



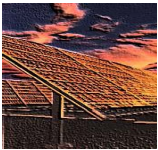
Grid Interconnection Technical Issues and Practices



Global Workshop on Grid Connected Renewable Energy

Washington, DC

29 August –6 September, 2009



Jaspal Deol, PE

Manager, New Services

Sacramento Municipal Utility District



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Generator Interconnection Process

- Application For An Interconnection With Utility
- Interconnection studies (system impact)
- Interconnection Agreement
- Design & Construction
- Commissioning Testing
- Parallel Operation



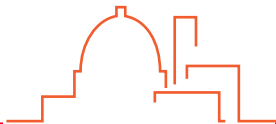
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Interconnection Requirements

- Operations
 - Technical
 - Administrative
- Revenue Metering
- System Protection
- SCADA - Monitoring



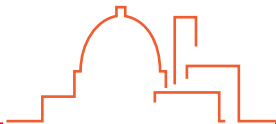
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Operational Requirements

- Power factor correction at inter-tie or point of delivery
- Voltage over ride capabilities (Wind)
- Firm vs Non Firm energy
- Forecast and operation reporting
- Prudent Operation and Maintenance Required
- Curtailment and Disconnection
- Design Reviews and Inspections
- Right to Access.



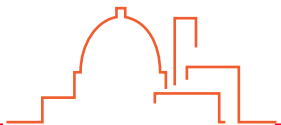
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Revenue Metering And Telemetry

- Gross, net, and station service revenue metering
- Remote communication to revenue meters
- Real time telemetry

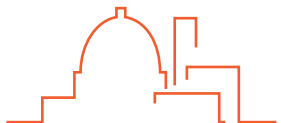


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Revenue Meters



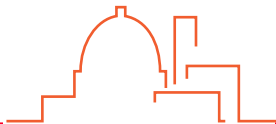
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System Protection

- Protection requirements by utilities are designed to protect utility system and not the generating facility.
 - Dedicated transformer with grounds at utility side. Transformer may need to have delta winding to suppress harmonic
 - Phase and ground fault protection
 - Direct transfer trip for anti-islanding
 - Over and under voltage trip functions
 - Over and under frequency
 - Direct transfer trip and relay communication
 - Auto reclose & synchronization with utilities
 - Visible disconnect
 - Fault interrupting device



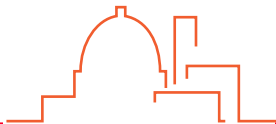
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System Protection - Continued

- Compliance with NERC, WECC and Balancing Authority requirements
 - Relay coordination
 - Relay maintenance
 - Outage investigation
 - Under voltage over-ride to stay on line during transmission disturbance
 - Documentation



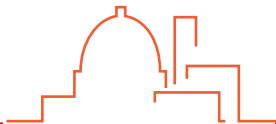
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SMUD Participation in – CAISO Participating Intermittent Resource Program (PIRP)

- Allows wind-powered generators to schedule energy without incurring imbalance charges when the delivered energy differs from the scheduled amount
- Access to Day-Ahead and Hour-Ahead MWh forecasts.
- Hourly imbalance from Actual and Scheduled energy are netted on a monthly basis and applied a weighted-average price.
 - *Moving Average Error = $\pm 12\%$*
 - *Forecasting Bias = $\pm 0.3\%$*
- Service fee of \$0.10 / MWh.
- *Terms of Participation*
 - *1 MW of rated capacity or higher.*
 - *Must have a single point of connection to the utility*
 - *Agreements and Letter of Intent*
 - *Install a Data Processing Gateway for MET data feeds and provide on-site forecast modeling information (plant size, location, turbine height, etc)*



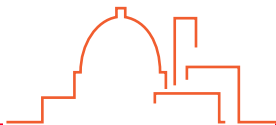
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PIRP PROCESS

- Data collected from real-time Meteorological (MET) towers, generation output, and scheduled outage information from the sites
- Data is sent to an independent Forecasting Service Provider (FSP) via high speed data links.
- The FSP processes the data through several modeling techniques and forwards the results to the interconnected utility.
- The interconnected utility sends Day-Ahead and Hour-Ahead MWh Forecast Schedules to generator's Scheduling Coordinators (SCs).
- The SCs then submit their DA/HA schedules based on the forecast back to the interconnected utility.
- The utility validates the actual hourly power delivery against the forecast and move that hour's imbalance to the "monthly netted".

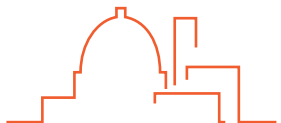
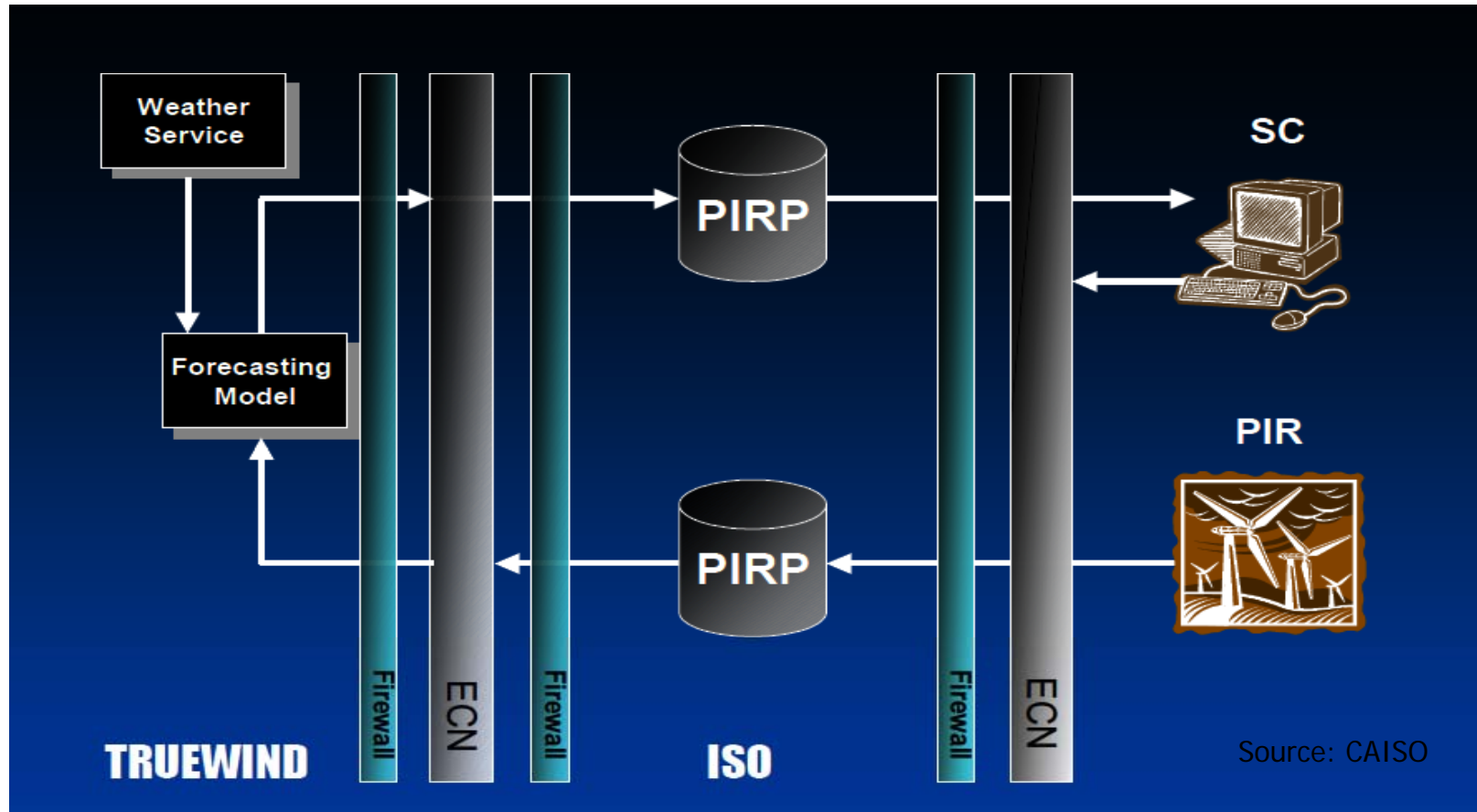


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PIRP PROCESS

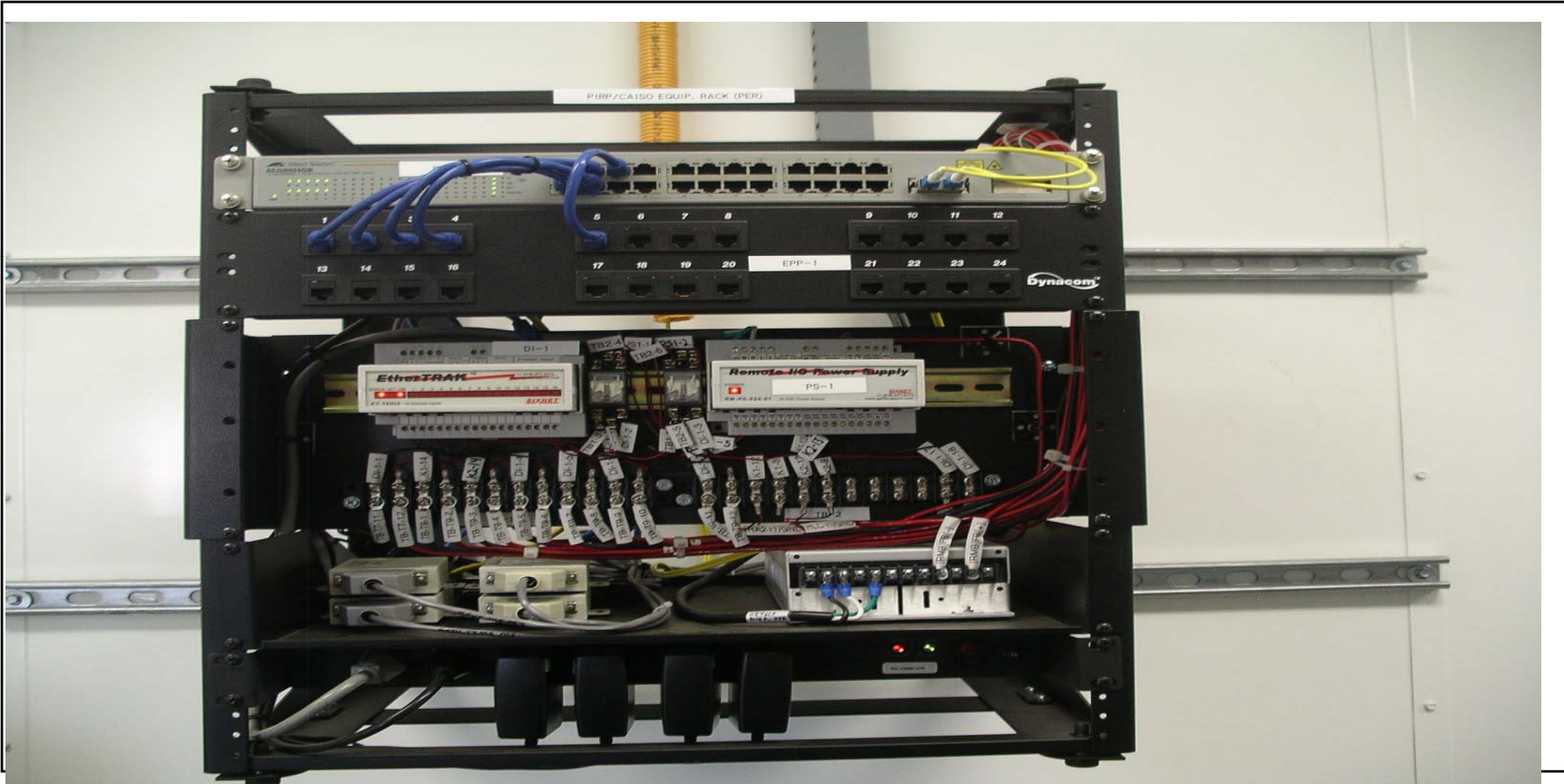


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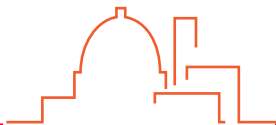
Communication Equipment For Meters To Participate In PIRP



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WECC Generator Low Voltage Ride-Through (LVRT) Criterion (PRC-024-WECC-1-CR)

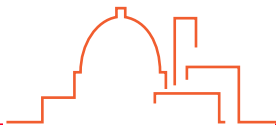
Purpose:

To ensure that generators remain in service during specified voltage excursions and do not trip off-line as a result of improper generator protective relays settings.

Effective Date: May 1, 2009

Applicability

- Individual generating unit or a site of generators where the sum of the of all generators at the high voltage side of the generating plant step-up transformer is ≥ 20 MVA and high side voltage levels are ≥ 60 kV.
- Wind generation units installed after January 1, 2008 are required to meet this criterion.
- Generating units existing before the effective date are exempt from meeting this criterion for the remaining life of the existing generation equipment. This includes generators under construction and generators with an executed interconnection agreement or Power Purchase Agreement, or generators with an executed equipment purchase contract and scheduled delivery within two years.
- Existing wind generators installed before January 1, 2008 that are replaced or upgraded that result in an increase of nameplate rating by more than 10 percent are required to meet this criterion



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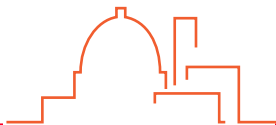
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Requirements – Cont'd

➤ FERC Rule 661A

- All generators required to remain in-service during three-phase faults on the transmission system with normal clearing (for nine cycles) unless clearing the fault disconnects the generator from the transmission system.
 - Clearing time requirement for a three-phase fault shall be specific to the generators' substation location, as determined by the Transmission Service Provider.
 - If fault is not cleared in the location-specific normal clearing time for three-phase faults, the generators may disconnect from the transmission system.
 - Generators shall remain interconnected during a three-phase fault on the transmission system for a voltage level as low as zero volts, as measured at the high voltage side of the generating plant step-up transformer.



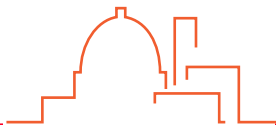
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Requirements – cont'd

- All generators are required to remain in-service during single-line-to-ground faults on the transmission system with delayed clearing unless clearing the fault disconnects the generator from the transmission system.
- Generators Protection Systems shall not trip the generator for the low voltage deviations of 20 percent for 40 cycles at the high voltage side of the generating plant step-up transformer.
 - Generators may be tripped after fault initiation if this action is intended as part of a Special Protection System (SPS).
- The Transmission Service Provider shall provide to the Generator Owner the normal breaker clearing time for three-phase faults and delayed clearing time for single-line-to-ground faults at the high voltage side of the generating plant step-up transformer.

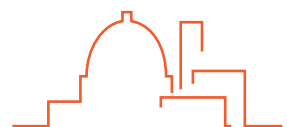
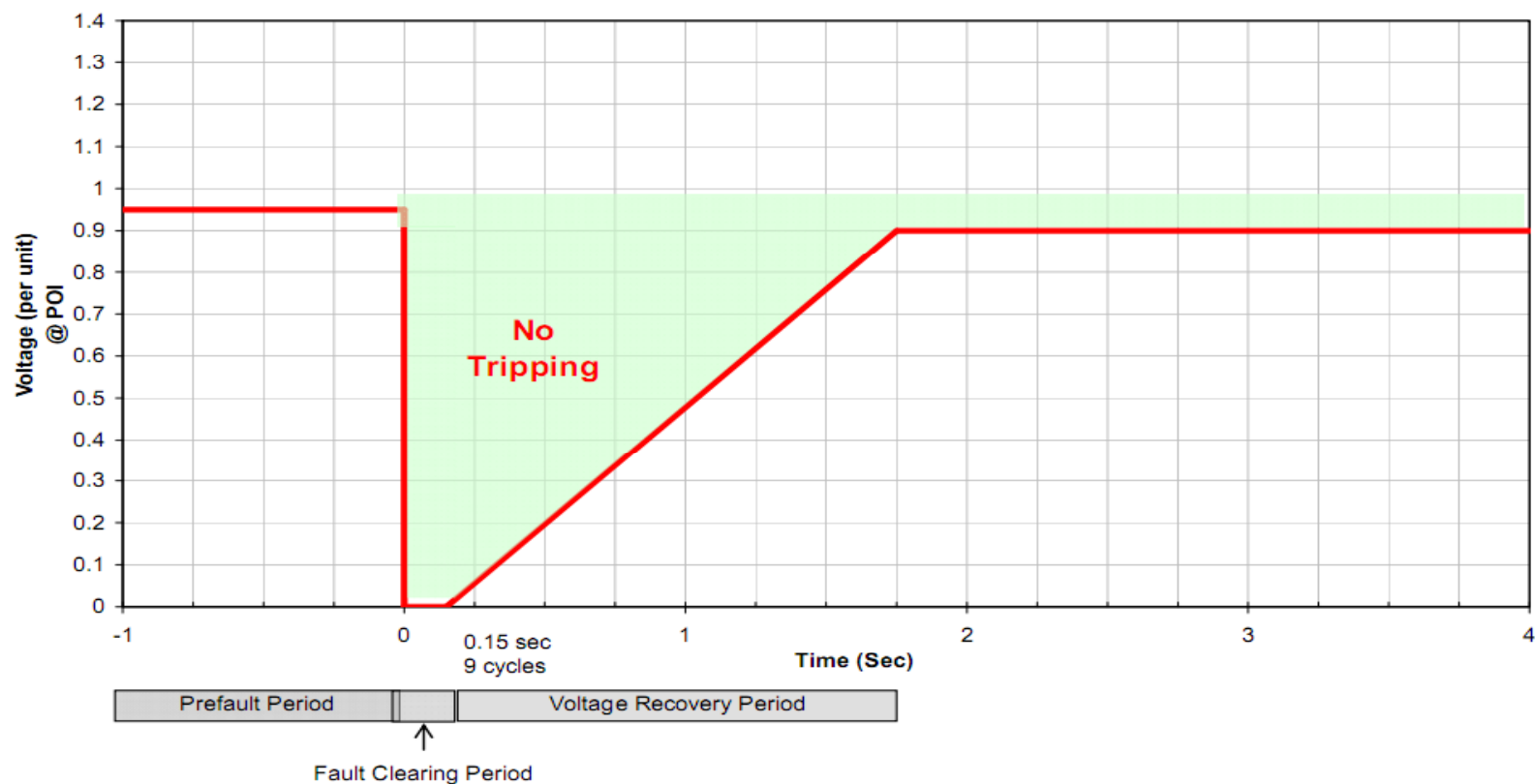


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Generator Low Voltage Ride-Through Criterion



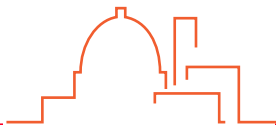
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California's Rule 21

- Why did we need Rule 21?
 - Different processes across California's utilities – vendors
 - Inconsistent applications of the rules (even within a utility)
 - Overly conservative, size based, rules
- Net-metering Legislation
- Inverter based technologies
- Quickly Identifies “Plug & Play” installations
 - Certified Inverters
- One Flowchart for all interconnection reviews
- Layouts Certification Process

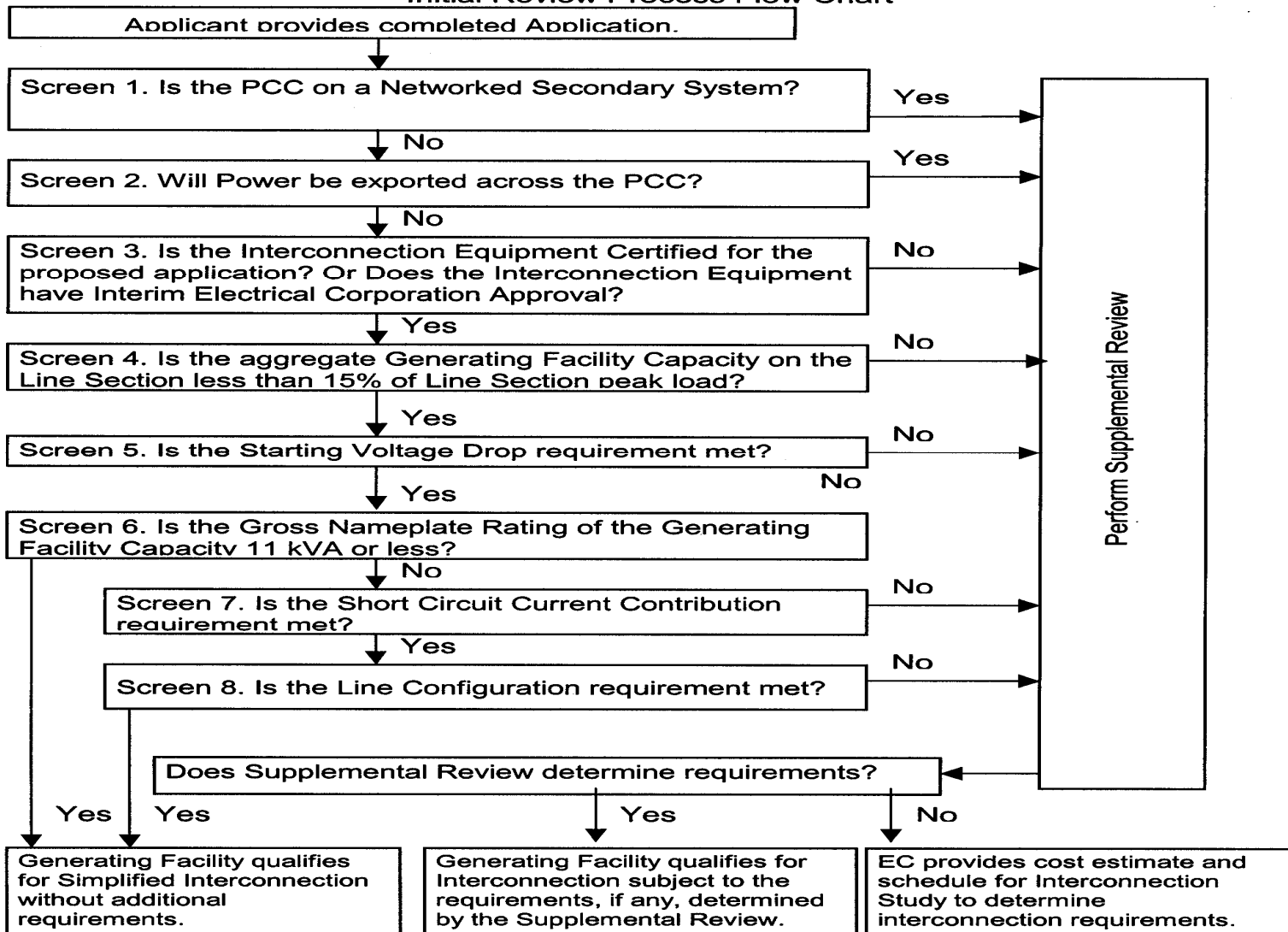


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Initial Review Process Flow Chart



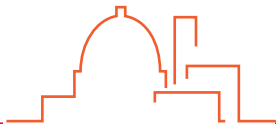
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Certified Equipment

- Integrated Relaying Functions
- Tested by a Nationally Recognized Testing Laboratory (UL, CSA)
- Set to IEEE 1547 relaying set points
 - Under/Over Voltage - 88% to 110% of Nominal
 - Under/Over Frequency – 59.3 Hz to 60.5 Hz (assuming 60 Hz nominal)
 - Active Anti-Islanding



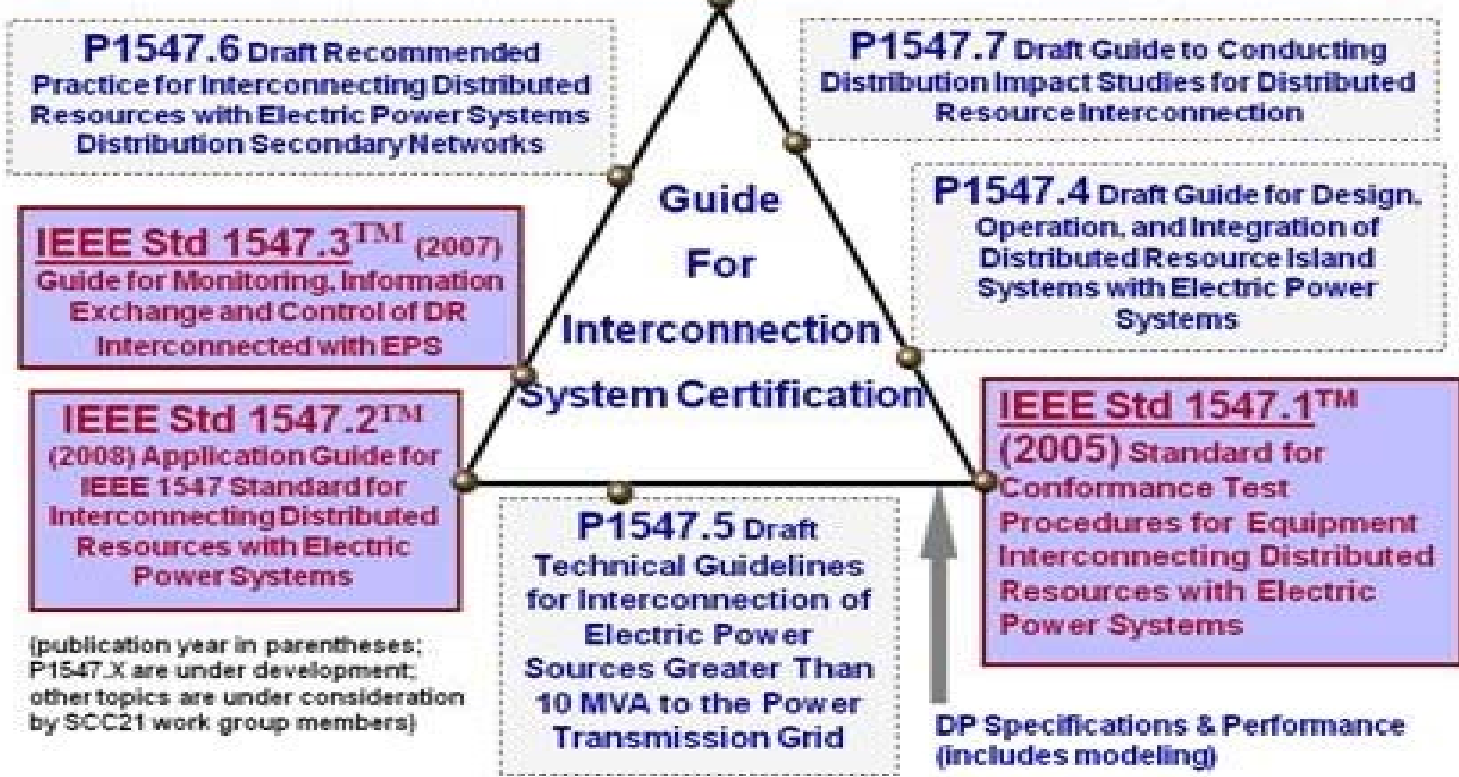
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IEEE SCC21 1547 Series of Interconnection Standards

IEEE Std 1547™ (2003) Standard for Interconnecting Distributed Resources with Electric Power Systems



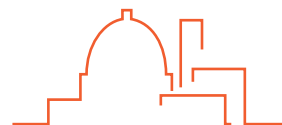
(publication year in parentheses; P1547.X are under development; other topics are under consideration by SCC21 work group members)

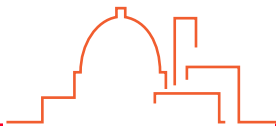
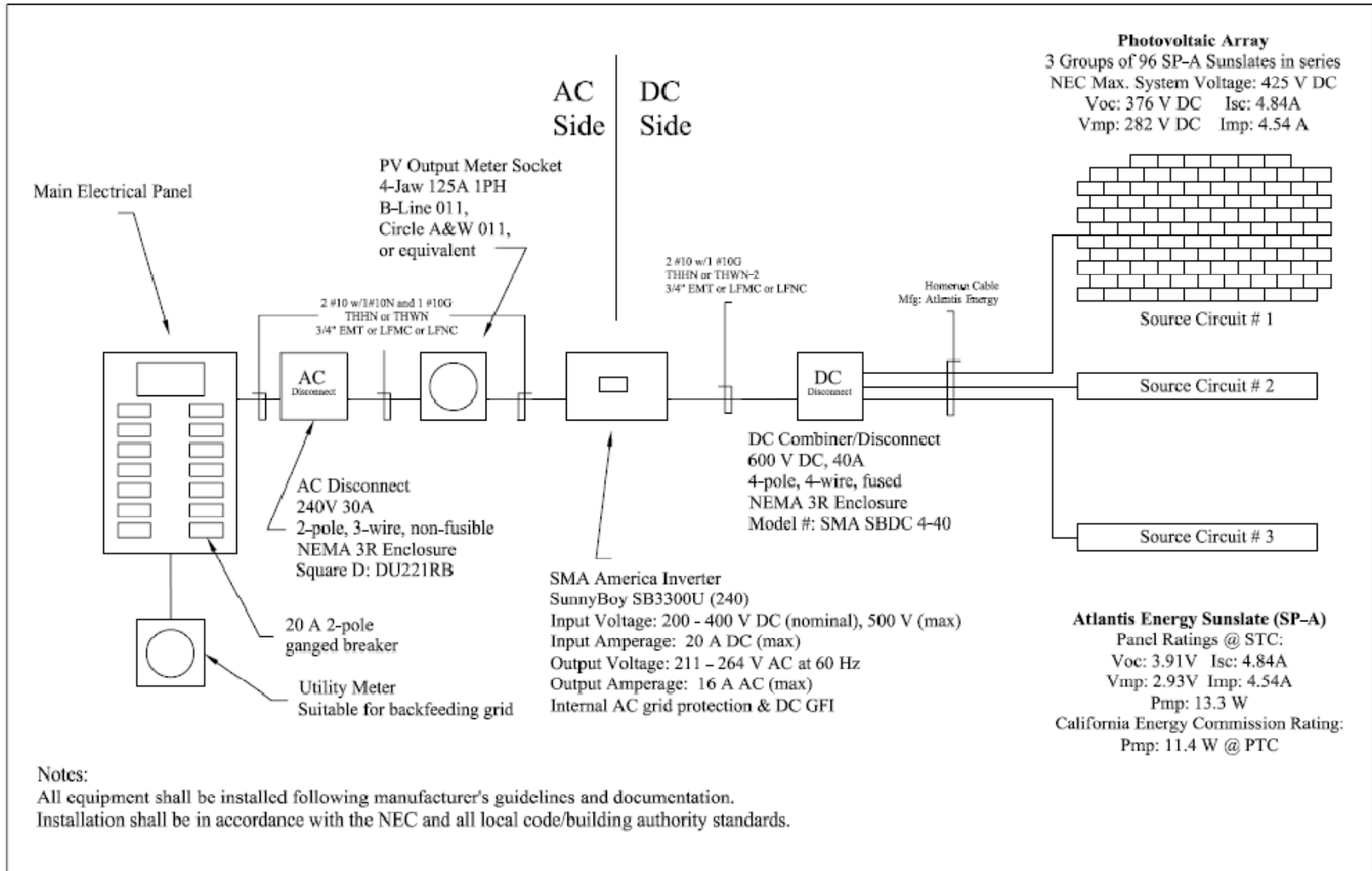


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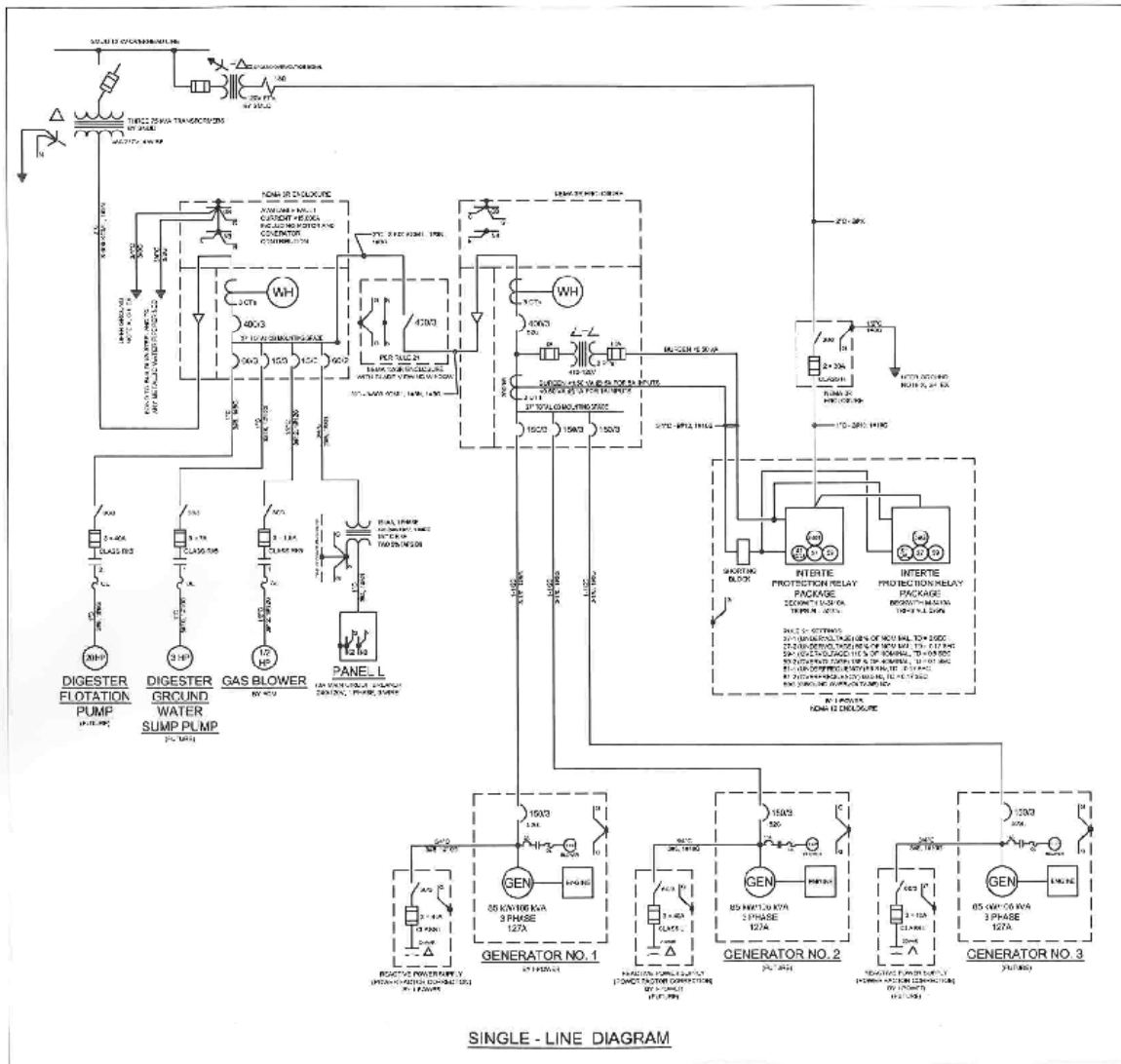




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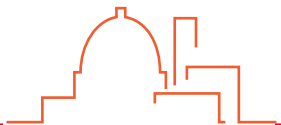
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LOAD	DIRECTION	WIRE	DEFLECTION	LOAD
3.0A	MULTIPLY LOADS	2/1	2/2	2/3
LOAD	DEFLECT LOADS	2/4	2/5	2/6
FLUOR VALVE	2/7	2/8	2/9	2/10
25KV/15KV TRANSFORMER	2/11	2/12	2/13	2/14
BLANK	2/15	2/16	2/17	2/18
PLATE CHATER	2/19	2/20	2/21	2/22
25KV/15KV TRANSFORMER	2/23	2/24	2/25	2/26
25KV/15KV TRANSFORMER	2/27	2/28	2/29	2/30
25KV/15KV TRANSFORMER	2/31	2/32	2/33	2/34
25KV/15KV TRANSFORMER	2/35	2/36	2/37	2/38
25KV/15KV TRANSFORMER	2/39	2/40	2/41	2/42
25KV/15KV TRANSFORMER	2/43	2/44	2/45	2/46
25KV/15KV TRANSFORMER	2/47	2/48	2/49	2/50
25KV/15KV TRANSFORMER	2/51	2/52	2/53	2/54
25KV/15KV TRANSFORMER	2/55	2/56	2/57	2/58
25KV/15KV TRANSFORMER	2/59	2/60	2/61	2/62
25KV/15KV TRANSFORMER	2/63	2/64	2/65	2/66
25KV/15KV TRANSFORMER	2/67	2/68	2/69	2/70
25KV/15KV TRANSFORMER	2/71	2/72	2/73	2/74
25KV/15KV TRANSFORMER	2/75	2/76	2/77	2/78
25KV/15KV TRANSFORMER	2/79	2/80	2/81	2/82
25KV/15KV TRANSFORMER	2/83	2/84	2/85	2/86
25KV/15KV TRANSFORMER	2/87	2/88	2/89	2/90
25KV/15KV TRANSFORMER	2/91	2/92	2/93	2/94
25KV/15KV TRANSFORMER	2/95	2/96	2/97	2/98
25KV/15KV TRANSFORMER	2/99	2/100	2/101	2/102
25KV/15KV TRANSFORMER	2/103	2/104	2/105	2/106
25KV/15KV TRANSFORMER	2/107	2/108	2/109	2/110
25KV/15KV TRANSFORMER	2/111	2/112	2/113	2/114
25KV/15KV TRANSFORMER	2/115	2/116	2/117	2/118
25KV/15KV TRANSFORMER	2/119	2/120	2/121	2/122
25KV/15KV TRANSFORMER	2/123	2/124	2/125	2/126
25KV/15KV TRANSFORMER	2/127	2/128	2/129	2/130
25KV/15KV TRANSFORMER	2/131	2/132	2/133	2/134
25KV/15KV TRANSFORMER	2/135	2/136	2/137	2/138
25KV/15KV TRANSFORMER	2/139	2/140	2/141	2/142
25KV/15KV TRANSFORMER	2/143	2/144	2/145	2/146
25KV/15KV TRANSFORMER	2/147	2/148	2/149	2/150
25KV/15KV TRANSFORMER	2/151	2/152	2/153	2/154
25KV/15KV TRANSFORMER	2/155	2/156	2/157	2/158
25KV/15KV TRANSFORMER	2/159	2/160	2/161	2/162
25KV/15KV TRANSFORMER	2/163	2/164	2/165	2/166
25KV/15KV TRANSFORMER	2/167	2/168	2/169	2/170
25KV/15KV TRANSFORMER	2/171	2/172	2/173	2/174
25KV/15KV TRANSFORMER	2/175	2/176	2/177	2/178
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25KV/15KV TRANSFORMER	2/183	2/184	2/185	2/186
25KV/15KV TRANSFORMER	2/187	2/188	2/189	2/190
25KV/15KV TRANSFORMER	2/191	2/192	2/193	2/194
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25KV/15KV TRANSFORMER	2/211	2/212	2/213	2/214
25KV/15KV TRANSFORMER	2/215	2/216	2/217	2/218
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25KV/15KV TRANSFORMER	2/235	2/236	2/237	2/238
25KV/15KV TRANSFORMER	2/239	2/240	2/241	2/242
25KV/15KV TRANSFORMER	2/243	2/244	2/245	2/246
25KV/15KV TRANSFORMER	2/247	2/248	2/249	2/250
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25KV/15KV TRANSFORMER	2/263	2/264	2/265	2/266
25KV/15KV TRANSFORMER	2/267	2/268	2/269	2/270
25KV/15KV TRANSFORMER	2/271	2/272	2/273	2/274
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25KV/15KV TRANSFORMER	2/303	2/304	2/305	2/306
25KV/15KV TRANSFORMER	2/307	2/308	2/309	2/310
25KV/15KV TRANSFORMER	2/311	2/312	2/313	2/314
25KV/15KV TRANSFORMER	2/315	2/316	2/317	2/318
25KV/15KV TRANSFORMER	2/319	2/320	2/321	2/322
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25KV/15KV TRANSFORMER	2/335	2/336	2/337	2/338
25KV/15KV TRANSFORMER	2/339	2/340	2/341	2/342
25KV/15KV TRANSFORMER	2/343	2/344	2/345	2/346
25KV/15KV TRANSFORMER	2/347	2/348	2/349	2/350
25KV/15KV TRANSFORMER	2/351	2/352	2/353	2/354
25KV/15KV TRANSFORMER	2/355	2/356	2/357	2/358
25KV/15KV TRANSFORMER	2/359	2/360	2/361	2/362
25KV/15KV TRANSFORMER	2/363	2/364	2/365	2/366
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25KV/15KV TRANSFORMER	2/375	2/376	2/377	2/378
25KV/15KV TRANSFORMER	2/379	2/380	2/381	2/382
25KV/15KV TRANSFORMER	2/383	2/384	2/385	2/386
25KV/15KV TRANSFORMER	2/387	2/388	2/389	2/390
25KV/15KV TRANSFORMER	2/391	2/392	2/393	2/394
25KV/15KV TRANSFORMER	2/395	2/396	2/397	2/398
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25KV/15KV TRANSFORMER	2/411	2/412	2/413	2/414
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25KV/15KV TRANSFORMER	2/435	2/436	2/437	2/438
25KV/15KV TRANSFORMER	2/439	2/440	2/441	2/442
25KV/15KV TRANSFORMER	2/443	2/444	2/445	2/446
25KV/15KV TRANSFORMER	2/447	2/448	2/449	2/450
25KV/15KV TRANSFORMER	2/451	2/452	2/453	2/454
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25KV/15KV TRANSFORMER	2/459	2/460	2/461	2/462
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25KV/15KV TRANSFORMER	2/483	2/484	2/485	2/486
25KV/15KV TRANSFORMER	2/487	2/488	2/489	2/490
25KV/15KV TRANSFORMER	2/491	2/492	2/493	2/494
25KV/15KV TRANSFORMER	2/495	2/496	2/497	2/498
25KV/15KV TRANSFORMER	2/499	2/500	2/501	2/502
25KV/15KV TRANSFORMER	2/503	2/504	2/505	2/506
25KV/15KV TRANSFORMER	2/507	2/508	2/509	2/510
25KV/15KV TRANSFORMER	2/511	2/512	2/513	2/514
25KV/15KV TRANSFORMER	2/515	2/516	2/517	2/518
25KV/15KV TRANSFORMER	2/519	2/520	2/521	2/522
25KV/15KV TRANSFORMER	2/523	2/524	2/525	2/526
25KV/15KV TRANSFORMER	2/527	2/528	2/529	2/530
25KV/15KV TRANSFORMER	2/531	2/532	2/533	2/534
25KV/15KV TRANSFORMER	2/535	2/536	2/537	2/538
25KV/15KV TRANSFORMER	2/539	2/540	2/541	2/542
25KV/15KV TRANSFORMER	2/543	2/544	2/545	2/546
25KV/15KV TRANSFORMER	2/547	2/548	2/549	2/550
25KV/15KV TRANSFORMER	2/551	2/552	2/553	2/554
25KV/15KV TRANSFORMER	2/555	2/556	2/557	2/558
25KV/15KV TRANSFORMER	2/559	2/560	2/561	2/562
25KV/15KV TRANSFORMER	2/563	2/564	2/565	2/566
25KV/15KV TRANSFORMER	2/567	2/568	2/569	2/570
25KV/15KV TRANSFORMER	2/571	2/572	2/573	2/574
25KV/15KV TRANSFORMER	2/575	2/576	2/577	2/578
25KV/15KV TRANSFORMER	2/579	2/580	2/581	2/582
25KV/15KV TRANSFORMER	2/583	2/584	2/585	2/586
25KV/15KV TRANSFORMER	2/587	2/588	2/589	2/590
25KV/15KV TRANSFORMER	2/591	2/592	2/593	2/594
25KV/15KV TRANSFORMER	2/595	2/596	2/597	2/598
25KV/15KV TRANSFORMER	2/599	2/600	2/601	2/602
25KV/15KV TRANSFORMER	2/603	2/604	2/605	2/606
25KV/15KV TRANSFORMER	2/607	2/608	2/609	2/610
25KV/15KV TRANSFORMER	2/611	2/612	2/613	2/614
25KV/15KV TRANSFORMER	2/615	2/616	2/617	2/618
25KV/15KV TRANSFORMER	2/619	2/620	2/621	2/622
25KV/15KV TRANSFORMER	2/623	2/624	2/625	2/626
25KV/15KV TRANSFORMER	2/627	2/628	2/629	2/630
25KV/15KV TRANSFORMER	2/631	2/632	2/633	2/634
25KV/15KV TRANSFORMER	2/635	2/636	2/637	2/638
25KV/15KV TRANSFORMER	2/639	2/640	2/641	2/642
25KV/15KV TRANSFORMER	2/643	2/644	2/645	2/646
25KV/15KV TRANSFORMER	2/647	2/648	2/649	2/650
25KV/15KV TRANSFORMER	2/651	2/652	2/653	2/654
25KV/15KV TRANSFORMER	2/655	2/656	2/657	2/658
25KV/15KV TRANSFORMER	2/659	2/660	2/661	2/662
25KV/15KV TRANSFORMER	2/663	2/664	2/665	2/666
25KV/15KV TRANSFORMER	2/667	2/668	2/669	2/670
25KV/15KV TRANSFORMER	2/671	2/672	2/673	2/674
25KV/15KV TRANSFORMER	2/675	2/676	2/677	2/678
25KV/15KV TRANSFORMER	2/679	2/680	2/681	2/682
25KV/15KV TRANSFORMER	2/683	2/684	2/685	2/686
25KV/15KV TRANSFORMER	2/687	2/688	2/689	2/690
25KV/15KV TRANSFORMER	2/691	2/692	2/693	2/694
25KV/15KV TRANSFORMER	2/695	2/696	2/697	2/698
25KV/15KV TRANSFORMER	2/699	2/700	2/701	2/702
25KV/15KV TRANSFORMER	2/703	2/704	2/705	2/706
25KV/15KV TRANSFORMER	2/707	2/708	2/709	2/710
25KV/15KV TRANSFORMER	2/711	2/712	2/713	2/714
25KV/15KV TRANSFORMER	2/715	2/716	2/717	2/718
25KV/15KV TRANSFORMER	2/719	2/720	2/721	2/722
25KV/15KV TRANSFORMER	2/723	2/724	2/725	2/726
25KV/15KV TRANSFORMER				

Protection – Ground Fault Detection Bank – Transformer connected Wye Grounded – Broken Delta



Employed on
larger (<100kW)
synchronous
generator
interconnections
to SMUD's
distribution



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Protection - Multi-Function Interconnection Relays



- Standard settings
- All-in one design
- Redundancy (shown) not typically required



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Landfill Gas Energy Project

- 1996 LES installed 145 gas collection wells
- 1999 Phase 2 construction began
- Phase 2 expanded generation to 9MW's
- Uses 3 Caterpillar 3616 engine generator sets, 3 MVA each.
- Phase 3 Expansion – 15 MW's total
- Interconnection to SMUD grid at 69kV
- Power purchased by SMUD under long-term agreement



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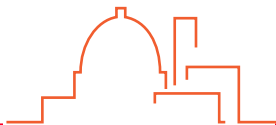
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Grid Interconnection

- Make it easy
- Simplified and standardized rules for interconnection
- Reduce time to deploy
- Lower cost to connect
- Eliminated uncertainty
- Enable renewable energy interconnection and development
 - Established an environment that supports renewable technologies
 - Incent distributed generation (Solar, PV, Wind, CHP, micro-turbines, fuel cells, etc)

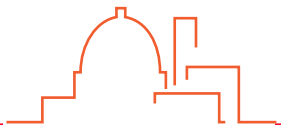


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Questions?



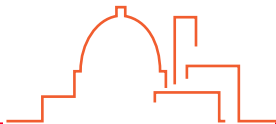
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Profile – *Jaspal Deol, PE*

- Registered Professional Engineer – State of California
- 26 years of Electric Utility experience
 - Generation, Transmission, and Distribution
- 20+ years in Renewables (Photovoltaic, Wind, Geothermal)
- Various leadership positions in Design & Construction, Grid operations, System Protection, Power Operations Planning, Customer Services, and New Services
- Board of Directors – Sacramento Hispanic Chamber of Commerce
- Board of Directors – Indus Valley American Chamber of Commerce
- Presidents Community Council member - California State University, Sacramento
- Past Vice-Chair – IEEE Sacramento Section



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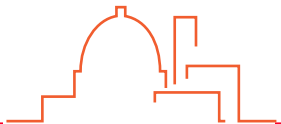
More Information

www.smud.org

www.ourgreencommunity.org



*Thank you,
Jaspal Deol
jdeol@smud.org*



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