PI-based Synchronized Phasor Measurement Infrastructure

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PI – The Defacto Standard in Power

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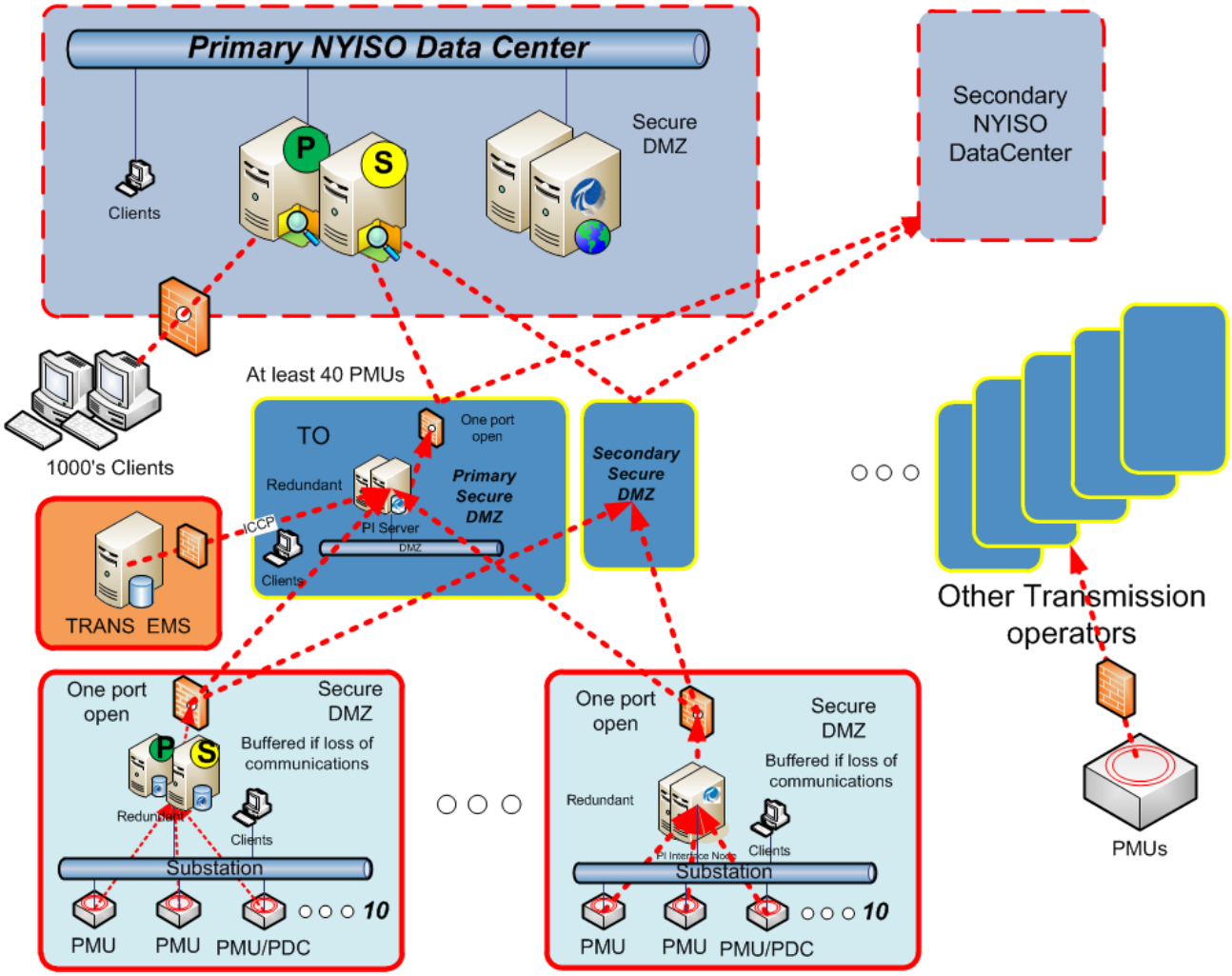
PI-based WAMS installations

Company	Installed	Contact	email	PMUs	Storage
Entergy	2005	Floyd Galvan	fgalvan@entergy.com	22	11 TB
North China Grid	2005	Xu Yong	xuwong@epri.ac.cn	35	22 TB
Chongqing Power Grid	2005	Xu Yong	xuwong@epri.ac.cn	21	10 TB
Anhui Electric Power	2006	Hongge Zhang	hzhange@opensystemscontrol.com	19	5 TB
Hebei Electric Power	2006	Xu Yong	xuwong@epri.ac.cn	22	13 TB
Gansu Electric Power	2008	Xu Yong	xuwong@epri.ac.cn	25	33 TB
Beijing Dispatch Center	2008	Xu Yong	xuwong@epri.ac.cn	17	9 TB
Tenaga (Malaysia)	2007	Sofizan Nik	niksofizan@tnb.com.my	11	5 TB
CFE Mexico	2009	Gilberto Badallo	gilberto.badallo@cfe.gob.mx	25	2 TB

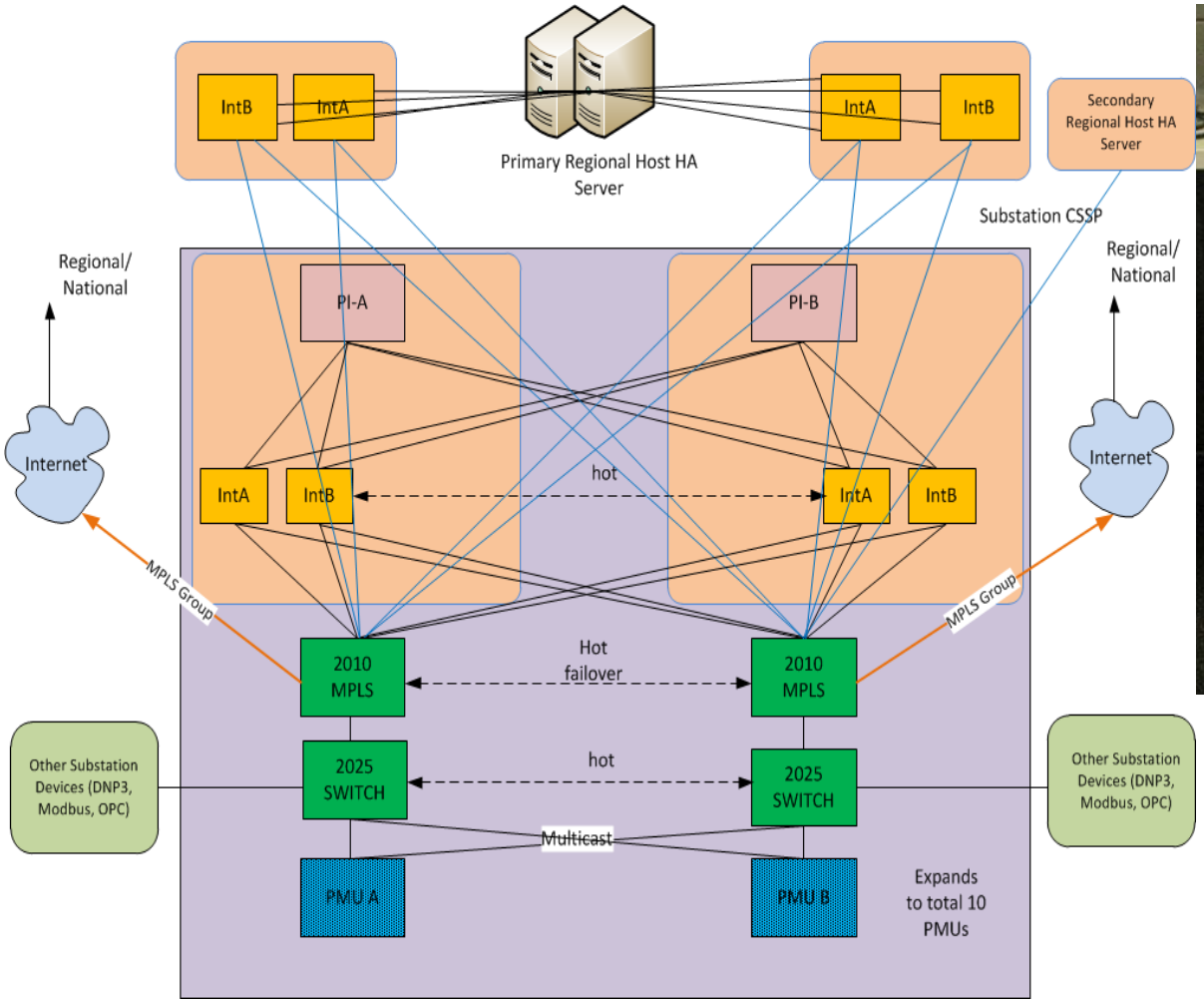
PI - Secure, Reliable, Highly Available and Scalable

- NERC CIP compliant installations
  - Full audit trails, patch management without loss of data
  - Standard PI tag security, multi-factor secure single sign-on
- PI HA system
  - Multiple HA servers in multiple collectives
  - SEL paper shows 99.99999% availability (3.1 seconds per year)
  - Redundant interfaces
    - Hot failover, Server failover
- Performance (simultaneous)
  - 100,000 events per second to hard drive
  - 250,000 events per second to SSD
  - 1,000,000 events per second to clients
  - Hierarchical network of PI Servers enables distributed processing

Reference Architecture

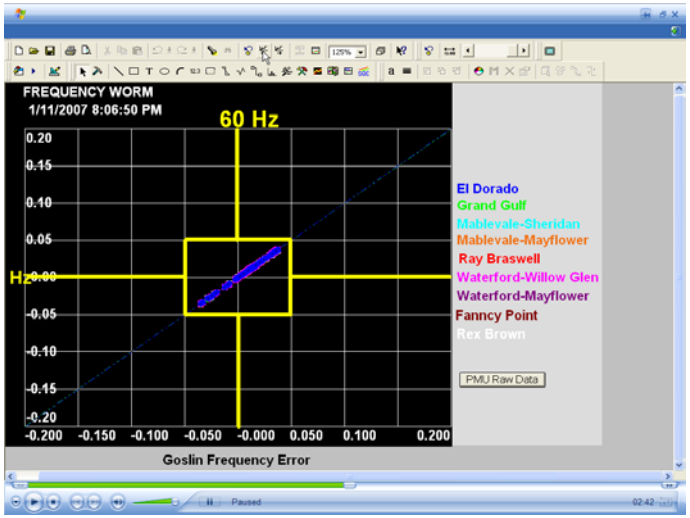


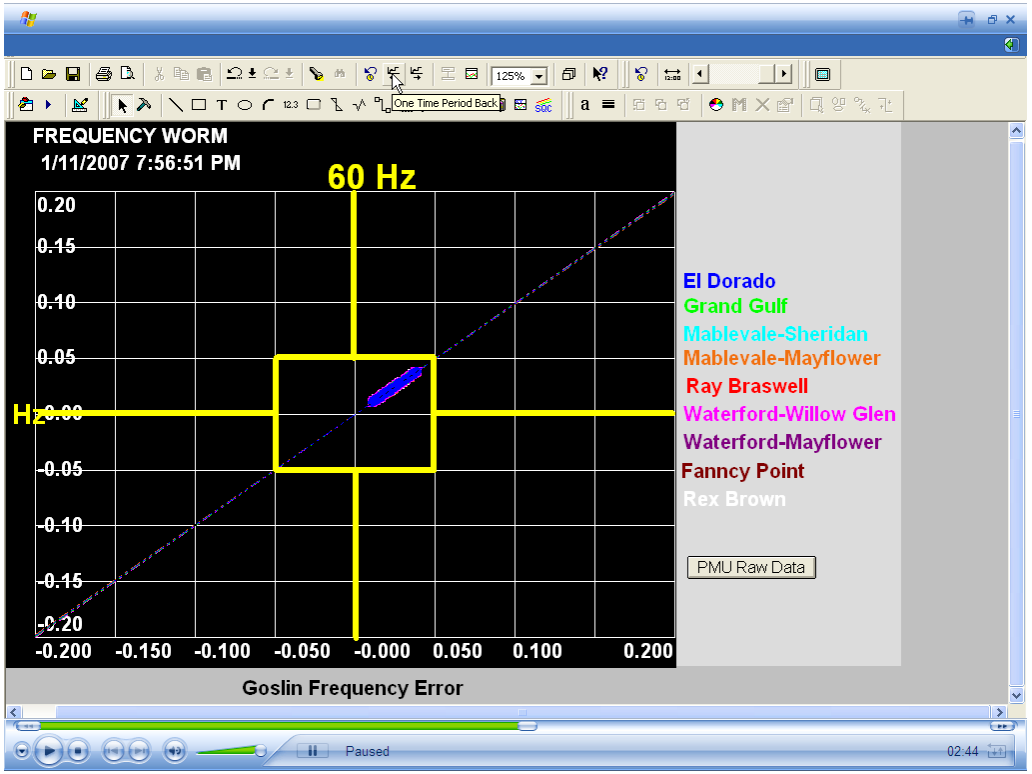
Substation detail



Customer Examples- Prior to major blackout

Customer Examples- Grid coherency





Real time FFTs, Phase portraits, SQC

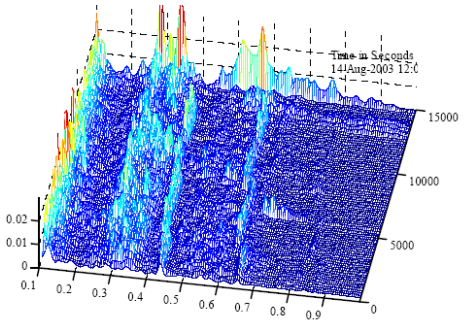
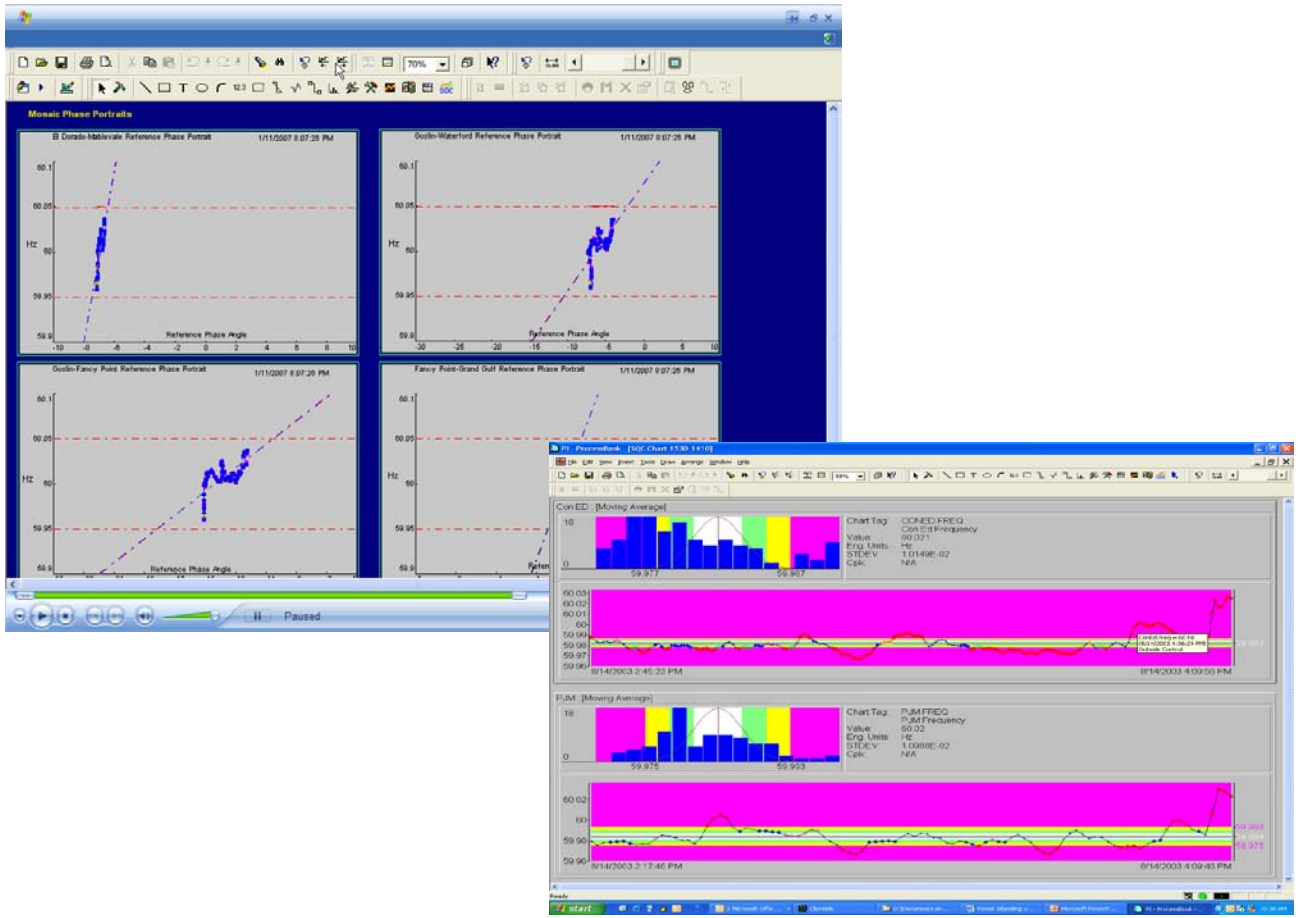
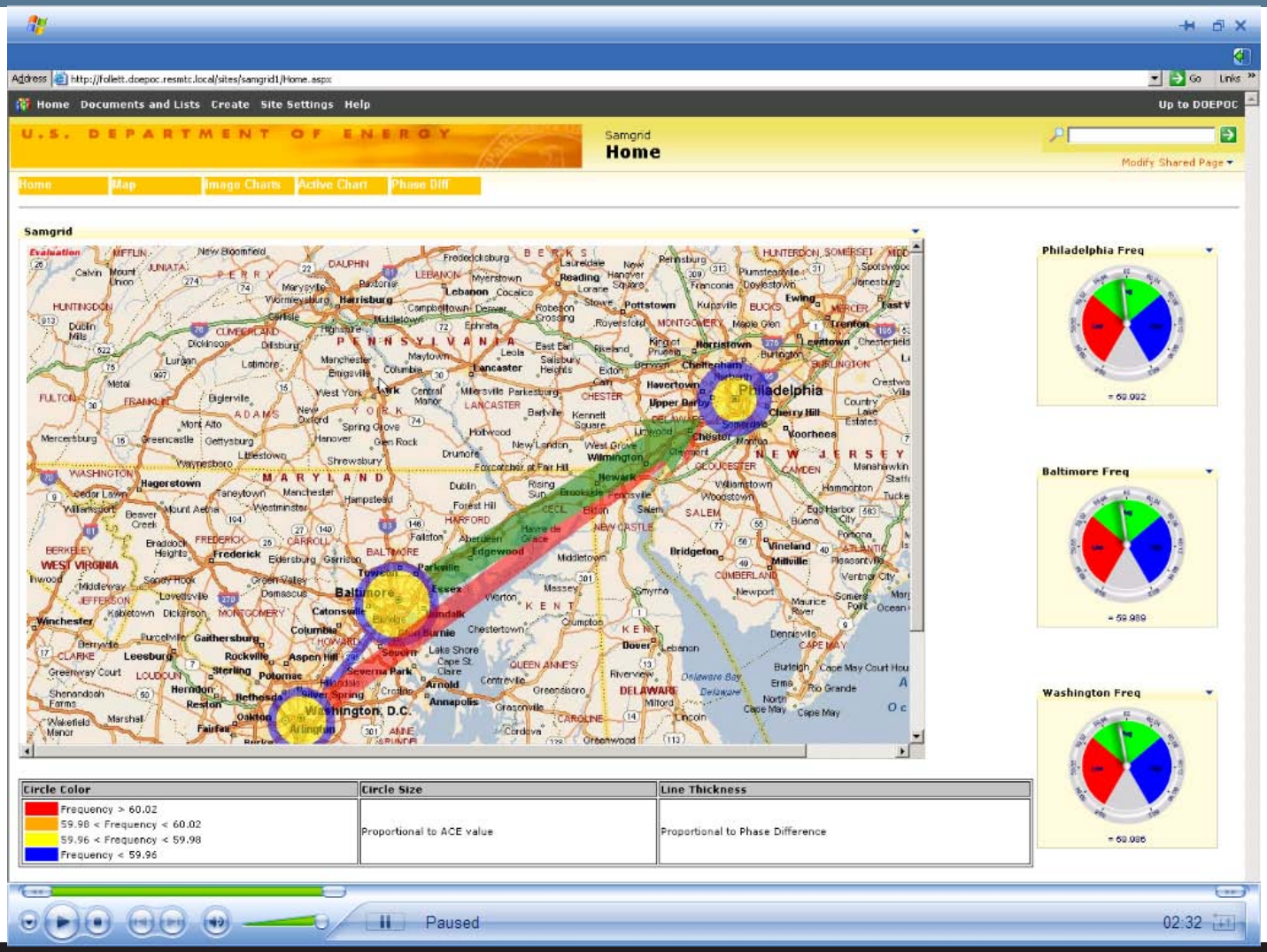


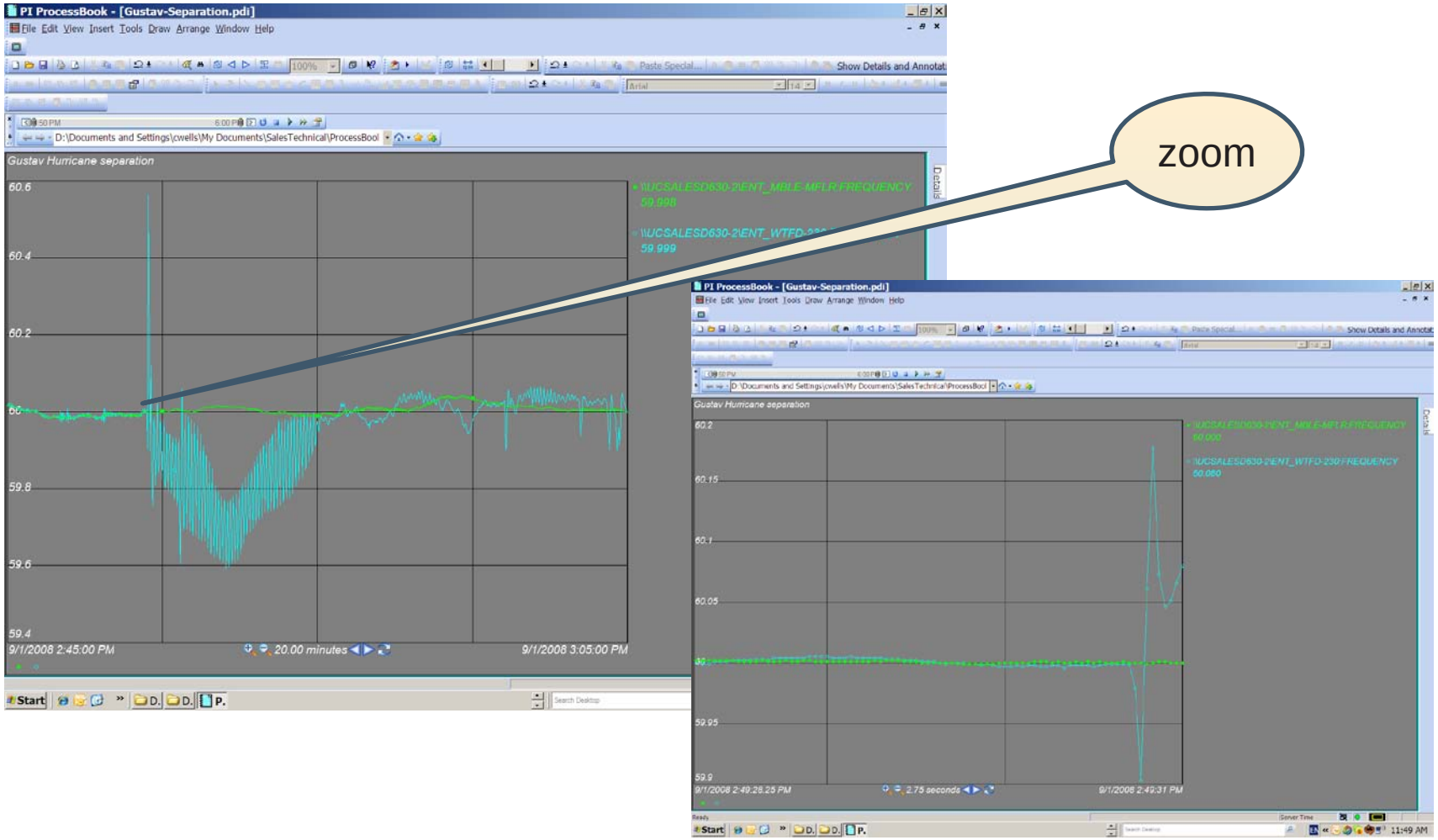
Fig. 12. Spectral history of AEP Kanawha River bus frequency for August 14 Blackout. 12:00-16:10 EDT



Customer Examples



Customer Examples- Island formation



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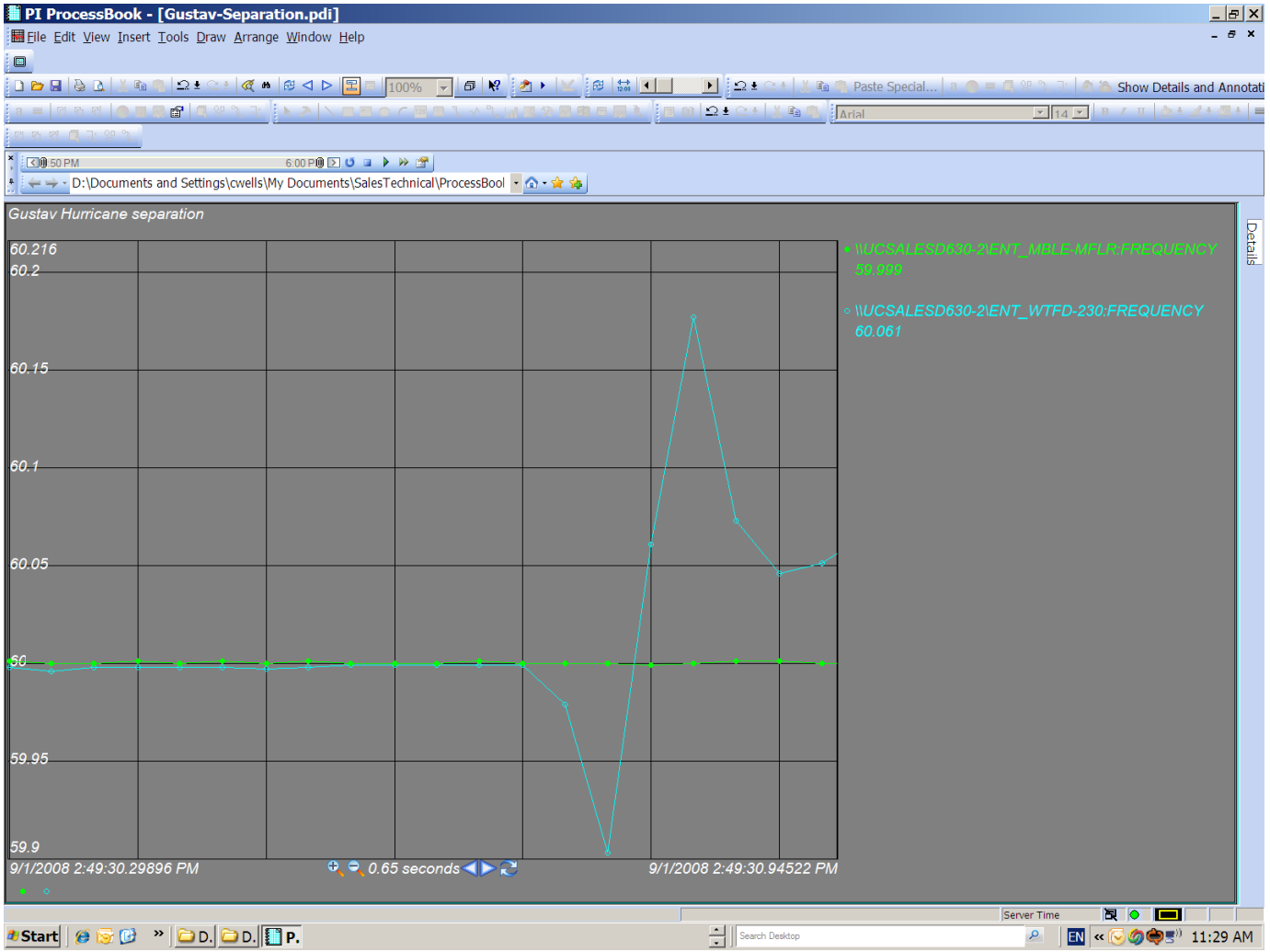
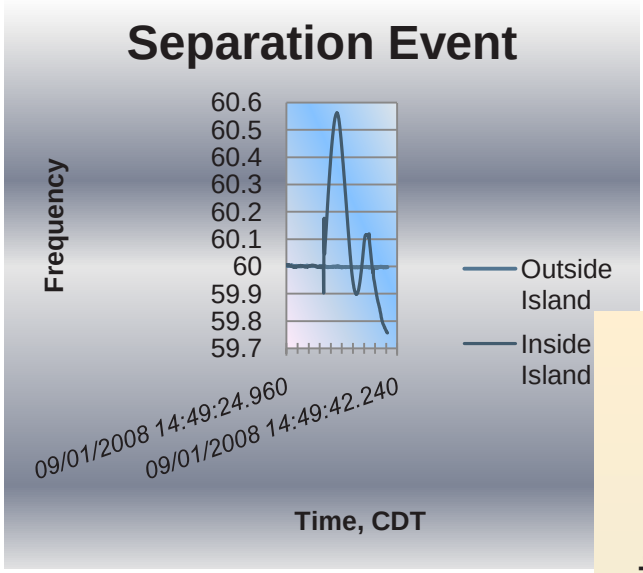
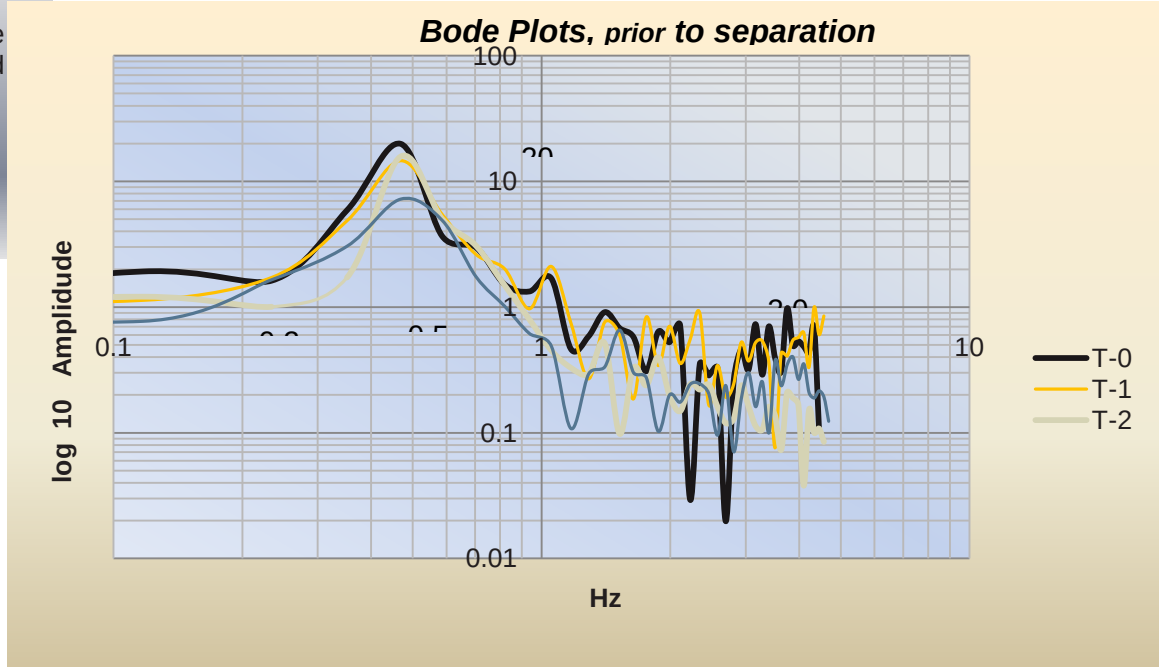


Customer Examples - (DataLink)





Customer Examples- (DataLink)

	A	B	C	D	E
1	Timestamp	Outside	Inside	Out Angle	In Angle
2	09/01/2008 14:45:00.000	60.017	60.016	-62.112	-53.047
3	09/01/2008 14:45:00.033	60.017	60.016	-61.905	-52.86
4	09/01/2008 14:45:00.066	60.017	60.016	-61.699	-52.668
5	09/01/2008 14:45:00.100	60.017	60.015	-61.492	-52.475
6	09/01/2008 14:45:00.133	60.018	60.016	-61.285	-52.283
7	09/01/2008 14:45:00.166	60.018	60.016	-61.078	-52.091
8	09/01/2008 14:45:00.200	60.017	60.016	-60.871	-51.898
9	09/01/2008 14:45:00.233	60.017	60.016	-60.664	-51.706
10	09/01/2008 14:45:00.266	60.017	60.017	-60.458	-51.5
11	09/01/2008 14:45:00.300	60.017	60.017	-60.251	-51.295
12	09/01/2008 14:45:00.333	60.018	60.017	-60.044	-51.09
13	09/01/2008 14:45:00.366	60.017	60.017	-59.837	-50.885
14	09/01/2008 14:45:00.400	60.018	60.017	-59.629	-50.68
15	09/01/2008 14:45:00.433	60.017	60.017	-59.422	-50.475
16	09/01/2008 14:45:00.466	60.017	60.018	-59.215	-50.254
17	09/01/2008 14:45:00.500	60.017	60.018	-59.007	-50.034
18	09/01/2008 14:45:00.533	60.017	60.018	-58.8	-49.813
19	09/01/2008 14:45:00.566	60.017	60.018	-58.593	-49.593

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