ERCOT STF MEETING

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Synchrophasor Taskforce Meeting
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Uses for PMUs within ERCOT

Examples of experience using PMU data

ERCOT USE FOR PMU

1. System Oscillation events

- SCADA cant detect or alarm for system oscillation events
- Addresses RC visibility for
  - Wide Area Oscillations
  - Inter-area Oscillations

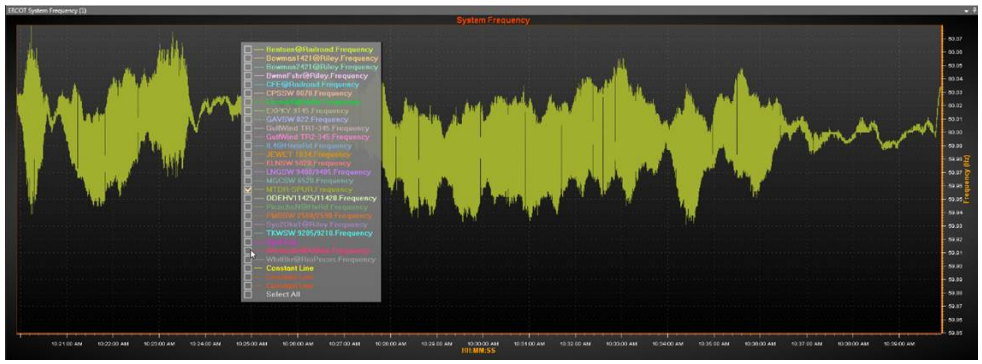
2. Generator Model Validation

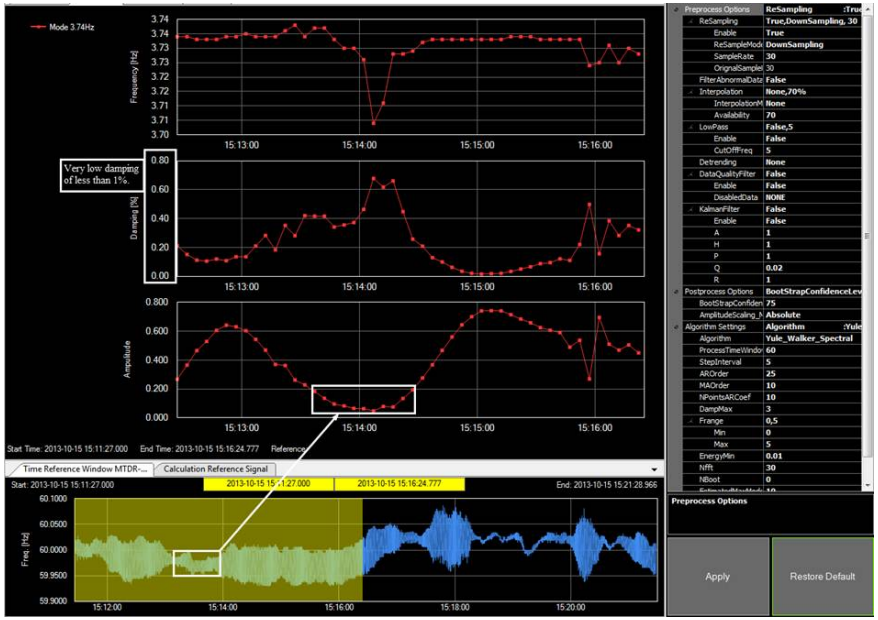
- NERC MOD-26 Excitation Model verification
- NERC MOD-27 Turbine/Governor Model verification
- Addresses requirements for:
  - Transmission Planner
  - Generator Owner

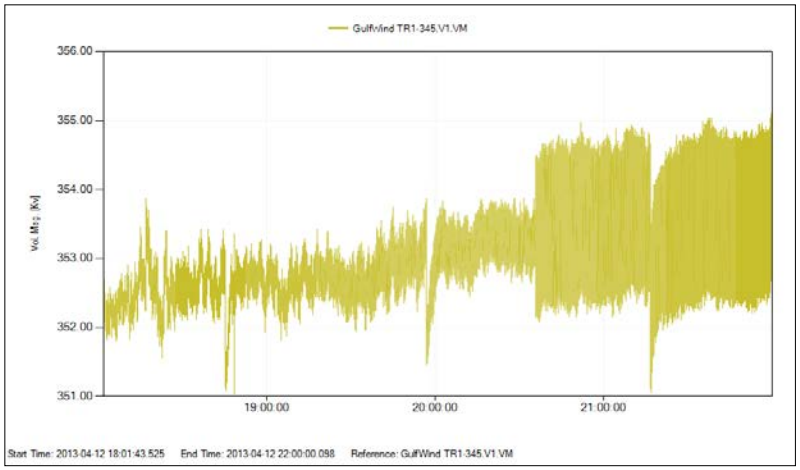
3. Post Event analysis/reporting

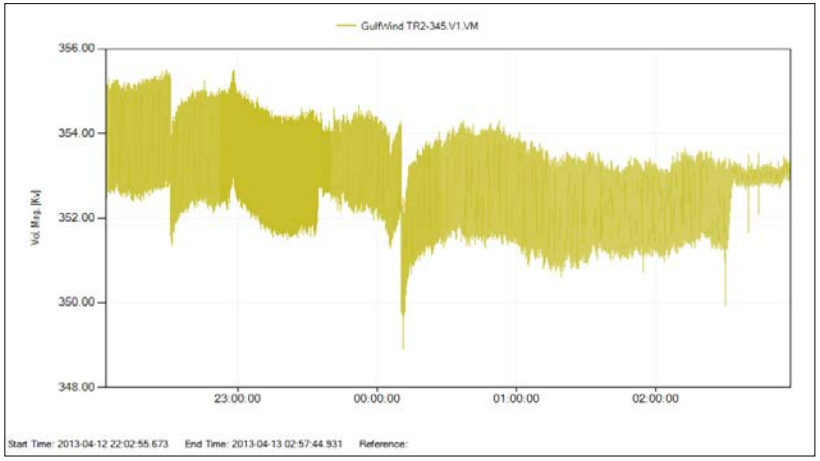
- PRC-002 Disturbance Monitoring and Reporting Requirements
- Applies to:
  - TO's
  - GO's
  - ERCOT

EXAMPLES OF ISSUES PMUS OSCILLATION EVENTS

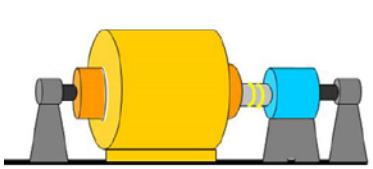


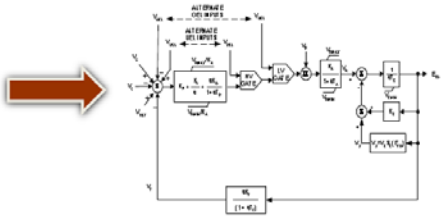




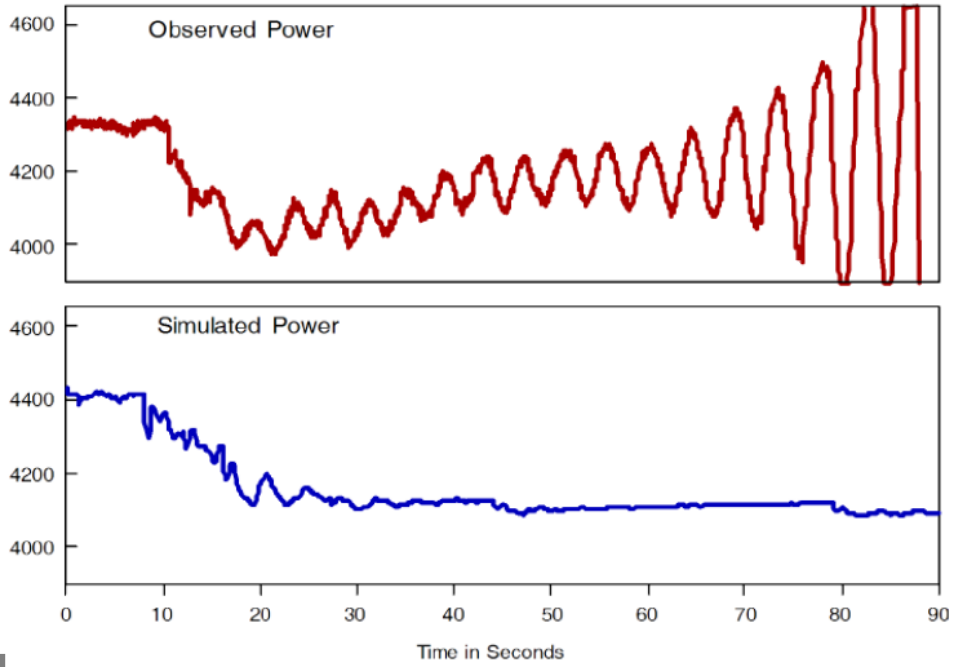


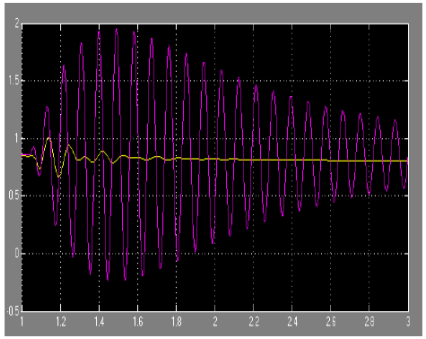
EXAMPLES OF HOW PMUS CAN BE USED WITHIN ERCOT FOR MODEL VALIDATION

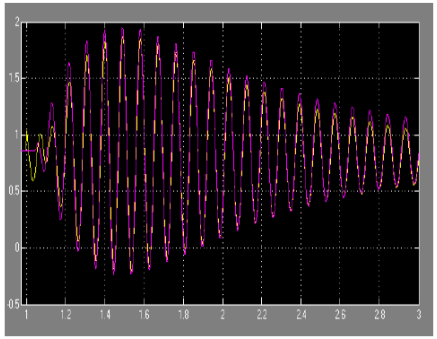




Challenge: Build a good dynamic model for a Generator/Excitation System that matches the actual equipment in the field and validate it through offline/online testing

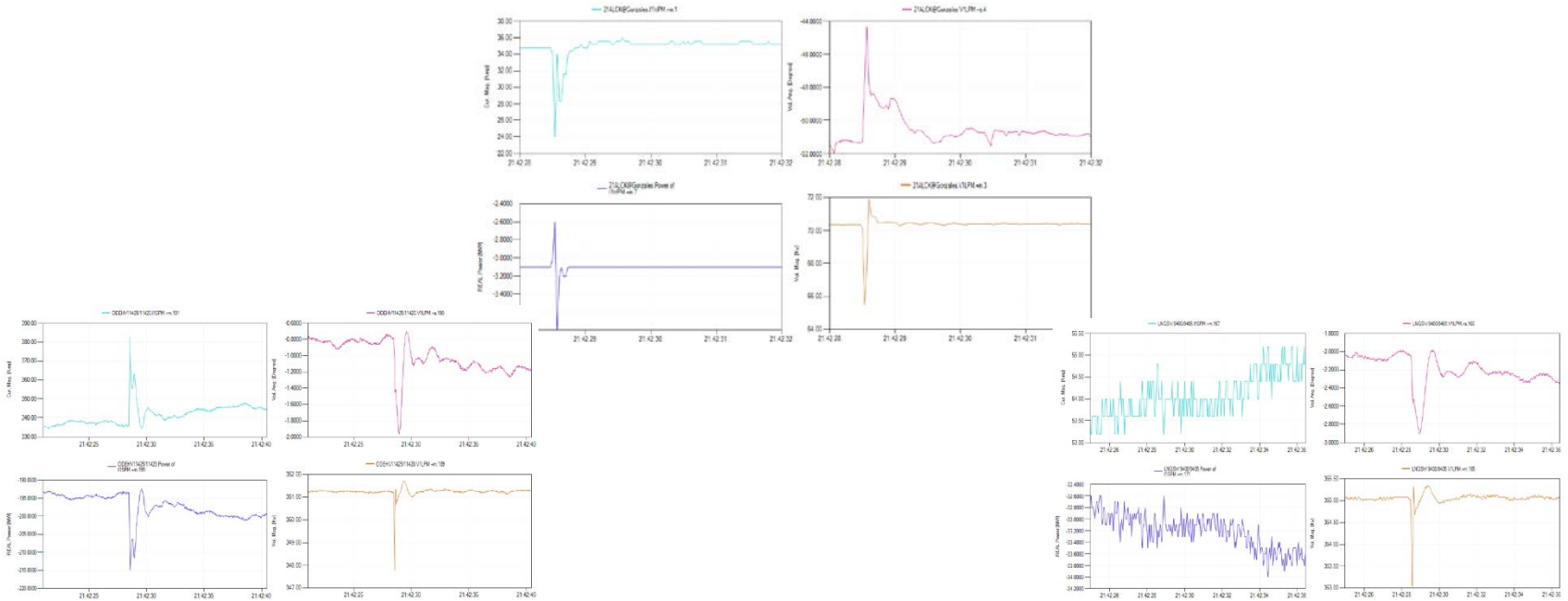






WSCC August 10, 1996 disturbance

POST EVENT ANALYSIS SYSTEM FAULT



A fault should in general cause an impulse drop in voltage and a corresponding rise in current.
In the report, the Odessa (345 kV) , Permian Basin (138 kV) and Morgan Creek (345 kV) all indicated a drop in voltage similar to expected response and also a sharp, temporary increase in current magnitude. Even the PMUs at CPSSW and GAVSW showed minor indications of the fault but the deviation at these locations was small.

The interesting responses were recorded at LNGSW and Gonzales.

At Gonzales, the current magnitude also saw a sharp drop along with the voltage. But looking at the power (MW) plot showed the reason. In general power was flowing into Gonzales from the rest of the system. So a major portion of the current flow would be redirected into the fault, thereby *reducing* the current flowing into Gonzales by a proportionate amount.

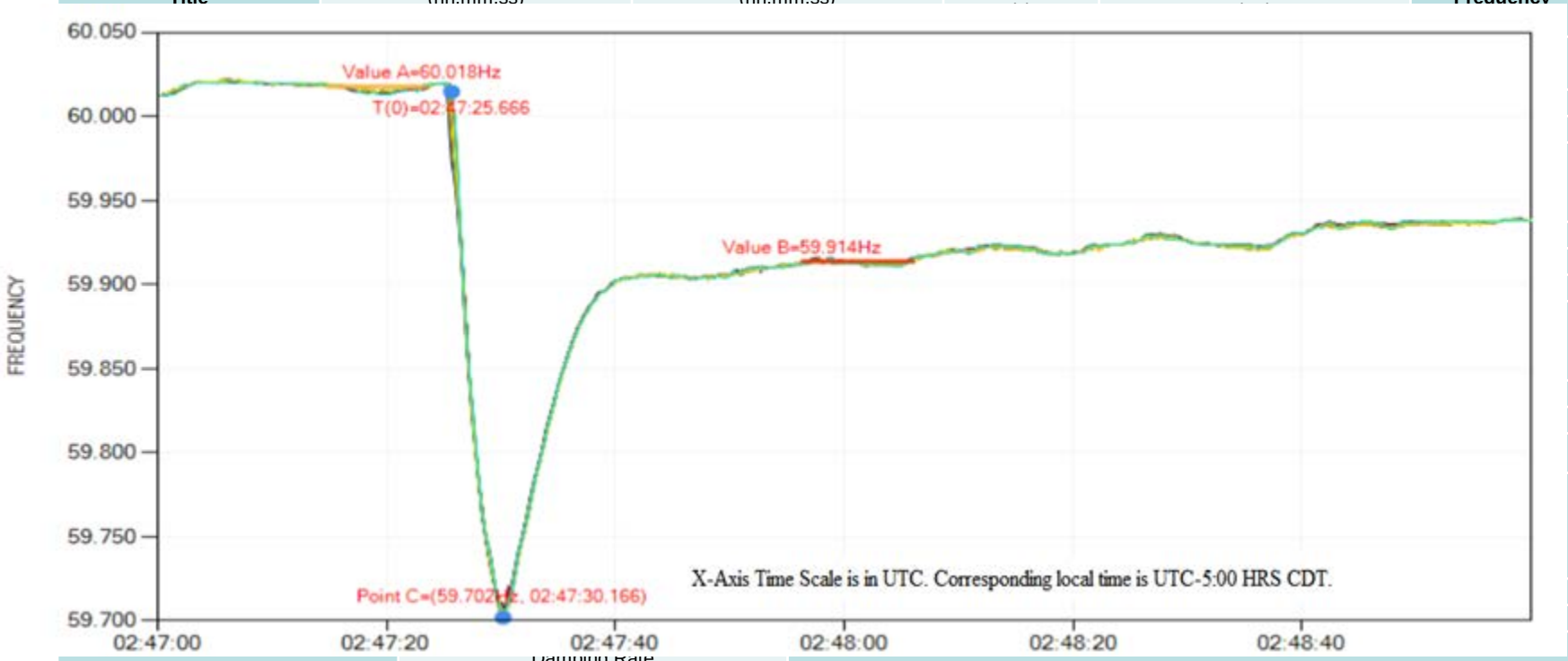
Even more interesting is the fact that *there was little to no fault current recorded at LNGSW*, even though it is located in between Morgan Creek and Odessa both of which showed fault current. The reason is that *the PMU at LNGSW directly measures the output of 3 wind farms*. Since wind farms produce little to no fault current, the PMU only recorded the sharp change in voltage (magnitude and angle) and no change in current or power flow (MW).

POST EVENT ANALYSIS FREQUENCY

Phasor Dynamics Event Summary

The RTDMS captured the following event at the time of 21:47:25 on XX/XX/XXXX. The Advanced Network Applications group studied the dynamic characteristics of this event based on recorded phasor data from 55 available PMUs. The system frequency recovered to 59.95 Hz in around 110 seconds.

Event Title	Start Time (hh:mm:ss)	Recovery Time (hh:mm:ss)	Event Duration	Pre-Event Frequency	Lowest Event Frequency



Frequency (Hz)	Damping Rate (%)	Mode Shape Description
0.64	8.6	

Identified by analysis of voltage angle data of PMUs in Central, North and West Texas referred to KLNSW

WHERE TO PUT THE PMUS

- **Given that so many approaches exist and are based on sound research and testing, the question is how to decide which approach adds the most value to monitoring the electric grid while giving the other benefits the PMU can provide.**

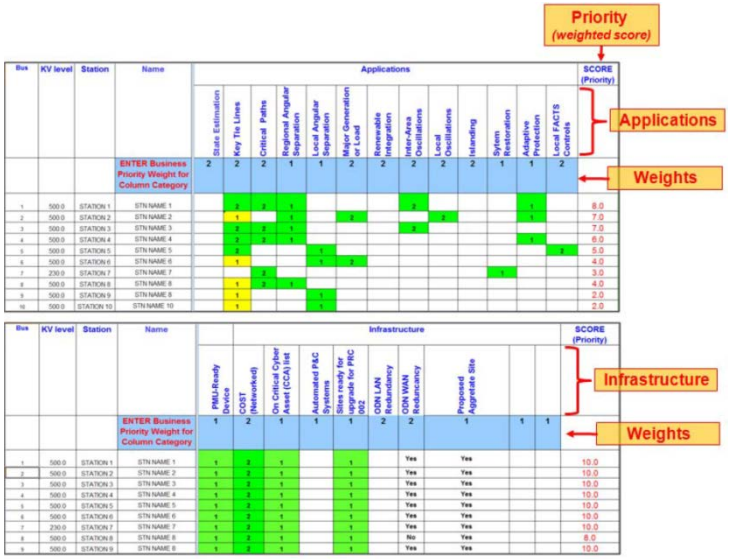
TECHNICAL PAPERS ON PLACEMENT OF PMUS

- **Analyzed publications related to identifying locations for PMUs.**
  - "Generator Black Start Validation Using Synchronized Phasor Measurement" by Kris Koellner, Chris Anderson and Roy Moxley [1]
  - PMU Placement Considerations – A Roadmap for Optimal PMU Placement" by V. Madani
  - "Applications of Synchrophasor Measurement Units (PMUs) in ERCOT" by Surya Santoso and W. Mack Grady
  - "Optimal PMU Placement to Ensure System Observability under Contingencies" by Ranjana Sodhi, S. C. Srivastava, and S. N. Singh
  - "Optimal PMU Placement for Improving Hybrid State Estimator Accuracy" by Markos Asprou, and Elias Kyriakides
  - "Use of Synchronized Phasor Measurements for Dynamic Stability Monitoring and Model Validation in ERCOT" by Jian Chen, Prakash Shrestha, Shun-Hsien Huang, N.D.R. Sarma, John Adams, Diran Obadina, and John Balance

PMU Location Algorithm tool

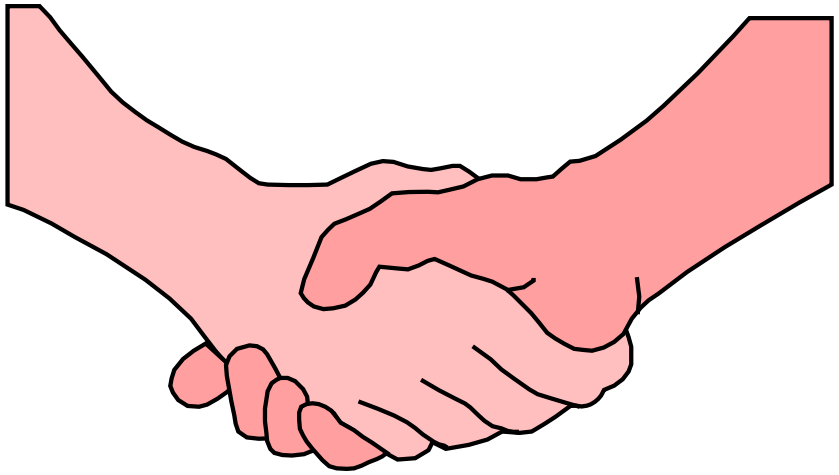
Weights based on a scale of importance from 1 to 4

Black Start Restoration……4
Contingencies (ranked by order: VSAT IROLs, TSAs, Generation (SPS), STPs)….4
Observability……..1
VSAT (voltage
stability)……..3
Inter-area Oscillations……..……...3
Major Generation (with lower short circuit capacity)……3
Renewable Sources and CREZ lines……3
Major 345kV lines……2
Local Oscillations……4



Comprehensive PMU Placement List

Rank	Bus Number	Planning Bus Name	EMMS Station Name	I.S. PMUs	Voltage (kV)	AreaName	Black Start	Generation	Load	N-1-1	N-1 Secure	Voltage Stability	CREZ	Renewables	Connectivity	Sensitive Buses	Score Subtotals	Score Adj
1	59951	BORLYNN_345K	NO MATCH		345	WETT								0.25	0.3764589	0.62646	34.08	34.70621
2	59950	STEPHENS-BOR	NO MATCH		345	WETT								0.1875	0.3793093	0.56681	26.16	26.730891
3	41450	SHELL__138A	SL		138	CNP_TSP		0.916						0.3125	0.4639619	1.69197	20.2	21.887732
4	44010	W_A_P__138A	WAP		138	CNP_TSP								0.1875	0.6514477	0.83895	18.45	19.287483
5	45515	T_H_W__138F	THW		138	CNP_TSP								0.1875	0.5012248	0.68872	17.13	17.814263
6	1032	MRGNCRK_8	MG5ES		138	ONCOR_ED								0.6875	0.3813305	1.06883	12.95	14.018567
7	41300	PSARCO__138A	PSA		138	CNP_TSP		0.743						0.25	0.5007584	1.49379	11.62	13.110456
8	110279	AMOCDOIL_6_8	AMOCDOIL		138	TNMP_TSP		2.954						0.1875	0.3831548	3.50425	9.548	13.05241
9	1891	DECRDOVA_8	DC5ES		138	ONCOR_ED					1.5			0.25	0.2090609	1.95906	9.726	11.684927
10	8395	FALCON 4	FALCON		138	STEC_TSP								0.1875	1.5441506	1.73165	9.149	10.880459
11	110797	CBEC_1_8	CBEC		138	CNP_TSP								0.125	0.212129	0.33713	10.48	10.816544
12	40715	GRNBYU__138F	GBY		138	CNP_TSP								0.25	0.5426338	0.79263	9.934	10.726167
13	9216	SANDMSYD	SANDMSYD		138	AEN_TSP								0.3125	0.1099479	0.41845	10.05	10.470403
14	160747	FG_LOSVI_1_8	NO MATCH		138	AEP_TCC								0.125	1.5699081	1.69491	8.742	10.436961
15	160750	FG_LOSVI_2_8	LV1		138	AEP_TCC								0.125	1.5713074	1.69631	8.739	10.435302
16	9030	BRAUNIG_E	BRAUNIG		138	CPS_TSP		0						0.3125	0.2589797	0.37148	9.391	9.962578
17	3100	MARTINLK_5	ML5ES		345	ONCOR_ED								0.25	0.7388159	0.98882	8.498	9.4869457
18	86111	FAM-138	NOT LISTED		138	CFE		1.0909091						0.4375	1.5920378	3.12045	6.364	9.484164
19	59300	PWRPLANT	SILASRAY		138	BPUB TSP								0.125	2.0666603	2.19166	7.06	9.2517041
20	131247	QALSW_1_5	QALSW		345	ONCOR_ED								0.125	0.3290899	0.45409	8.792	9.2456188
21	86112	MTM-138	NOT LISTED		138	CFE		1.0909091						0.25	1.590794	2.9317	6.301	9.2329202
22	1900	COMCHPKW_5	CP5ES		345	ONCOR_ED			0.021		1.5			0.25	0.1361314	1.90731	7.292	9.1993646
23	40480	DS_BAT__138A	DIB		138	CNP_TSP			2.043					0.375	0.4649466	2.88329	6.282	9.1656099
24	18100	PBGENBUS_B	PB2SES		138	TEMPORARY								0.125	0.5936617	0.71866	8.386	9.1046684
25	5260	LEON_CRK	LEON_CRK		138	CPS_TSP			0					0.1875	0.2620383	0.4497	8.63	9.079597



Thank U !!