

Power Analytics Overview

Innovation in Power

2017

Power Analytics – Value Proposition

POWER ANALYTICS™

Power Analytics is a software and power engineering company with thousands of customers globally. Power Analytics maintains a library of over 25,000 devices (grid elements) for unparalleled ability to model and simulate virtually any size power system.

- Paladin DesignBase™ Power Analysis software, training and support
  - Desktop and network software for professional power engineers around the world
  - ISO 9001 (International Organization for Standardization certified)
  - NUPIC (Nuclear Regulatory Agency certified)
  - Real time dashboards and "what if" scenarios

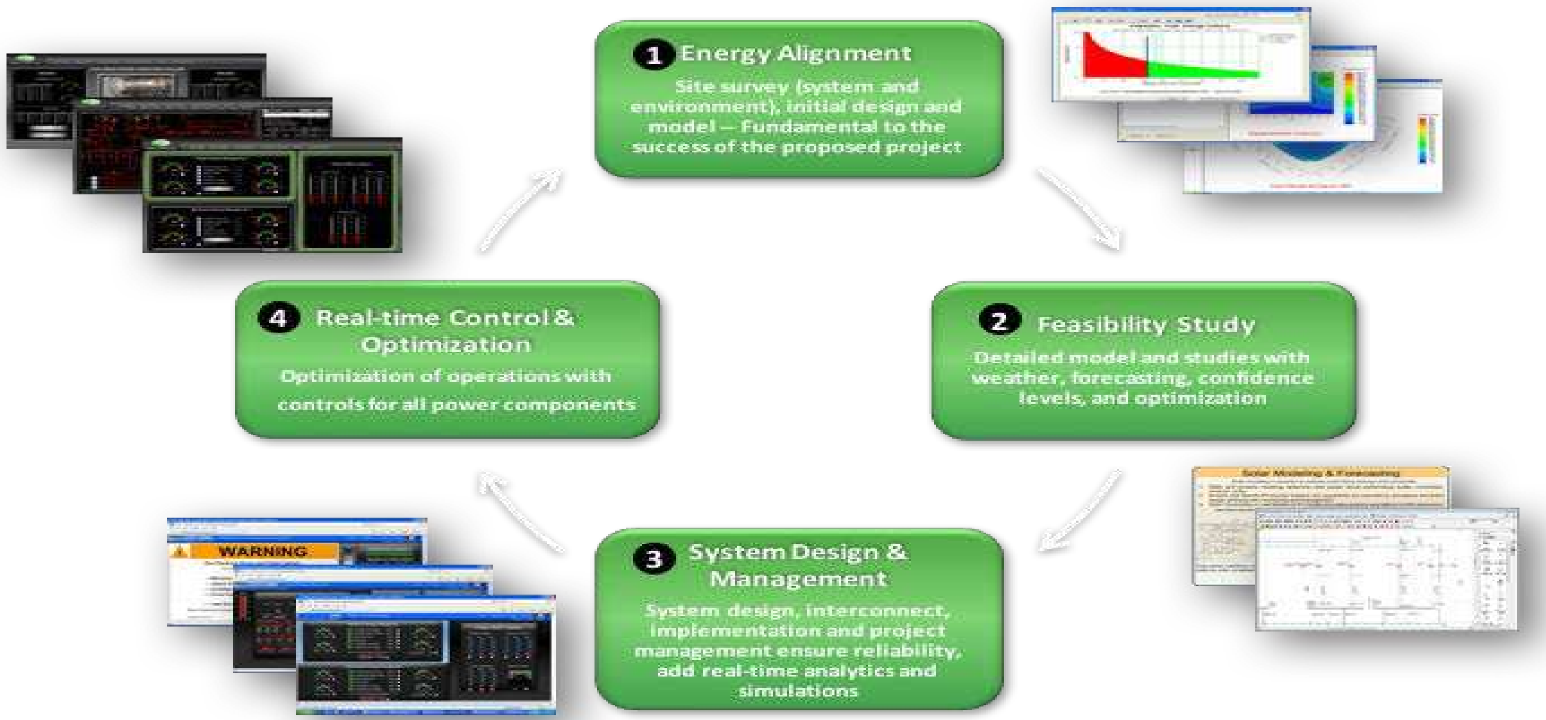
- Professional power engineering services
  - Extensive use case examples
  - Arc Flash (AC & DC), transient analysis etc.

- Power & Economic analysis for distributed generation, microgrids, mission critical environments
  - Specific expertise in solar, energy storage, market/tariff analysis
  - Specific expertise and experience in the regulatory and rulemaking processes related to the Independent System Operator (ISO) and utility markets
  - An integrated approach to power and economic modeling, the Energy Alignment Plan™

Energy Alignment Plan – It all starts with a power model

Power Analytics approach is based on advanced systems power modeling using power models and results to create a new dynamic power model in Power Analytics DesignBase. The initial analysis process includes the ability to use existing time series data to validate and refine the dynamic analysis.

The approach, called an Energy Alignment Plan™ is an approach that Power Analytics and our customers have used repeatedly in mission critical power use cases for over 10 years.



Example Typical Assets For Energy Alignment Planning

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Transmission Connection

Sub-station

Distributed Generation

Wind

Solar

Energy Storage

Major components in a power system

Typical Equipment (Scaled Model)

2.5MVA Grid Interconnect

Switchgear up to 1300 KW

NG Gensets 170 KW

WT Sim 125 KW

Solar Sim 25KW, 10KW

Load Bank 400 KW 0.8 PF

Paladin DesignBase™

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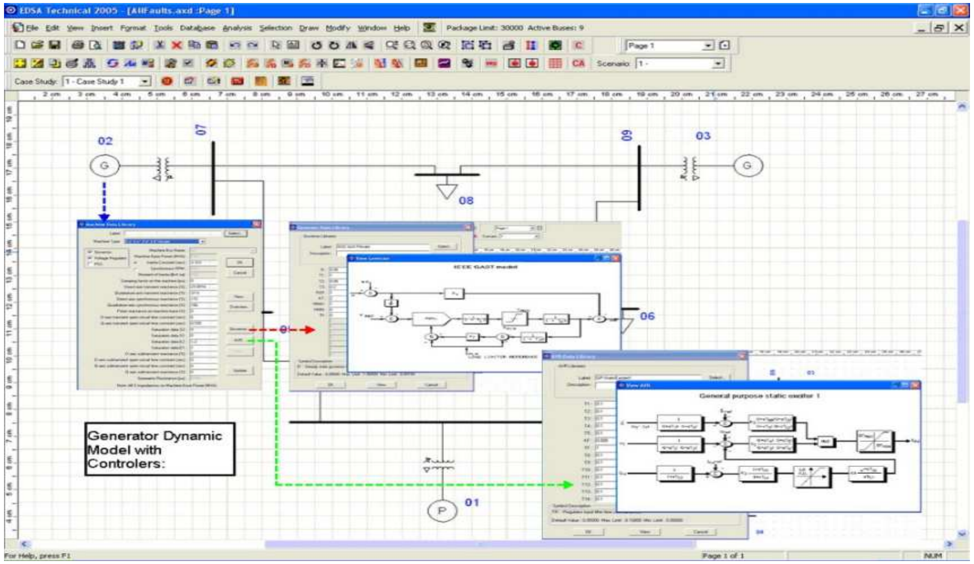
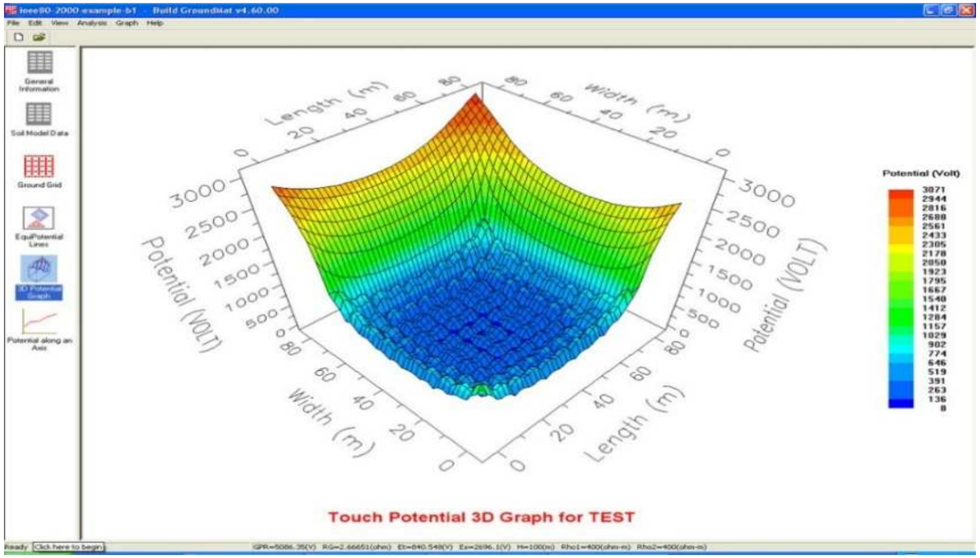
- **Paladin DesignBase**
  - Professional Computer aided design (CAD) application for the design and analysis of any power network.
  - Globally recognized for advanced power analysis including dynamic analysis of complex power systems
    - ✓ Core to power analytics intellectual property and capability
    - ✓ Sold globally as shrink wrap software (secure download from PAC web site)
    - ✓ Massively scalable for any size network design.





Paladin DesignBase – Energy Storage Modeling

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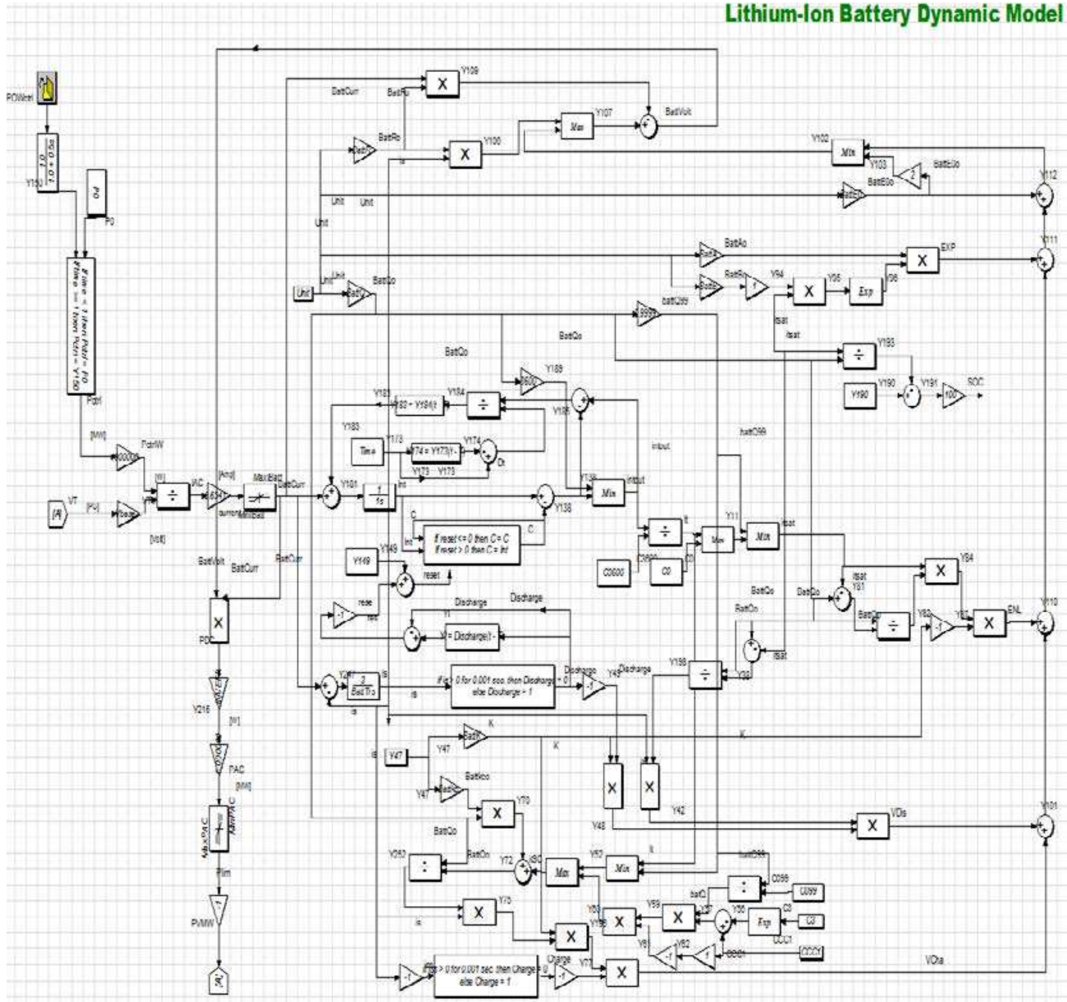
- Utilizing the DesignBase power modeling algorithms software to dynamically model the energy storage is fundamental to the power and economic analysis.
- For example, the diagram to the right is based on a lithium-ion battery transient model for dynamic battery behavior during the charging/discharging modes.
- This model receives the battery DC current as input and calculates the battery DC voltage.
- This model can track the state of the charge (SOC) of the battery during the simulation and providing appropriate transient behavior of battery voltage during charging and discharging modes by modeling the charge/discharge voltage curves versus the energy usage.
- The output of the model is the source of the control settings, which is itself a function of the overall dynamic optimization. As input (real time data) changes, the model is continually re-optimized.



Paladin DesignBase Real Time Dashboard Control
The Power of a Model

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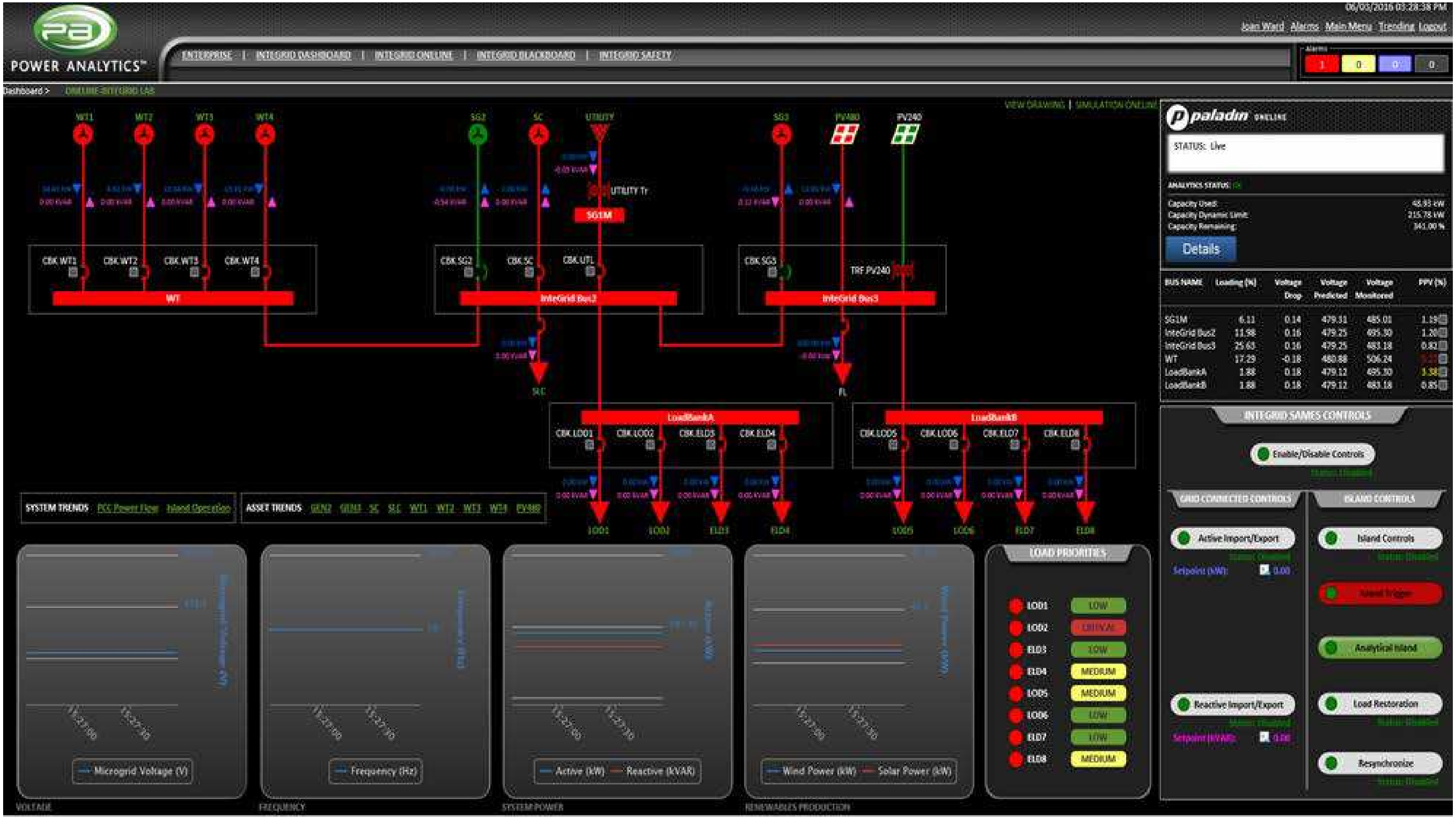

Power Analytics depth of experience

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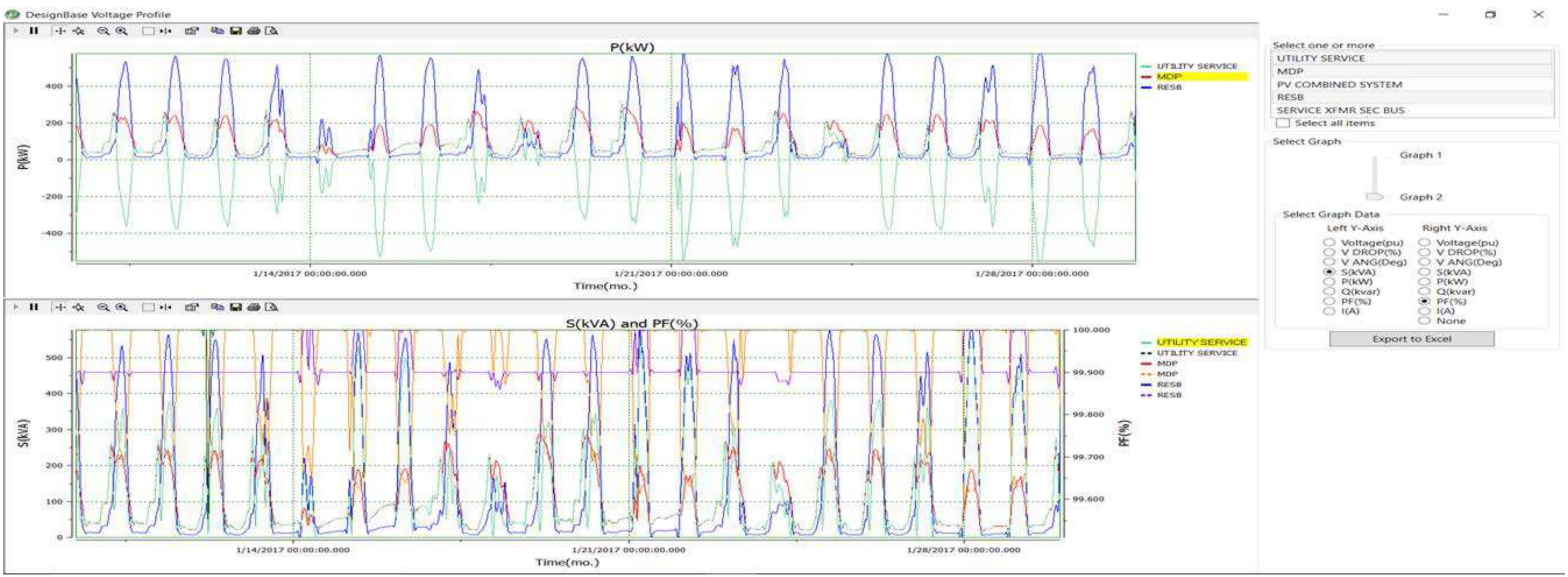
- Major Power Studies:
  - Power Flow (AC/DC)
  - Short Circuit (AC/DC)
  - Protection Device Coordination
  - Arc Flash (AC/DC)
  - Cable Ampacity
  - Transmission Line Parameters
- Advanced Power Studies:
  - Transient Stability
  - Harmonic Analysis
  - Ground Grid Design
  - Motor Starting
  - Voltage Stability
  - Unbalanced Power Flow
- Optimization Analysis:
  - Power System Optimization
  - Reliability Assessment
- Feasibility Analysis:
  - On-site Distributed Generation & grid Interconnection
  - Distributed Energy Resources (DER)
  - Microgrid Implementation
  - Electrical Reliability Improvement
  - Voltage Sag Solution
  - Damping of Electrical Voltage and Power Transient
- Economic Analysis
  - Energy storage sizing
  - Photo voltaic sizing
  - Cost comparison/optimization
  - Electric rate (tariff) analysis
  - Risk mitigation
- Regulatory and Rulemaking Analysis
  - Independent System Operator (ISO) and utility markets

Power Analytics – Time Series Analysis

- **Power Analytics Time Series Power Modeling:**
    - Power Analytics creates a basic power model from existing or planned data focusing on a high level power model without constraints or power violations.
    - With the power model complete, time series data from existing sources, are loaded into the dynamic model and run evaluated in the power model. Typically covering one year of one hour data (8760 data) identifying critical peak loads, generation and any violations of the power design.



Power Analytics – Economic based power modeling

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- **Power Analytics Economic Modeling Tied to the Power Flow:**
  - With a successful power model analysis, the economic model is added based on energy rate (tariff's), potential energy market programs and other relevant financial variables.
  - This example is based on photo voltaic production and two different market programs

Month	Average Load	Actual Load	Net kW	60% kWh Charge	70% kWh Charge	100% kWh Charge	Demand	Demand Charge	Minimum (Demand)	Min (kWh)	Sell All Amt	Sell All Receipts
Jun	56,354.21	50,788.71	-41,594.05	$2,669.17	$1,783.11	-$875.06	254.81	$639.57	24,836.80	$907.29	-73,309.70	$2,565.84
Jul	56,354.21	27,991.23	-44,198.71	-$915.28	-$1,801.34	-$4,459.51	53.07	$133.21	12,048.07	$440.12	-77,797.50	$2,722.91
Aug	56,354.21	55,331.45	-40,325.16	$3,383.42	$2,497.36	-$160.81	278.03	$697.86	33,359.80	$1,218.63	-70,893.81	$2,481.28
Sep	56,354.21	70,421.22	-35,342.38	$5,755.98	$4,869.93	$2,211.76	316.16	$793.56	41,890.59	$1,530.26	-62,366.70	$2,182.83
Oct	56,354.21	66,348.08	-29,106.44	$5,115.57	$4,229.51	$1,571.34	255.56	$641.46	44,566.53	$1,628.02	-51,576.80	$1,805.19
Nov	56,354.21	55,215.21	-23,830.58	$3,365.14	$2,479.09	-$179.09	231.29	$580.54	38,717.04	$1,414.33	-42,436.55	$1,485.28
Dec	56,354.21	49,115.65	-19,124.08	$2,406.11	$1,520.05	-$1,138.12	260.84	$654.71	37,121.83	$1,356.06	-34,439.78	$1,205.39
Jan	56,354.21	64,027.97	-30,968.98	$4,750.77	$3,864.72	$1,206.55	272.63	$684.30	41,817.40	$1,527.59	-55,564.85	$1,944.77
Feb	56,354.21	56,951.59	-26,168.50	$3,638.15	$2,752.10	$93.93	270.45	$678.83	37,716.72	$1,377.79	-46,693.76	$1,634.28
Mar	56,354.21	59,811.51	-34,026.73	$4,087.82	$3,201.76	$543.59	210.31	$527.88	35,846.77	$1,309.48	-60,677.41	$2,123.71
Apr	56,354.21	45,620.58	-45,072.72	$1,856.58	$970.52	-$1,687.65	198.10	$497.23	19,942.77	$728.51	-79,103.93	$2,768.64
May	56,354.21	74,627.33	-49,903.85	$6,417.31	$5,531.25	$2,873.08	261.04	$655.21	36,320.99	$1,326.81	-87,387.27	$3,058.55
Totals		**676,250.53**	**-419,662.18**	**$42,530.75**	**$31,898.06**	**$0.00**	**2,862.29**	**$7,184.35**	**404,185.31**	**$14,764.89**	**-742,248.06**	**$25,978.68**

Power Analytics – Economic based power modeling

- **Power Analytics Return on Investment:**
  - The model then evaluates various options, what size PV, battery storage, does combined heat and power make sense, what energy programs make sense. An empirical, data based analysis and recommendation

Month	Actual Load	Net kW	Sell All Receipts	Utility Payment (60% Net)	Utility Payment (70% Net)	Utility Payment (100% Net)
Jun	50,788.71	-41,594.05	$2,565.84	$132.36	$0.00	$0.00
Jul	27,991.23	-44,198.71	$2,722.91	$0.00	$0.00	$0.00
Aug	55,331.45	-40,325.16	$2,481.28	$15.88	$0.00	$0.00
Sep	70,421.22	-35,342.38	$2,182.83	$3,602.18	$2,716.12	$0.00
Oct	66,348.08	-29,106.44	$1,805.19	$3,339.41	$2,453.35	$0.00
Nov	55,215.21	-23,830.58	$1,485.28	$1,908.89	$1,022.84	$0.00
Dec	49,115.65	-19,124.08	$1,205.39	$1,229.75	$343.69	$179.70
Jan	64,027.97	-30,968.98	$1,944.77	$2,835.03	$1,948.98	$0.00
Feb	56,951.59	-26,168.50	$1,634.28	$2,032.90	$1,146.85	$0.00
Mar	59,811.51	-34,026.73	$2,123.71	$1,993.14	$1,107.08	$0.00
Apr	45,620.58	-45,072.72	$2,768.64	$0.00	$0.00	$0.00
May	74,627.33	-49,903.85	$3,058.55	$3,387.79	$2,501.73	$0.00
Totals	**676,250.53**	**-419,662.18**	**$25,978.68**	**$20,477.34**	**$13,240.64**	**$179.70**

Evaluating the Costs and Benefits of Distributed Generation/microgrids

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- **Scope of cost analysis:**
  - Initial design and planning costs
  - Capital investments
  - Operation and maintenance (O&M) costs
  - Environmental costs
- **Scope of benefits analysis:**
  - Energy benefits
  - Reliability benefits
  - Power quality benefits
  - Environmental benefits
  - Benefits of avoiding major power outages

Development of a Project Risk and Value Guide

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The Project Risk and Value Guide will allow the project team to quantify risk of the project elements established in the design criteria and also serve as an input for evaluating the commercial viability and other risks associated with the business case for the project. The following approach would be followed:

- **Identify Risks** - When project elements are not well-defined, uncertainty and risk are introduced.
- **Analyze Risks** - Once the technical and business case risks are identified, determine the probability and impact of these risks.
- **Prioritize Risks** - Rank the risks by probability of occurrence and impact on the scope of work, schedule, and cost, making it possible to prioritize the management of the identified risks – Risk Register.
- **Risk Response** - Once the risks are identified, response strategies can be prepared.
- **Monitor and Control Risks** - Continuously monitor for new, changing, and outdated risks.

Development of a Project Risk and Value Guide

The business plan will detail the project structure, agreements, execution plan, and financing plan. This will be the roadmap for implementation of the microgrid project. Key elements of the business plan will include, but are not limited to, the following:

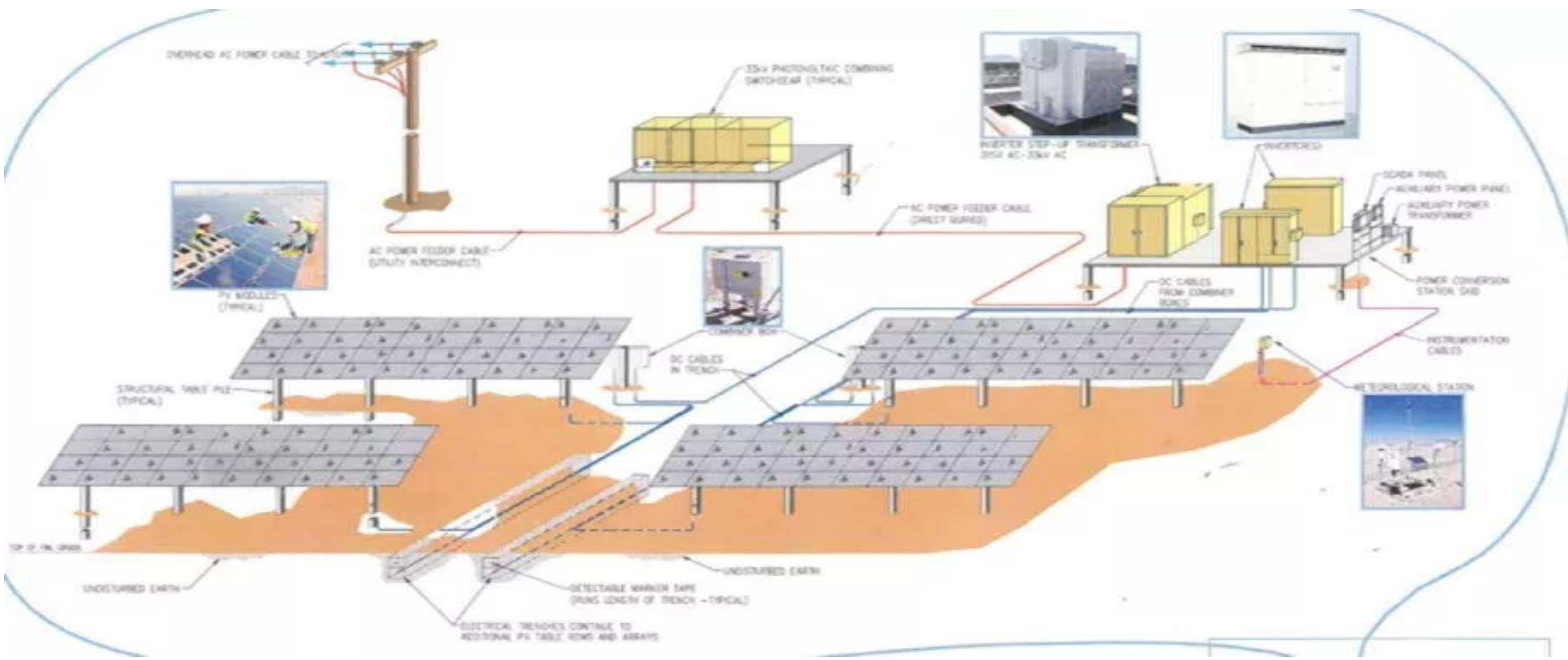
- Development of revenue expectations from distributed generation
- Identify Commercial terms and relationships between the stakeholders
- Identification of all products/services to be provided to all stakeholders from the microgrid
- A detailed project estimate of all on-going operating costs and justification of their magnitude
- Provide the project financial model including profit, revenues and cash flows for the life of the project
- Provide documentation as requested on sources and type of financing utilized on the project
- Provide documentation on management of regulation, details of project ownership structure and evidence of appropriate permitting and approvals
- Provide documentation on all operating agreements related to the microgrid project

Relevant experience managing feasibility studies

Arco Solar

Client: **Arco Seco Solar - Panama**
Project: **Feasibility study for development first stage of a 39.6MW Solar PV Project**

Arco Seco Solar Project: In 2017, Power Analytics, and our partner Wizard Engineering International Corp. ("PAC Team"), were awarded a contract from the USTDA to conduct a feasibility study for the Arco Seco Solar Power Project in Panama. The objective of the Arco Seco Solar project is to support the development of a 39.6MW solar photovoltaic project in central Panama. The project would be built in four phases of 9.9MW each. This project is among the first utility-scale projects in Panama.



Panama Arco Seco Solar Power - Project Details

Data	Description
Project Promoter	PARQUE SOLAR PANAMA S.A.
Project Capacity	4 stages x 9.9 MW/each for a total of 39.6 MW
Project Area	
Latitude	8° 26’
Longitude	-80° 05’
Altitude	112 m
Area available	70 Ha
Nature of land	Mostly semi plain terrain profile with scrubs and savannah
Connectivity	
Nearest national highway and distance	Carretera Panamericana (5 km)
Nearest airport and distance	Aeropuerto Internacional Scarlett Martinez (12 km) Aeropuerto Internacional Marcos A. Gelabert (115 km)
Nearest port and distance	Puerto de Balboa (115 km)
Solar Radiation and Climate Data Source	NASA
At Hzl. Surface, $kWh/m^2/day$	4,35
At. 10° tilted surface, $kWh/m^2/day$	4,35
Average Temp., °C	Max Avg: 31 °C - Avg: 26 °C - Min Avg: 22 °C
Wind Speed, m/s	3,4 m/s
Precipitation, mm	1030 mm
Rainy Days, days	73 days
Power Evacuation	
Power Substation Interconnection	El Higo 34,5 kV
Power Line Length	12 km

Panama's Smart Grid goals:

- As Panama moves forward, the government hopes to meet its energy needs by ensuring a diversified energy matrix that is stable, reliable, and affordable. Completing the interconnection with Colombia will further bolster the nation's energy security.
- New regulatory policies and laws will be a part of a much broader effort to re-balance the nation's energy matrix and to build a system that is open, transparent, and ultimately stable. As Panama's government embarks on its first long-term strategic energy planning process, issues of diversification, security, efficiency, and community engagement will come into play.
- Diversification of the energy matrix must focus on the larger role for energy efficiency, on both a household and industrial scale.
- However, significant challenges remain. Panama's transition will take time, and the government recognizes that greater education and communication will be required. A better understanding of energy sources and resources, as well as the role of consumers in promoting energy efficiency, will ultimately enable the government's national energy goals.

Relevant experience managing feasibility studies
Caterpillar

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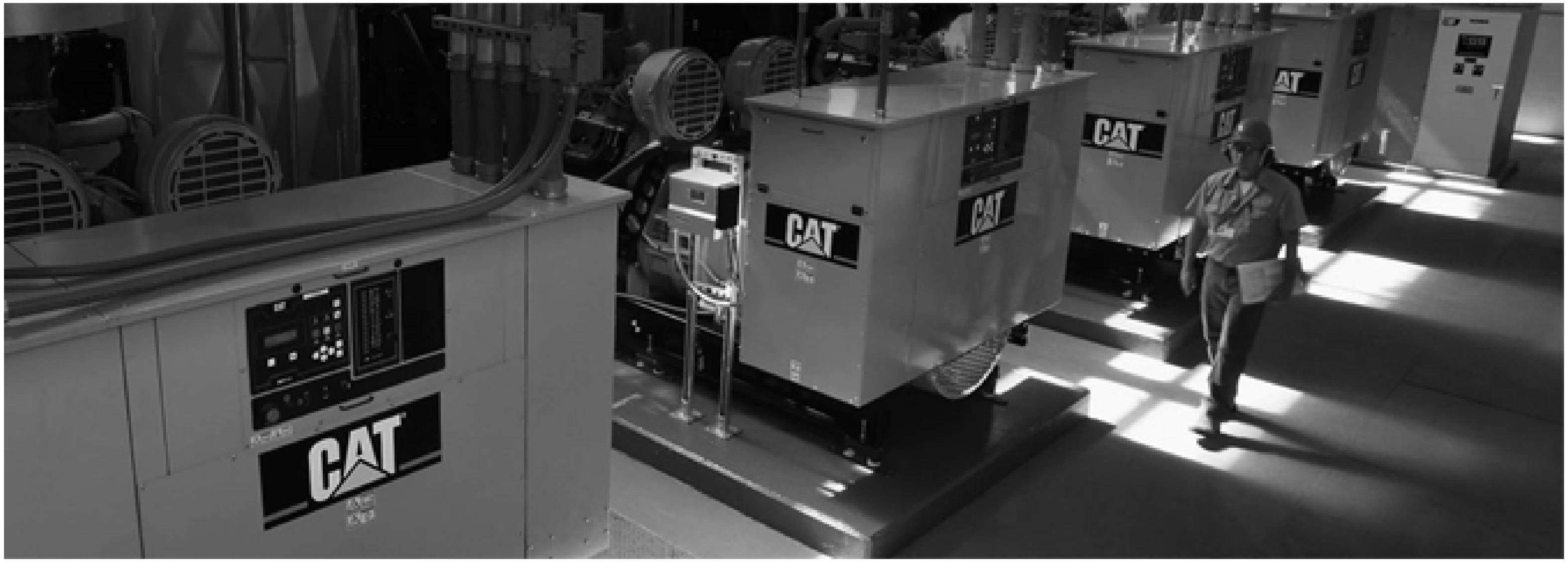
Client: **Caterpillar Manufacturing Plant - Pontiac, Illinois**
Project: **Feasibility Analysis for Voltage Sag Damping and Local Gas/Solar Generation**

Caterpillar's plant in Pontiac, Illinois, is a critical part of Caterpillar's supply chain. Due to its position on the Commonwealth Edison sub-transmission network, it has been susceptible to voltage sags, causing material damage and resulting in cascading effects across the entire supply chain. The plant itself is large and complicated, with over 50,000 individual machines, numerous motors > 50 HP, and generator backup for only a portion of the plant. Power Analytics created a model that accurately reproduced the effects of the voltage sags based on the known supply conditions, then provided two alternative solutions to mitigate the issues, one using traditional UPS technology and the second with a combination of various distributed generation technologies.



Relevant experience Energy Alignment Plan
Architectural – Engineering Firm – North Carolina

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Client: **Architectural – Engineering Firm North Carolina**
Project: **Net Zero Energy Cost for public buildings**

The team that includes Power Analytics has proposed and built more than 5 locations in North Carolina, South Carolina and planning for Georgia. The current generation of buildings are all new construction with photo voltaic (PV) with plans to participate in energy plans to achieve zero energy cost. Available programs are capped at 1 MW of solar and below and require electrically isolating PV production.

Not actual sites, examples

Relevant experience Energy Alignment Plan Architectural – Engineering Firm – North Carolina

Client: **Architectural – Engineering Firm North Carolina**
Project: **Net Zero Energy Cost for public buildings**

Power Analytics approach was to create a power/economic model with our proprietary DesignBase software and using one year of hourly time series data determine the following:

- For existing facilities, were they getting the economic value from the PV (based on time of use, available energy tariffs and actual generation/load)
- For planned facilities, how much solar should they install and which programs should they participate in (using hourly generation and load projections for all four seasons for the Lat/long siting)
- Does energy storage make sense, if so how much storage and what is the potential ROI?
- What other energy generation technologies make sense (micro CHP, wind, fuel cells, diesel or natural gas generation)

Not actual sites, examples

Relevant experience Energy Alignment Plan
Architectural – Engineering Firm – North Carolina

Client: **Architectural – Engineering Firm North Carolina**
Project: **Net Zero Energy Cost for public buildings**

Through the power and modeling process, Power Analytics identified the following items typical of this type of professional service engagement:

- A location was in the wrong tariff structure, and was not receiving credits correctly. Annual loss over $100,000

- A location would have installed 250kW of PV that would not be eligible for ANY market program. Representing a change in capital cost of over $200,000

- A location interested in adding energy storage to offset peak demand would have had a payback of over 100 years. The savings on capital was over $500,000

Not actual sites, examples

Relevant experience managing feasibility studies Mohave Solar

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Client: Mohave Solar
Project: Feasibility Analysis for Operational Optimization and Safety Assessments of 250MW Solar Thermal Plant

The Mojave Solar plant is a 280MW utility-scale solar thermal electric plant located approximately 100 miles' northeast of Los Angeles, near Barstow, California. The plant is owned by Atlantica Yield, and is operated by Abengoa, and international sustainable power developer, with offices in the U.S. The financing for this plant was facilitated by a $1.2B loan guarantee from the U.S. Department of Energy. The plant became operational in December 2014, and the output is sold too Pacific Gas & Electric (PG&E) through a 25-year Power Purchase Agreement (PPA).

Relevant experience managing feasibility studies Mohave Solar

Client: Mohave Solar

Power Analytics has been the primary electrical engineering consultant for the Abengoa Mojave Solar plant since March 2014. Our team has completed multiple discrete power engineering projects for this plant, including in-depth safety assessments during its construction, commissioning, and daily operations. Our services, which continue today, include:

- Modeling the power system, using our Paladin® DesignBase™ software suite: Performing simulations and studies, including power flow, protective relay coordination studies (including coordination improvement of prior vendor studies), device settings' review and improvement, short circuit analysis, and arc flash analysis of both the plant systems and the solar field equipment; and, updating electrical one-line diagrams, schematics, and management dashboards and reports.

- The Power Analytics professional engineers, and our patented power safety software, enabled the owners of the Mojave Solar plant to meet all the safety specifications of the California Bureau Veritas during plant construction, and all necessary approvals of the California Public Utility Commission when this facility was being commissioned. Today, Power Analytics continues to serve the site personnel and owners of the Mojave Solar plant through services and software that allow this plant to operate safely, efficiently, and profitably, while providing reliable, renewable power to PG&E.

Relevant experience managing feasibility studies DCWASA

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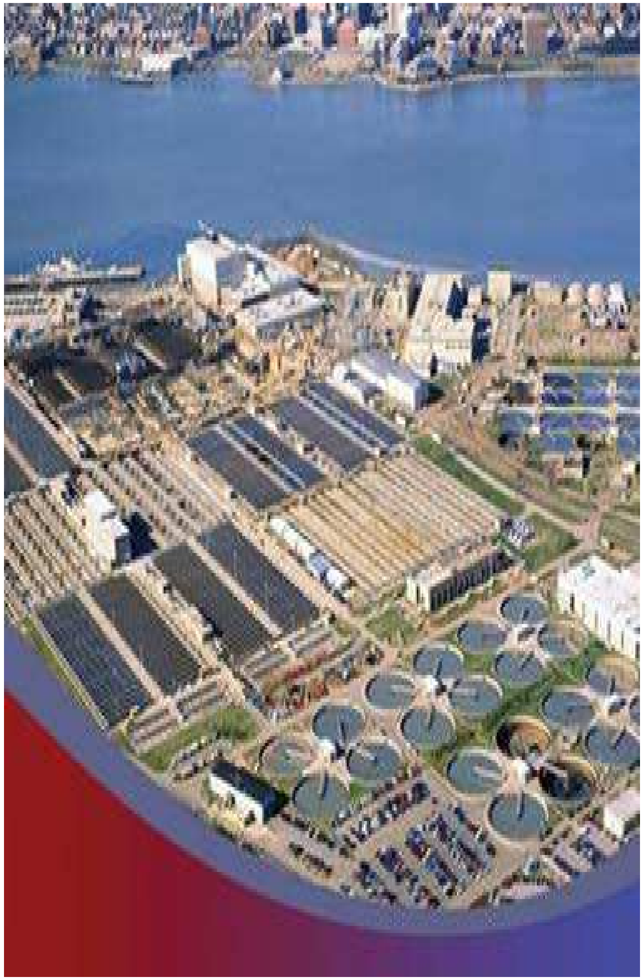
Client: District of Columbia Water and Sewer Authority
Project: Feasibility Analysis for Reliability Improvement and Local Generation for Waste Water Treatment Plant

Power Analytics continues to provide power system analysis and studies for new and existing energy technology generation sources at Water Treatment Plant in Washington, D.C.

The DC Water Blue Plains Advanced Wastewater Treatment plant is the largest advanced wastewater treatment plant in the world. The plant has been a Power Analytics software user since 2005. From 2011 to present, Power Analytics has provided training and power engineering consulting services to support plant expansion including multiple short circuit, protective device coordination, and arc flash studies on the power system infrastructure for the Nitrification Sedimentation plant.

Power Analytics is helping DCWASA with the feasibility analysis of self generation solution with gas generators, solar panels and battery storage. This analysis includes load shifting and optimized on site generation to reduce energy cost with the potential to save them hundreds of thousands of dollars annually.



Relevant experience managing feasibility studies Huntsman Chemical

Client: **HUNTSMAN**
Project: **Petrochemical Plant**

Power Analytics continues to provide power system studies for multiple multiyear projects currently in progress. Petrochemical plant power system modeling, design verification and studies, short circuit analysis, protective device coordination analysis, arc flash safety analysis, as well as, system protection upgrades and start-up/commissioning of multiple substations. 100+ MW under management.

Huntsman is a global manufacturer and marketer of differentiated chemicals. The Port Neches Performance Products Plant manufactures ethyl tertiary butyl ether, propylene oxide, and propylene glycols. The plant has recently undergone expansion to increase production, resulting in the need to expand and upgrade their power system infrastructure. Power Analytics has been providing software and engineering consulting services to Huntsman since 2006, including a recent project involving the entire plant power system infrastructure. PAC's engineering consulting services include the modeling and design verification for the plant's power system using Paladin DesignBase software. Additionally, PAC performs computer simulations on the system including power flow analysis, short circuit analysis, protective device coordination analysis, and arc flash studies. This is a large industrial power system, greater than 100MW, and these consulting projects supported the system protection upgrade, start-up and commissioning of 50 electrical substations. An arc flash study of the entire power system was completed by Power Analytics in 2015.

Relevant experience managing feasibility studies UCSD

POWER ANALYTICS™

Client: **University of California at San Diego (UCSD)**
Project: **Renewable Energy Sustainable Community**

In this project, Power Analytics provided the master controller and supported the development of 45 MW microgrid at the University of California at San Diego (UCSD) campus. This development has been partially funded by a California Energy Commission (CEC) grant as part of the Renewable Energy Secure Community (RESCO) project.

Using PAC's software for system management, UCSD currently self-generates 92 percent of the annual campus electricity demand. The distributed energy resources (solar, directed biogas fuel cells, electricity and thermal energy storage, combined cooling, heat and power, diesel generators, and electric vehicles) are optimized based upon market price signals, weather, fuel costs, operational considerations and environmental objectives. The system includes 125 networked buildings and 70 associated building control systems across 1200 acres. The campus power infrastructure is very dynamic with additions and deletions from the microgrid resources on a regular basis. With PAC's software, the campus is able to see what impact each of these changes would have on the microgrid prior to the addition or removal of the power system asset (generation, storage or load). During a recent demand response event, the campus reduced its grid electricity consumption by 80 percent with no impact on critical loads. As well as improving reliability, the microgrid has produced $10 million per year in cost avoidance from offsetting utility demand with self-generation. It has also substantially reduced the UCSD carbon footprint.

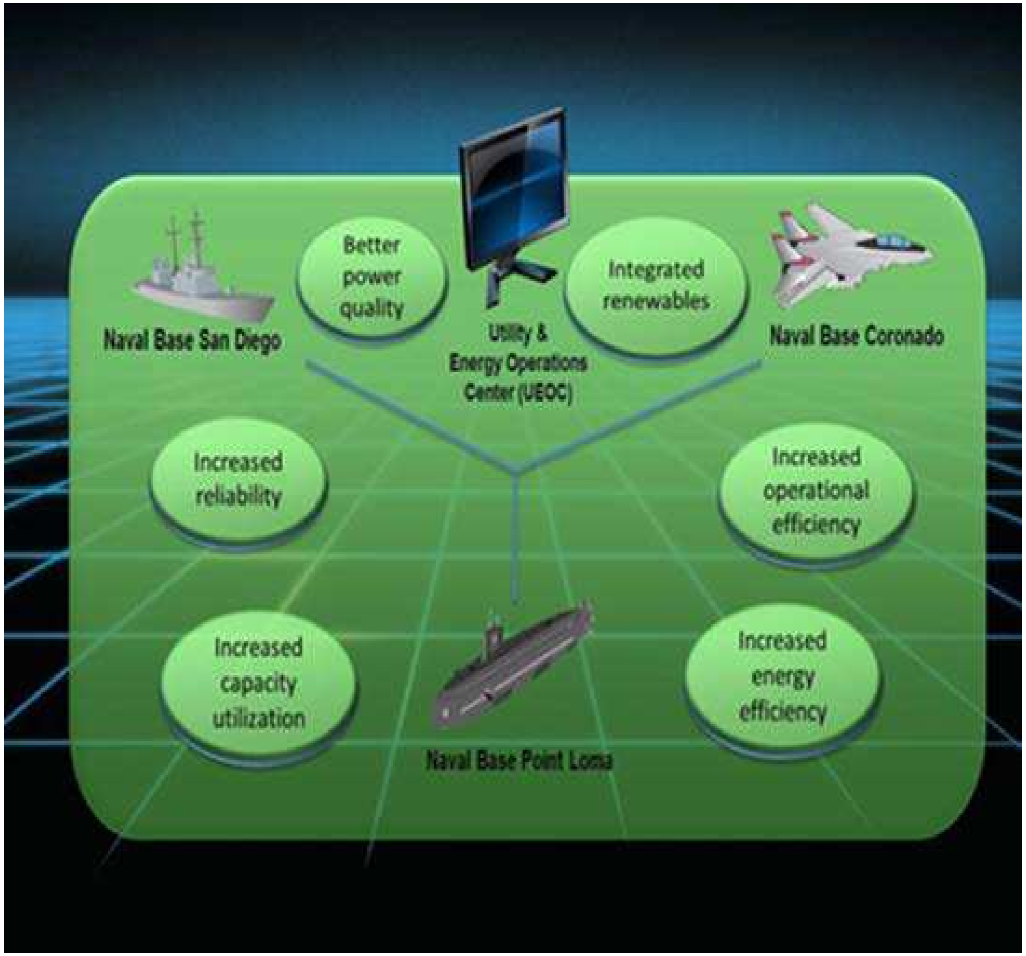
Microgrid Demonstration Overview

Technology
- An integrated platform with management, modeling, control and optimization in a cyber-secure architecture.

Topology
- A cluster of 3 geographically separated military microgrids managed through an enterprise system at a single facility.

Benefits
- Improved reliability, eased integration of renewables, and reduced costs.
- **Sites**
  Naval Bases San Diego, Coronado and Point Loma

To download a copy of the final report click here: https://www.serdp-estcp.org/Program-Areas/Energy-and-Water/Energy/Microgrids-and-Storage/EW-201340/EW-201340/(language)/eng-US



Microgrid Main Screen – Naval Base San Diego