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SEMI Voltage Sag Immunity Task Force:

Task Force Meeting No. 12, Project Update

“Addressing Continued Voltage Sag Induced Downtime”

3:30 to 5 PM Eastern, October 7, 2021

Task Force Leader, Mark Stephens, PE

Electric Power Research Institute, mstephens@epri.com

Meeting Agenda

- Welcome/Call to Order
  - Introductions/Use Chat to Sign In
  - Welcome New Participants!
  - Agenda Review
  - Review SEMI® Standards Required Meeting Elements
  - Quick TF Charter Overview
- Review TF Topics
  - Task Force Co-Leader Input
  - Schedule Update
  - Task Discussion – What is a Three-Phase Voltage Sag?
  - Task 3 Updates
  - Discussion of Tool Testing Paths
- Next Meeting
- Action Item Review
- Adjourn

TF Members/Meeting Attendees (Please Sign in Through Chat)

No	First Name	Last Name	E-mail	Company	Type	Present?
1	Imran	Afzal	Imran_Afzal@amat.com	AMAT	Tool OEM	
2	Uwe	Haller	Uwe_Haller@amat.com	AMAT	Tool OEM	
3	Bilgehan	Donmez	Bilgehan.Donmez@amsc.com	AMSC	OEM	
4	John	Leech	John.Leech@aps.com	APS	Utility	
5	Giel	Croonen	giel.croonen@asml.com	ASML	Tool OEM	
6	Willem	Meijs	willem.meijs@asml.com	ASML	Tool OEM	
7	Bill	Sparks	William.Sparks@austinenergy.com	Austin Energy	Utility	
8	Michael	Noth	Michael.Noth@austinenergy.com	Austin Energy	Utility	
9	Scott	Bayer	Scott.Bayer@austinenergy.com	Austin Energy	Utility	
10	Tri	Tran	Tri.Tran@austinenergy.com	Austin Energy	Utility	
11	Ruby	Chan	rchan@cenhud.com	Central Hudson	Utility	
12	Brian	Gutierrez	BGutierrez@CPSEnergy.com	CPS ENERGY	Utility	
13	Byron	Yakimow	byron.yakimow@asml.com	Cymer LLC (ASML Division)	Tool OEM	
14	Bob	Hay	hayrw@epb.net	EPB	Utility	
15	Angie	Henegar	ahenegar@epri.com	EPRI	Researcher	
16	Bill	Howe	bhowe@epri.com	EPRI	Researcher	
17	Mark	Stephens	mstephens@epri.com	EPRI	Researcher	
18	Scott	Bunton	sbunton@epri.com	EPRI	Researcher	
19	Annete	Mosley	amosley@epri.com	EPRI	Researcher	
20	Dean	Vanetten	dean.vanetten@globalfoundries.com	Global Foundries Fishkill	Semi Fab	
21	Tim	Makara	Tim.Makara@globalfoundries.com	Global Foundries Fishkill	Semi Fab	
22	Jacques	Pouliot	jacques.pouliot@globalfoundries.com	Global Foundries Malta	Semi Fab	
23	Susana	Redrovan	Susana.Redrovan@globalfoundries.com	Global Foundries Malta	Semi Fab	
24	Brian	Sweeney	brian.sweeney@globalfoundries.com	Global Foundries, Burlington	Semi Fab	
25	Greg	Rieder	gregory.rieder@globalfoundries.com	Global Foundries, Burlington	Semi Fab	
26	John	Fiske	John.Fiske@greenmountainpower.com	Green Mountain Power	Utility	
27	Phil	Sarikas	Philip.c.sarikas@intel.com	INTEL	Semi Fab	
28	Sean	Larsen	Sean.Larsen@lamresearch.com	Lam Research	Tool OEM	
29	Dan	Beck	DBeck@megafluidsystems.com	Mega Fluid Systems	OEM	
30	Clay	Burns	Clayton.Burns@nationalgrid.com	National Grid	Utility	
31	Lucian	Girlea	lucian.girlea@nikon.com	Nikon	Tool OEM	
32	Raymond	Sanchez	raymond.sanchez@nxp.com	NXP	Semi Fab	
33	David	Ezer	david@omniverter.com	Omniverter	OEM	
34	Stephane	Do	stephane@powerstandards.com	PSL	OEM	
35	Josh	Kagerbauer	jkagerbauer@ra.rockwell.com	Rockwell	OEM	
36	Cliff	Greenberg	cliff@safetymaven.co	Safety Maven Co	Consultant	
37	Derek	Grant	d.grant@samsung.com	Samsung	Semi Fab	
38	Terry	Ault	t.ault@samsung.com	Samsung	Semi Fab	
39	YS	Jang	ys.jang@samsung.com	Samsung Korea	Semi Fab	
40	Dan	Sabin	dan.sabin@se.com	Schneider-Electric	OEM	
41	Danie	Radu	daniel2.radu@se.com	Schneider-Electric	OEM	
42	Laura	Nguyen	lnguyen@semi.org	SEMI	Standards Rep	
43	Kevin	Lopez	Kevin.MendezLopez@srpnet.com	SRP	Utility	
44	Jose	Reynoso	j-reynoso@ti.com	TI	Semi Fab	
45	Supika	Mashiro	supika.mashiro@tel.com	Tokyo Electron	Tool OEM	
46	Marcos	Rodriguez	marcos.rodriguez@tuvsud.com	TUV	Testing Lab	
47	Melinda	Mendolla	melinda.mendolla@tuvsud.com	TUV	Testing Lab	
48	Ro-Hyun	Park	Ro-Hyun.Park@tuv-sud.kr	TUV	Testing Lab	

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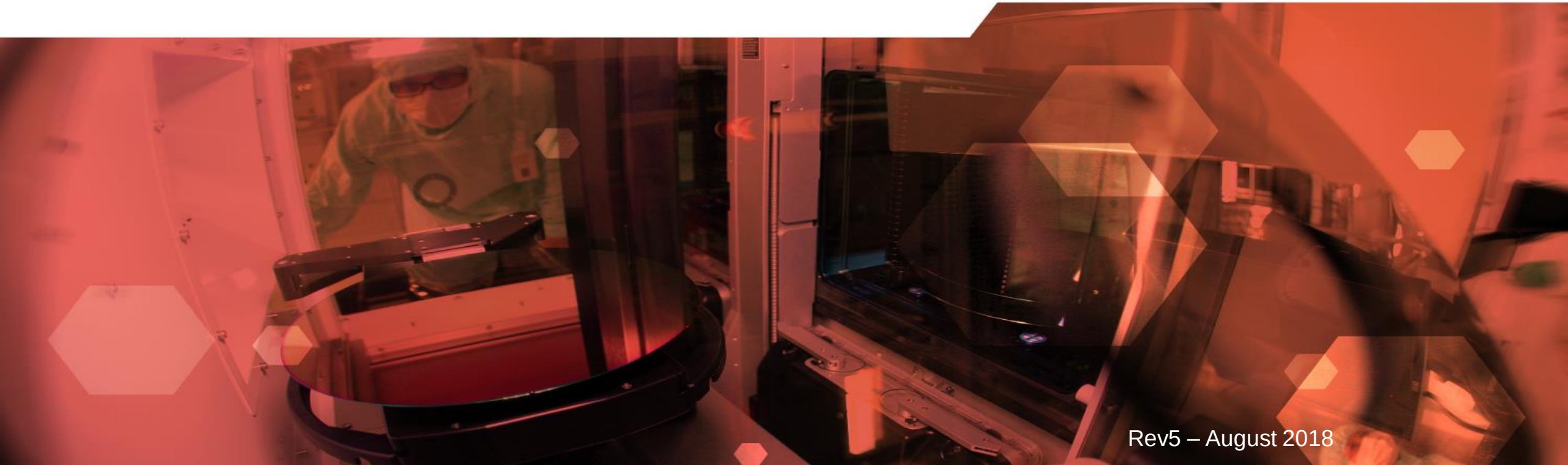
Required Meeting Elements



Rev5 – August 2018

SEMI Standards Program Membership Requirement

- To participate in a SEMI Standards meeting, a person must be a SEMI Standards Program Member
  (Regulations ¶ 1.5.2)
- This ensures that all meeting attendees have agreed to abide by the Regulations.
- If you are not a Program Member, please proceed to the Standards Information Desk and complete a SEMI Standards Program Membership application.
  - Also available at: www.semi.org/standardsmembership

Task Force Membership – Additional Details…

- To join the task force as a participating member, e-mail mstephens@epri.com and copy lnguyen@semi.org.
- Please note that Standards meetings are open to all, but you must be a SEMI Standards Program Member to attend. If you are not a Standards Member, please complete an application form: http://www.semi.org/en/standardsmembership.
- When you register, there are two options: *Program Member* or *Program & Technical Committee Membership*
- If you choose the "Program & Technical Committee Membership," option, you will receive specific information on any of the committees you sign up for, and be notified of letter ballots issued by the global committee when they are available for voting. **(Please note, you are required to vote on all ballots.** Otherwise, continue with "Program Membership")
- As a SEMI Standards Program Member you will receive general information about the SEMI International Standards Program, be able to participate in SEMI Standards meetings, and be able to vote on SEMI Standards ballots.

SEMI Standards Antitrust Reminder

- SEMI Standards activities are a coordinated effort among competitors in the semiconductor, FPD, PV and other related industries. Accordingly, every effort must be made to avoid even the appearance of impropriety.

- Do **NOT** discuss or participate in topical areas such as:
  - Pricing, purchasing, or marketing of either a company or of specific products
  - Industry or customer allocation, production, or capacity
  - Topics that might result in undue bias for or against one or more companies or products

If any participant has a question as to the legality of a proposed course of action, the matter should be immediately referred to SEMI Staff

Intellectual Property Reminder [1/2]

- When possible, SEMI Standards and Safety Guidelines should be written in such a way that patented technology, copyrighted items, or trademarks is not necessary to use, comply with, or implement the Standard or Safety Guideline.

- All Program Members are responsible to make known any
  - patented technology,
  - published patent applications,
  - copyrighted items, and
  - trademarks

  which may be required to use, comply with, or implement the Standard or Safety Guideline being developed.

Contact SEMI Staff if you are unable to publicly announce or discuss known intellectual property

Intellectual Property Reminder [2/2]

- Intentional concealment of any intellectual property, *while knowing it could have an effect on the document under development,* may render the intellectual property rights unenforceable in the future.
- See Section 16 of the *Regulations* for more information.

Contact SEMI Staff if you are unable to publicly announce or discuss known intellectual property

Sag Generator Technology and EPRI

"Tri-Mode" Power Disturbance Generators is Patented

"Tri-Mode" Power Disturbance Generator is Free Licensed Technology

EPRI Developed Technology Access is non-discriminatory

US 7,218,122 B1 May 15, 2007

First License to Omniverter

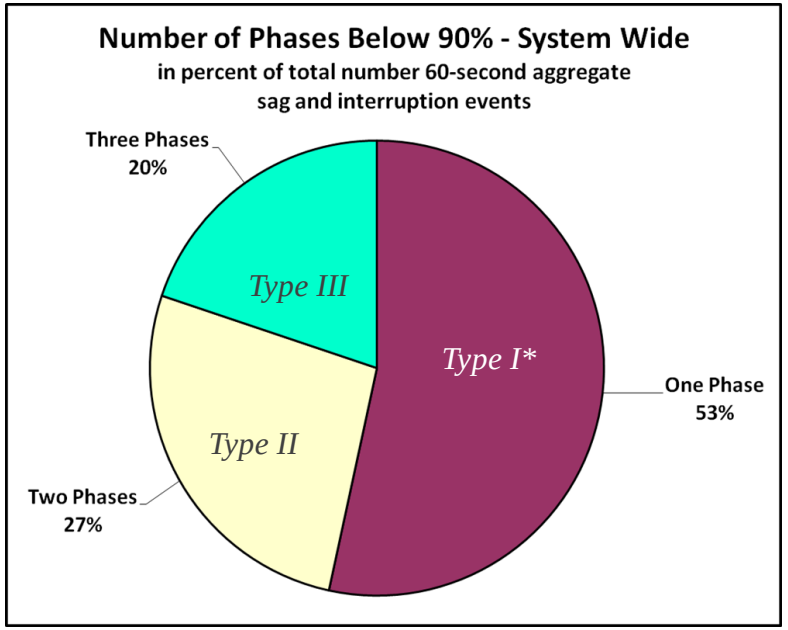
EPRI is a 501C3

SEMI International Effective Meeting Guidelines

- Ground rules
  - Leader or meeting facilitator should formally welcome any international guests
    - Invite participants to take part in the discussions
  - Treat each other with respect (no interrupting, talking over another, etc.)
  - Speak slowly and clearly to allow all participants to hear and understand
  - State your ideas concisely
  - Summarize your comments with a result or request
  - **Teleconference participants should mute their phone lines when not speaking**

Charter

- SEMI F47 requires voltage sag immunity levels for single-phase and two-phase voltage sag events.
  - Since the implementation of SEMI F47, the vulnerability of semiconductor manufacturing to voltage sags has improved significantly.
- Semiconductor manufacturers have realized that they continue to experience significant product loss and downtime due to three-phase voltage sag events.
- Three-phase voltage sag testing was not included in the SEMI F47 standard but make up to 20 percent of voltage sags according to recent studies.



Ref: EPRI TPQ-DPQ III Study, June 2014

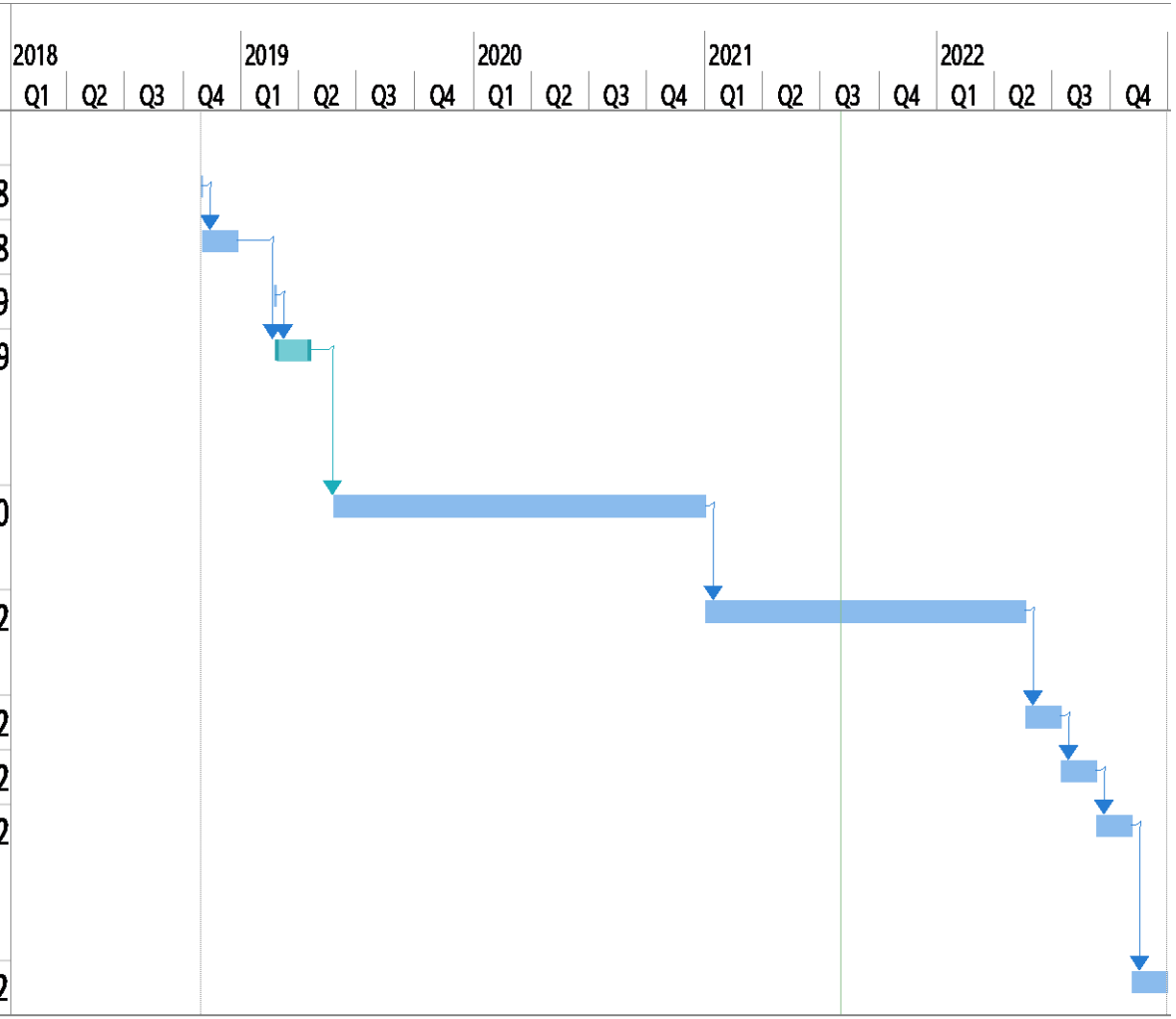
*CIGRE C4.110 WG and IEEE Std. 1668-2017 refer single, two, and three-phase voltage sag events as Type I, Type II, and Type III, respectively

Objectives

- The key objectives of this task force are to:
  - Review the characteristics of the power quality events that are still causing semiconductor plant process downtime
  - Take a new look at the sensitivities in the process equipment
  - To determine any potential adjustments to equipment design, facility design, utility systems, or standards to further reduce voltage sag induced losses by the semiconductor industry.
- This important work will:
  - Help utilities, semiconductor manufacturers, and tool equipment providers to better understand the tolerance and susceptibility of today's generation of semiconductor processing tools
  - Potentially lead to effective strategies to improve uptime and lower product losses due not only to single-phase (Type I) and two-phase (Type II) voltage sag events but for three-phase (Type III) events as well

SEMI F47 VS Task Force Schedule and Tasks*

ID	Task Name	Duration	Start	Finish
1				
2	SEMI Task Force Approval	1 day	Mon 10/29/18	Mon 10/29/18
3	Pre-Work: Task Force Membership Recruitmer	2 mons	Tue 10/30/18	Mon 12/24/18
4	Begin Work - TF Kick Off Webcast	1 day	Fri 2/22/19	Fri 2/22/19
5	Task 1: Review Existing SEMI F47-0706 Requirements with respect to three-phase voltage sags.	1.95 mons	Mon 2/25/19	Thu 4/18/19
6	Task 2: Baseline Voltage Sags Causing Downtime at Semiconductor Fabs	21 mons	Fri 5/24/19	Thu 12/31/20
7	Task 3: Baseline Type III Sag Immunity of Select Tools	18 mons	Fri 1/1/21	Thu 5/19/22
8	Task 4: Determine Viable Mitigation Strategies	2 mons	Fri 5/20/22	Thu 7/14/22
9	Task 5: Communicate Findings of Task Force	2 mons	Fri 7/15/22	Thu 9/8/22
10	Task 6: Provide Recommendations to update SEMI F47 standard accordingly to reflect findings of the Task Force.	2 mons	Fri 9/9/22	Thu 11/3/22
11	Task 7: EPRI Research Project Final Report	2 mons	Fri 11/4/22	Thu 12/29/22



**Latest Revision 8/3/2021*

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Related Ongoing SEMI VS TF Meetings and Activities

- SEMI Approved Voltage Sag Immunity Task Force Effort - November 6, 2018
- Mtg. 1: Task Force Kickoff WebEx - February 22, 2019
- Mtg. 2: Task 1 Working WebEx Meeting 1 - March 15, 2019
- Mtg. 3: Task 1 Working WebEx Meeting 2 - April 18, 2019
- SEMI F47 Voltage Sag Task Force Update, EPRI Grid Analytics and PQ Conference, St. Louis, MO, May 8, 2019
- Mtg. 4: Task 1 Report Out, Task 2 Begin – May 28, 2019
- SEMI F47 Voltage Sag Task Force Update, Guangzhou, China PQ Week 2019, June 18, 2019
- Mtg 5: SEMICON West July 8, 2019
- Mtg 6: Task 2 Progress Update, September 9, 2019
- Task 2 Breakout Meetings with Utilities and Fabs (WebEx 10/1, 11/15, At Fab Site: 12/09/2019)
- Mtg 7: TF Update WebEx Meeting/Reboot , 10/1/2020
- Mtg 8: TF Update Meeting Task 2 and Task 3, 12/1/2020
- Mtg 9: TF Planning Meeting, 1/14/2021
- Voltage Sags for Manufacturing Fabs Workshop, April 21, 2021
- Task 2 and 3 Breakout Meetings with Utilities and Fabs May 3-7
- Mtg 10: Progress Update, Tuesday, May 18, 2021 - 3:30 PM-5:00 PM (UTC-05:00) Eastern Time
- Mtg 11: Task 2 and 3 Progress Update, August 17,2021 - 3:30 PM-5:00 PM (UTC-05:00) Eastern Time
- Mtg 12: Task 2 and 3 Progress Update, October 7,2021 - 3:30 PM-5:00 PM (UTC-05:00) Eastern Time
- Semiconductor Tool Testing – Through Q2 2022

Task Force and Research Project Participants and Company Types (7/13/2021)

- ***Fabs***
  - GF Fishkill
  - GF Malta
  - GF Burlington
  - Intel
  - NXP
  - Samsung Austin
  - Samsung Korea
  - TI

- ***Tool OEMs***
  - AMAT
  - ASML
  - Cymer LLC (ASML Division)
  - Lam Research
  - Nikon
  - SEMI
  - Tokyo Electron

- ***Testing Entities***
  - TUV
  - Powerside
  - EPRI

- ***Consultants***
  - *Safety Maven Co*

- ***Utilities***
  - APS
  - ***Austin Energy***
  - ***Central Hudson***
  - CPS Energy
  - EPB
  - Green Mountain Power
  - ***National Grid***
  - ***Salt River Project***

  - Potential Additional Utility (Pending)

- ***Other OEMs***
  - *AMSC*
  - *Powerside*
  - *Omniverter*
  - *Rockwell*
  - *Schneider Electric*
  - *Mega Fluid Systems*

- ***Researchers***
  - *EPRI*

Related EPRI Research Project Funders

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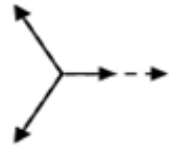
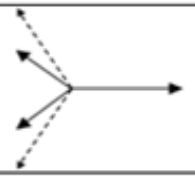
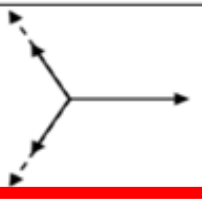
Review Task 2 Discussion: What is a Three-Phase Sag?

Scope Task 2: Baseline Voltage Sags Causing Downtime at Semiconductor Fabs.

- The objective of this task is to work with tool suppliers, semiconductor fabs and the electric utilities to base-line the power quality events that are causing the continued downtime.
- The more granular this data collection effort, the better the outcome of the analysis.
  - Data from Utility, Data from Fab, Data at Tool
- The Task Force looks to receive power quality data from participating tool suppliers, semiconductor fabs and utilities in order to perform analytics on the characteristics of the voltage sags along with correlations of tool downtime.
- The effort will culminate with a report that details the voltage sag type findings and correlations to tool shutdowns. The report will propose a target for Type III voltage sags immunity based on the correlated data. Locations of the sites where the power quality data is received, and the tool specifics (make/model information) will be presented generically in this task force report to protect confidentiality.
- STATUS:
  - Baseline Data from 4 Participant Fabs Received with Tool Shutdown info
  - Completed two Fab Visits in May
  - Characterizing all datasets and looking for commonalities in sag types and VS Shutdown Issues.

Understanding Standards and Required Test Vectors

IEEE 1668-2017
Covers All Types

Type Description	Example Test Vector Method	Applicable Published Standards	Notes
Recommended Type I		ITIC Curve SEMI F47 IEC 61000-4-11/34	
Recommended Type II (IEC Type 3c)		SEMI F47 IEC 61000-4-11/34	
Allowable Type II.A1 (IEC Type 3b)		SEMI F47 IEC 61000-4-11/34	
Allowable Type II.A2 (IEC Type 3d)		SEMI F47	IEC 61000-4-11 & 34 forbid this Test Scenario. CIGRE report recommends including.
Recommended Type III		None	

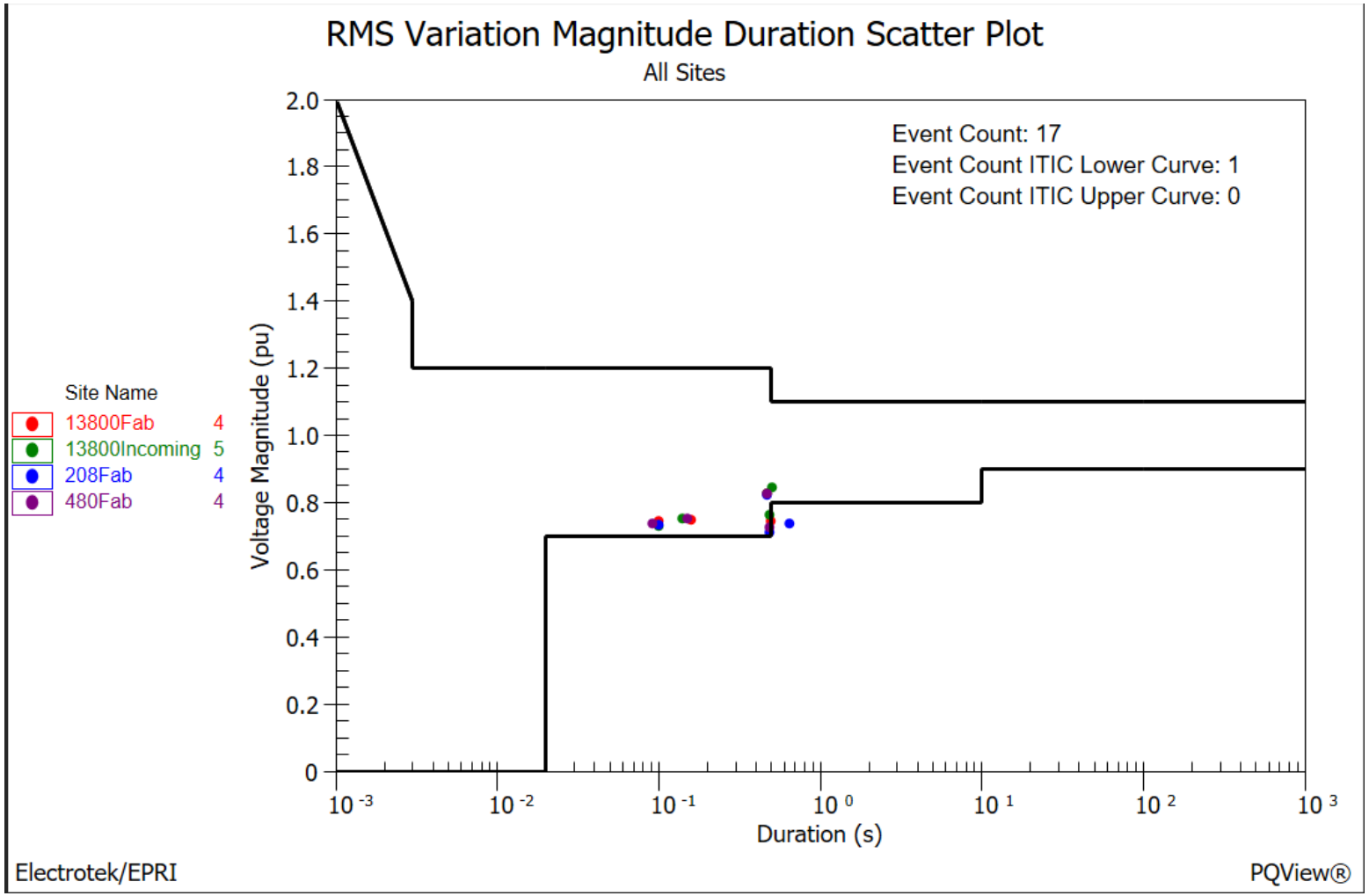
Fab “Z” Major Tool Downtime Events (Recap TF Meeting 7, *October 1, 2020)*

Event	Dur (Sec)	% Voltage	Date	Time of PQ Event	Tool Hours	Comments	Impact Notes
1	0.49	85%	3/8/17	2:07:15 PM	Y	CSV files for MV incoming, at FAB, 480 and 208V sub. included	34 tools;
2	0.08	75%	7/17/18	7:51:00 AM	Y	CSV files for MV incoming, at FAB, 480 and 208V sub. included	23 tools
3	0.32	66%	7/27/18	6:32:39 PM	Y	SEMI F47 Violation	202 tools
4	0.10	73%	11/10/18	11:05:06 AM	Y	CSV files for MV incoming, at FAB, 480 and 208V sub. included	31 tools (Includes 8 tools that were part of prober and tester tool sets), without these, same impact as event 2
5	0.06	89%	1/24/19	1:32:18 AM	Y	CSV files for MV incoming, at FAB, 480 and 208V sub. included	1 tools; 3 scrap;
6	0.46	74%	8/26/19	2:16:31 PM	Y	CSV files for MV incoming, at FAB, 480 and 208V sub. included	25 tools; 3 scraps; 5000 moves
7	0.07	72%	11/1/19	8:51:00 AM	N		55 tools* (total count for the day - multiple hits on 11/1/2019)

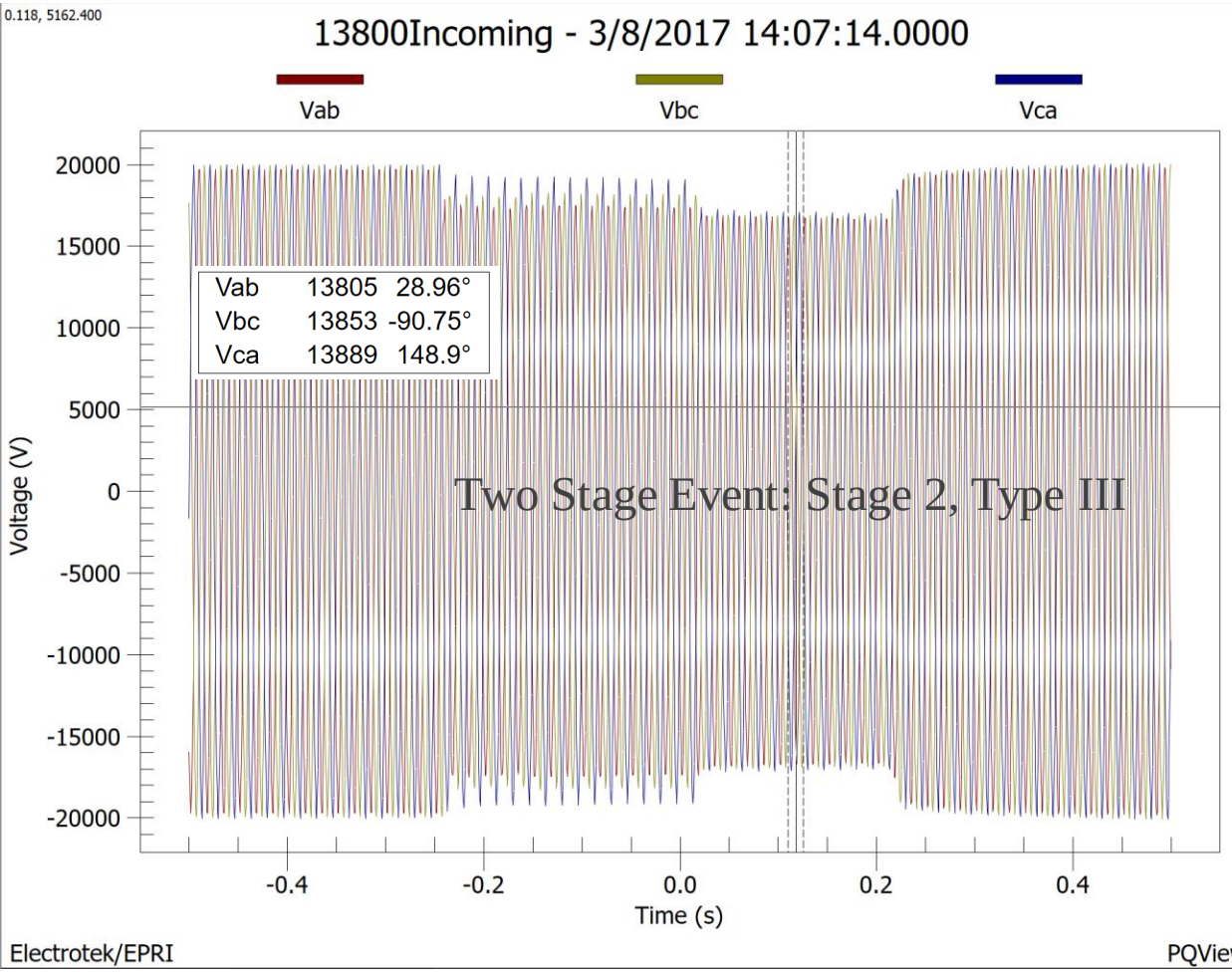
Imported into PQ View …

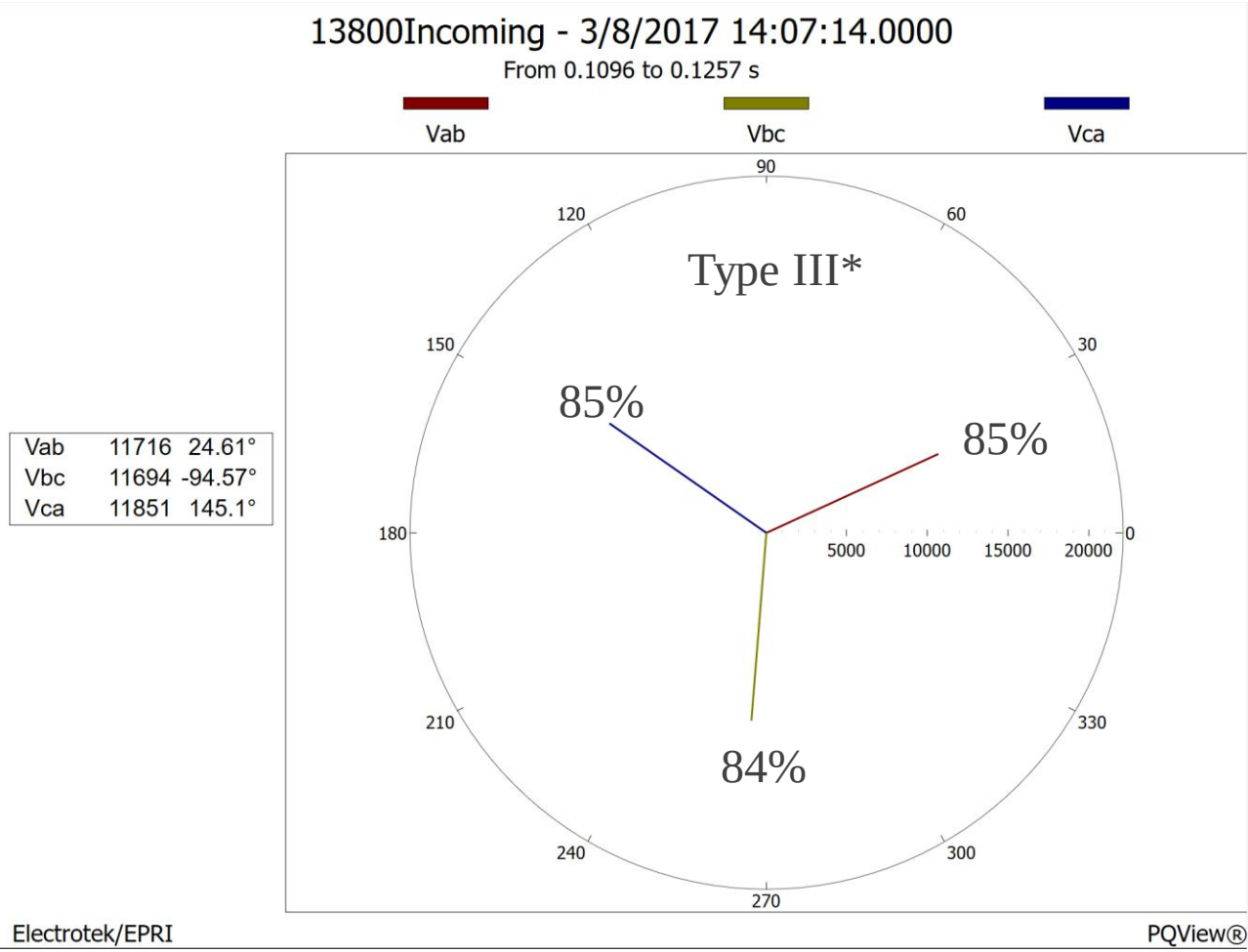
Monitor	Time Stamp	Phase	Mag (kV)	Mag (pu)	Dur (s)	Dur (cyc)
13800Incoming	3/8/2017 14:07:14.0000	AB	11.667	0.845	0.508	30.5
13800Fab	7/17/2018 10:41:16.0000	CA	10.305	0.747	0.158	9.5
13800Incoming	7/17/2018 10:41:16.0000	BC	10.365	0.751	0.142	8.5
208Fab	7/17/2018 10:41:16.0000	C	0.088	0.737	0.642	38.5
480Fab	7/17/2018 10:41:16.0000	C	0.208	0.750	0.150	9.0
13800Fab	11/10/2018 11:05:06.0000	BC	10.252	0.743	0.100	6.0
13800Incoming	11/10/2018 11:05:06.0000	BC	10.065	0.729	0.100	6.0
208Fab	11/10/2018 11:05:06.0000	C	0.088	0.734	0.100	6.0
480Fab	11/10/2018 11:05:06.0000	C	0.204	0.736	0.092	5.5
13800Fab	8/26/2019 14:16:31.0000	BC	10.242	0.742	0.492	29.5
13800Incoming	8/26/2019 14:16:31.0000	CA	10.533	0.763	0.483	29.0
208Fab	8/26/2019 14:16:31.0000	A	0.085	0.711	0.483	29.0
480Fab	8/26/2019 14:16:31.0000	A	0.201	0.725	0.483	29.0
13800Fab	11/1/2019 08:54:10.0000	AB	11.412	0.827	0.467	28.0
13800Incoming	11/1/2019 08:54:10.0000	AB	11.415	0.827	0.467	28.0
208Fab	11/1/2019 08:54:10.0000	B	0.099	0.822	0.467	28.0
480Fab	11/1/2019 08:54:10.0000	B	0.229	0.827	0.467	28.0

Fab Z: All Monitoring Locations Vs. SEMI F47 Major Downtime Events Only



Event	Dur (Sec)	% Voltage	Date	Time of PQ Event	Tool Hours	Comments	Impact Notes
1	0.49	85%	3/8/17	2:07:15 PM	Y	CSV files for MV incoming, at FAB, 480 and 208V sub. included	34 tools;

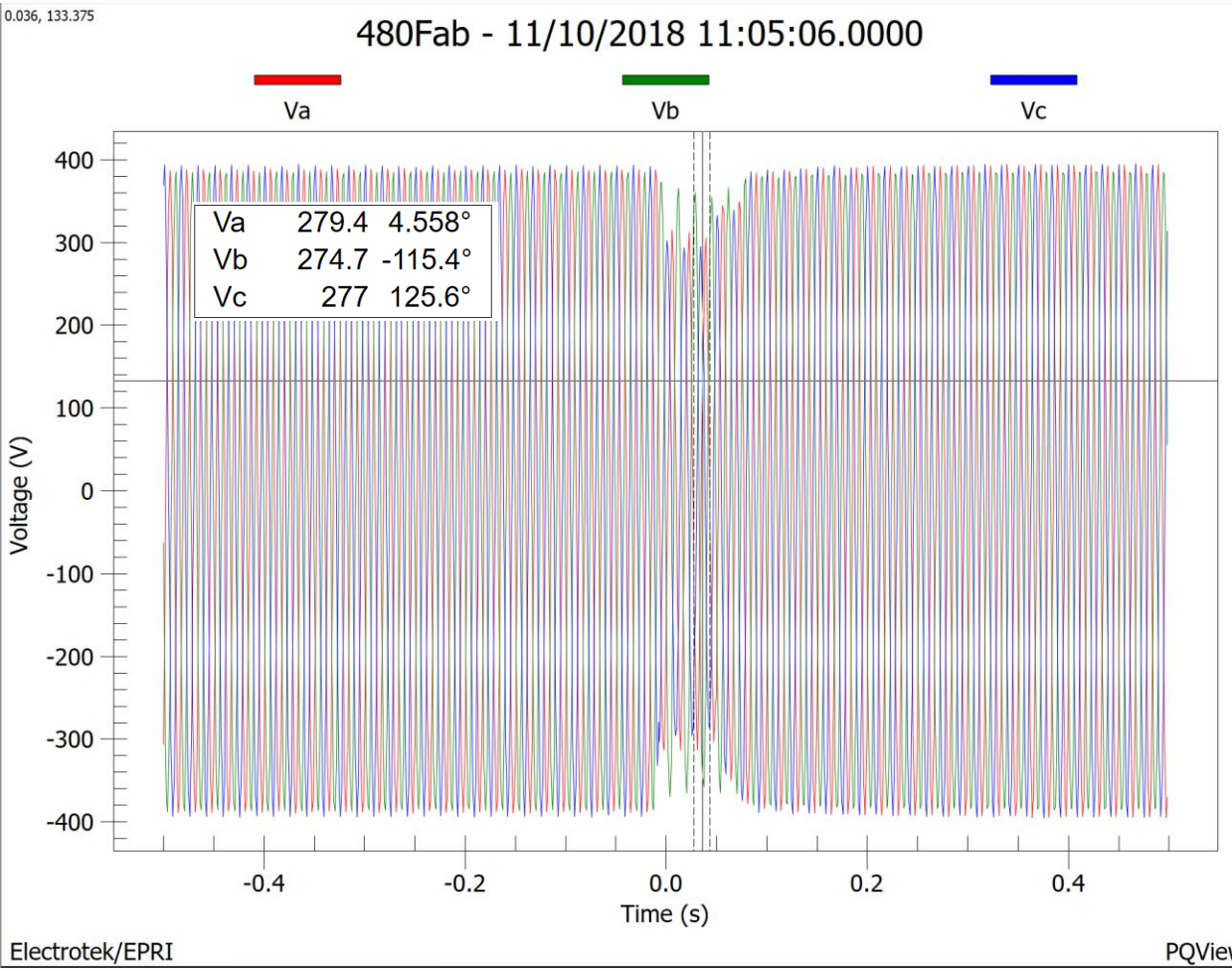


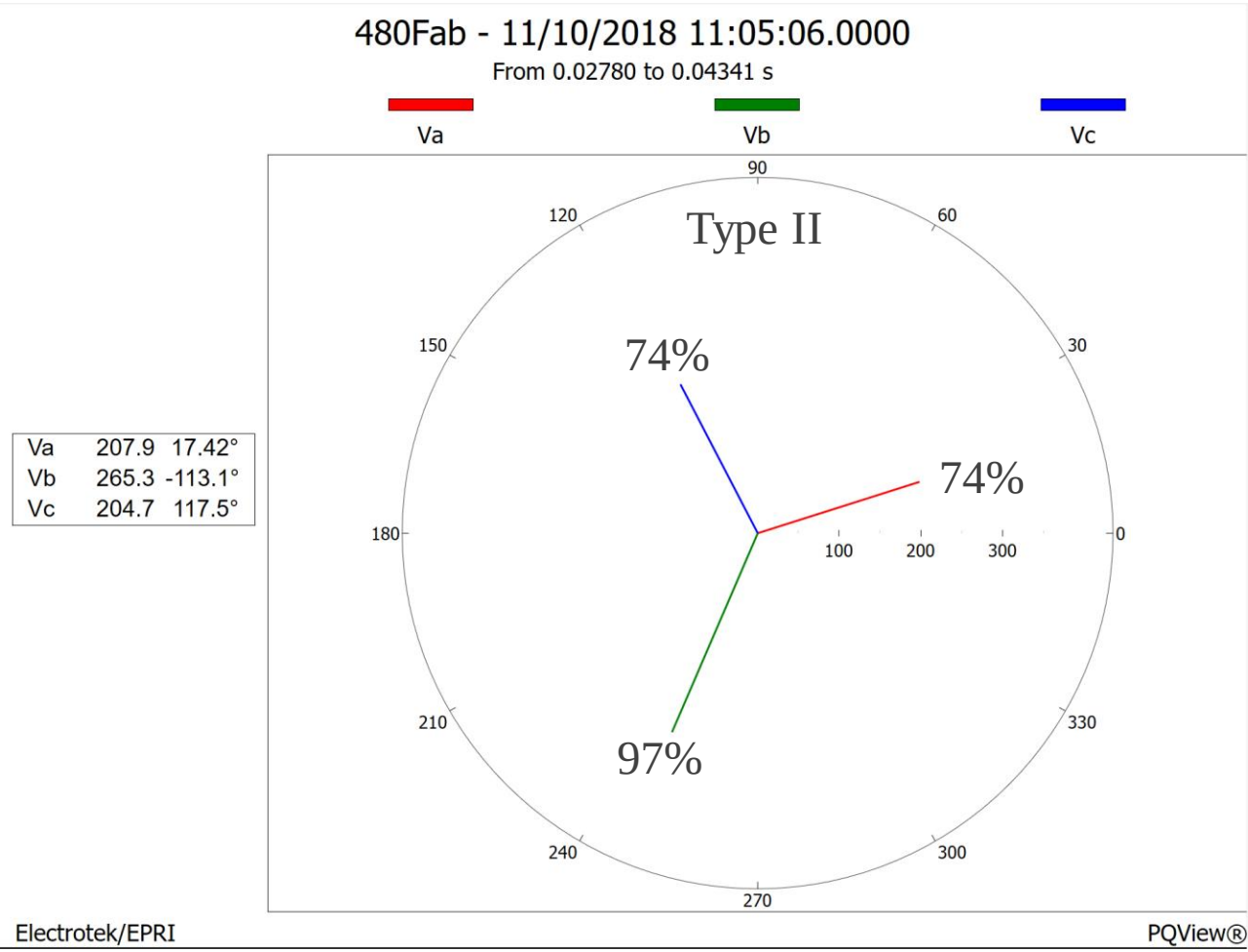


Note: Measurement is Phase-to-Phase in this Case

*Will result in Type III Event at 408/208.

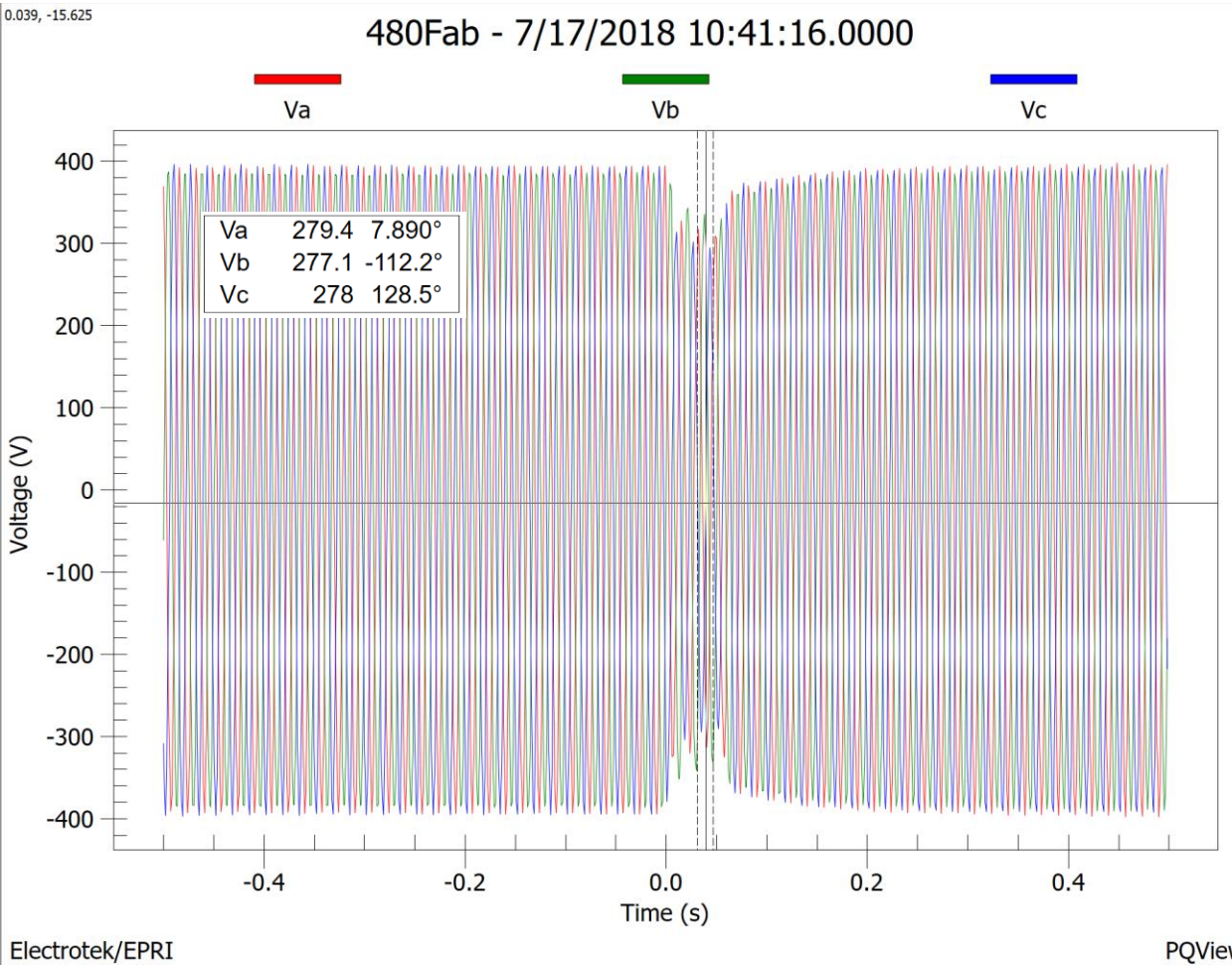
Event	Dur (Sec)	% Voltage	Date	Time of PQ Event	Tool Hours	Comments	Impact Notes
4	0.10	73%	11/10/18	11:05:06 AM	Y	CSV files for MV incoming, at FAB, 480 and 208V sub. included	31 tools



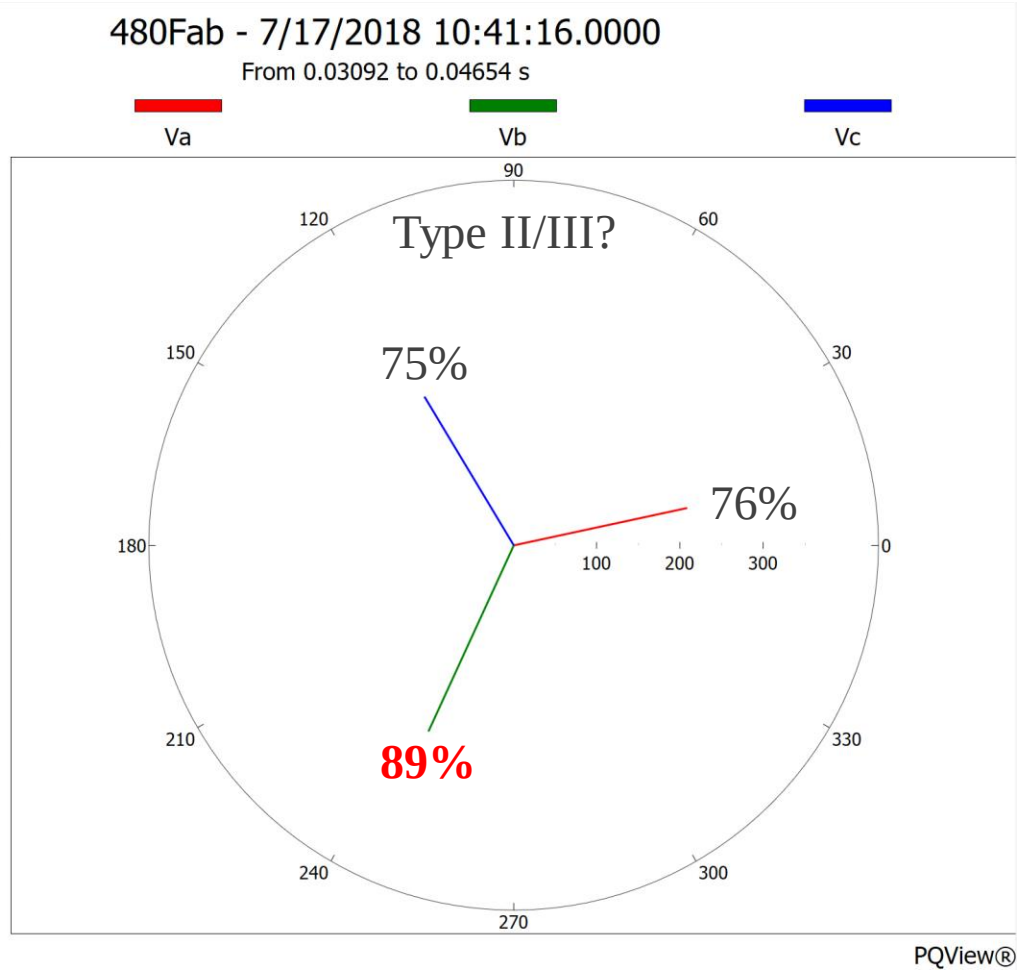


Note: Measurement is Phase-to-Neutral in this Case

Event	Dur (Sec)	% Voltage	Date	Time of PQ Event	Tool Hours	Comments	Impact Notes
2	0.08	75%	7/17/18	7:51:00 AM	Y	CSV files for MV incoming, at FAB, 480 and 208V sub. included	23 tools



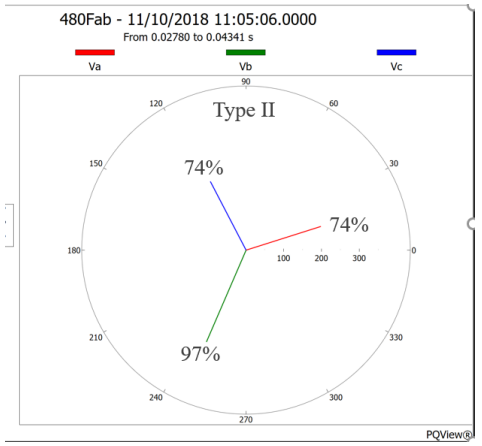
Va 213.7 12.07°
Vb 245.9 -114.6°
Vc 207.7 120.9°



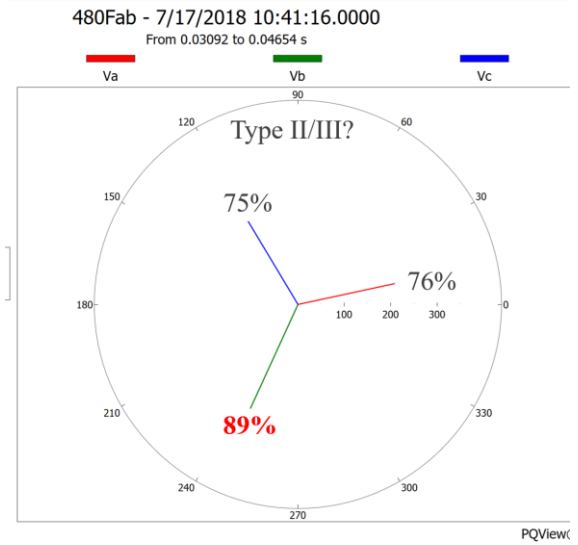
Note: Measurement is Phase-to-Neutral in this Case

Type III Discussion

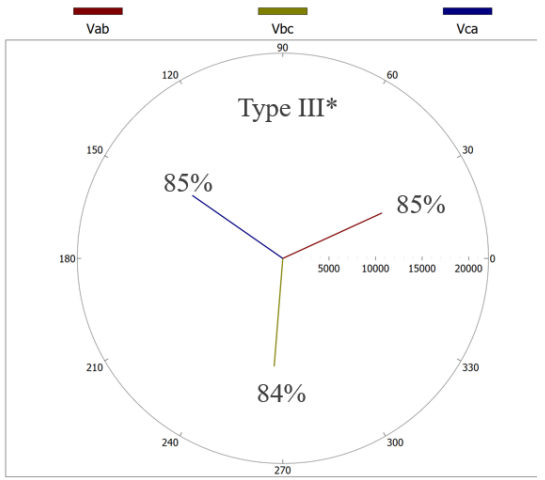
Type II



Type II.A3?
Type III Unbalanced?



Type III



Discussion Notes:

Review Task 3 Updates

Scope Task 3: Baseline Type III Sag Immunity of Select Tools

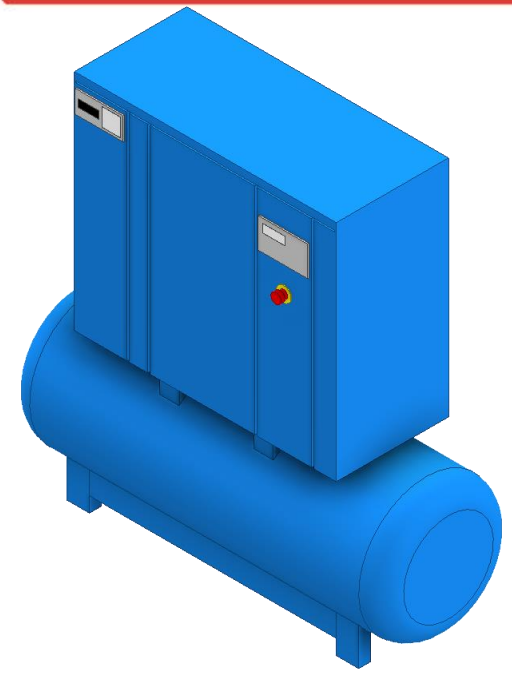
- This task will begin with reviewing existing tool specification with respect to three-phase voltage range tolerance.
  - Working with the tool manufacturers, it is expected that a subset of tools will be characterized against Type I, II, and III voltage sags in either the tool manufacturer locations or within semiconductor fabs themselves.
- The proposed Type III voltage sag immunity target from Task 2 will be evaluated as well.
- The outcome of this work will provide critical information with respect to the voltage sag robustness of the tool sets with respect to Type I, II, and III voltage sags and define gaps between the actual immunity level and the proposed target.
- When possible, mitigation strategies may be tested simultaneously against the defined voltage sag immunity targets. The report out for this effort will be presented generically with respect to tool specifics (make/model information) to protect confidentiality.
- STATUS:
  1. Received Tool Specific Shutdown Data from multiple participant fabs
  2. Currently Stratifying Data Sets to Determine Common Tool Platforms and shutdown issues
  3. EPRI and Fabs to coordinate VS testing of to Tool or related components with specific OEMs
  4. Test Locations
     1. Tool OEM Site
     2. In EPRI Lab
     3. Training Area Tool Sets at Fabs
     4. In Fabs

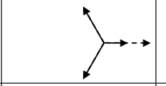
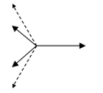
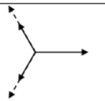
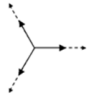
Recent SEMI F47 Testing

- EPRI tested a facility air compressor for SEMI F47 compliance.
- Customer has a 350HP compressor system shutting down in semiconductor fabrication facilities in Malaysia.
- Two-part project:
  - Test single-phase control panels at the customers manufacturing facility
    - Two panels were tested
      - One already tested by another entity as a stand-alone unit
        - » Customer requested verification the control panel meets SEMI-F47 when controlling the compressor
      - Second panel had never been tested
        - » A DC power supply had to be substituted to meet SEMI-F47 Compliance
    - Customer requested characterization testing of the panel to learn the actual voltage sag tolerance of the panel.
  - Test a smaller version of the same model soft starter in the compressor
    - Why not test at the manufacturer?: Starter and motor in the compressor too large for the 200A Sag Generator
    - All 5 Types of voltage sags to be conducted

Complete

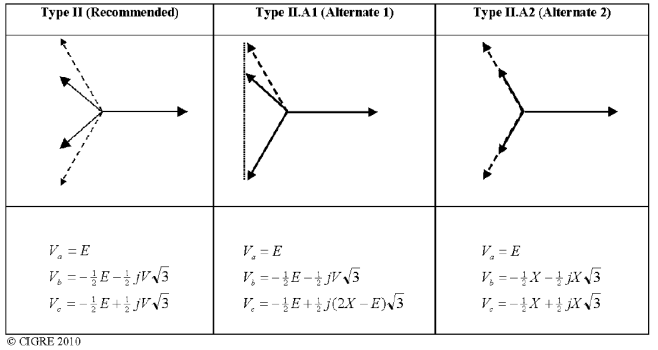
In Progress



Type description	Example test-vector method	Vector descriptions	Comments
Recommended Type I		$V_a = X$ $V_b = -\frac{1}{2}E - \frac{1}{2}jE\sqrt{3}$ $V_c = -\frac{1}{2}E + \frac{1}{2}jE\sqrt{3}$	This testing is most relevant to single-phase equipment or three-phase equipment with a neutral.
Recommended Type II (IEC Type 3c)		$V_a = E$ $V_b = -\frac{1}{2}E - \frac{1}{2}jV\sqrt{3}$ $V_c = -\frac{1}{2}E + \frac{1}{2}jV\sqrt{3}$	CIGRE C4.110 study indicated that this type of voltage sag makes up 82 to 91 percent of Type II events on HV and MV networks.[2]
Allowed Type II.A1 (IEC Type 3b)		$V_a = E$ $V_b = -\frac{1}{2}E - \frac{1}{2}jE\sqrt{3}$ $V_c = -\frac{1}{2}E + \frac{1}{2}j(2X - E)\sqrt{3}$	CIGRE C4.110 study indicated that this type of voltage sag makes up 9 to 18 percent of Type II events on HV and MV networks.[3]
Allowed Type II.A2 (IEC Type 3d)		$V_a = E$ $V_b = -\frac{1}{2}X - \frac{1}{2}jX\sqrt{3}$ $V_c = -\frac{1}{2}X + \frac{1}{2}jX\sqrt{3}$	This type of voltage sag can occur when two phases are shorted to ground at the same time.
Recommended Type III		$V_a = V$ $V_b = -\frac{1}{2}V - \frac{1}{2}jV\sqrt{3}$ $V_c = -\frac{1}{2}V + \frac{1}{2}jV\sqrt{3}$	This is a common type of voltage sag that occurs in 11% to 20% of the events recorded per EPRI[4] and CIGRE C4.110 studies.[5]

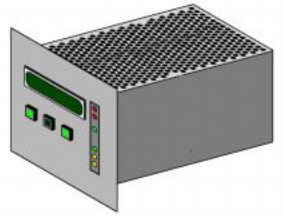
SEMI F47 Power Supply Testing last Month

- As a part of the research effort and Task Force work, EPRI recently tested high frequency and DC power supplies at a power supply manufacturer in September
- Voltage sag testing:
  - ½ and full load testing
  - Single-, two-, and three-phase tests
  - Testing all three two-phase test modes
  - Understand the voltage sag sensitivities of RF & DC power supplies with passive and active front ends



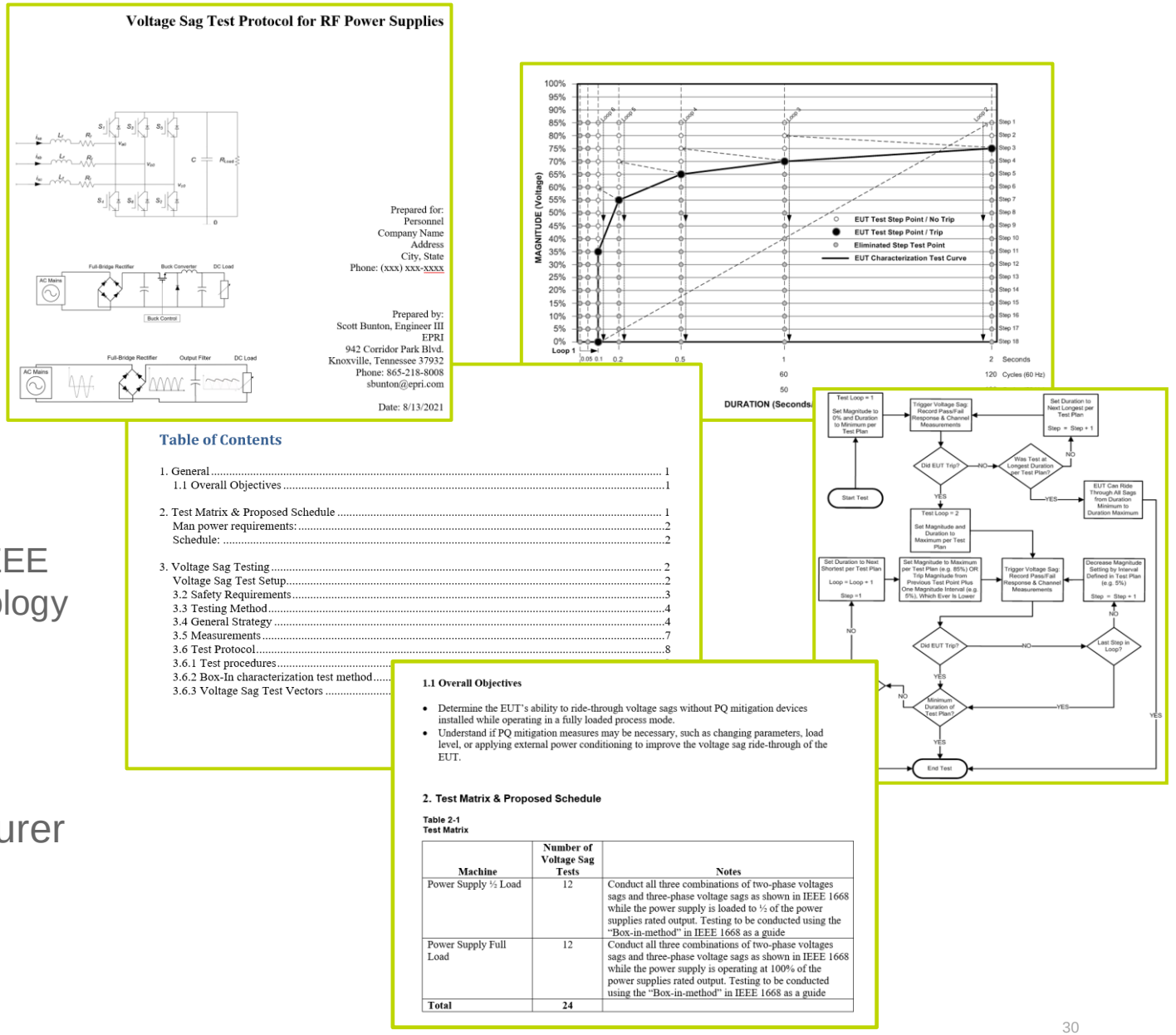
Passive Front-End

Active Front-End



Power Supply Testing Preparation and Objectives

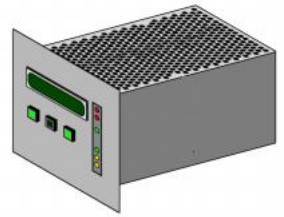
- Preparation
  - Test Protocol
  - Sag Generator verification and shipping
  - Team Coordination
- Site Testing
  - Travel
  - Two days on site
    - Test two power supplies using SEMI F47 & IEEE 1668-2017, Using IEEE 1668 Box-in-methodology
      - ½ and full load conditions
      - All 5 types of voltage sags
- Deliverable
  - Detailed test report for supporting manufacturer
  - Generic findings for Task Force



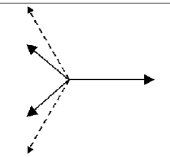
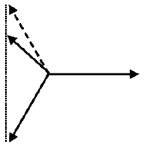
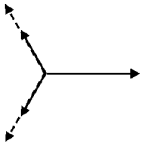
Low and High Frequency Power Supply Testing

- Testing at OEM was conducted September 8th and 9th
  - Tested Two Power supplies
    - 30kW DC Power Supply
      - Input Voltage: 400V three phase delta configuration
      - Output Voltage: 1000 volts
    - 6kW high frequency supply
      - Input Voltage: 480V three-phase delta configuration
      - Output Voltage: ?
      - Frequency: ?Mhz
  - Test Conditions: ½ and Full Load
    - Tested two power supplies using IEEE 1668-2017, Box-in-methodology
  - Voltage Sag Types:
    - Type I – Single Phase (6kW PS only)
    - Type II – Recommended Two-Phase
    - Type II A1 – Two-Phase Alternate 1
    - Type II A2– Two-Phase Alternate 2
    - Type III – Three-Phase

Passive Front-End

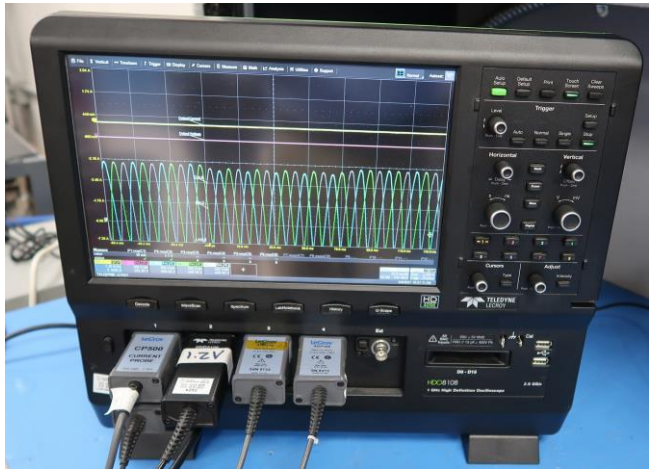


Active Front-End

Type II (Recommended)	Type II.A1 (Alternate 1)	Type II.A2 (Alternate 2)
		
$V_a = E$ $V_b = -\frac{1}{2}E - \frac{1}{2}jV\sqrt{3}$ $V_c = -\frac{1}{2}E + \frac{1}{2}jV\sqrt{3}$	$V_a = E$ $V_b = -\frac{1}{2}E - \frac{1}{2}jV\sqrt{3}$ $V_c = -\frac{1}{2}E + \frac{1}{2}j(2X - E)\sqrt{3}$	$V_a = E$ $V_b = -\frac{1}{2}X - \frac{1}{2}jX\sqrt{3}$ $V_c = -\frac{1}{2}X + \frac{1}{2}jX\sqrt{3}$

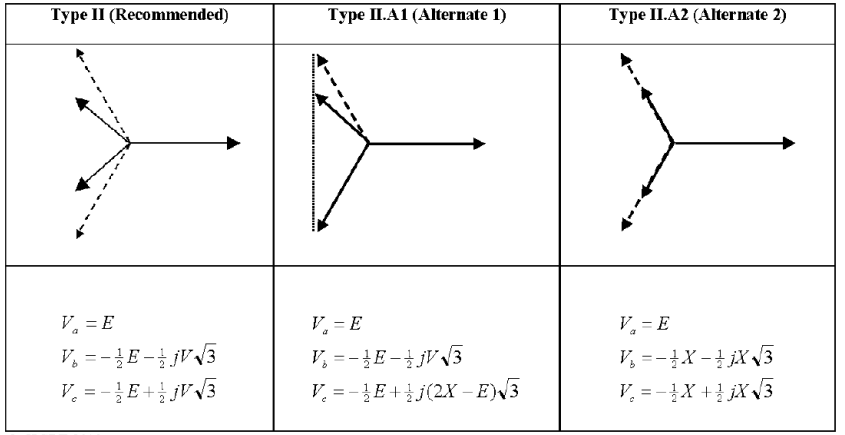
Data Analysis to Begin Soon

- EPRI's voltage sag generator was used to create voltage sags as well as collect data:
  - Over 500 voltage sags were conducted in two days
  - Voltage and current measured with onboard data acquisition
    - Line-to-neutral voltages
    - Line-to-line voltages
    - Phase currents
- Lecroy HD8108 Oscilloscope
  - Screen capture data only
    - Two line-to-line voltage measurements
    - Supply output voltage
    - Supply output current
- Hioki 3198
  - Power Analyzer
  - May be able to investigate phasor diagrams of select voltage sags



High Level Findings

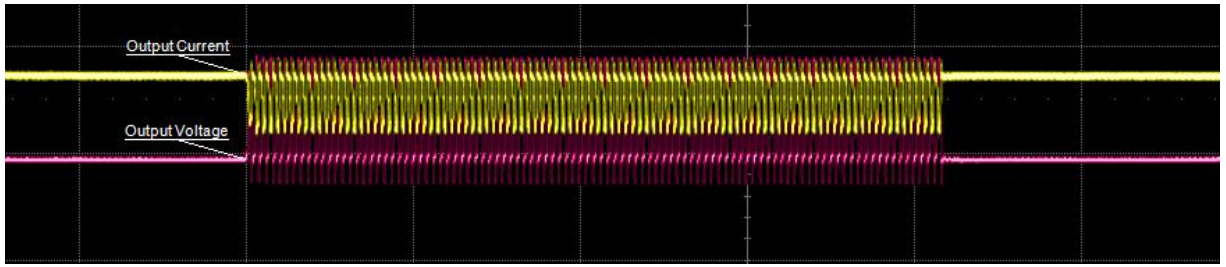
- All 5 types of voltage sags as per IEEE 1668 were applied at the input of each power supply at ½ and Full load
- High level findings from full load tests of each power supply (longest sag 60-cycles that caused the output to shut off only discussed here)
  - Type I Voltage sags
    - Not conducted on 30kW DC Supply
      - Ran out of time and the same AC levels achieved in Type II A2 test without tripping
    - 6kW HF power supply
      - Power supply continued to operate
  - Type II Voltage sags
    - 30kW DC Supply
      - 60cycle-60% trip (max duration cut off via firmware)
      - 58cycle - 38% P/S Rides Through
    - 6kW HF Supply
      - 60-cycle 30% (A-B, B-C or C-A)

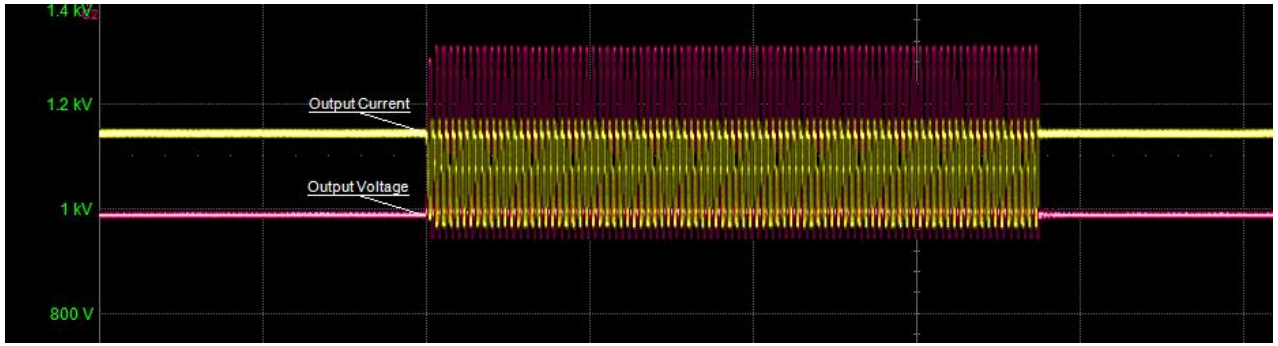


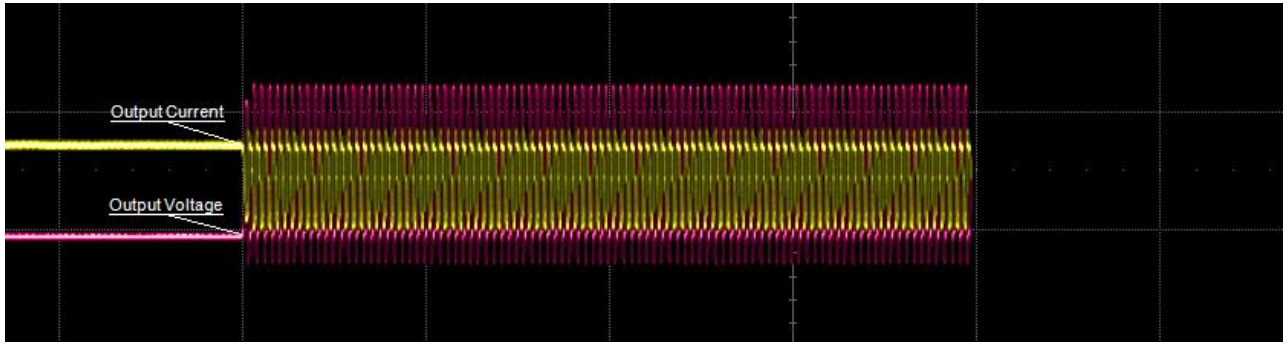
  - Type II.A1 Voltage Sags (KEY FINDING)
    - 30KW DC Power Supply
      - ***Did not trip for any sags and out to a 60-cycle interruption***
    - 6kW HF Supply
      - ***Did not trip for any sags and out to a 60-cycle interruption***
    - What are these Implications?
  - Type II.A2 Voltage Sags (worst case magnitude)
    - 30kW DC Supply
      - 58-cycles 70%
    - 6kW HF Supply
      - 60-cycles 50%
  - Type III
    - 30kW DC Supply
      - 60-cycles 85%
    - 6kW HF Supply
      - 60-cycles 70%

Define What Constitutes a Trip

- During the voltage sags the output may have deviated or shut off completely
- How much deviation may a process tolerate?
- Examples of the response of the DC power supply due to voltage sags are shown.
  - Less Ripple and recovered after sag
  - More ripple and recovered after sag
  - Ripple during sag and output shuts off and required a manual restart
- SMEs state that if a voltage sag occurs causing the magnet power supplies to shut off or deviate then the tool may lose control of the plasma, sourced by these supplies damaging the wafer and contaminating the chamber such that the process must be shut down to clean the particles from the chamber before wafer processing may resume.







Discussion of SEMI F-47 Compliance

- What are the requirements for components to pass SEMI F47?
- To meet the requirements of SEMI F47 the following must apply at the required test levels
  - Section 7.7 Test Conditions
    - Tested as per the EUT manufacturer
      - "approximate expected factory operation conditions"
      - Tested under maximum specified load
  - Section 7.8.2 Pass/Fail Criteria for Subsystems and Components
    - a) performs at full rated operation
    - b) Not perform at full operation but recovers without operator and/or host controller. Must not send error signal to controller when full operation is not achieved.
    - c) Not perform at full operation but recovers without operator and/or host controller. May send signal to controller when full rated operation is not achieved.

7.7 *Test Conditions* — The intent of this specification is to make reasonable efforts at determining that semiconductor processing equipment, subsystems, and components will be immune to typical voltage sags that occur at semiconductor factories. The EUT shall be tested for voltage sag immunity under conditions that will, according to the reasonable engineering judgment of the equipment manufacturer, approximate expected factory operating conditions. Engineering judgment shall take into account the following considerations:

- The EUT shall be tested in its most sensitive process states, as determined by the EUT manufacturer. For example, this may include robot movement, maximum power processing, most sensitive measurement, etc. If the sensitivity of the EUT to voltage sags may be affected by process recipe, the EUT shall be tested with a baseline recipe as defined in SEMI S2.
- Components, and subsystems when tested independently shall be tested under load (for example, DC power supplies and RF generators should be loaded at their expected levels, chillers and cryos should be thermally loaded, etc.)

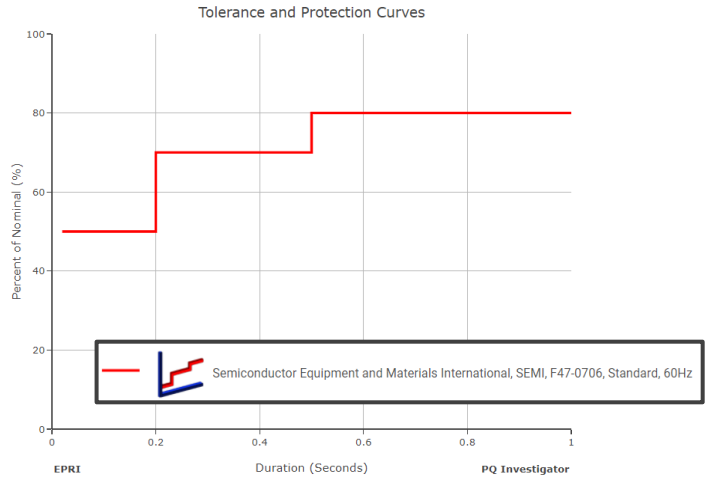
7.8.2 *Pass/Fail Criteria for Subsystems and Components* — Voltage sag immunity testing of subsystems and components should meet one of the following:

a) Performs at full rated operation

b) May not perform at full rated operation but recovers operation without operator and/or host controller intervention. Must not send error signals to the equipment host controller indicating when full rated operation is not achieved.

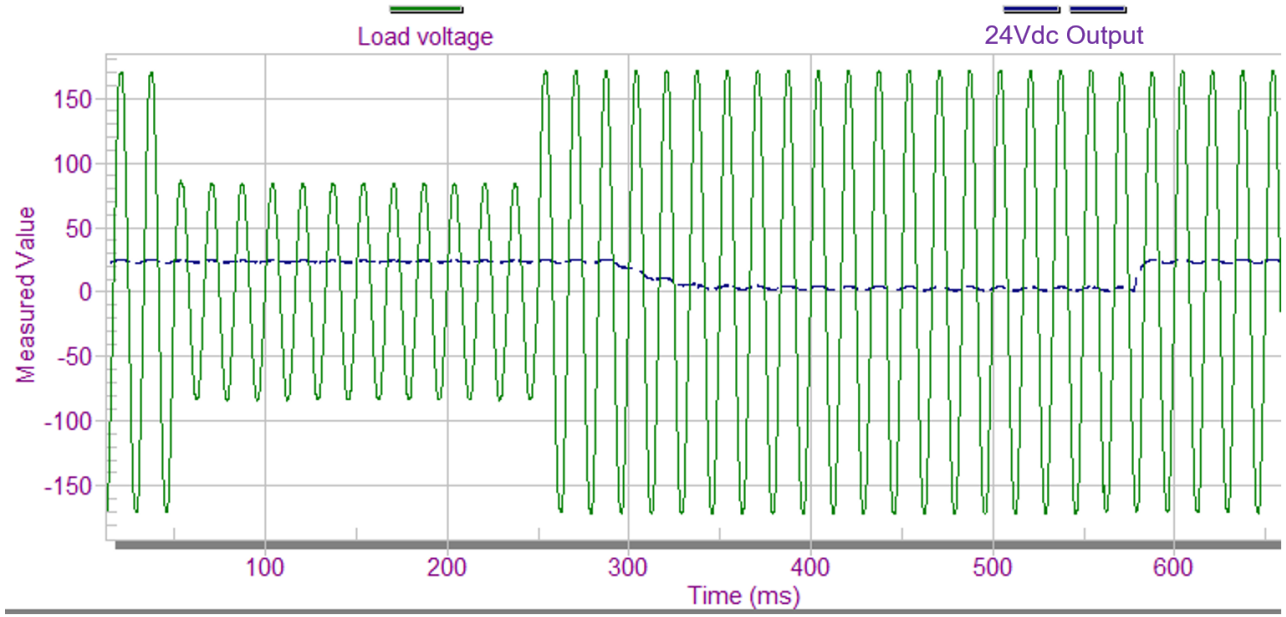
c) May not perform at full rated operation but recovers operation without operator and/or host controller intervention. May send signals to the equipment host controller indicating when full rated operation is not achieved.

Voltage Magnitude	Sag Duration	
	Time (sec)	Cycles at 60hz
80%	1	60
70%	0.5	30
50%	0.2	12



Question: Would the Response of the Following DC Supply be Considered SEMI F47 Compliant?

- The waveform shows the response of the output of a 24Vdc power supply just after a 12-cycle 50% voltage sag
  - Does this power supply meet the requirements of SEMI F47-2007?
    - **Yes (category B/C)**
  - If installed in process equipment would the equipment be SEMI F47 compliant?
    - **Maybe**
- **How do I find out how a SEMI F47 compliant component responds to SEMI F47 voltage sags? (See next slide)**



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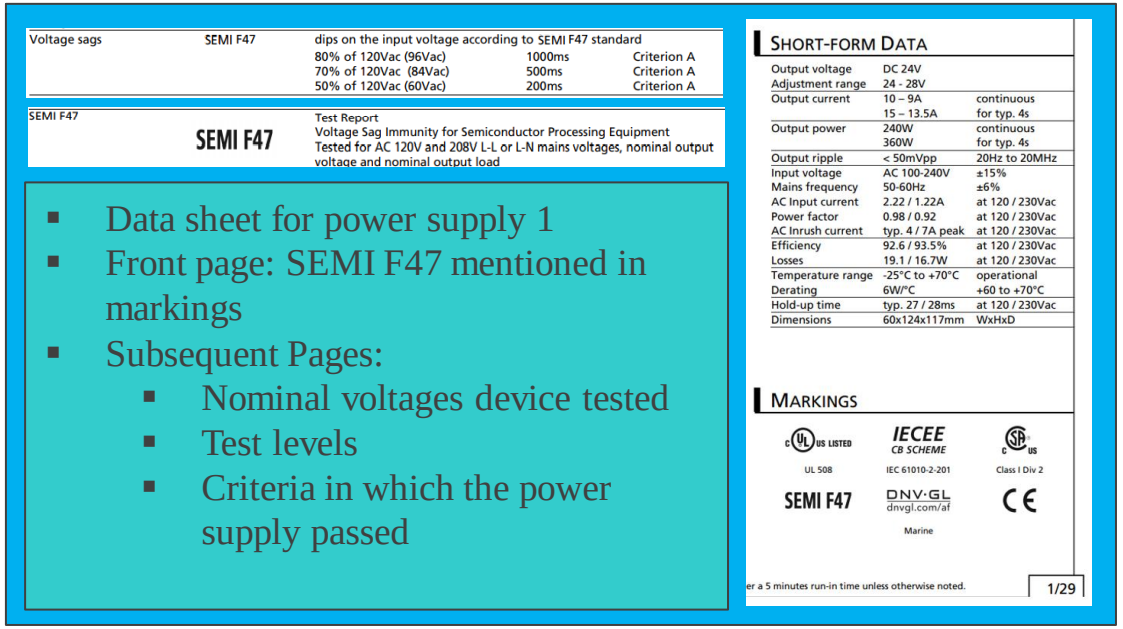
Example of SEMI F47 Compliant Component Spec Sheets

- Data sheets for 2 SEMI F47 compliant DC power supplies
- Differences:
  - Level of information provided
  - Ease of finding the information in the data sheet
- Consideration:
  - Request the compliance documentation for components when designing equipment to be SEMI F47 compliant.
- **Answer from previous slide**
  - If the data sheet does not specify how it was tested and criteria in which it passes SEMI F47, request the compliance document from the manufacturer



Voltage sags	SEMI F47	dips on the input voltage according to SEMI F47 standard		
		80% of 120Vac (96Vac)	1000ms	Criterion A
		70% of 120Vac (84Vac)	500ms	Criterion A
		50% of 120Vac (60Vac)	200ms	Criterion A
SEMI F47	SEMI F47	Test Report Voltage Sag Immunity for Semiconductor Processing Equipment Tested for AC 120V and 208V L-L or L-N mains voltages, nominal output voltage and nominal output load		

- Data sheet for power supply 1
- Front page: SEMI F47 mentioned in markings
- Subsequent Pages:
  - Nominal voltages device tested
  - Test levels
  - Criteria in which the power supply passed

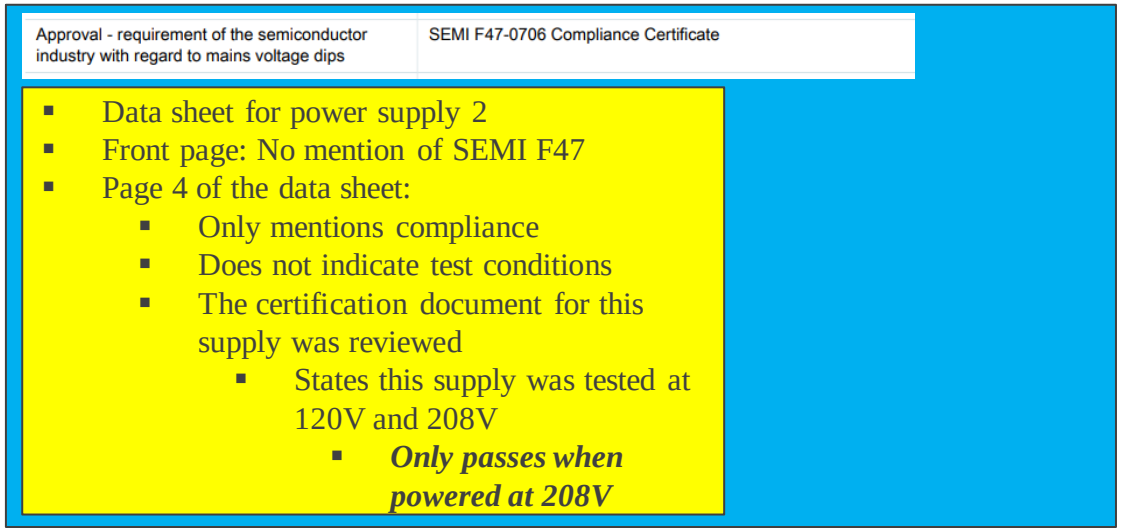
SHORT-FORM DATA

Output voltage	DC 24V	
Adjustment range	24 - 28V	
Output current	10 – 9A	continuous
	15 – 13.5A	for typ. 4s
Output power	240W	continuous
	360W	for typ. 4s
Output ripple	< 50mVpp	20Hz to 20MHz
Input voltage	AC 100-240V	±15%
Mains frequency	50-60Hz	±6%
AC Input current	2.22 / 1.22A	at 120 / 230Vac
Power factor	0.98 / 0.92	at 120 / 230Vac
AC Inrush current	typ. 4 / 7A peak	at 120 / 230Vac
Efficiency	92.6 / 93.5%	at 120 / 230Vac
Losses	19.1 / 16.7W	at 120 / 230Vac
Temperature range	-25°C to +70°C	operational
Derating	6W/°C	+60 to +70°C
Hold-up time	typ. 27 / 28ms	at 120 / 230Vac
Dimensions	60x124x117mm	WxHxD

MARKINGS

UL 508 IEC 61010-2-201 Class I Div 2 SEMI F47 Marine

er a 5 minutes run-in time unless otherwise noted. 1/29

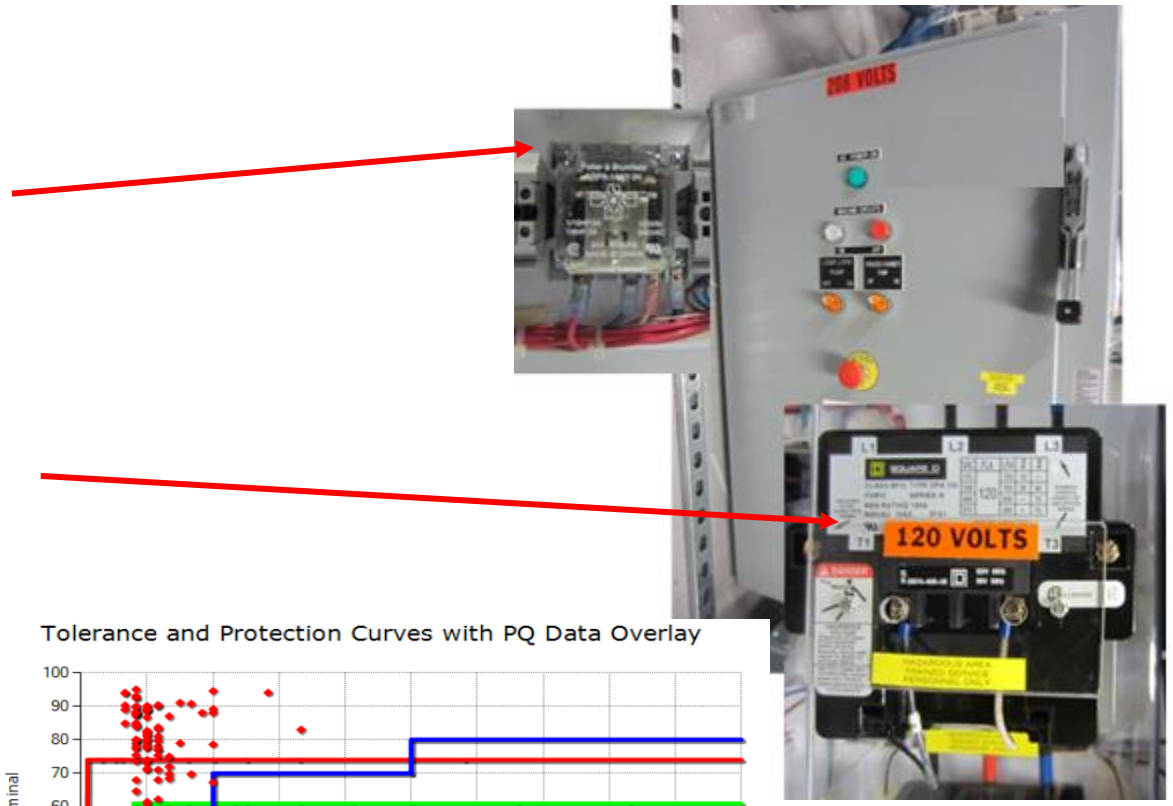


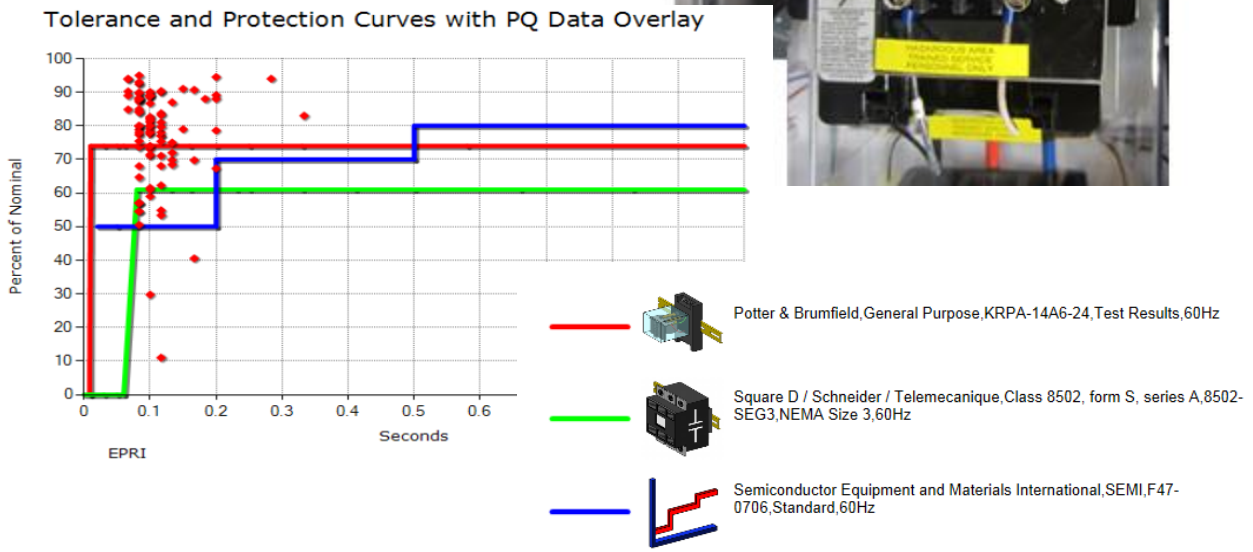
Approval - requirement of the semiconductor industry with regard to mains voltage dips	SEMI F47-0706 Compliance Certificate

- Data sheet for power supply 2
- Front page: No mention of SEMI F47
- Page 4 of the data sheet:
  - Only mentions compliance
  - Does not indicate test conditions
  - The certification document for this supply was reviewed
    - States this supply was tested at 120V and 208V
      - ***Only passes when powered at 208V***

300mm Fab A-Box Sensitivities to Voltage Sags (2015)

- *Utilized in a 300mm fab in 79 locations*
- Inside the A-box there is an Ice Cube relay with a 24Vac coil.
- These relays are known to be sensitive to short duration voltage sags.
  - 1cycle 73%
- The contact from the Ice Cube relay supplies power for a Contactor that permits power to flow to the Metrology tool.
  - 5 cycles 60%
- The voltage sag ridethrough curve below shows the voltage sag ridethrough curves for the Ice cube relay and the Square D contactor with some voltage sag event data experienced at the site from 2009-2012





Technical Project Steps (Task 2 and Task 3)
(Some portions will be confidential to Fabs and Tool OEMS)

1. Continue to gather PQ and Tool Downtime Data from Fabs
2. Refine information to confidentially understand which specific equipment is still an issue
3. NDAs with Fabs/OEMS are required
4. Visits to FABs/Tool OEMS to conduct on-site review and testing of tool sets
5. General Progress Reports to Task Force

Update: Recent Fab Inquiry – Potential Test Bed for 300mm Tools

- A large 300mm semiconductor fab has reached out to EPRI and asked for assistance in testing multiple tools that are certified as compliant to SEMI F47 but are shutting down above the curve.
- EPRI is working with Fab to determine if generic test results can be shared with the Task Force.
  - NDA in process
- This could be a significant test bed to understand the issues with the current problem 300mm tools.

Update: Beginning to work with Tool Suppliers

- TF has gathered some common Tool Makes and Models that are known to be presenting voltage sag issues still.
- TF is Working with Fabs leading to approach OEMs and encourage participation.
  - Still Actively Seeking input from Fabs on list of tools to include.
- Task Force will be working with SEMI to issue a “Call for Participation” in the Task 3 Voltage Sag Testing in this effort.
- Task Force is currently coordinating with Tool Suppliers and starting the process
  - Lining up 1Q2022 tests to be done at OEM Locations

Next Meeting

- December 16, 2021: 3:30 TO 5:00 pm

Action Items

Action Item Review

- Open Items
  - –
- New Items
  - – TF Leader
    - Send out post meeting presentation with notes, recording of meeting
    - Send out through Secure Mail
    - Send out invite to December meeting
  - – New Participants
    - Reach out to Laura copy Mark with request for joining