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PMU-based EMS and Power Network Analysis Applications

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April 16 - 17, 2024





Linear State Estimation: Foundation for Measurement-Based Advanced Applications

- The framework was pioneered by V&R Energy during NASPI Voltage Stability Workshop on October 22, 2014:
 - Invented the concept of a "PMUbased State Estimator Case" or "LSE Case"
 - Prior to this, "standard" output of LSE was conditioned and expanded PMU stream
- Only the use of LSE produced accurate results





2014 NASPI Voltage Stability Case 1

NASP North American SynchroPhasor Initiative

 Correct results announced by NASPI at the Workshop

Voltage Stability Case 1

First Time of Unacceptable Operating Conditions	303.4 sec
Shunt Cap Switching Time	247.8 sec
Pre-Switching Real Power Margin	343.75 MW
Post-Switching Real Power Margin	400.00 MW
Real Power Margin @ 0 sec	618.75 MW
Real Power Margin @ 150 sec	506.25 MW
Real Power Margin @ 305 sec	112.50 MW
Real Power Margin @ 445 sec	400.00 MW
Description of Method	PV Analysis

NASP North American SynchroPhasor Initiative

Results submitted by vendors one week before the Workshop



C		Electric Power Group	RPI	V&R	Alstom Grid	ABB
C	First Time of Unacceptable	170	None	303.5	None	None
	Operating Conditions					
	Shunt Cap Switching Time	247	247.8	245	247.8	248
	Pre-Switching Real Power Margin	23.53 kV/100 MW	411	335	29	92
	Post-Switching Real Power Margin	7.5 kV/100 MW	461	391	86	92
	Real Power Margin @ 0 sec	0.38 kV/100 MW	645	617	Not Available	196
	Real Power Margin @ 150 sec	3.1 kV/100 MW	520	515	76	193
	Real Power Margin @ 305 sec	6 kV/100 MW	190	111	46	32
	Real Power Margin @ 445 sec	2.9 kV/100 MW	388	385	69	107
	Description of Method	Voltage Sensitivity to	AQ Bus Method	Linear State	RVII – local voltage	Equivalencing, PV
		Change in Real Power		Estimation, PV/QV	instability detector	analysis
				Analysis		

VOLTAGE STABILITY CASE 1 RESULTS AND COMMENT SHEET

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2014 NASPI Voltage Stability Case 2

 Correct results announced by NASPI at the Workshop

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VOLTAGE STABILITY CASE 2 RESULTS AND COMMENT SHEET

		North America	r
		SynchroPhasor Initiativ	/e

Voltage Stability Case 2

Analysis, VS assessment (PV/QV, Sensitivity)

First Time of Insecure (N-1) Operating Condition	1312 seconds
Reason(s) for Insecurity	Voltage Violation in Zone 10 – N-1 Outages
First Time of Unacceptable N-0 Operating Condition	None
Reason for Unacceptable Condition	N/A
Time of Instability	4012 seconds
Security Margin (Transfer into Zone 10) @ 1500 sec	50.0 MW
Stability Margin (Transfer into Zone 10) @ 1500 sec	250.0 MW
Security Margin (Transfer into Zone 10) @ 4000 sec	0.0 (-) – Insecure
Stability Margin (Transfer into Zone 10) @ 4000 sec	0.0 (-) – N-1 Unstable
Assumptions Used	50/50 Pickup
Noticeable System Changes	1. Line 115-130 Trips
	2. Line 115-130 Returned to Service
	3. Bus 122 STATCOM Trips
	4. Bus 122 STATCOM Switched Back In
	5. Bus 112 Shunt Cap Switches In
	Line 116-120 Trips - Unstable
Description of Method	PV, Contingency Analysis

	Alstom Grid	V&R Energy
First Time of Insecure (N-1) Operating Condition	2410	1312
Reason(s) for Insecurity	Line L02	Contingency L02
		Contingency L11
First Time of Unacceptable N-0 Operating Condition	4064	None
Reason for Unacceptable Condition	Voltage Violation @ Bus 113	N/A
Time of Instability	4070	4012
Security Margin (Transfer into Zone 10) @ 1500 sec	730	40
Stability Margin (Transfer into Zone 10) @ 1500 sec	760	250
Security Margin (Transfer into Zone 10) @ 4000 sec	170	Negative
Stability Margin (Transfer into Zone 10) @ 4000 sec	200	Negative
Assumptions Used	-Total generation is the sum of three branches:	Ignored 500kV equivalents & their voltages
	 Bus 151 to Bus 156 CKT 1 	
	 Bus 151 to Bus 156 CKT 2 	←
	 Bus 136 to Bus 130 CKT 1 	
	-Upper bound voltage limit criteria was relaxed	
	-Bus 136 generator Pmax increased from	
	1000MW to 1070MW for transfer analysis	
Noticeable System Changes	At t=502s, line 130-115 circuit 1 tripped and	Event 1 - 502 s. Switching off line 130-115 "1".
	reconnected at t=800s	Event 2 - 802 s. Line 130-115 "1" switched back.
	At t=2246s, first shunt cap (100 MVAR at bus	Event 3 - 1302 s. Switching off FACTS at bus 122.
	112) gets switched in at load in zone 10=912MW	Event 4 - 1602 s. Switching in FACTS at bus 122.
	At t=2868s, Second shunt cap (125 MVAR at bus	Event 5 - 2462 s. Shunt cap switching at bus 112
	120) gets switched in at load in zone	Event 6 - 2868 s. ("non-switching"). Increase in
	10=1152MW	transformer 116-117 flow. FACTS reaches
		reactive limit, loses control of bus 116 voltage.
		Event 7 - 4012 s. Contingency 116-120 which
		causes system collapse at 4012 s. There is no
		State Estimator solution after this N-1
		contingency occurs.
Description of Method	PV Analysis	Linear State Estimation, AC Contingency

 Results submitted by vendors one week before the Workshop

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PMU ROSE at TNB: Estimating Values Using LSE and Cascading Analysis

• LSE results:

- LSE (dark green line) successfully suppresses the error and estimates voltage with a difference of less than 0.01% compared to the true value
- Substation with multiple PMU measurements with random errors and noise denoted by yellow, light green and red lines
- The true value is blue line

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- Cascading results:
 - Cascading Viewer visualizes results of online cascading analysis
 - 1877 N-1 initiating events are analyzed in one run
 - 41 critical cascading events were identified and ranked based on severity measured using the Performance Index (PI)



TNB PMU ROSE: Alleviating Voltage Stability Violation

- A critical Initiating event results in stability violation
- The initiating event was tripping a transformer which leads to overload on other branches



- Optimal mitigation measures are identified to alleviate this stability violation
- The effect of these measures can be seen in the PMU Viewer





LSE calculation accurately represents transient event

TNB PMU ROSE: Alleviating Frequence Violation

- A significant decrease in system frequency following the occurrence of critical cascading events
- These events were triggered by the tripping of a 500kV transmission line



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- Optimal mitigation measures are identified to alleviate frequency violation
- The effect of these measures can be seen in the PMU Viewer





PMU-Based Linear State Estimator at SDG&E[®]

Robin Manuguid, PE

April 16-17, 2024



About SDG&E®

- SDG&E is a regulated public utility in southern California.
- Serves San Diego & Southern Orange Counties: 1.46 million electric meters
- System Peak = 4,890 MW (9/16/14)
- Service area span 4,100 square miles.
- NERC-Registered: TO/P, GO/P, TP, LSE
- Within the CAISO BA area boundary in the RC West footprint





Presentation Outline

- About SDG&E.
- Existing Real-Time Tools
 - State Estimator / RTCA
 - Phase angle difference
 - Voltage Stability Analysis
 - SEL Synchrowave Operations
- Linear State Estimator
 - PMU additions
 - Observability Analysis Update
 - LSE Case Update
- Conclusions



Real-Time Tools – State Estimator and RTCA

Study Case :	0 04/15/24 16:	37:49.019 PDT: RTNA: SE: time	execution				
Note: Status: CASE	CONTAINS CONVERG	ED SOLUTION					
29 0.9660E+0	06 ANG -0.00	490 SIGPLANT 92	SIGPLANT				
	VOL -0.000	692 OCO G1 U1	OCO-GEN1				
	TRA 0.003	353 OCO BK 2	OCO-GEN1				
30 0.1489E+0	04 ANG -0.00	490 SIGPLANT 92	SIGPLANT				
	VOL -0.000	692 OCO G1 U1	OCO-GEN1				
STATE ESTIMATO	R CONVERGENCE SU	JMMARY - REGION OF INTEREST					
ACTIVATED OPTI NUMBER OF ITER	ACTIVATED OPTIONS : SCN FLT HYB STP TPE WRD TFX STR NUMBER OF ITERATIONS : 30						
PERFORMANCE IN	IDEX : 0.14886E4	⊷ 04					
ISLAND NO. NO. BUSE	OF PERFORMANCE S INDEX	E CONVERGENCE STATUS					
1 519	0.15E+04	4 STATE ESTIMATOR SOLVED					

SE Convergence Report

Always a good thing when SE is converging. Calls are made by the System Operator to the Operating Engineer and EMS support when not solving.

Stud	γCase :	0 04/15/24 16:32:	49.102 PDT: RTCA:	CS/CA: event	execution					
N Stat	Note: Status: CASE CONTAINS CONVERGED SOLUTION									
	Branches Voltage									
Ove	· Limit 3	:Over Limit 2	:Over Limit 1	High /	Low :Other					
MDE	#	Contingency Name	# of Viol	SPS Fired	Acknowledge Violations					
55	4 : TLE			0	: Acknowledge					
11	6 : VC_	-2_RAS_N		0	: Acknow] edge					
58	5 : 230	NC	: 1	0	: Acknowledge					
57	6 <mark>:</mark> 500	NC	: 2	0	: Acknowledge					
57	5 : 500	NC	: 1	0	: Acknowledge					
50	4 : 50003	3-50001 NC	: 1	0	: Acknowl edge					

Real-Time Contingency Analysis Report

Always a good thing when no contingencies are showing limit exceedance. Calls are made to the CAISO when issues show up. Operating Engineer assists in providing operating plan to mitigate issues.



Real-Time Tools – Phase Angle Difference

9022

9023 % SUPY

9029

B/F LOR

SUPY

SUPY

1

G

EMS Display with PMU data to calculate phase angle difference for transmission line with closing angle limit.

Study Case		0 04	/15/24	17:02	:09.021	PDT:	RTNA:	SE:	event	execution	
Note: Status:	CASE	CONTAIN	IS CON	VERGED	SOLUTIO	N					

Limit Name	Limit Status	Limit Type	Actual Differen	ice
: Close	Normal	Angle	13.179	Deg
: Closin	Normal	Angle	1.669	Deg
: Close	Normal	Angle	-3.059	Deg
: Close	Normal	Angle	5.369	Deg
: Closin	Normal	Angle	9.976	Deg
: Closin	Normal	Angle	1.750	Deg
: Close 23040 TJI	Normal	Angle	-1.259	Deg





Real-Time Tools – Voltage Stability Analysis

utilizing RC West's export of EMS model in CIM15 and loaded in V&R's ROSE





Real-Time Tools – SEL Synchrowave Operations

power system visualization, oscillation detection and notification





Linear State Estimator

- Linear State Estimator (LSE) is based on PMU measurements of voltage and current:
 - Voltage and current vectors are considered as the state variable

• Advantages of LSE:

- Improves real-time resilience:
 - A backup to the conventional SE solution if it fails to solve or SCADA data/communication is not available
- Improves real-time reliability:
 - A check/validation for the quality of conventional state estimator
- High speed state estimation due to using a direct non-iterative solution
 - Solves at PMU sample rate (30 times/sec)
 - Buses with no PMUs could become observable.



SDG&E PMU ROSE Architecture

LSE POM Server

Inputs:

- 1. PMU Voltage and current magnitude signals where PMUs are installed
- 2. SE in RAW conventional State Estimator cases in Siemens PSS/E .raw data format
- 3. Mapping File pmu signals mapped to bus and branches

Outputs:

- 1. LSE PMU LSE result at PMU locations
- 2. Observable PMU LSE result at locations observable with existing PMUs
- 3. RAW PMU Voltage and current from conventional State Estimator cases, converted to IEEE standard C37.118
- 4. LSE RAW PMU-based State Estimator cases in Siemens PSS/E .raw data format
- POM Real-Time Contingency Analysis App

3 apps: LSE POM Server, POM-RTCA, RTCA Viewer







SEL Synchrowave: PMU streams vs LSE conditioned

Apr. 1	0, 2024			Real-Tim	e Data				08:33:42			
	08:06	08:09 0	8:12 08:15	08:18	08:21	08:24	08:27 08:30	08:33	₿ 04/10/2024	👤 User 🕂 🖉) Frequency $ ightarrow$ Angle	P Power
								2	3m		Oscillation M. Malkana	A
								< >> -+ 1x	Minute Chart Range	⊘ General	V Oscillation V Voltage	All
♠	Dashboards		System > LSE Outputs >	Measurement Su	mmary Measuremer	nt Summary [±] Current Co	ompare Voltage Compare	Power Compare			ා ල් 🕂 Panel	+ Dashboard
-		Phase1		Phase1		Phase1		Phase1	·	ThreePhase	· · · · · · · · · · · · · · · · · · ·	ThreePhase
H	Measurement Points	Current	Measurement Points	Current	Measurement P	Points A Current	Measurement Poi	nts 🔺 Current	Measurement Points	Power Real	Measurement Points	Power Real
Ŷ		Magnitude		Magnitude		Magnitude		Magnitude	AL.TL6904		PLAL.TL6904	-5.875 MW
	PA.TL698	409.292 k	AL.116904	52.235 A		52.307 A		49.552 A	AV.TL691	-6.855 MW	PI.AV.TL691	-6.811 MW
Ŧ	AV.TL698	207.965 k	AV.11691	66.462 A	LSE.AV.IL691	66.215 A		69.408 A	AV.TL698	8.248 kW	PLAV.TL698	-1.184 kW
	ML.TL23023	99.762 k	AV.11698	0.257 A	LSE.AV.IL698	479.630 A		0.000 A	BB.TL23020	-336.962 MW	PI.BB.TL23020	-336.100 MW
	ECO.TL23018	187.979	BB.1L23020	853.000 A		821.243 A	TSM.BB.TL23020	890.400 A	BB.TL23026	552.895 MW	PI.BB.TL23026	551.400 MW
	SX.TL23051	115.424	BB.1L23026	1.405 KA	LSE.BB.TL23026	1.547 KA		1.4/2 KA	BB.TL23042	-339.320 MW	PI.BB.TL23042	-338.000 MW
	TA.TL23030	100.000	BB.1L23042	858.701 A	LSE.BB.IL23042	832./21 A	TSM.BB.IL23042	904.657 A	DW.TL23066	904.347 MW	PI.DW.TL23066	903.000 MW
	MS.TL23004	100.000	DW.1L23066	2.263 KA	LSE.DW.TL23066		TSM.DW.TL23066		DW.TL23067	-677.226 MW	PI.DW.TL23067	-676.000 MW
	MS.TL23001	100.000	DW.1L23067	1.698 KA	LSE.DW.1L23067	-	TSM.DW.IL23067	-	EA.TL13852	-25.033 MW	PI.EA.TL13852	-24.500 MW
	SA G.TL23001	100.000	EA.IL13801	15.623 A	LSE.EA.IL13801	14.339 A	TSM.EA.TL13801	8.845 A	EA.TL23003	282.565 MW	PI.EA.TL23003	280.000 MW
	SA G.TL23004	100.000	EA.IL13804	70.511 A	LSE.EA.IL13804	70.750 A	TSM.EA.TL13804	89.908 A	EA.TL23012	-243.384 MW	PI.EA.TL23012	-242.000 MW
	IV.TL50002	99.987	EA.IL13806	23.035 A	LSE.EA.1L13806	23.342 A	TSM.EA.TL13806	24.761 A	EA.TL23053	-243.817 MW	PI.EA.TL23053	-242.000 MW
	MLTL13824	80.568	EA.IL13849	15.037 A	LSE.EA.IL13849	16.443 A	TSM.EA.TL13849	10.149 A	EA.TL23074	4.644 MW	PI.EA.TL23074	4.000 MW
	ML.TL23041	64.086	EA.IL13852	103.561 A	LSE.EA.TL13852	103.075 A	TSM.EA.TL13852	113.605 A	ECO.TL13844	2.684 MW	PI.ECO.TL13844	2.900 MW
	SCR.TL23055	52.177	EA.TL23003	707.363 A	LSE.EA.TL23003	726.653 A	TSM.EA.TL23003	741.931 A	ECO.TL23018	1.888 MW	PI.ECO.TL23018	1.900 MW
	LCS.TL13824	47.579	EA.TL23012	609.560 A	LSE.EA.TL23012	554.244 A	TSM.EA.TL23012	611.010 A	ECO.TL50001	1363.680 MW	PI.ECO.TL50001	1363.200 MW
	TA.TL23052	45.870	EA.TL23053	611.239 A	LSE.EA.TL23053	555.331 A	TSM.EA.TL23053	612.203 A	ECO.TL50004	-1369.390 MW	PI.ECO.TL50004	-1369.300 MW
	SO.TL23052	44.436	EA.TL23074	11.851 A	LSE.EA.TL23074	11.987 A	TSM.EA.TL23074	0.418 A	IV.TL23043	-69.870 MW	PI.IV.TL23043	-67.000 MW
	IV.TI 50004	42.893	ECO.TL13844	167.996 A	LSE.ECO.TL13844	4 176.673 A	TSM.ECO.TL13844	172.934 A	IV.TL23045		PI.IV.TL23045	0.000 W
		Phase1	ECO.TL23018	19.080 A		51.187 A	TSM.ECO.TL23018	22.721 A	IV.TL23050	90.909 MW	PI.IV.TL23050	93.900 MW
		Voltage	ECO.TL50001	1.503 kA	LSE.ECO.TL50001	1.143 KA	TSM.ECO.TL50001	1.440 KA	IV.TL23061	-124.467 MW	PI.IV.TL23061	-124.000 MW
	Measurement Points	Magnitude	ECO.TL50004	1.506 kA	LSE.ECO.TL50004	4 858.362 A	TSM.ECO.TL50004	0.000 A	IV.TL23066	-893.357 MW	PI.IV.TL23066	-891.000 MW
		LseDeltaPct	IV.TL23043	175.508 A	LSE.IV.TL23043	175.117 A	TSM.IV.TL23043	167.004 A	IV.TL23082	90.655 MW	PI.IV.TL23082	90.000 MW
	PQ.1123012	0.883	IV.TL23045	12.443 A	LSE.IV.TL23045		TSM,IV,TL23045	2.233 A	IV.TL2305	48.947 MW	PI.IV.TL230S	50.000 MW
	PQ.IL23053	0.856	IV.TL23047	10.138 A	LSE.IV.TL23047		TSM.IV.TL23047	8.964 A	IV.TL50002	-436.528 MW	PI.IV.TL50002	-436.000 MW
	PQ.1123013	0.772	IV.TL23050	253.426 A	LSE.IV.TL23050	256.242 A	TSM.IV.TL23050	212.370 A	IV.TL50004	1377.150 MW	PI.IV.TL50004	1377.500 MW
	PQ.1123071	0.763	IV.TL23061	314.570 A	LSE.IV.TL23061	313.951 A	TSM.IV.TL23061	306.302 A	IV.TL50005	676.696 kW	PI.IV.TL50005	0.000 W
	ECO.TL50004	0.355	IV.TL23066	2.260 kA	LSE.IV.TL23066	2.173 kA	TSM.IV.TL23066	2.234 kA	LCS.TL13824	-90.235 MW	PI.LCS.TL13824	-89.900 MW
	ECO.TL50001	0.181	IV.TL23082	253.951 A	LSE.IV.TL23082	258.511 A	TSM.IV.TL23082	212.457 A	LI.TL688	944.768 kW	PI.LI.TL688	500.000 kW
	SX.TL23041	0.095	IV.TL230S	151.367 A	LSE.IV.TL2305	-	TSM.IV.TL230S	-	🚽 🔲 LI.TL6932	3.650 MW	PI.LI.TL6932	3.750 MW



PMU Additions / Mapping File Changes

(from 9/2022 to today)

Version 11	Version 14
(9/2022)	(4/2024)

	Voltage	Current	Voltage	Current
138kV Bus	Internal Buses/w PMU: 30/8		External Buses/w PMU	: 0/0
BUE 138	0	0	2	2
EA 138	0	0	4	3

69kV Bus	Internal Buses/w PMU	: (111+3 taps) / 19	External Buses/w P	MU: 0/0
ARR 69	n/a	n/a	4	4
AV 69	2	2	3	3
BUE 69	0	0	1	1
CN 69	0	0	0	1
ES 69	0	0	2	2
FE 69	0	0	1	1
KNY 69	0	0	2	2
LL 125	0	0	1	1
LL 190	0	0	1	1
OR 69	0	0	2	2
SX 69	0	0	6	6
VC 69	0	0	1	1



PMU Additions / Mapping File Changes

(from 9/2022 to today)

Version 11	Version 14
(9/2022)	(4/2024)

	Voltage	Current	Voltage	Current
500kV Bus	Count: Internal Buses/w PMU: 5/5		External Buses/w PMU:	6/0
N. Gila	2	4	0	0
Devers	2	5	0	0
Hassayampa	2	5	0	0
Palo Verde	3	3	0	0
Serrano	2	8	0	0
ValleySC	2	6	0	0

230kV Bus	Internal Buses/w PMU: 23/23		External Buses/w PM	U: 7/0
ALMITOSE	4	2	0	0
ALMITOSW	0	1	0	0
SANTIAGO 230	2	8	0	0
SERRANO 230	2	6	0	0
VIEJOSC 230	2	4	0	0
VILLA PK 230	2	7	0	0
S.ONOFRE	5	9	5	5
ARR 230	n/a	n/a	2	2



LSE – Observability Analysis and the LSE Case

Se	p-2	22

Observability						
Analysis	Initial	Stage 1	Stage 2	Stage 3	Stage 4	LSE Case
Buses						78
Branches						112

Sep-23

Observability							
Analysis	Initial	Stage 1	Stage 2	Stage 3	Stage 4	LSE Case	Delta
Buses	44	106	5 118	119	119	115	37
Branches	89	192	212	212	213	160	48

Apr-24

Observability							n.
Analysis	Initial	Stage 1	Stage 2	Stage 3	Stage 4	LSE Case	Delta
Buses	44	121	129	129	129	127	12
Branches	90	210	224	225	225	171	11

Apr-24 Buses Branches

5	225	171	
	_		
	SE	Case	
		278	
		567	

	LSE Cases	_
are	View	
LSE	► LSE Cases v (🖞 Search LSE Cases
	Name	Date modified
	20240405_182609_001	4/5/2024 6:26 PM
	40240405_182537_941	4/5/2024 6:25 PM
	20240405_182533_916	4/5/2024 6:25 PM
	20240405_182531_457	4/5/2024 6:25 PM
	30240405_182519_297	4/5/2024 6:25 PM
	30240405_182513_959	4/5/2024 6:25 PM
	40240405_182414_304	4/5/2024 6:24 PM
	40240405_182408_216	4/5/2024 6:24 PM
	40240405_182338_970	4/5/2024 6:23 PM
	40240405_182333_789	4/5/2024 6:23 PM
	20240405_182245_105	4/5/2024 6:22 PM
	30240405_182239_112	4/5/2024 6:22 PM
	40240405_182227_605	4/5/2024 6:22 PM
	20240405_182223_717	4/5/2024 6:22 PM
	20240405_182132_508	4/5/2024 6:21 PM

More installation of PMU data and bad data correction are needed to have meaningful comparison of the LSE case with the conventional SE case.

Delta 151

396



LSE Case – Pacific Southwest to local 69kV areas



Pacific Southwest Major Corridors

Adding PMUs of external entities in the corridors will be future endeavor to expand observability into external areas.



Shifting focus to local areas

As more IBRs connect to the local areas, creation of the LSE case for contingency analysis is more important as the actual condition changes quicker with batteries



Conclusions

- SDGE PMU ROSE is installed at SDG&E for LSE and RTCA.
- "Bad data" and modelling/mapping errors will continue to be investigated.
- More PMUs are needed to have good comparison between the SE and LSE case.
- Focus adding PMUs to the 69kV network (select buses) where existing and future batteries will be installed.







Robin Manuguid

Robin is a staff engineer in Grid Operations and leads the long-term outage coordination studies to sequence multi-phase transmission projects and successful completion of major projects. He provides realtime support for real-time tools (i.e., SE, RTCA, and near-RTVSA) and conducts next-day studies. He reviews and updates operating procedures which are often triggered by operating studies. Robin joined SDG&E in 1992 after earning his BSEE from Cal Poly, San Luis Obispo. He is a Principal Engineer with SDG&E. He is an IEEE member.



Project Costs & Benefits (slide for potential EPIC funding)

Enhance real-time monitoring, analysis, situational awareness, and control of SDG&E's grid. Facilitate transition to the dynamic grid of the future.

Estimated Budget: **\$2.5M** | Estimated Project Duration: **24-36 Months**

Outcomes

- Increased reliability
 - Fast and redundant SE and RTCA
- Increased size of observable parts of the system
- Improved accuracy and extent of PMU-based contingency analysis
- Deployment of other advanced application

Community Benefits

- Inverter based resources (IBR) connection at the transmission and distribution system.
- System Operators
- Plant Operators

Communities

•Select 69kV local areas

- •Existing batteries/new batteries
- High Fire Threat
 Districts
- Disadvantaged communities

