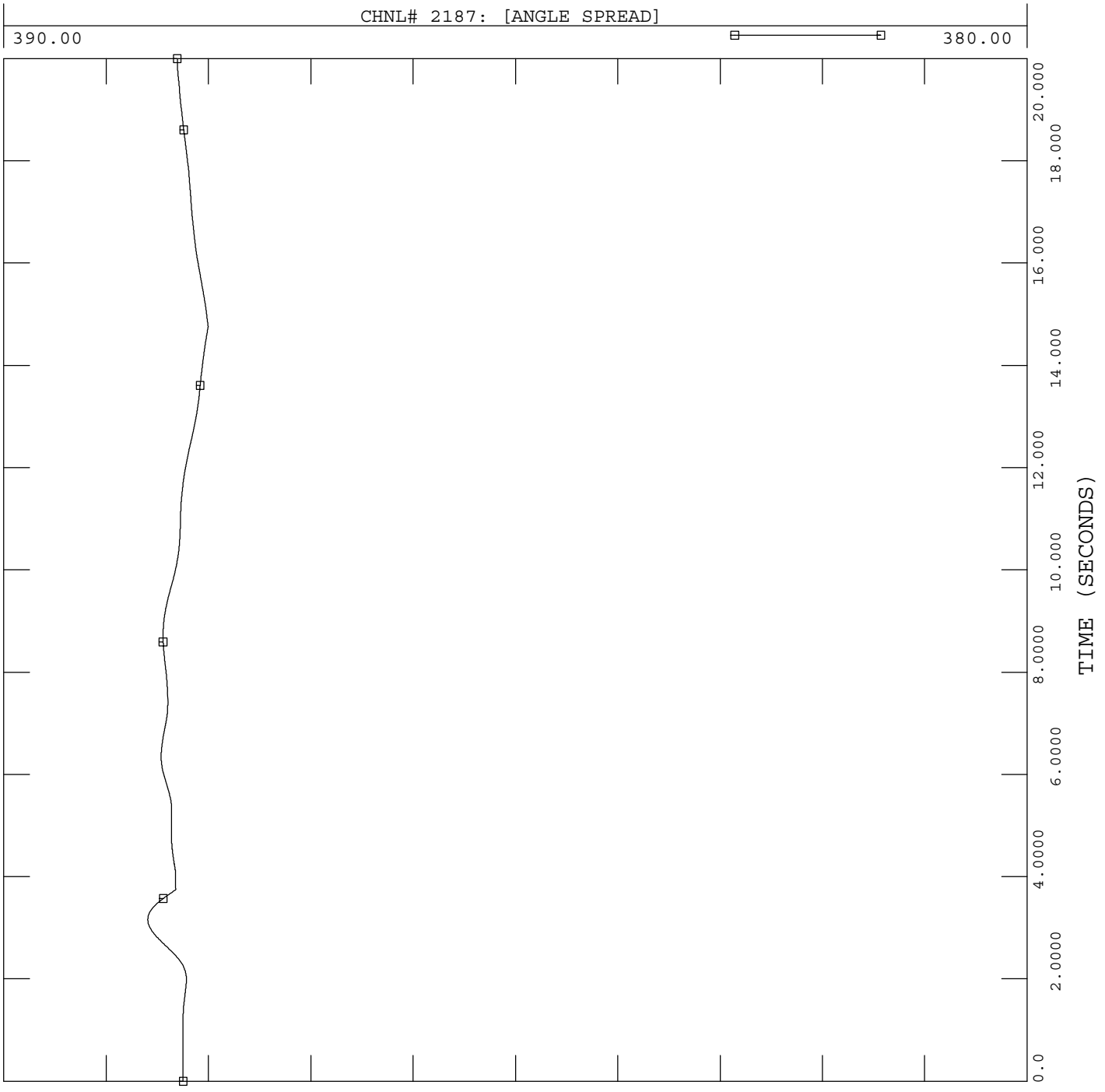

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CHNL# 125: [POWR 70145[CHEROKEE5 18.000]G5]
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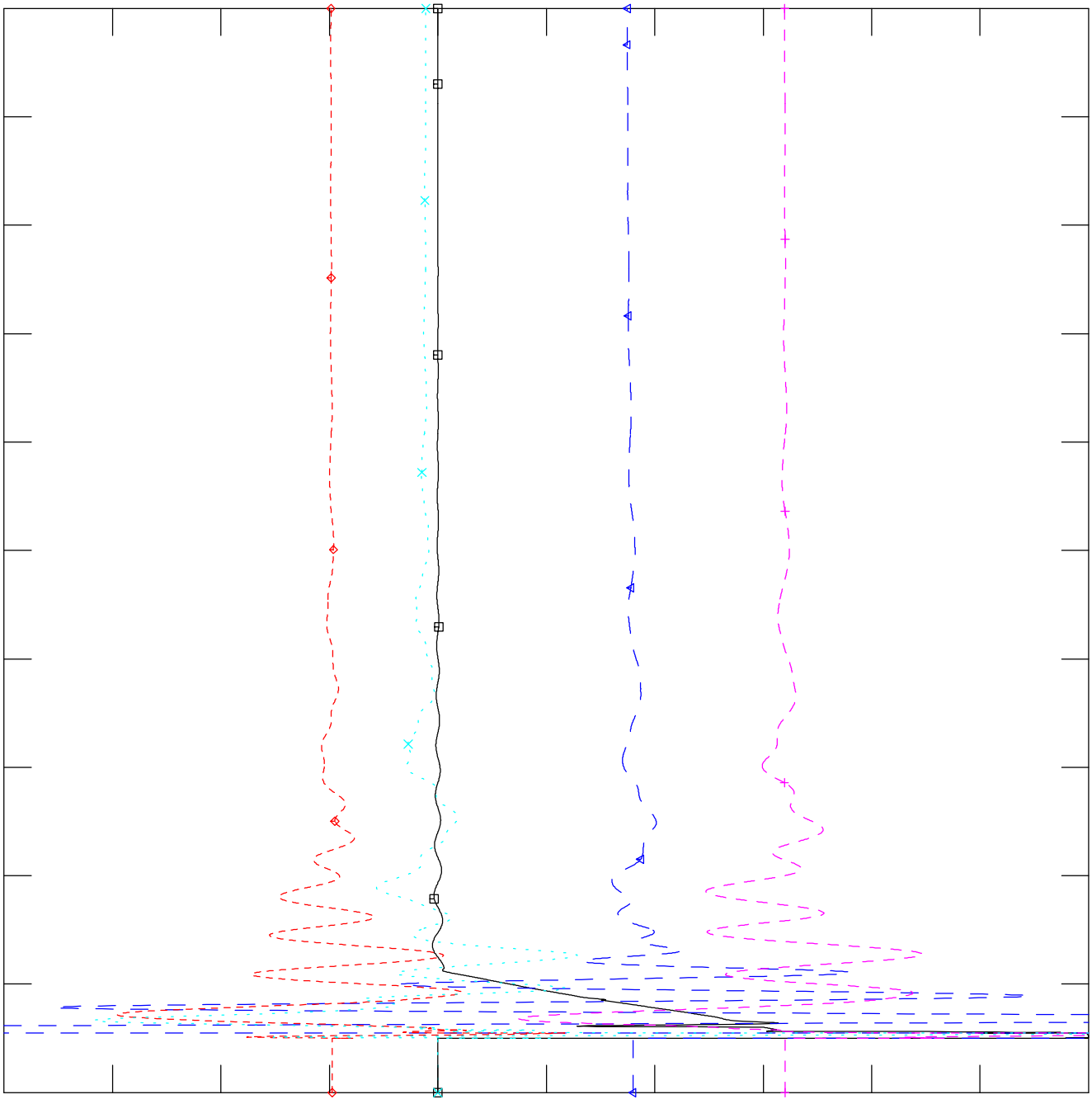

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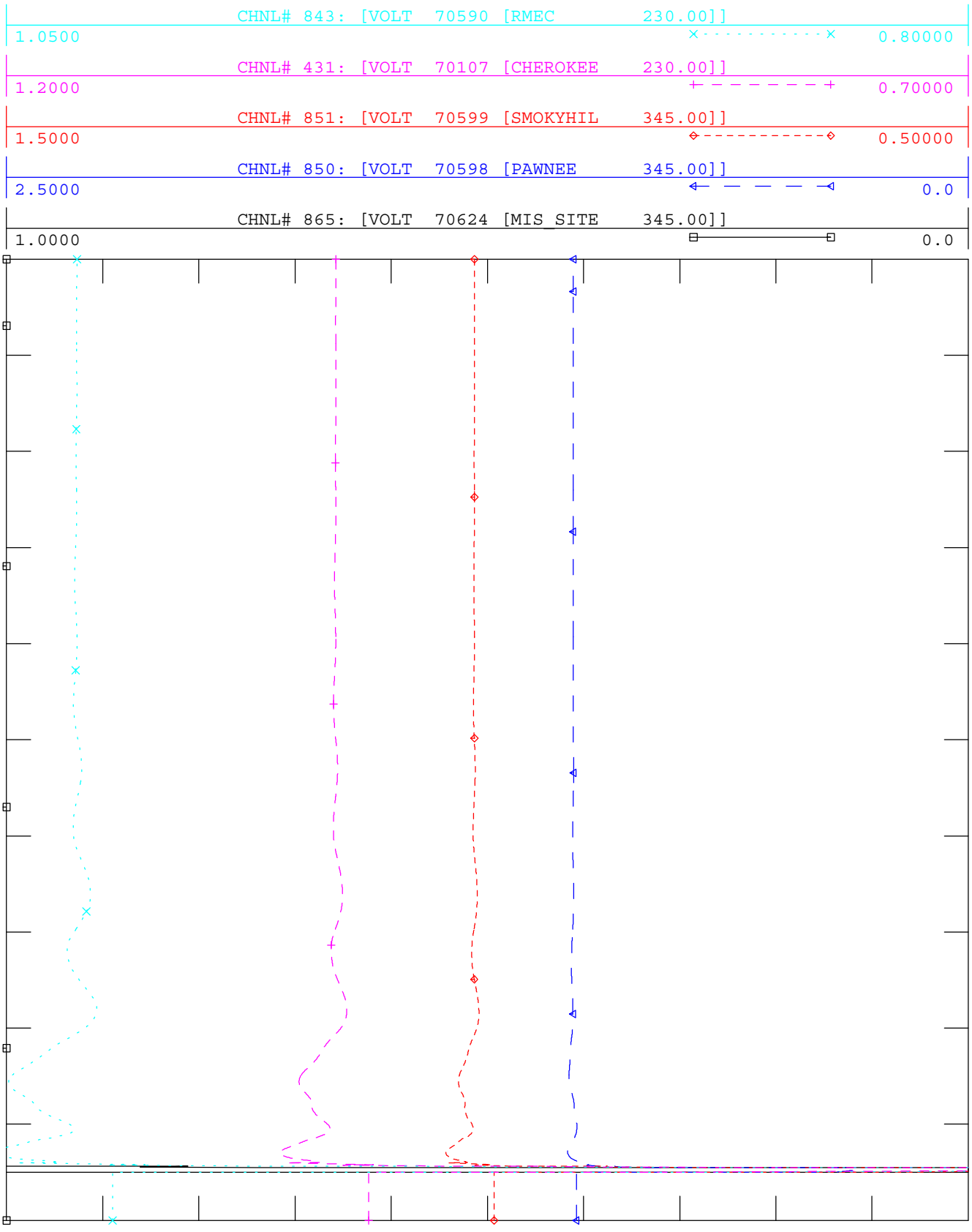

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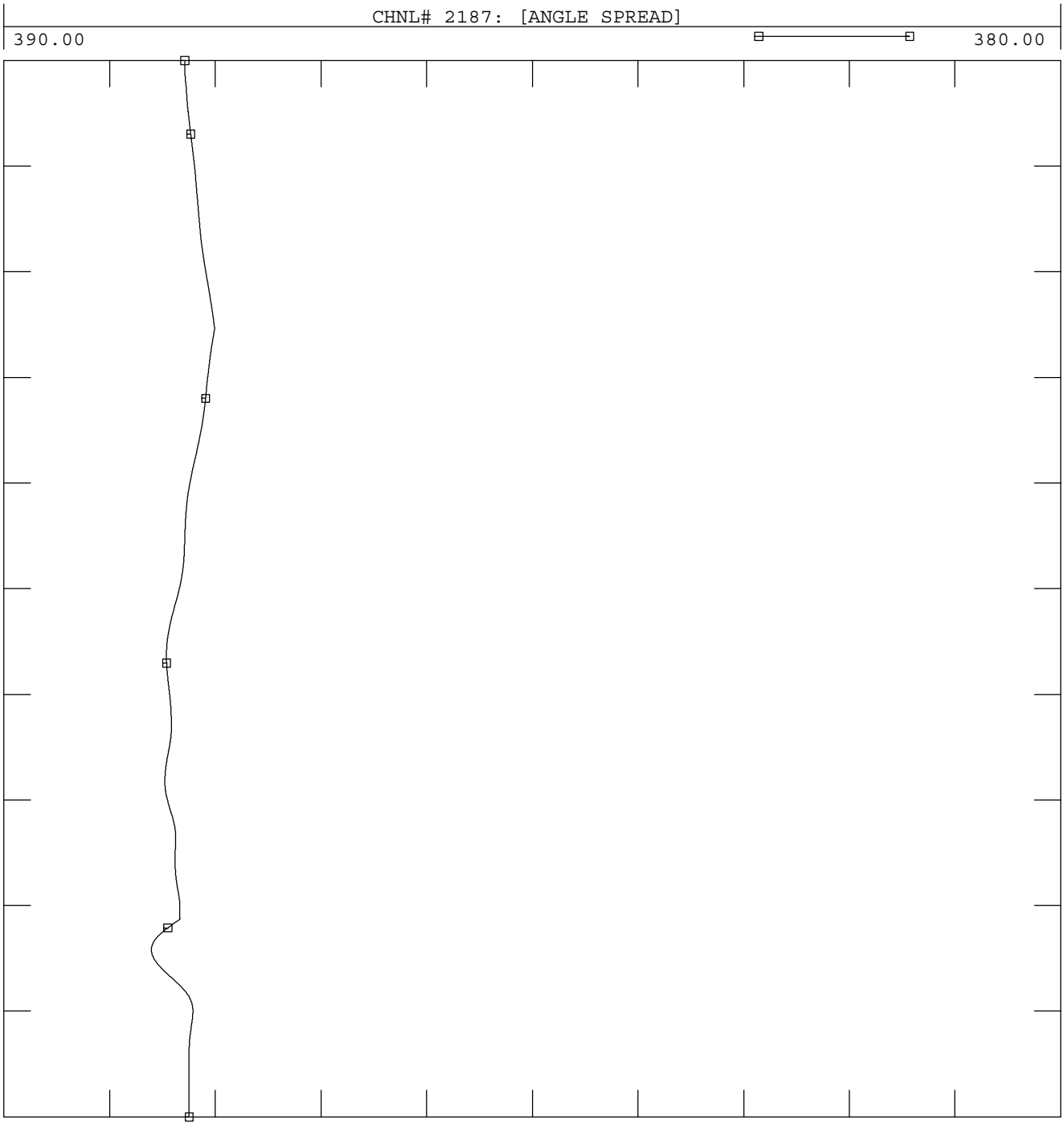

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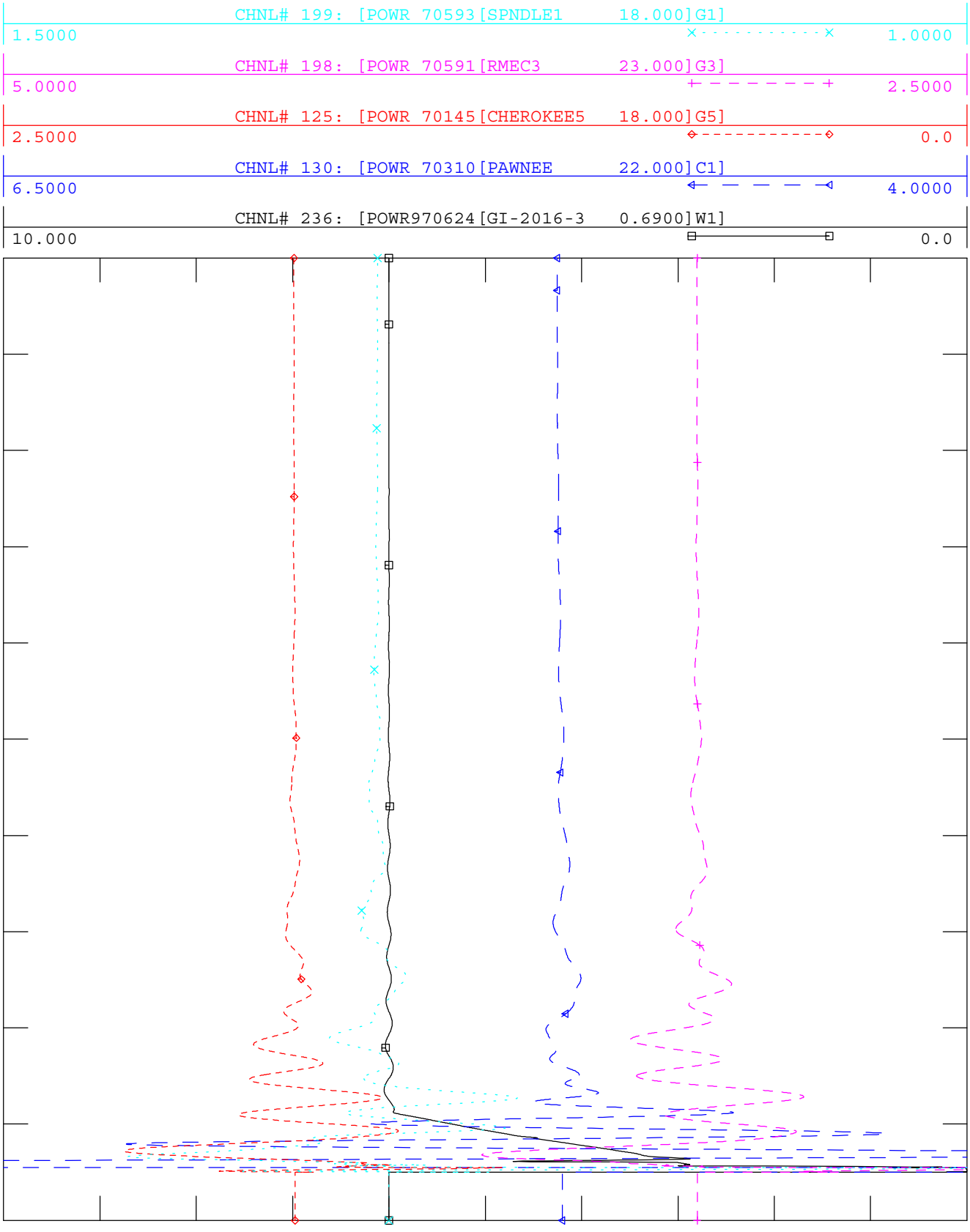

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FILE: C:\Users\209759\Desktop\GI-2016-3\GI-2016-3_ST_M-S-D_DCTL.out

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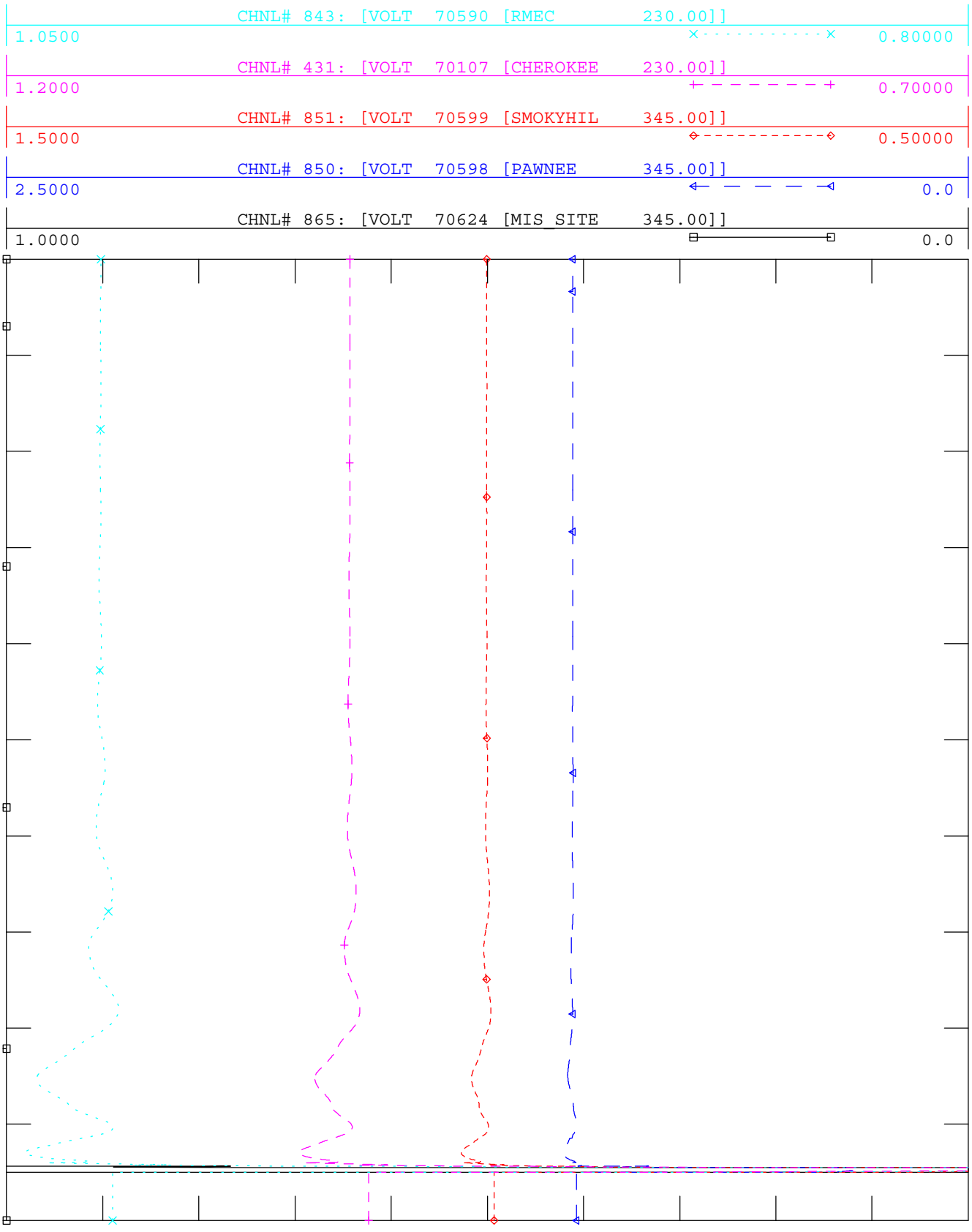

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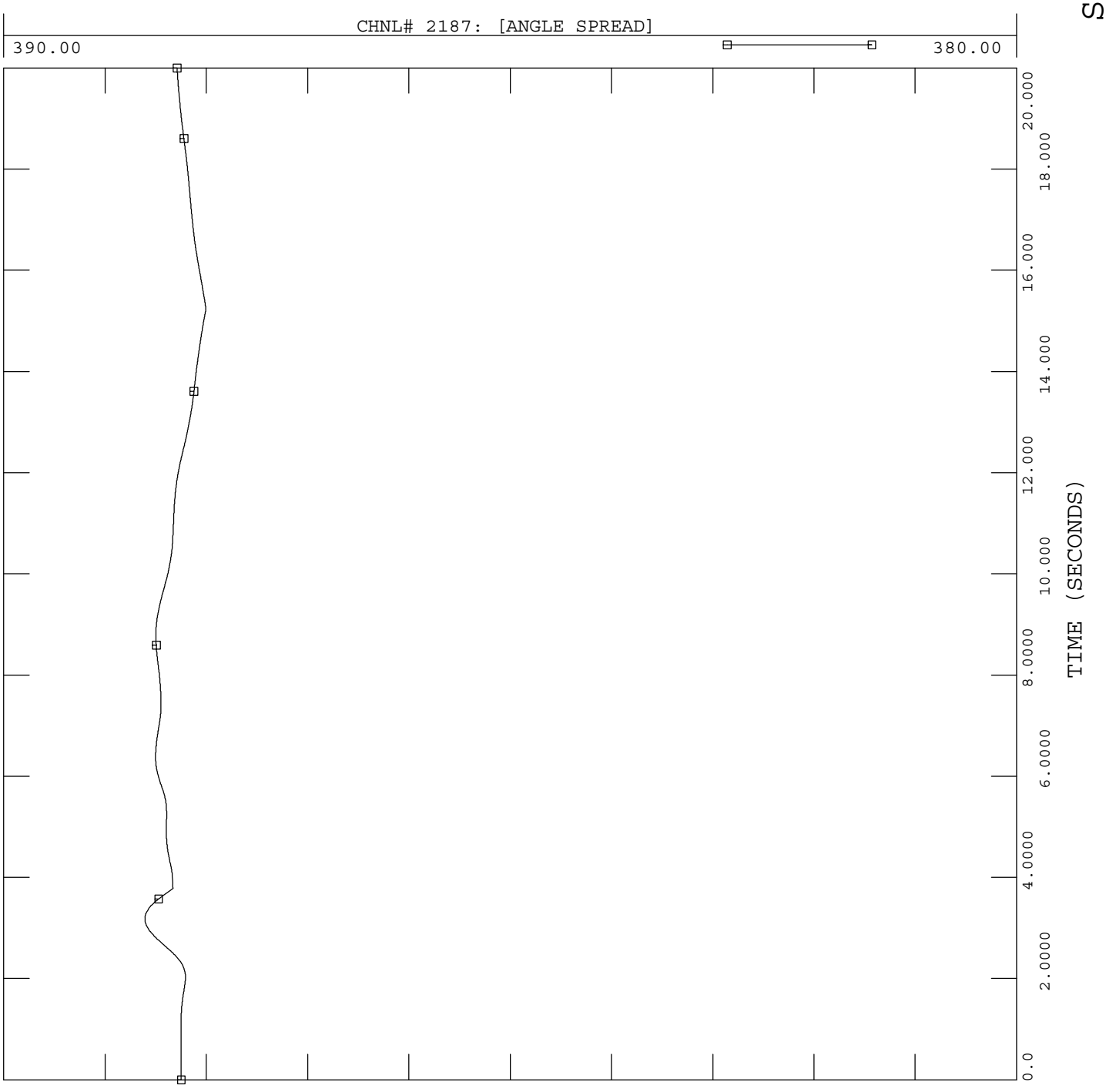

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