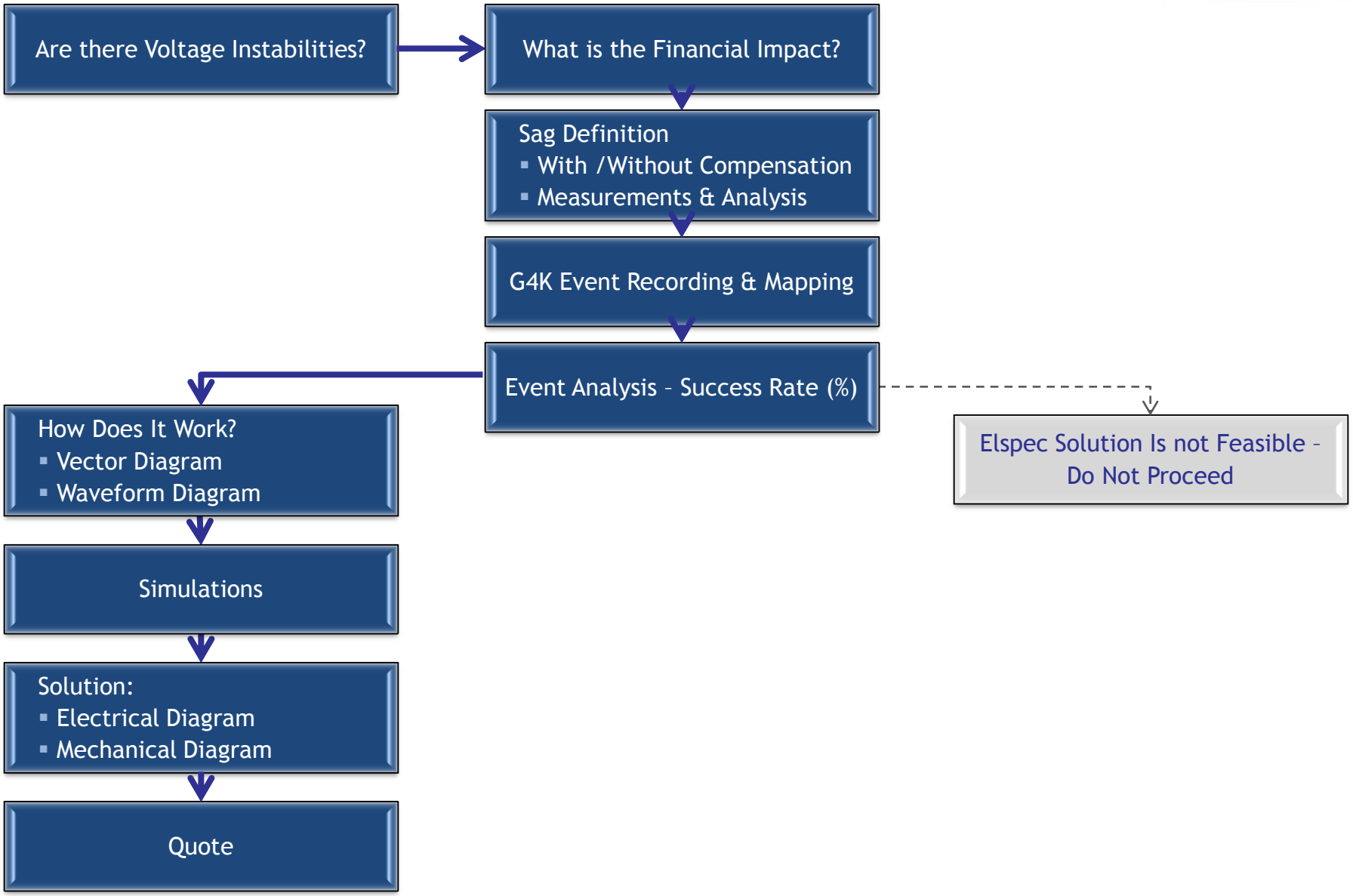
EQUALIZER TURBO

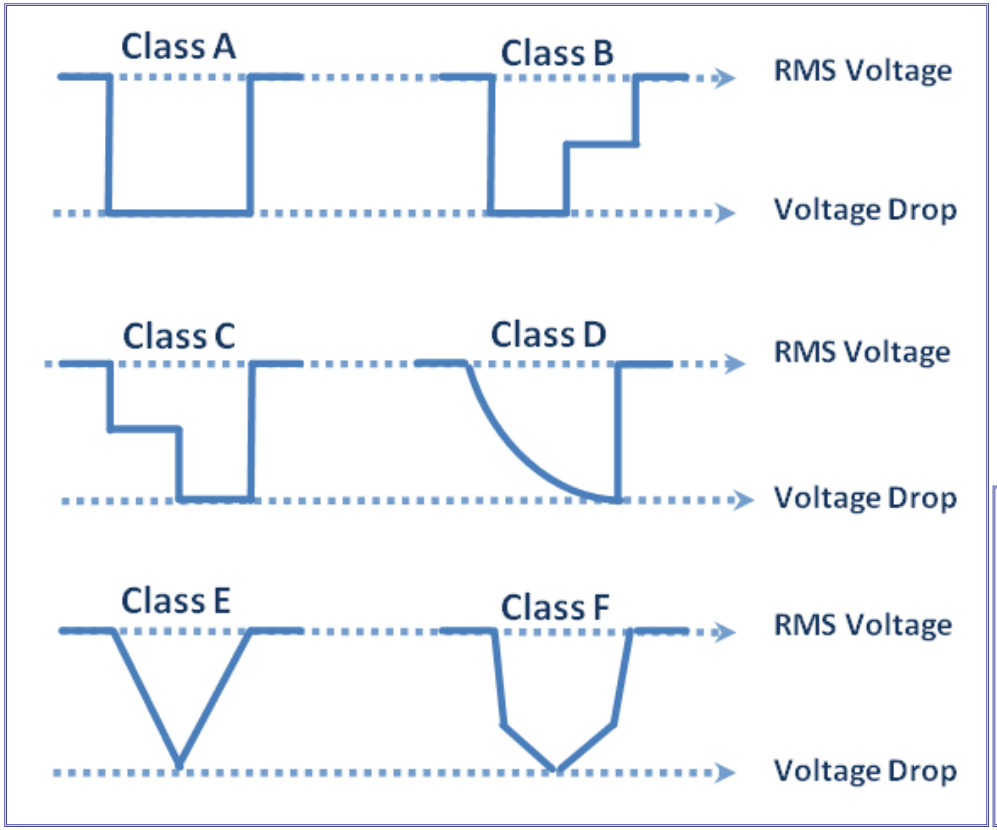
VOLTAGE INSTABILITIES

Problem Identification, Decision Process, Simulations & Proposals

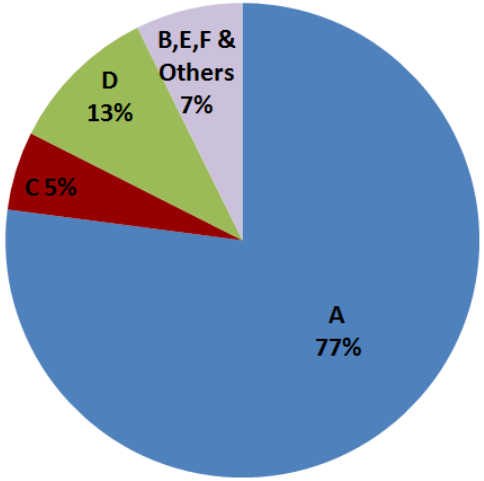
ELSPEC'S APPROACH



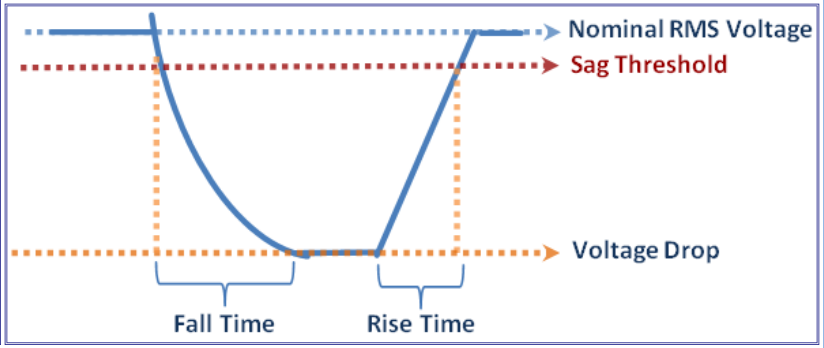
SAG DEFINITION - MEASUREMENTS & ANALYSIS



Sag Classifications

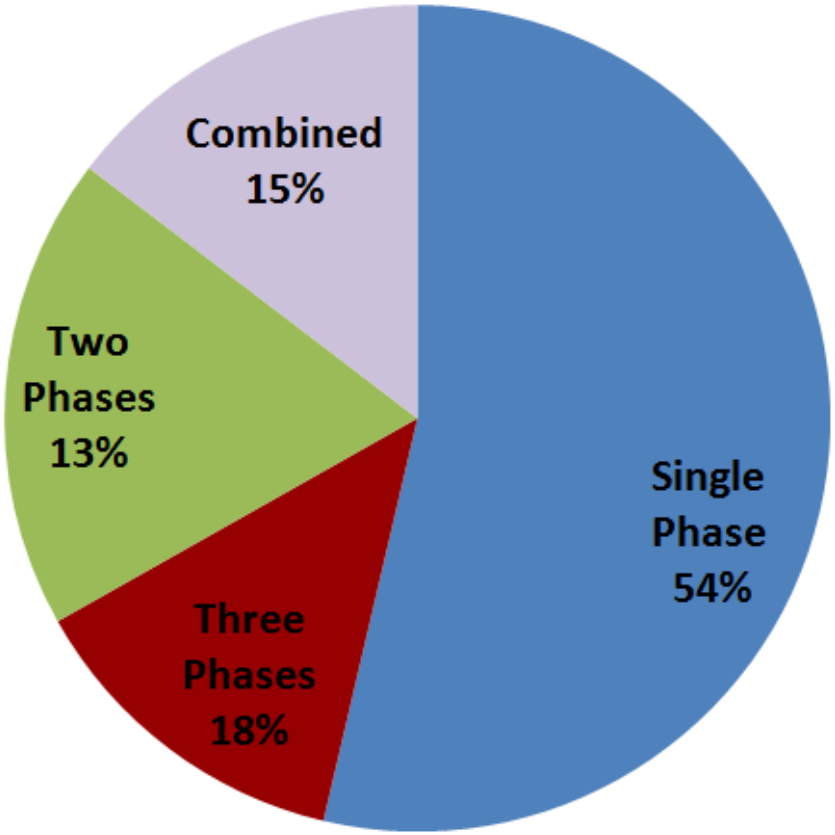


Sag Classes



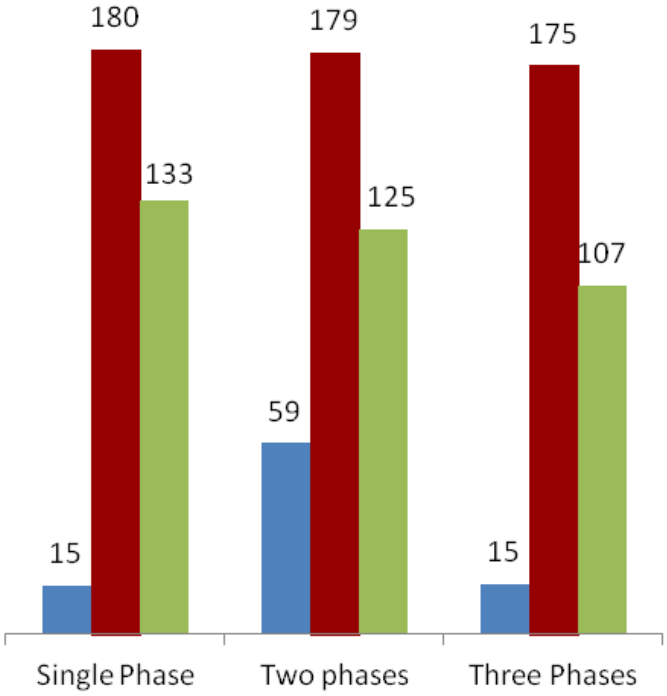
RMS Voltage (Single Phase)
Fall Time & Rise Time

SAG DEFINITION - MEASUREMENTS & ANALYSIS



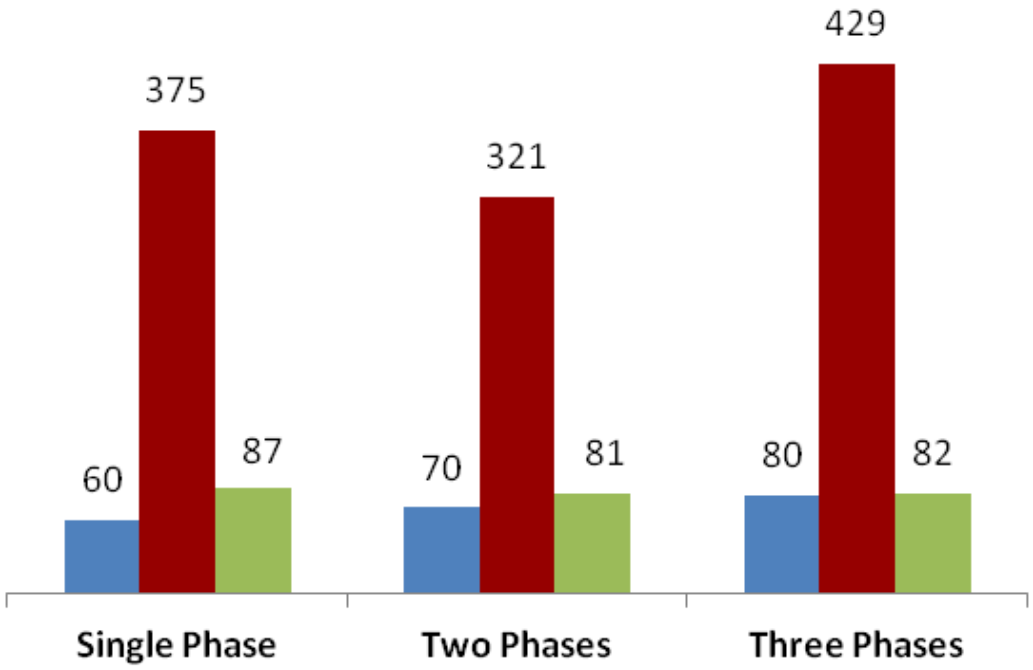
Sag Types

SAG DEFINITION - MEASUREMENTS & ANALYSIS



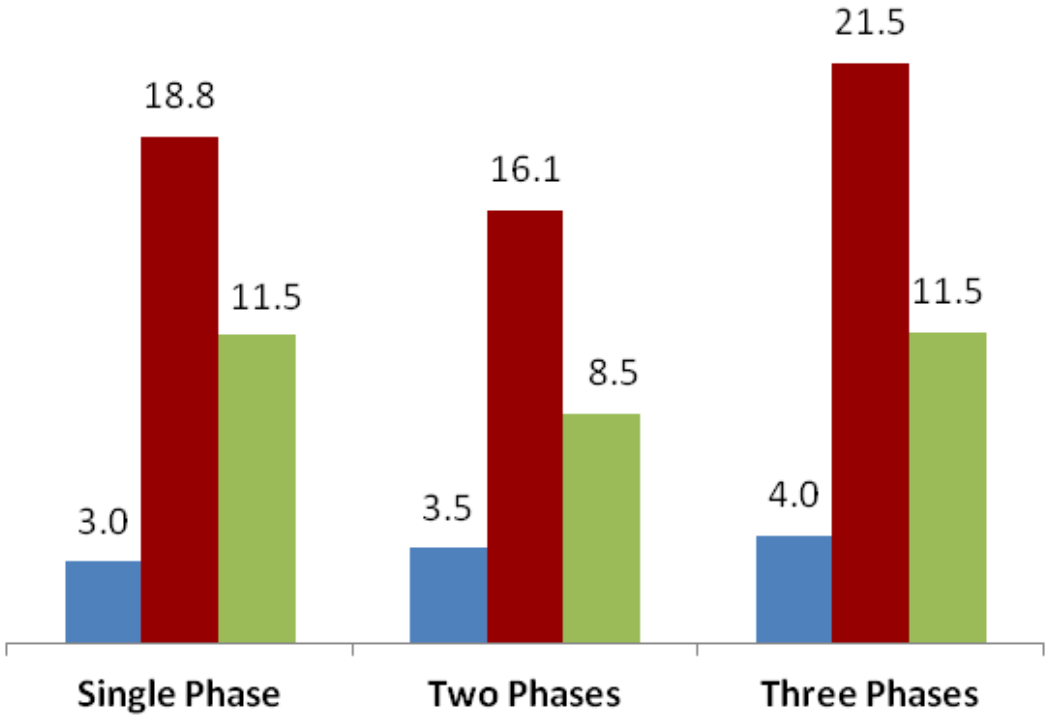
Min/Max Average Voltage During a Sag

SAG DEFINITION - MEASUREMENTS & ANALYSIS



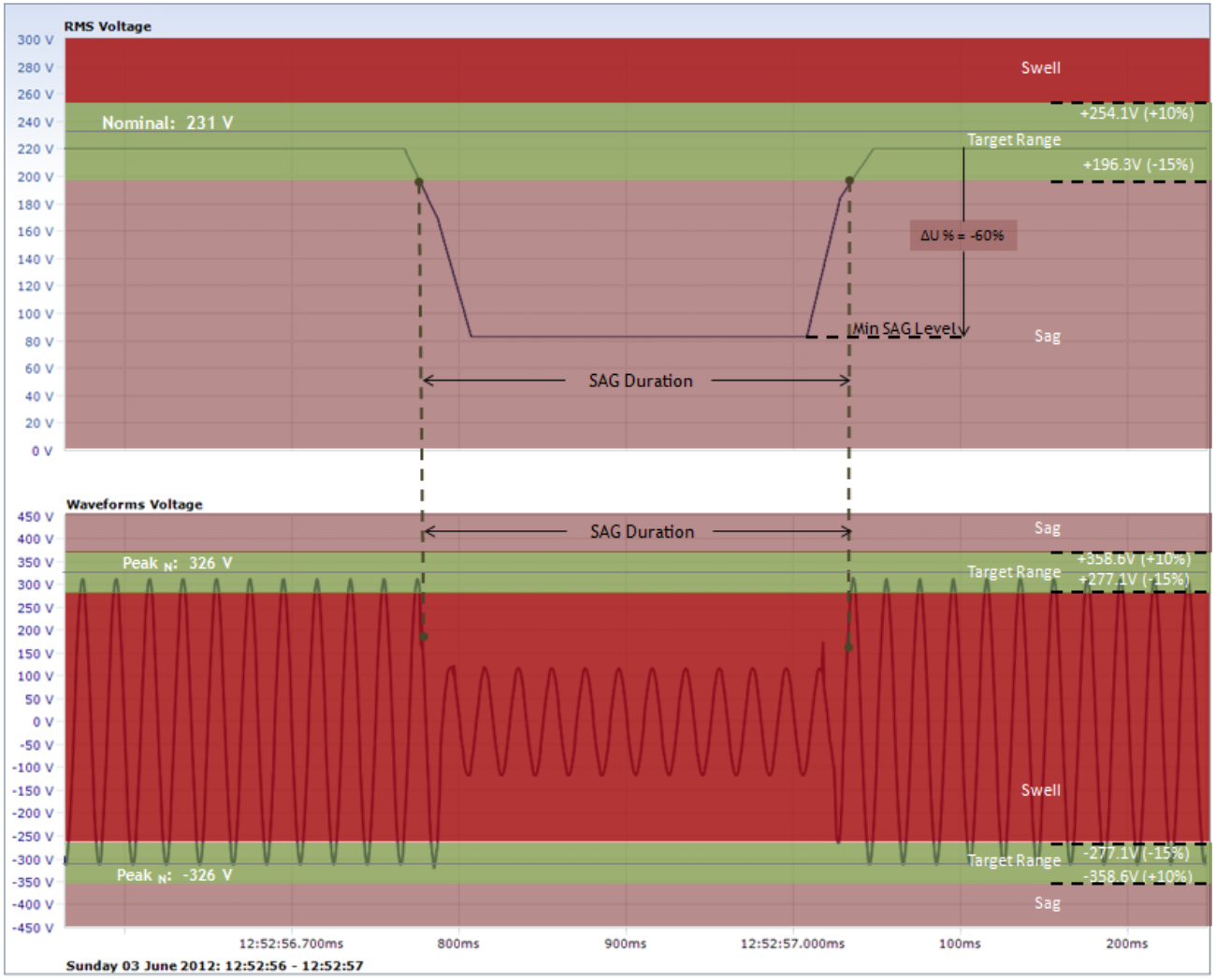
Min/Max
Average Voltage Sag
Duration (msec)

SAG DEFINITION - MEASUREMENTS & ANALYSIS

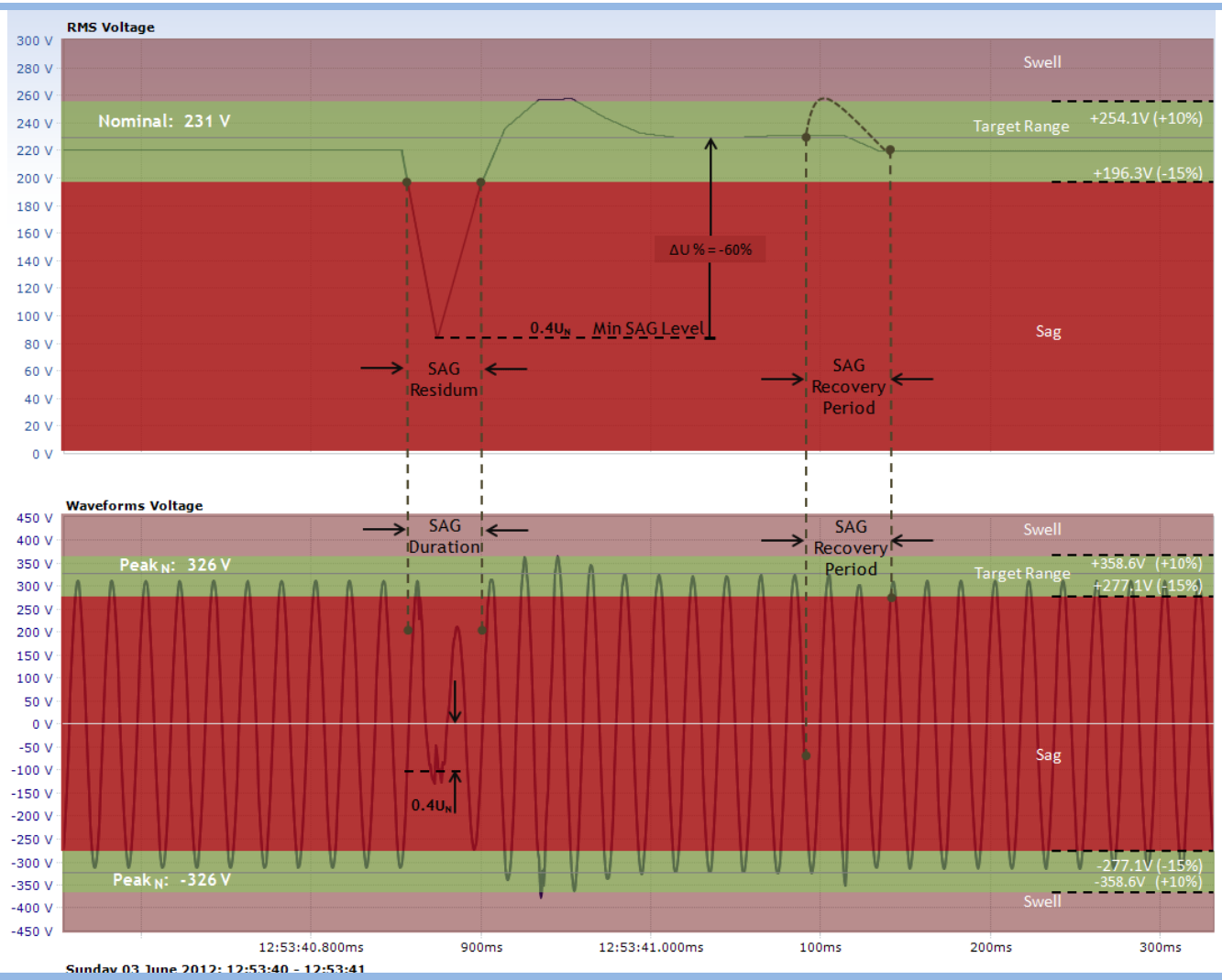


Min/Max
Average Voltage Sag
Duration (Cycle) @50Hz

SAG DEFINITION - WITHOUT COMPENSATION



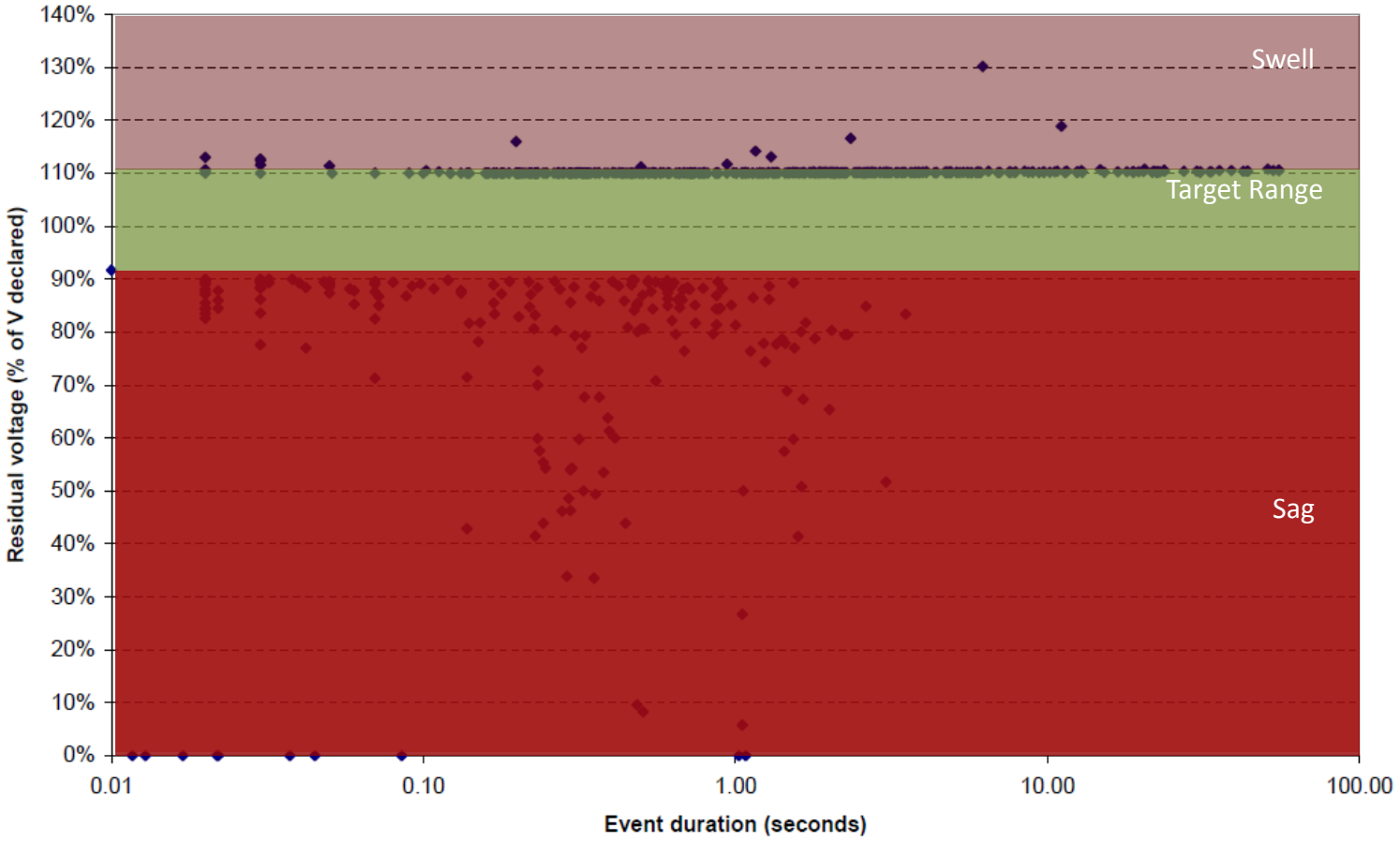
SAG DEFINITION - WITH COMPENSATION



EVENT RECORDINGS - SURVEY

	Start Date	Start Time	Category	Phases	Duration	Residual Voltage	Description
1	Thu 1 Dec 2011	1:34	Dip type S	1,2,3	0.31	62.30%	137132.4 Volt minimum
2	Thu 1 Dec 2011	9:40	Dip type Z1	1,2,3	1.06	81.40%	179174.8 Volt minimum
3	Thu 1 Dec 2011	15:12	Dip type Y	1,2,3	0.48	81.30%	178858.1 Volt minimum
4	Thu 1 Dec 2011	16:34	Dip type S	1,2,3	0.38	40.30%	88597.7 Volt minimum
5	Fri 2 Dec 2011	0:54	Dip type S	1,2,3	0.32	76.40%	168011.0 Volt minimum
6	Fri 2 Dec 2011	1:34	Dip type S	1,2,3	0.35	64.20%	141289.2 Volt minimum
7	Sat 3 Dec 2011	3:50	Dip type Y	1,2	0.25	81.40%	179135.2 Volt minimum
8	Sat 3 Dec 2011	5:22	Interruption	1,2,3	51.68	0.00%	0.0 Volt minimum
9	Sat 3 Dec 2011	5:28	Dip type Y	1,3	0.03	87.20%	191803.3 Volt minimum
10	Sun 4 Dec 2011	3:28	Dip type Y	2	0.03	87.20%	191763.7 Volt minimum
11	Sun 4 Dec 2011	7:55	Dip type Y	2	0.05	87.80%	193070.1 Volt minimum
12	Sun 4 Dec 2011	9:51	Dip type Z1	2	1.22	78.50%	172801.1 Volt minimum
13	Sun 4 Dec 2011	11:53	Dip type Y	1,3	0.52	81.30%	178897.7 Volt minimum
14	Sun 4 Dec 2011	15:31	Dip type Y	1,2	0.03	88.10%	193861.9 Volt minimum
15	Sun 4 Dec 2011	15:32	Dip type Y	1,2	0.03	87.90%	193466.0 Volt minimum
16	Sun 4 Dec 2011	16:19	Interruption	1,2,3	1:35:42	0.00%	0.0 Volt minimum
17	Sun 4 Dec 2011	17:54	Dip type Y	1,2	0.03	87.80%	193149.3 Volt minimum
18	Sun 4 Dec 2011	17:57	Dip type Y	1,2	0.02	89.10%	195960.0 Volt minimum
19	Sun 4 Dec 2011	17:57	Interruption	1,2,3	0:13:24	0.00%	0.0 Volt minimum
20	Sun 4 Dec 2011	18:10	Dip type Y	1,2	0.06	84.40%	185588.0 Volt minimum
21	Sun 4 Dec 2011	18:12	Dip type S	1,2,3	0.24	51.90%	114250.6 Volt minimum
22	Sun 4 Dec 2011	18:20	Dip type Z1	1,3	0.67	82.80%	182223.0 Volt minimum
23	Sun 4 Dec 2011	18:21	Dip type Y	2,3	0.02	88.90%	195564.2 Volt minimum
24	Sun 4 Dec 2011	19:08	Dip type Y	3	0.03	89.10%	196078.8 Volt minimum
25	Sun 4 Dec 2011	19:08	Dip type Y	3	0.19	89.60%	197226.8 Volt minimum
26	Sun 4 Dec 2011	19:44	Dip type Y	3	0.03	88.90%	195524.6 Volt minimum
⬇	Up to Record 1362						
1362	Wed 23 May 20	2:29	Dip type X1	1,2,3	0.09	60.50%	133134.1 Volt minimum

EVENT RECORDINGS - DIPS & SWELLS MAPPING



EVENT ANALYSIS – SUCCESS RATE 79%

Nominal Voltage [%]	0 > t > 0.04s	0.04 > t > 0.06s	0.06 > t > 0.08s	0.08 > t > 1s	1 > t > 2s	2 > t > 3s	3 > t > 4s	4 > t > 5s	5 > t > 10s	10 > t > 20s	20 > t > 30s	30 > t > 40s	40 > t > 60s	90 > t > 120s	2 > t > 3 min	3 > t > 5 min	5 > t > 10 min	10 > t > 20 min	t > 20 min	Duration [sec / min]
125% to 135%				1	2				1											
122.5% to 125%									2											
120% to 122.5%										1										
117.5% to 120%	1	1								1	1									
115% to 117.5%	1	1		2		1				1										
112.5% to 115%	7			1	2	2	1		1											
110% to 112.5%	31	8	2	163	63	44	25	16	31	20	13	7	7							
85% to 110%	139	89	28	144	13	4							1							
82.5% to 85%	18	7	9	38	6	1	1													
80% to 82.5%	1		2	37	10	4	2													
70% to 80%	1	6	6	69	18	5	1		1											
60% to 70%				56	7	3		1												
57.5% to 60%				15	2															
55% to 57.5%				7	3															
52.5% to 55%				19	1															
50% to 52.5%				12	5		1	1												
47.5% to 50%				9	1															
45% to 47.5%				10	1					1										
42.5% to 45%				9	1															
40% to 42.5%				4	2															
30% to 40%				8	1															
0% to 30%				6	4															
0	5		1	1	2			1			3	3	2	5	2	3	6	11	4	

291 Sag Events: Duration < 2 sec, ΔU= + 25%

456 Swell Events: Duration < 60 sec, ΔU = - 15%

195 Sag & Swell Events Unsolved

EVENT ANALYSIS – SUCCESS RATE 90%

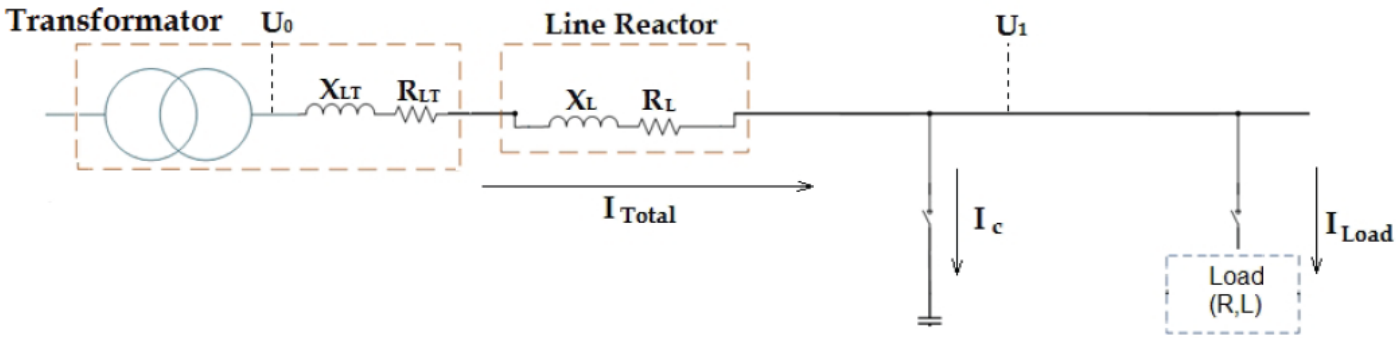
Nominal Voltage [%]	0 > t > 0.04s	0.04 > t > 0.06s	0.06 > t > 0.08s	0.08 > t > 1s	1 > t > 2s	2 > t > 3s	3 > t > 4s	4 > t > 5s	5 > t > 10s	10 > t > 20s	20 > t > 30s	30 > t > 40s	40 > t > 60s	90 > t > 120s	2 > t > 3 min	3 > t > 5 min	5 > t > 10 min	10 > t > 20 min	t > 20 min	Duration [sec / min]
125% to 135%				1	2				1											
122.5% to 125%									2											
120% to 122.5%										1										
117.5% to 120%	1	1								1	1									
115% to 117.5%	1	1		2		1				1										
112.5% to 115%	7			1	2	2	1		1											
110% to 112.5%	31	8	2	163	63	44	25	16	31	20	13	7	7							
85% to 110%	139	89	28	144	13	4							1							
82.5% to 85%	18	7	9	38	6	1	1													
80% to 82.5%	1		2	37	10	4	2													
70% to 80%	1	6	6	69	18	5	1		1											
60% to 70%				56	7	3		1												
57.5% to 60%				15	2															
55% to 57.5%				7	3															
52.5% to 55%				19	1															
50% to 52.5%				12	5		1	1												
47.5% to 50%				9	1															
45% to 47.5%				10	1					1										
42.5% to 45%				9	1															
40% to 42.5%				4	2															
30% to 40%				8	1															
0% to 30%				6	4															
0	5		1	1	2			1			3	3	2	5	2	3	6	11	4	

391 Sag Events: Duration < 2 sec , ΔU= + 45%

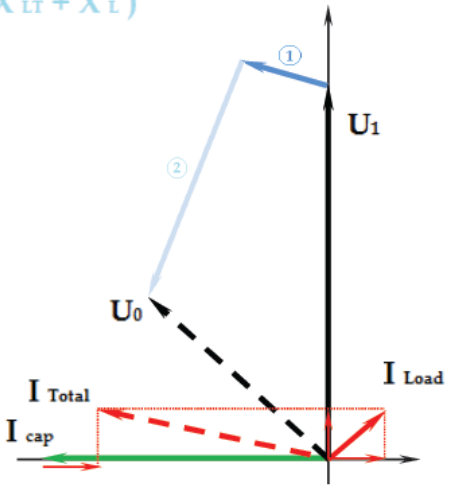
456 Swell Events: Duration < 60 sec, ΔU = - 15%

94 Sag & Swell Events Unsolved

PRINCIPAL OF OPERATION - SAG CONTROL

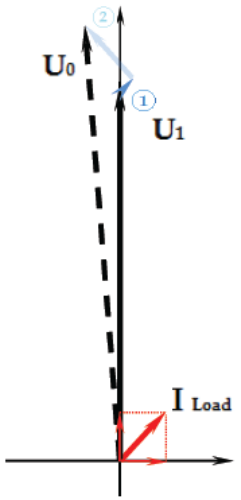


1. $\Delta U_R = I_{Total} * (R_{LT} + R_L)$
2. $\Delta U_x = I_{Total} * (X_{LT} + X_L)$



b: Operation During Sag

A>>1



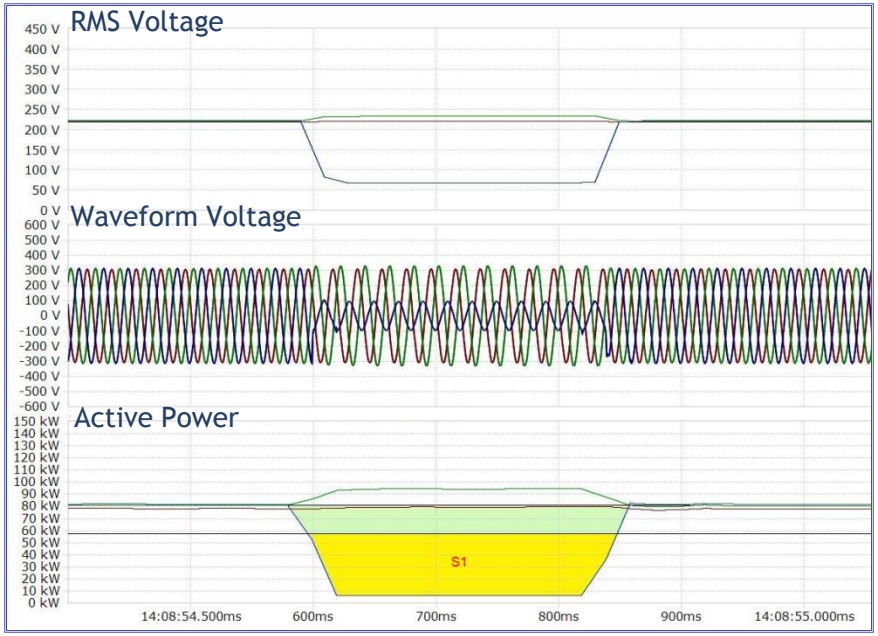
a: Normal Operation

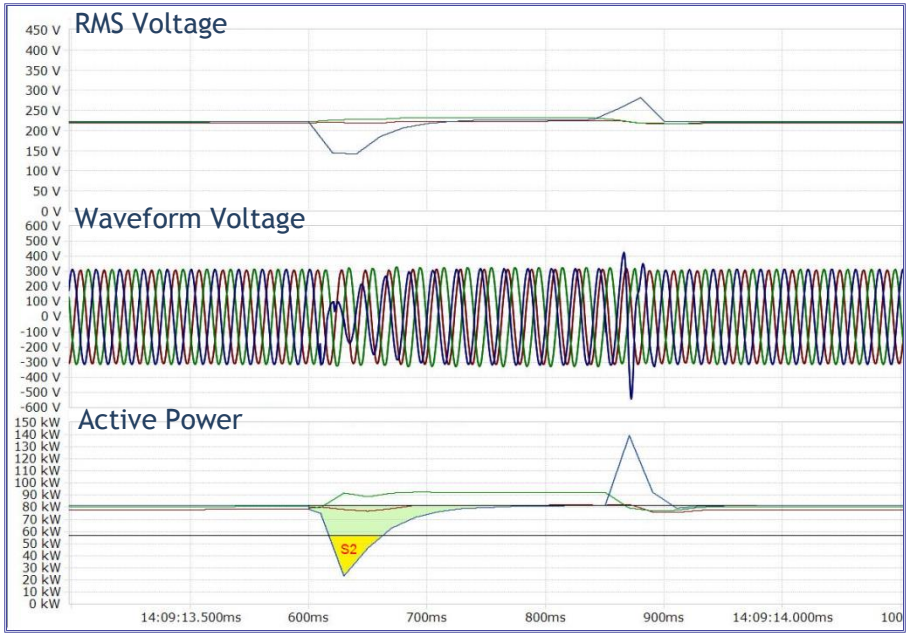
A<1 $(A = \frac{U_1}{U_0})$

WAVEFORM
SINGLE PHASE - POWER ANALYSIS

[0.7225Pu, 1Pu] = [57.8,80]kW

Power Level Below 0.7225Pu = 57.8kW



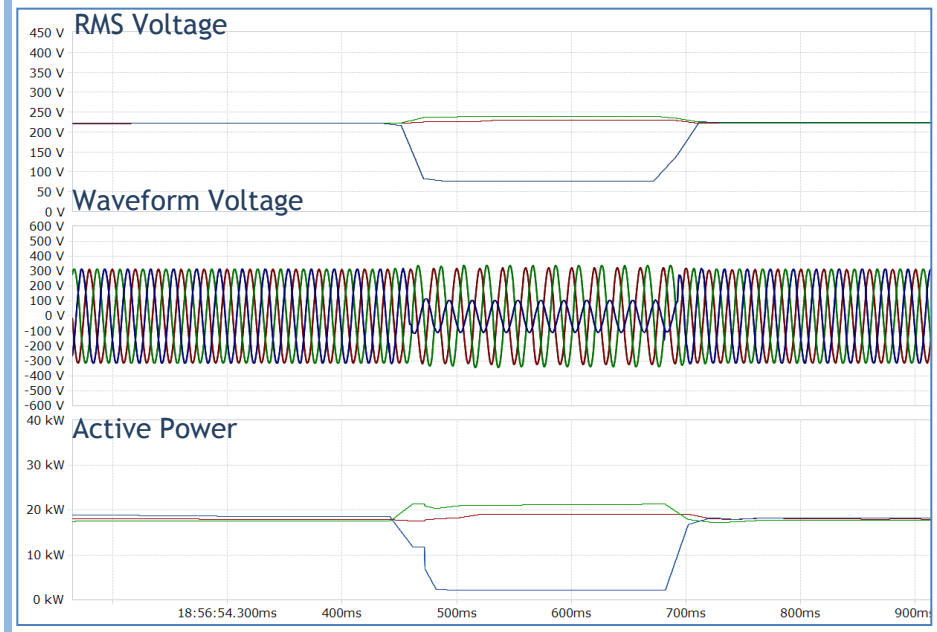


Without Compensation

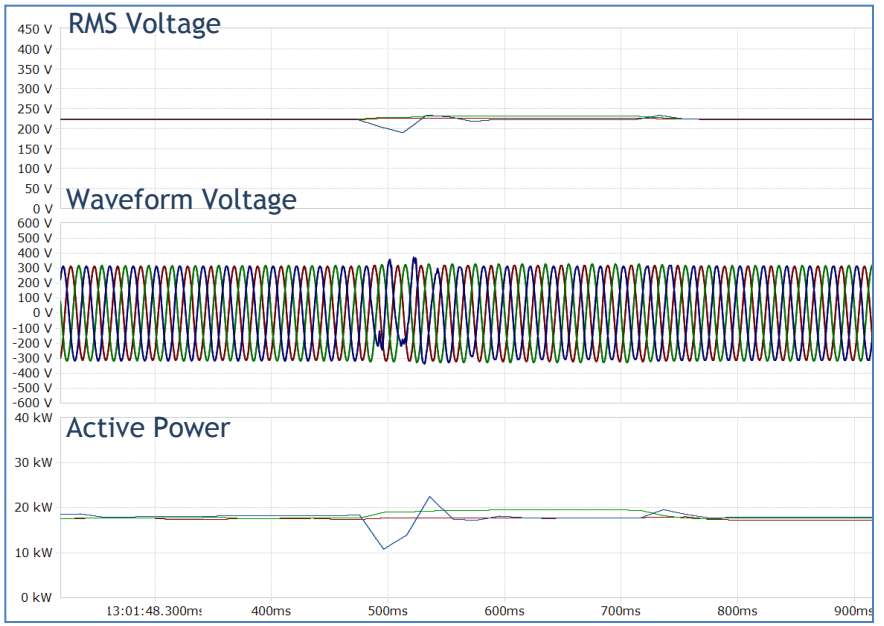
With Compensation

WAVEFORM
SINGLE PHASE - VOLTAGE DROP TO 60%

Load per Phase
20kW



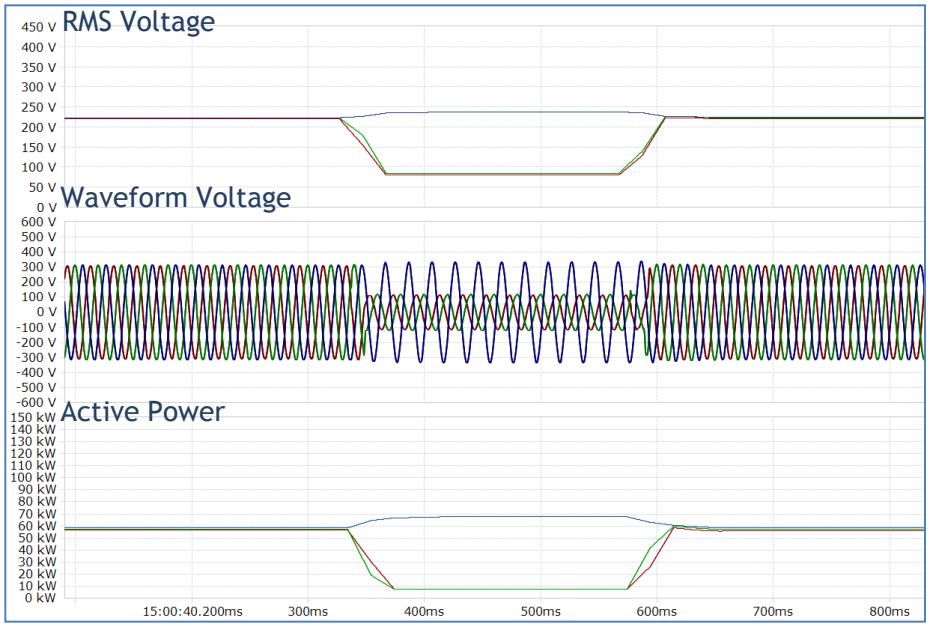
Without Compensation



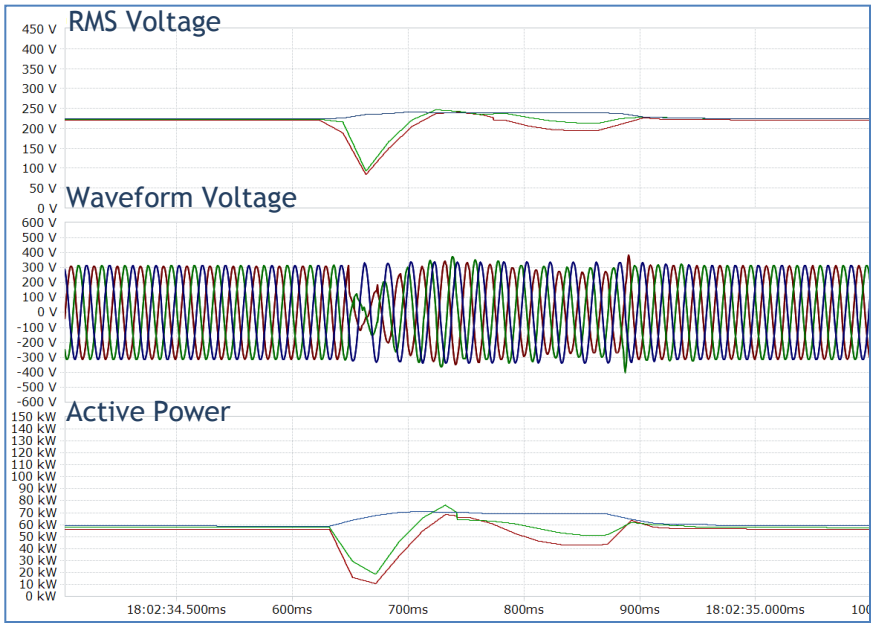
With Compensation

WAVEFORM
TWO PHASES - VOLTAGE DROP TO 60%

Load per Phase
59kW



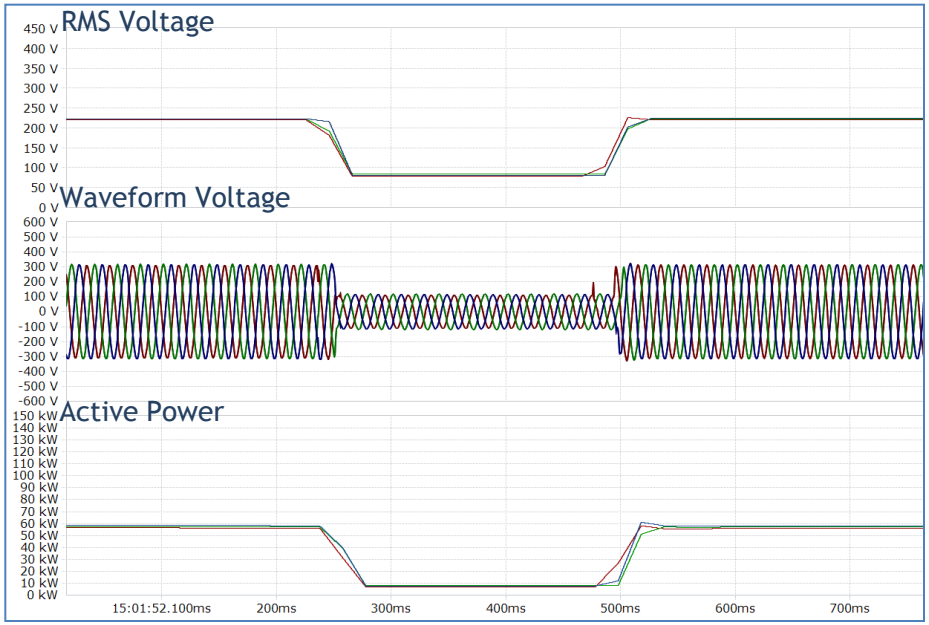
Without Compensation



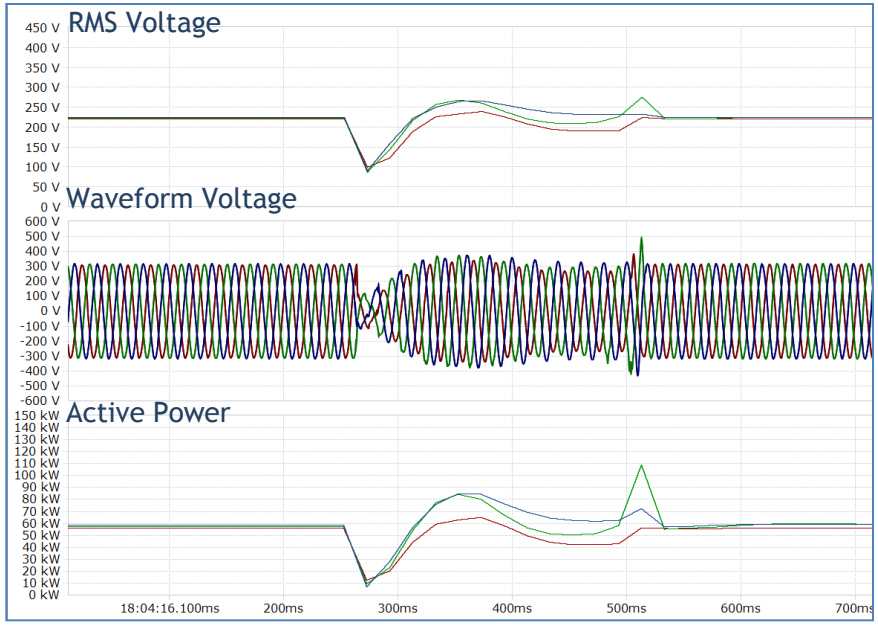
With Compensation

WAVEFORM
THREE PHASES - VOLTAGE DROP TO 60%

Load per Phase
59kW

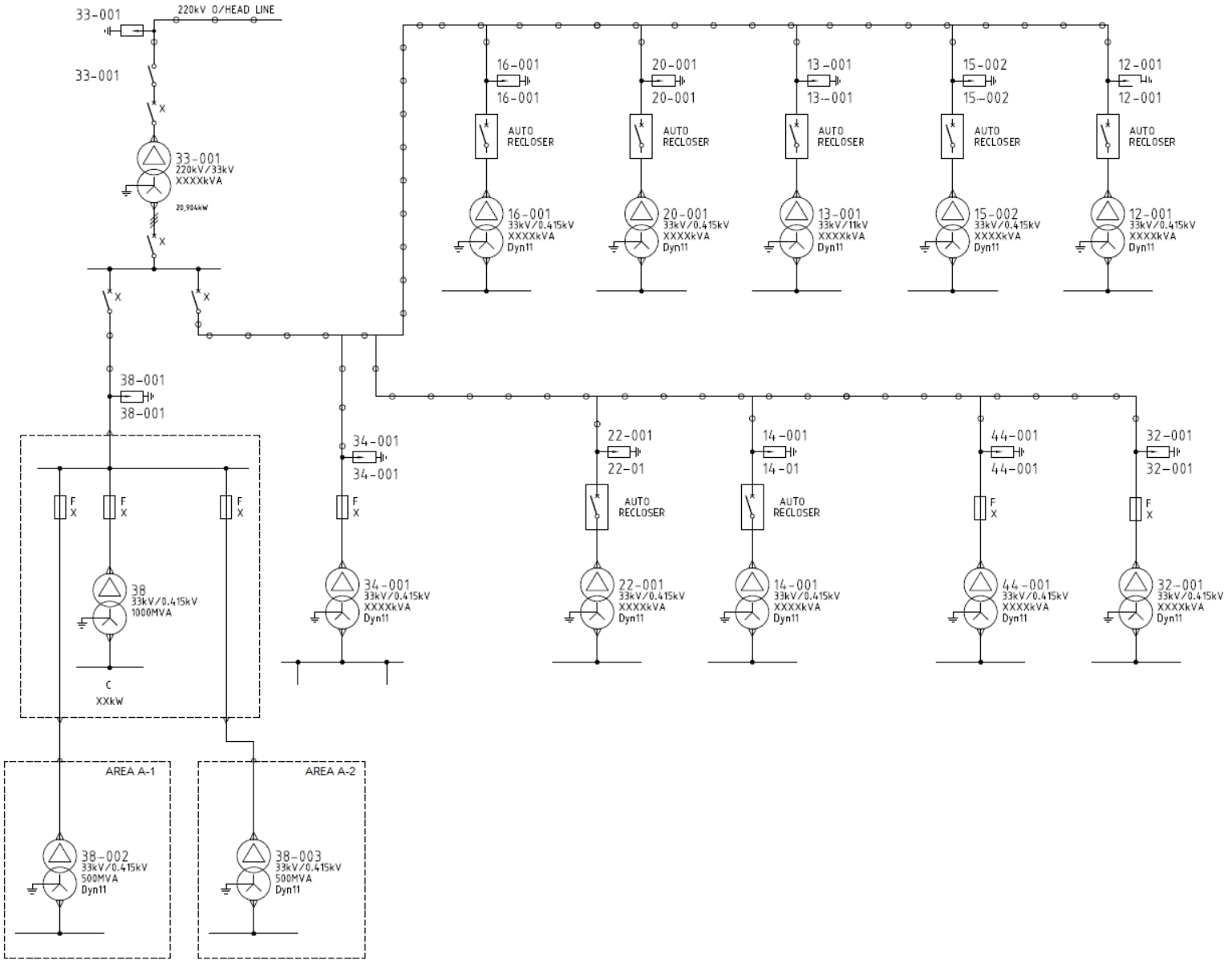


Without Compensation



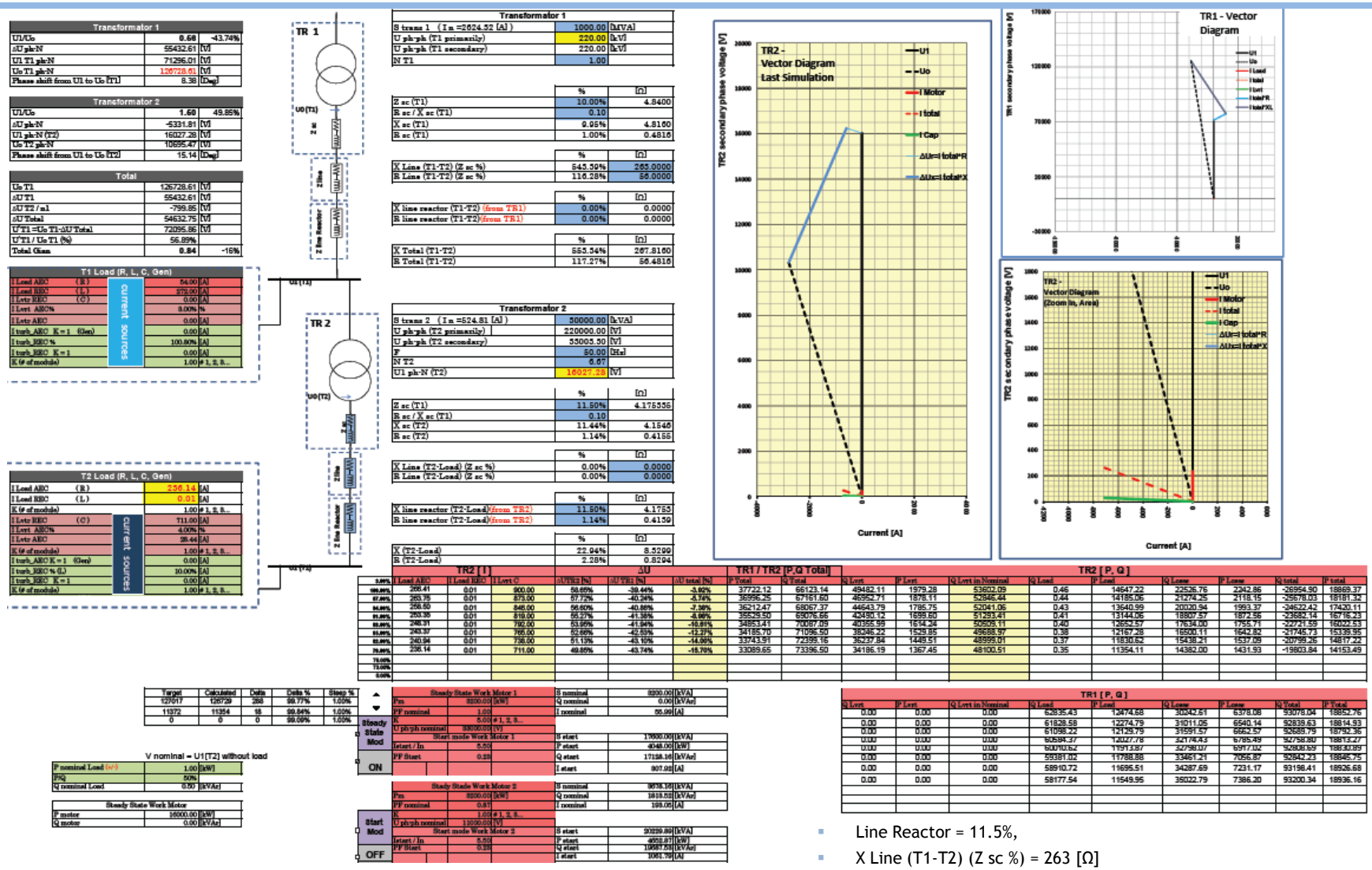
With Compensation

SINGLE LINE DIAGRAM - 220kV



PLANNED SIMULATION

16[MW] , 0 [MVAr], ΔU = - 60 % , step=3%



Transformator 1		
U1/Uo	0.68	-43.74%
ΔU ph-N	55432.61	[V]
U1 T1 ph-N	71296.01	[V]
Uo T1 ph-N	126728.61	[V]
Phase shift from U1 to Uo [T1]	8.38	[Deg]

Transformator 2		
U1/Uo	1.68	49.85%
ΔU ph-N	-5331.81	[V]
U1 ph-N (T2)	16027.28	[V]
Uo T2 ph-N	10695.47	[V]
Phase shift from U1 to Uo [T2]	15.14	[Deg]

Total		
Uo T1	126728.61	[V]
ΔU T1	55432.61	[V]
ΔU T2 / n1	-799.85	[V]
ΔU Total	54632.75	[V]
U T1 =Uo T1-ΔU Total	72095.86	[V]
U T1 / Uo T1 (%)	56.89%	
Total Gain	0.84	-16%

Transformator 1		
S trans 1 (I n =2624.32 [A])	1000.00	[kVA]
U ph-ph (T1 primarily)	220.00	[kV]
U ph-ph (T1 secondary)	220.00	[kV]
N T1	1.00	
	%	[n]
Z sc (T1)	10.00%	4.8400
R sc / X sc (T1)	0.10	
X sc (T1)	9.95%	4.8160
R sc (T1)	1.00%	0.4816
	%	[n]
X Line (T1-T2) (Z sc %)	545.39%	263.0000
R Line (T1-T2) (Z sc %)	116.28%	56.0000
	%	[n]
X line reactor (T1-T2) (from TR1)	0.00%	0.0000
R line reactor (T1-T2)(from TR1)	0.00%	0.0000
	%	[n]
X Total (T1-T2)	553.34%	267.8160
R Total (T1-T2)	117.27%	56.4816

Transformator 2		
S trans 2 (I n =524.81 [A])	50000.00	[kVA]
U ph-ph (T2 primarily)	220000.00	[V]
U ph-ph (T2 secondary)	55005.50	[V]
F	50.00	[Hz]
N T2	0.07	
U1 ph-N (T2)	16027.28	[V]
	%	[n]
Z sc (T1)	11.50%	4.175536
R sc / X sc (T1)	0.10	
X sc (T2)	11.44%	4.1545
R sc (T2)	1.14%	0.4155
	%	[n]
X Line (T2-Load) (Z sc %)	0.00%	0.0000
R Line (T2-Load) (Z sc %)	0.00%	0.0000
	%	[n]
X line reactor (T2-Load)(from TR2)	11.50%	4.1753
R line reactor (T2-Load)(from TR2)	1.14%	0.4139
	%	[n]
X (T2-Load)	22.94%	8.3299
R (T2-Load)	2.28%	0.8294

T1 Load (R, L, C, Gen)		
I Load AEC (R)	54.00	[A]
I Load REC (L)	272.00	[A]
I Lvtr REC (C)	0.00	[A]
I Lvrt AEC%	0.00%	%
I Lvtr AEC	0.00	[A]
I turb_AEC K = 1 (Gen)	0.00	[A]
I turb_REC %	100.00%	[A]
I turb_REC K = 1	0.00	[A]
K (# of module)	1.00	# 1, 2, 3...

T2 Load (R, L, C, Gen)		
I Load AEC (R)	236.14	[A]
I Load REC (L)	0.01	[A]
K (# of module)	1.00	# 1, 2, 3...
I Lvtr REC (C)	711.00	[A]
I Lvrt AEC%	4.00%	%
I Lvtr AEC	28.44	[A]
K (# of module)	1.00	# 1, 2, 3...
I turb_AEC K = 1 (Gen)	0.00	[A]
I turb_REC % (L)	10.00%	[A]
I turb_REC K = 1	0.00	[A]
K (# of module)	1.00	# 1, 2, 3...

Target	Calculated	Delta	Delta %	Step %	
12/2017	12672.9	2.9	99.77%	1.00%	
11372	11354	18	99.84%	1.00%	Steady State Mod
0	0	0	99.00%	1.00%	

V nominal = U1[T2] without load

P nominal Load (+)	1.00	[kW]
PFQ	50%	
Q nominal Load	0.50	[kVAr]

Steady State Work Motor		
P motor	16000.00	[kW]
Q motor	0.00	[kVAr]

Steady State Work Motor 1				
Pn	8000.00	[kW]	S nominal	8000.00 [kVA]
PF nominal	1.00		Q nominal	0.00 [kVAr]
K	5.00	# 1, 2, 3...	I nominal	55.99 [A]
U ph/ph nominal	80000.00	[V]		
Start mode Work Motor 1			S start	17600.00 [kVA]
Ietart / In	5.50		P start	4048.00 [kW]
PF Start	0.23		Q start	17138.10 [kVAr]
			I start	807.99 [A]

Steady State Work Motor 2				
Pn	8000.00	[kW]	S nominal	9638.10 [kVA]
PF nominal	0.87		Q nominal	1818.53 [kVAr]
K	1.00	# 1, 2, 3...	I nominal	198.06 [A]
U ph/ph nominal	12000.00	[V]		
Start mode Work Motor 2			S start	50220.89 [kVA]
Ietart / In	5.50		P start	4052.87 [kW]
PF Start	0.23		Q start	19987.53 [kVAr]
			I start	1081.76 [A]

Start Mod

ON

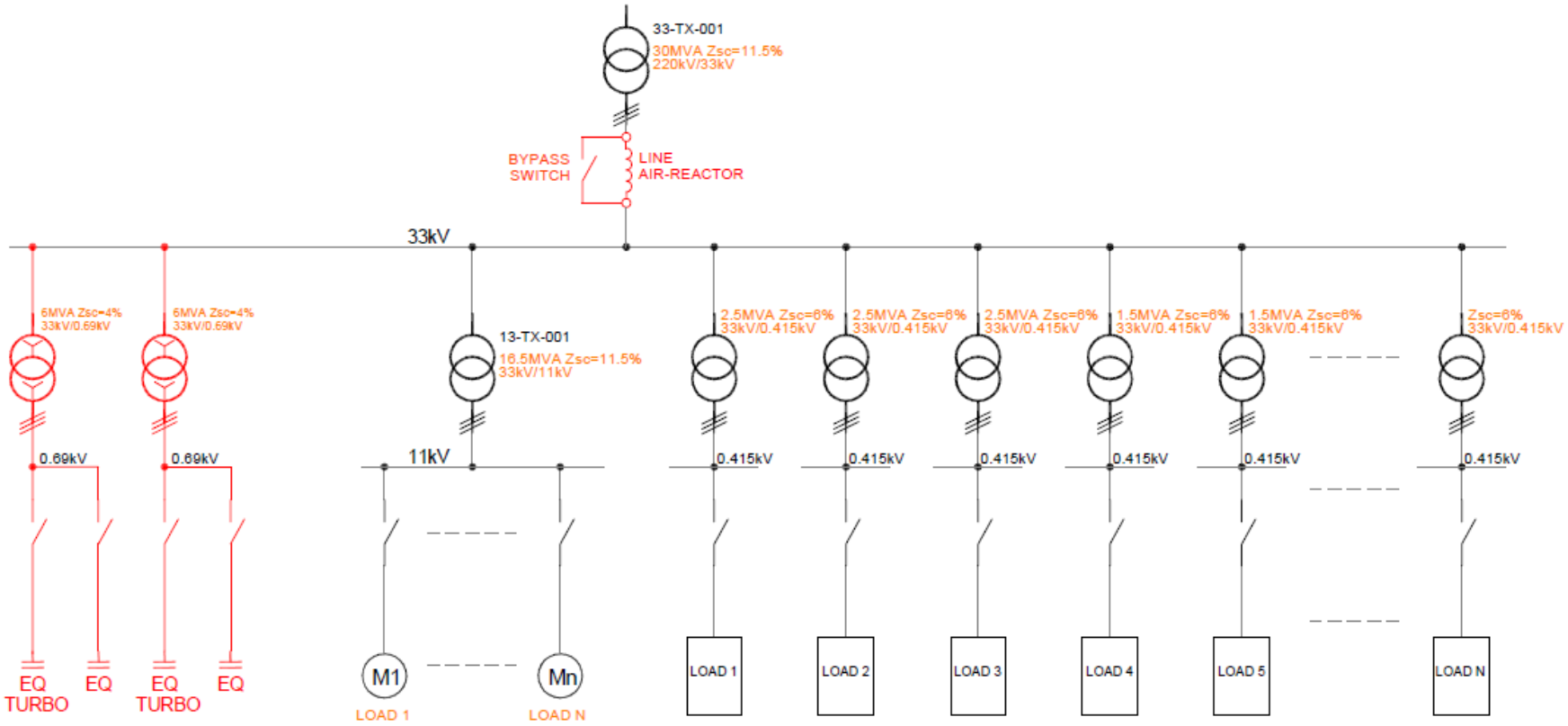
OFF

TR1 / TR2 [P,Q Total]			TR2 [P, Q]									
P Total	Q Total	Q Lvrt	P Lvrt	Q Lvrt in Nominal	Q Load	P Load	Q Loss	P Loss	Q total	P total
37722.12	66123.14	48482.11	1979.28	53602.09	0.46	14647.22	32526.75	2242.86	-26954.90	18869.37
36996.25	67161.60	46952.71	1878.11	52846.44	0.44	14185.06	21274.25	2118.15	-25678.03	18181.32
36212.47	68067.37	44643.79	1785.75	52041.06	0.43	13640.99	20020.94	1993.37	-24622.42	17420.11
35529.50	69076.66	42490.12	1698.60	51293.41	0.41	13144.06	18807.57	1872.56	-23682.14	16716.23
34851.41	70087.09	40355.99	1614.24	50595.11	0.40	12652.57	17634.00	1755.71	-22721.59	16022.53
34185.70	71096.50	38246.22	1529.85	49888.97	0.38	12167.28	16500.11	1642.82	-21745.73	15339.95
33743.51	72395.16	36237.84	1448.51	48995.01	0.37	11830.62	15438.21	1537.09	-20799.26	14817.22
33089.65	73396.50	34186.19	1367.45	48100.51	0.35	11354.11	14382.00	1431.93	-19803.84	14153.49

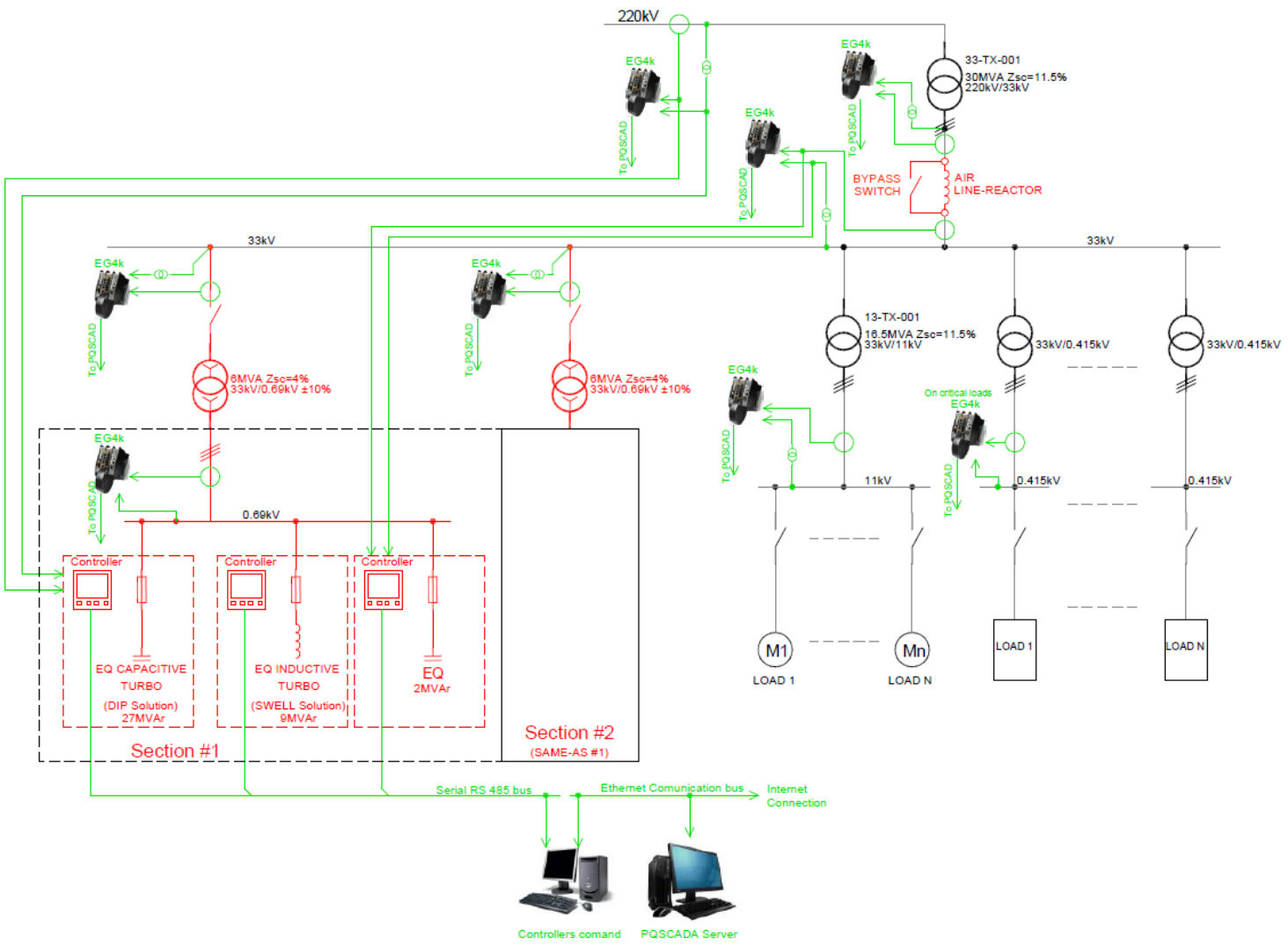
TR1 [P, Q]								
Q Lvrt	P Lvrt	Q Lvrt in Nominal	Q Load	P Load	Q Loss	P Loss	Q Total	P Total
0.00	0.00	0.00	62835.43	12474.68	30042.51	6378.08	93078.04	18852.76
0.00	0.00	0.00	61828.58	12274.79	31011.05	6540.14	92839.63	18814.93
0.00	0.00	0.00	61098.22	12129.79	31491.57	6662.57	92688.79	18792.36
0.00	0.00	0.00	60594.37	12027.78	32174.43	6785.49	92768.80	18813.27
0.00	0.00	0.00	60010.62	11911.87	32758.07	6917.02	92808.69	18830.89
0.00	0.00	0.00	59381.02	11788.88	33461.21	7056.87	92842.23	18845.75
0.00	0.00	0.00	58810.72	11695.51	34287.69	7231.17	93198.41	18926.68
0.00	0.00	0.00	58177.54	11549.95	35022.79	7386.20	93200.34	18936.16

- Line Reactor = 11.5%,
- X Line (T1-T2) (Z sc %) = 263 [Ω]
- R Line (T1-T2) (Z sc %) = 56 [Ω]
- Q LVRT in Nominal (EQ-Turbo) =51 [MVAr] for ΔU = -10%,
- Q LVRT in Nominal (EQ-Turbo) =48 [MVAr] for ΔU = -15%,

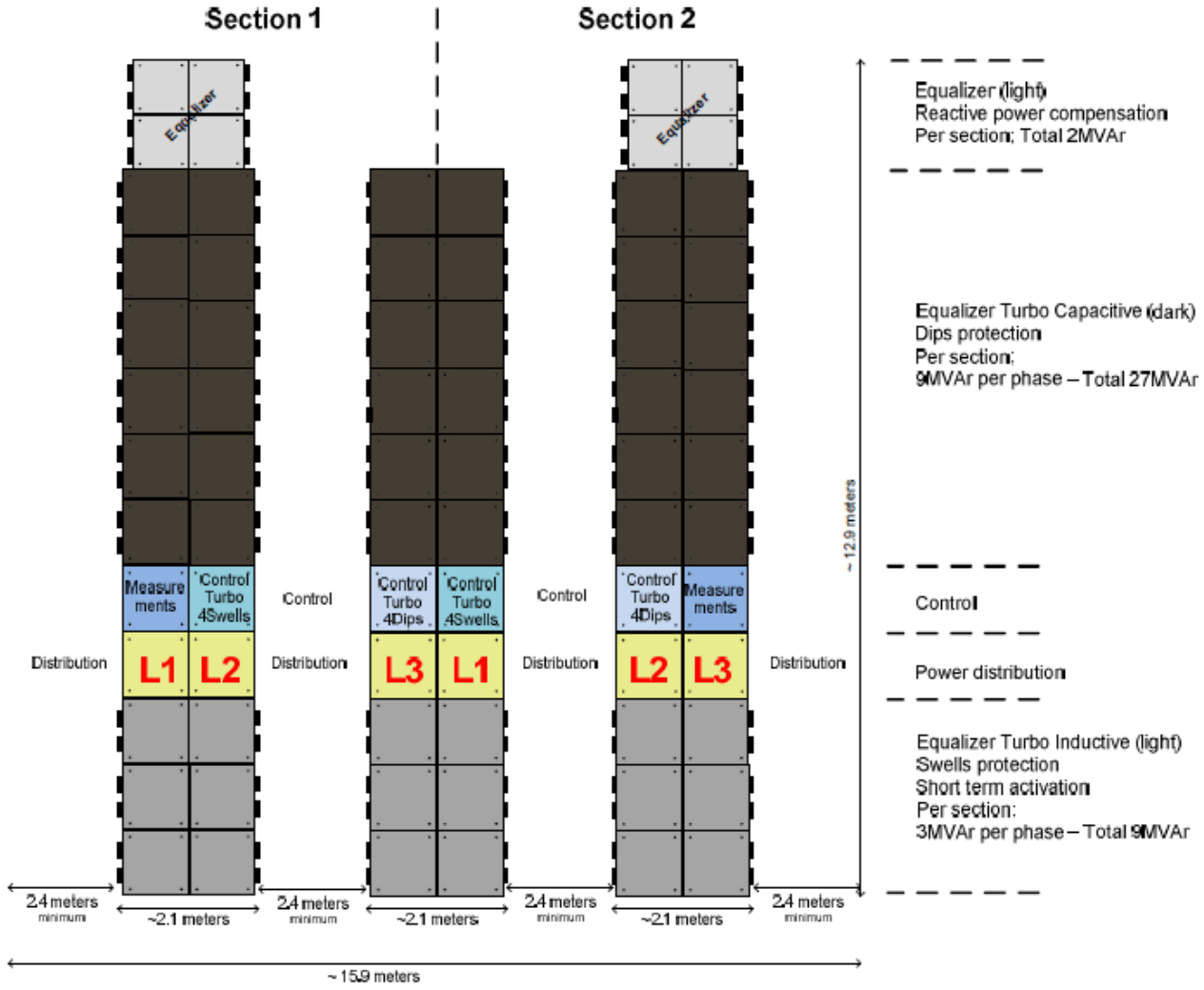
SOLUTION – GENERAL ELECTRICAL DIAGRAM



SOLUTION – DETAILED ELECTRICAL DIAGRAM



SOLUTION - MECHANICAL DIAGRAM



EQUALIZER TURBO
VOLTAGE INSTABILITIES

The Equalizer TURBO provides a ride-through three-phase (balanced & unbalanced) voltage sag & swell compensation solution 0.2pu, voltage dip ΔU 70% with typical duration up to 2 seconds duration for sags and no limitation for swells. Clients may also specify an even longer duration to meet their individual requirements and national compliance standard.

EQUALIZER TURBO
VOLTAGE INSTABILITIES

This ride-through compensation capabilities resolve a significant portion of voltage disruptions in both developing and developed countries. In addition the device restores the voltage to 1.0pu of its nominal value ± 15%.

EQUALIZER TURBO
VOLTAGE INSTABILITIES

Due to independent phase compensation, the Equalizer TURBO can correct each phase accurately and independently. Equalizer TURBO comes with integrated software monitoring system with event notification and remote access facility.

EQUALIZER TURBO | System Attributes

- Obtain full compensation within 1-2 network cycles
- Up to 2 seconds of full sag compensation using residual voltage as low as 30% of nominal voltage, with voltage target range between 0.9Un and 1.1Un
- Unlimited swell compensation period
- Independent compensation for each phase
- Parallel connection to network without power consumption during normal conditions [standby mode]
- Can be applied in any industrial applications
- Proven Elspec & Industrial Technology

EQUALIZER TURBO | Customer Benefits

- Return On Investment [ROI] period can be as low as several months up to one year, due to reduction in local power generation & higher production capabilities
- Very high energy efficiency - no power consumption due to parallel connection and operation during the event only
- The Equalizer TURBO has a long lifetime

EQUALIZER TURBO | Solution Design Process

- Assessment of power quality financial impact on client's profitability
- Client site data transfer - facility power consumption, transformers and generators etc.
- Measurements are taken on site and analyzed
- Simulations are made using Elspec's unique proprietary simulation tools
- Success rate is calculated for each solution alternative
- Electrical and mechanical diagrams are supplied
- Quote is sent to the client for approval

- If You Can't Measure It You Can't Manage It
- If You Can Measure It You Can Manage It

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