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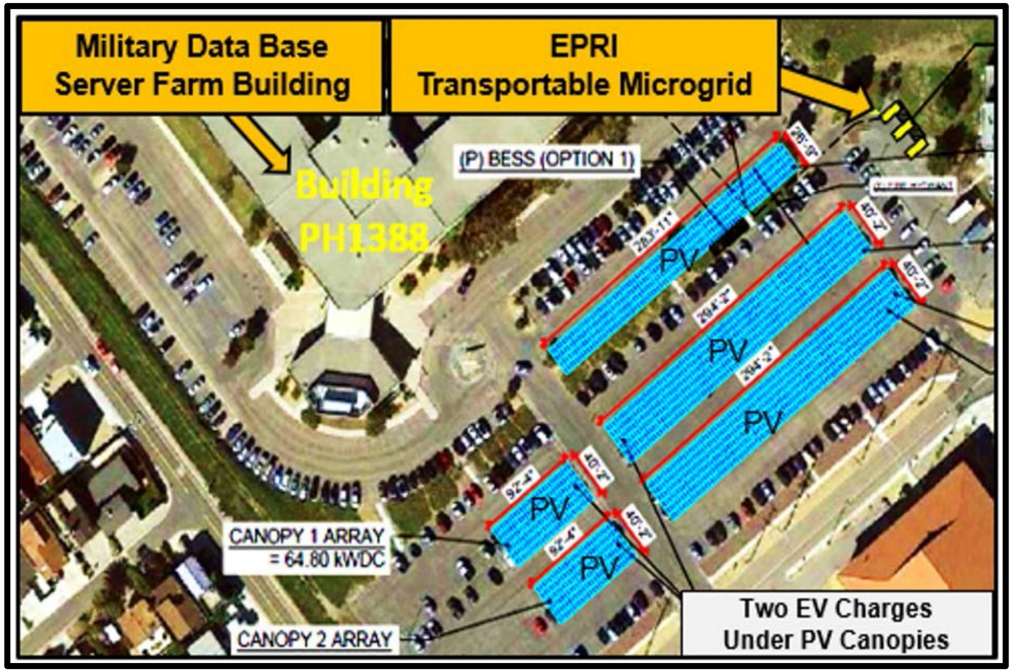


Navy Post Graduate School Lecture:

EPRI Microgrid Projects At Navy Base Ventura County

(Also Known As Port Hueneme Naval Base)

Presented by:
Dr. Robert Schainker
Senior Technical Executive
Electric Power Research Institute (EPRI)

May 10, 2019

Presentation Outline

1. Introduction
2. Historical Perspective (Remembering World's First Power Plant / Microgrid)
3. EPRI Microgrid Projects: Objectives & Locations
   - Transportable Microgrid with Energy Storage (TMES) Project (DoD-ESTCP Funded)
   - Adaptive Microgrid (AM) Project (Energy Commission, CEC, Funded)
4. Combined Microgrid Project Descriptions
   - Team Approach
   - Technology & Methodology Descriptions
   - Expected Benefits
   - Lessons-Learned (As of May 10, 2019)
5. Open Discussion / Q & A's

Appendices

Glossary

EPRI Mission

Advance ***safe***, ***reliable***, ***affordable,*** and ***environmentally responsible*** electricity for society through global collaboration, thought leadership and science & technology innovation

EPRI members generate about 90% of the electricity in the United States (which includes U.S. military bases)

Independent

Objective, scientifically based results address reliability, resilience, efficiency, affordability, health, safety, and the environment

Collaborative

Bring together scientists, engineers, industry experts, and academic researchers

Nonprofit

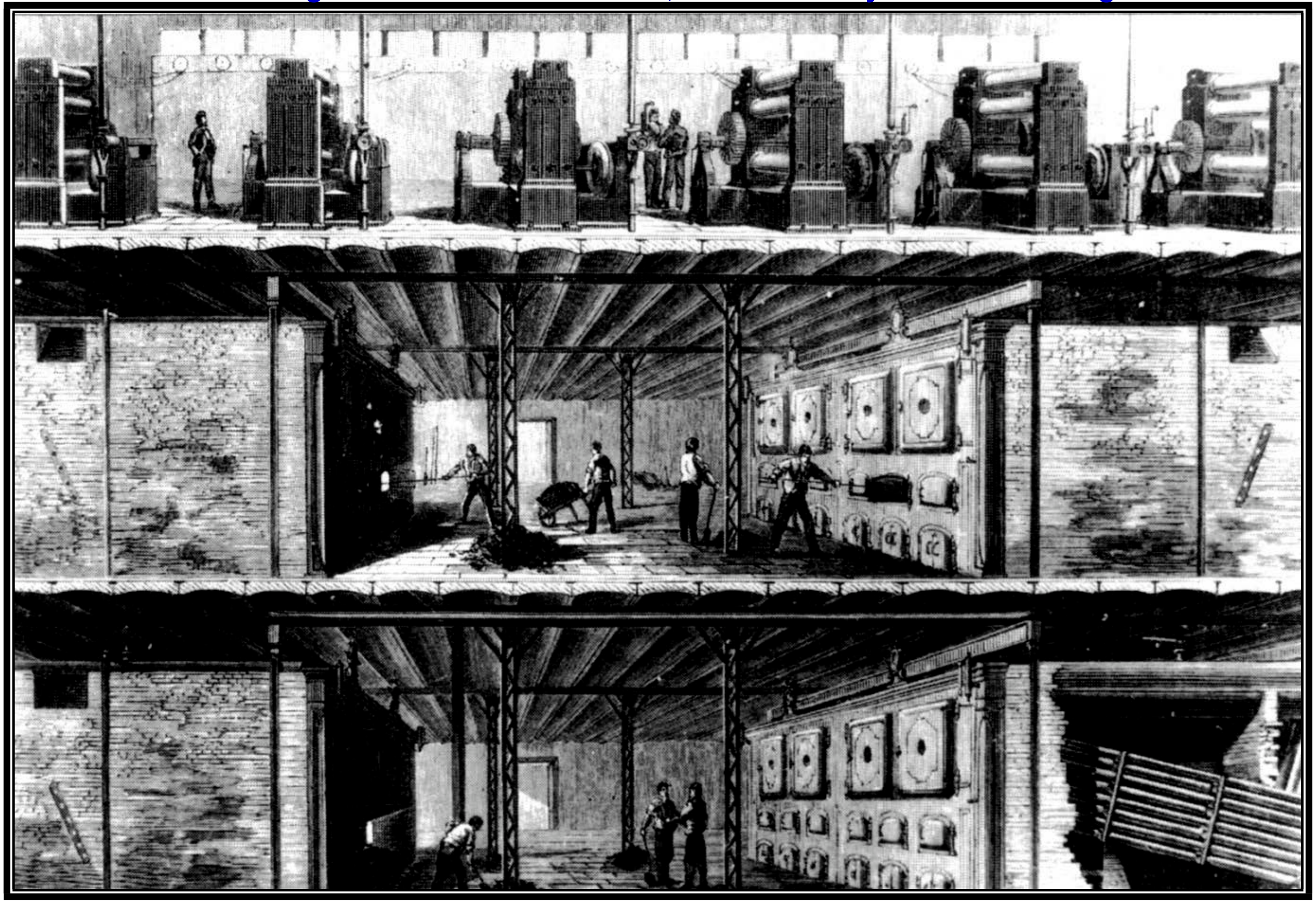
Chartered to serve the public benefit

Historical Perspective: Key People Who Developed The World-Wide Electric Power Industry

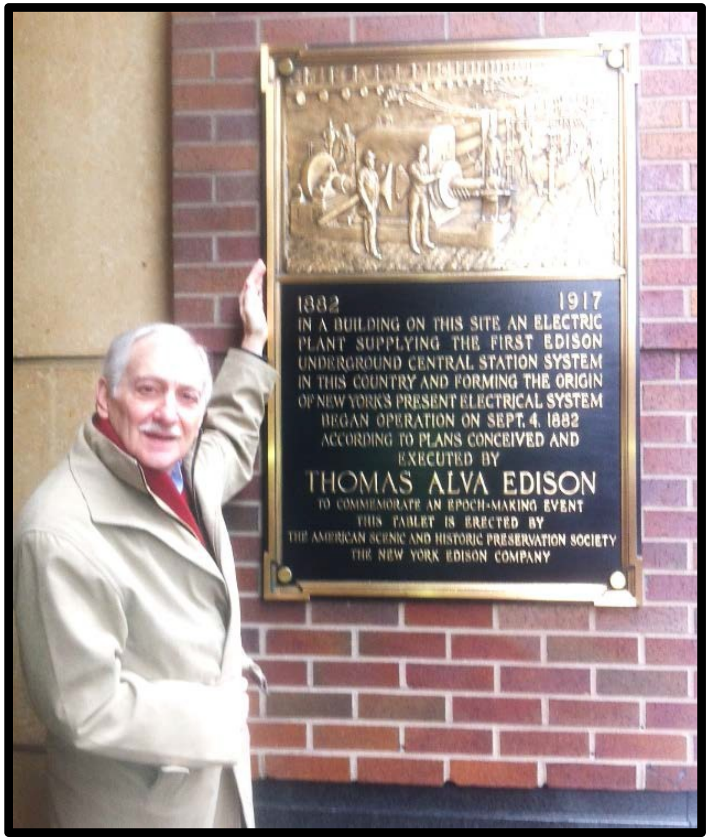
From lower left: Thomas Edison, Nikola Tesla, George Westinghouse, Charles Steinmetz

World's First Power Plant (Which Was a Type of Microgrid):
600 kW, Constant Voltage (100V) Generation Station, Commissioned September 4, 1882
Located at 255-257 Pearl Street, New York , NY

Efficiency = 2.5% (Heat Rate = 138,000 Btu's/kWh)
$'s / kWh Operating Cost In1882 Dollars = $0.24 / kWh; Which Is About $5.62 / kWh in 2019 Dollars
Initially, This Plant Powered 44 Light Bulbs for 4 Customers, And Ultimately Powered 400 Light Bulbs for 85 Customers.



World’s First Electric Generation/Microgrid Plant: “Pearl Street Station” At 255 to 257 Pearl Street, NY City



Operational Date: September 4, 1882. Initially, The Pearl Street Station Had One Coal Fired Locomotive Engine Producing Steam That Powered A Steam Turbine Connected To An Edison DC Dynamo. Later, This Plant Was Expanded To Six Locomotive-Steam-Generator Systems.

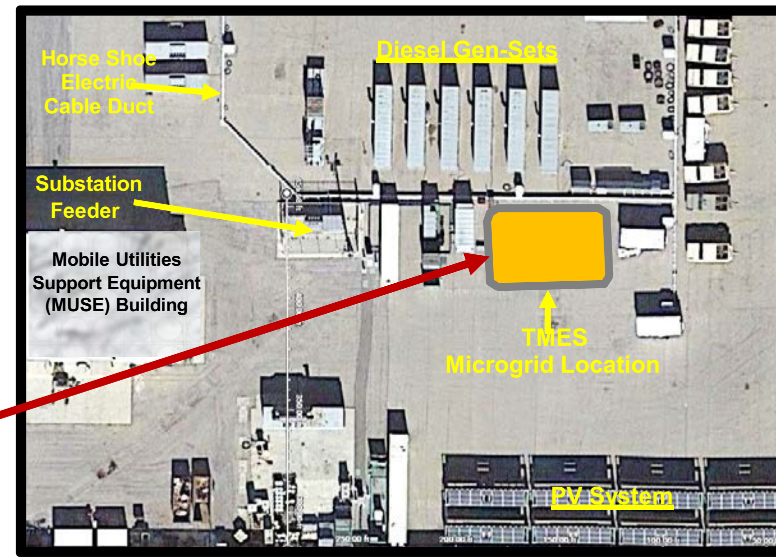
EPRI Microgrid Projects

- **Problem Statement:** At Military Bases, Reduce Energy Usage And Intensity, Increase Renewable Onsite Energy Generation, And Improve Energy Security/Resiliency
- **Objective of Each of Two EPRI Microgrids at Naval Base Ventura County**
  - DoD Funded Transportable Microgrid with Energy Storage (TMES) Project: Install and Perform Performance Tests at Naval Base Ventura County's Microgrid Test Bed facility.
  - CEC Funded Adaptive Microgrid (AM) Project: Transport, Install, Test and Deploy the AM at the NAVSEA-Port Hueneme Division's Database Server Farm Building PH1388. Testing Data Is To Confirm The AM Has Islanding and Resynchronization Performance Superior To That Of PH1388's Current Uninterruptible Power Supply (UPS) System.
- **Compare TMES Performance With Or Without The Operation Of One Or More Of The Following Other Microgrid Subsystems:**
  - ♦ Synchronous Condenser
  - ♦ Battery Subsystem
  - ♦ Diesel Gensets
  - ♦ PV Renewable Resources
  - ♦ Two Electric Vehicle Charging Stations

Transportable Microgrid with Energy Storage (TMES) Project Location

Location of Naval Base Ventura County, CA

Naval Base Ventura County NAVFAC Engineering and Expeditionary Warfare Center



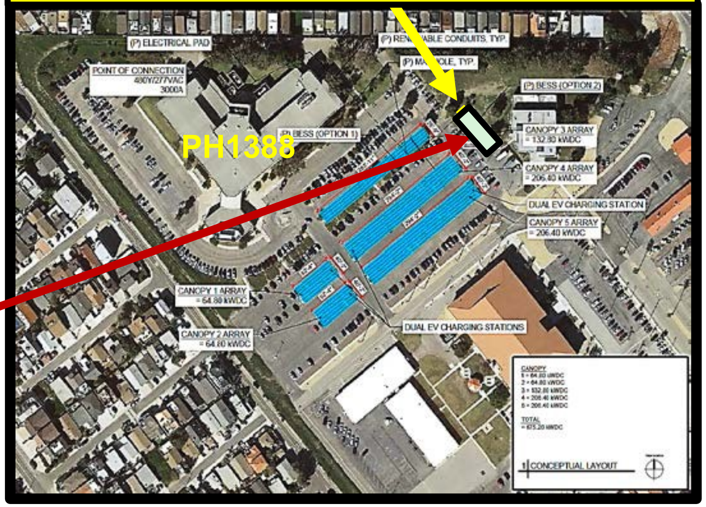
Naval Base Ventura County NAVFAC Microgrid Test Facility Showing Location of NBVC-EPRI Transportable Microgrid with Energy Storage

Database Server Farm Building PH1388 “Adaptive Microgrid” Project: Location

Location of Naval Base Ventura County, CA

Naval Base Ventura County, NAVSEA-Port Hueneme Division

NAVSEA Database Server Farm Building (PH1388) Annexed Parking Lot Area



Database Server Farm Building PH1388 Site Location Within Naval Base Ventura County, Where Microgrid Will Be Installed, Tested, Performance Monitored, and Operated. Blue Panels Are For Parking Lot Planned Canopy Based PV System [Contracted by NAVSEA To Local Utility, Southern California Edison]

Photos of Navy Building PH1388, and Nearby Parking Lot Location for Microgrid

NAVSEA Database Server Farm
Building PH1388

Location For Planned
EPRI Adaptive Microgrid

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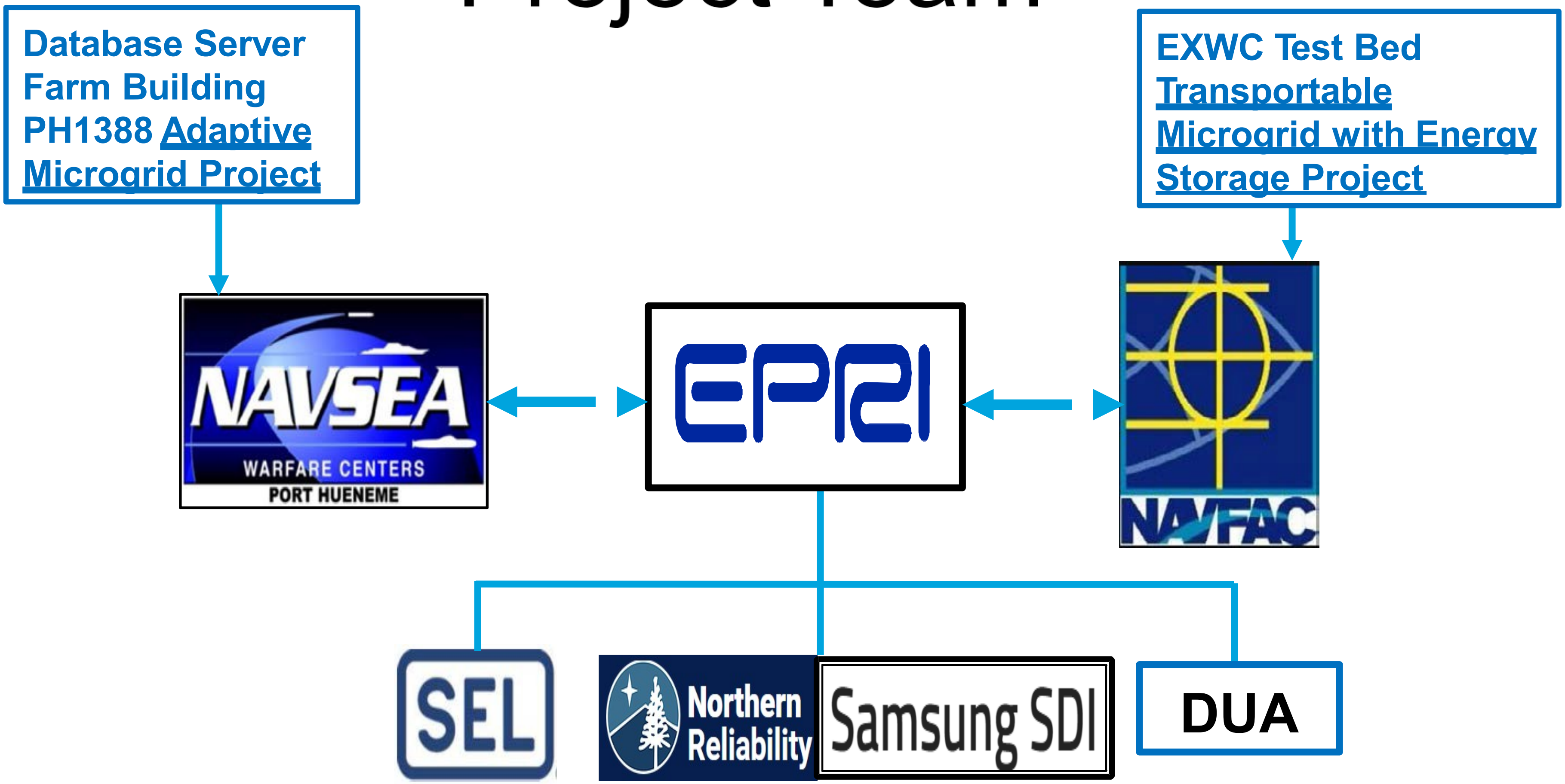
Project Team



DUA: Distributed Utility Associates (Field Test Data Analysis)

NRI: Northern Reliability, Inc. (Battery System Packager, Using Samsung SDI Lithium-Ion Battery Modules)

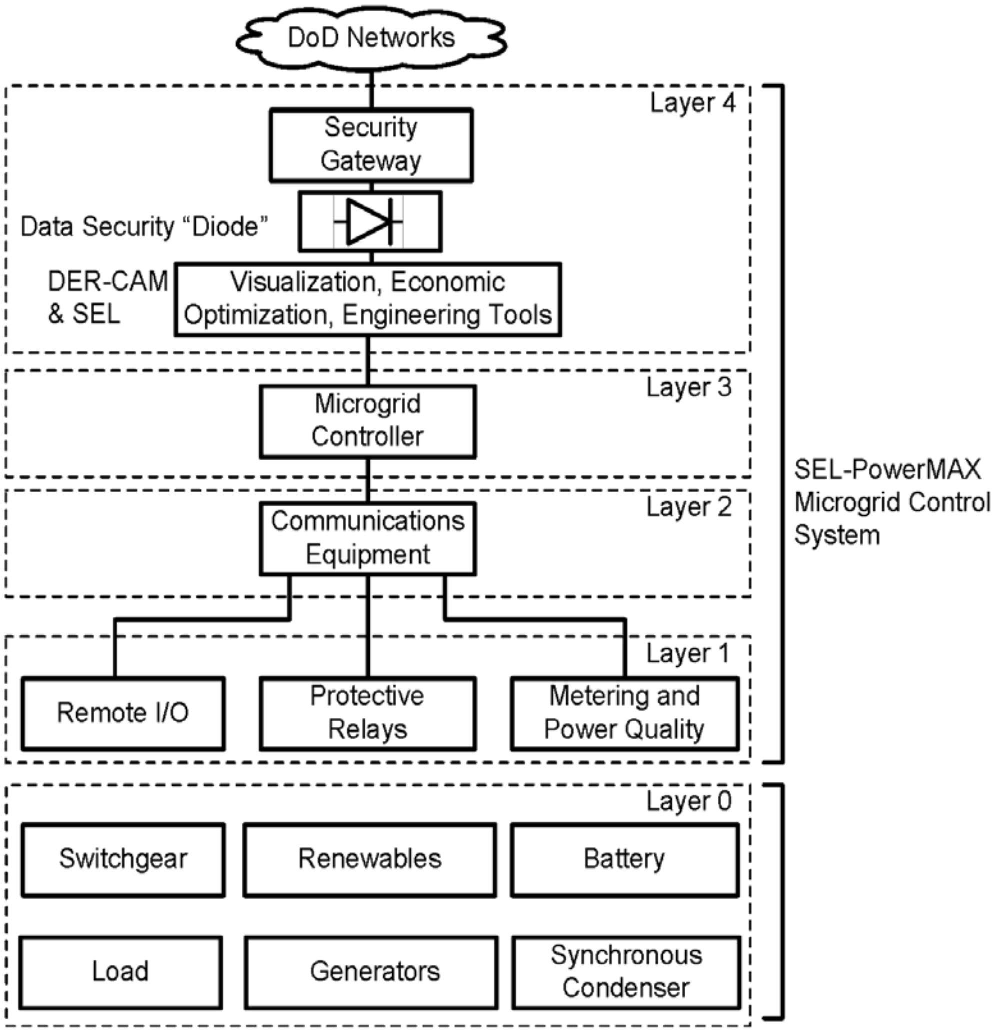
SDI: Battery Subsidiary of Samsung

SEL: Schweitzer Engineering Laboratory (Adaptive Protection Relays, Synchronous Condenser, Real-Time Simulator, Circuit Breakers, Control System)

Methodology Description

Microgrid Project Components & Architecture

- **Modular & Transportable**
- **Monitors and Controls:**
  - **Diesels** - **Battery**
  - **PV** - **EV Chargers**
  - **PH1388 Building Transformer**
  - **Circuit Breakers**
  - **Synchronous Condenser**
  - **Adaptive Protection Relays**
- **Factory Acceptance Testing**
- **For Cybersecurity, No Wi-Fi, No Internet, and Firmware Updates Done By Navy Staff Trained by Vendors**
- **DoD Cybersecurity Risk Management Framework (RMF) Implemented**



Synchronous Condenser

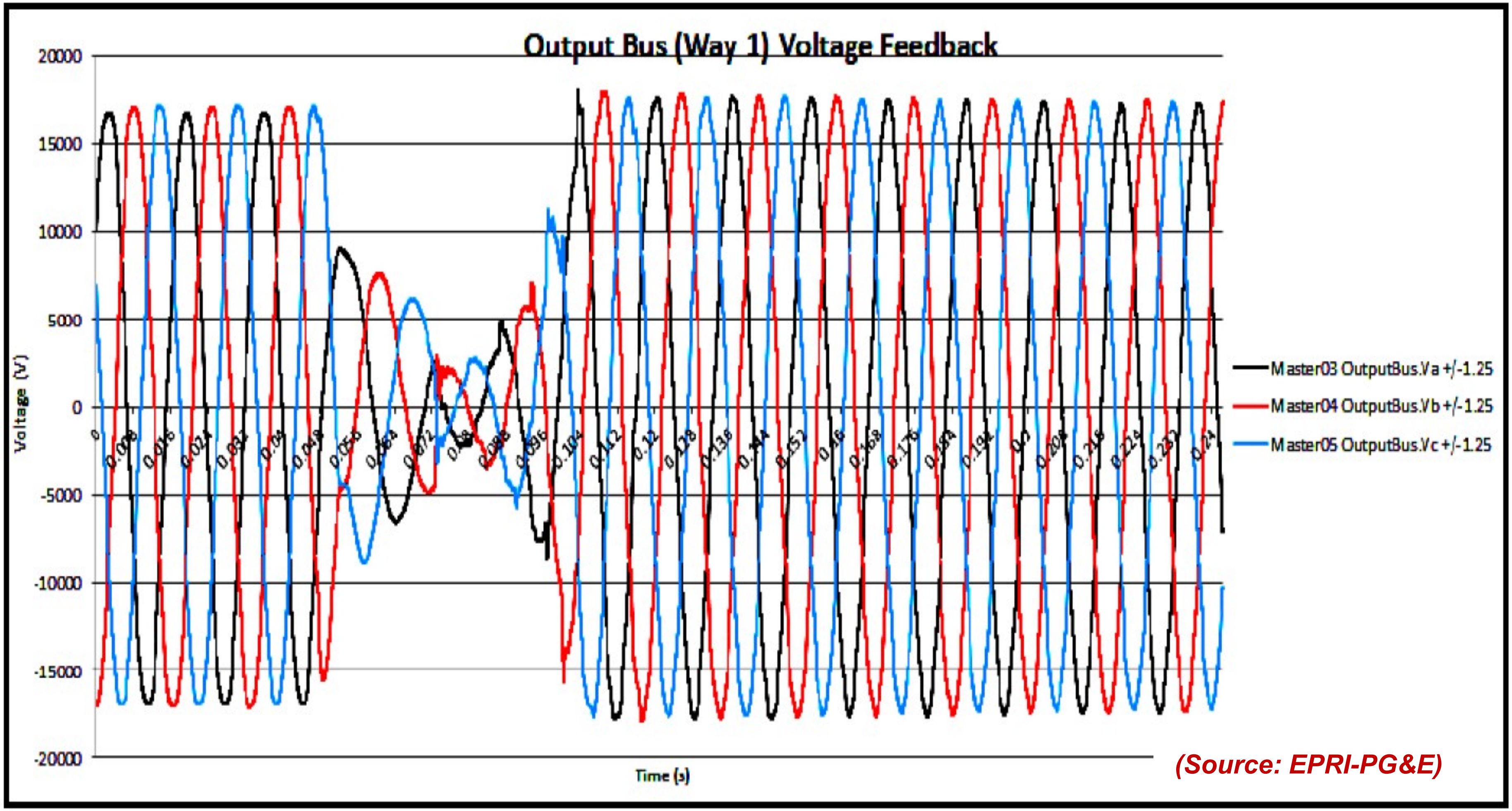
- Stator Excitation System Over-Sized To Extract 10x To 20x Rated Current
- Rotational Mass Provides 2 To 3 Second Frequency And Voltage Ride-Through
- Prevents Battery Inverters And Microgrid From Failing and Tripping Off *
- Advanced Schweitzer Energy Laboratory SEL-710-5 Protection System Maximizes Energy Extraction From The Synchronous Condenser

Example Synchronous Condenser Which Has Rotational Copper Mass To Deliver Inductive kWh's To Limit In-Rush Currents From Military or Utility Customer Loads During Normal Operations and During Grid Islanding and Grid Re-Synchronous Events

*Solid State Static Compensator and Inverter Devices Usually Fail When Subjected To High In-Rush Currents From Large Electric Disturbances (e.g., From Microgrid Islanding/Resynchronization Events, Large Motor Start-Up Events, and/or Lightning Events).

Field Test Example:

Microgrid Test Results Showing Islanding Event Transition From A Three Phase System to Another Three Phase System



(Source: EPRI-PG&E)

Combined Microgrid Project: Expected Benefits

➢ Electricity Cost Savings & Reduced Diesel Emissions

- Enables Economic Benefits To Military Bases When Used To Peak Shave Demand Charges From Local Grid; Reduces Emergency Generator Fuel Costs (And Their Emissions) By Reducing Part Load Inefficient Operation By Using The Samsung SDI Battery System To "Levelize" The Load On Diesel Generators

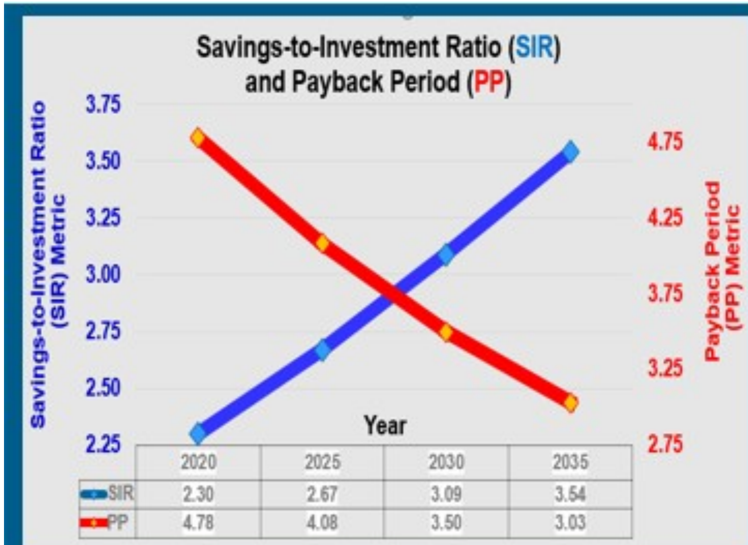
➢ Reduced Costs (Capital, Operational, and Life Cycle Costs)

- Lower Capital Cost, High Efficiency (AC Rd-Trip 88.5% to 90.3%), 10 Year Guarantee, Reliable, Commercial, and Mass Produced Samsung SDI Battery-Inverter System. Also, The Overall Microgrid System Will Smooth-Out DoD Emergency Generator Loads, Thereby Reduced Diesel Maintenance Costs Due To Reduced Cycling
- Use of Standardized Interconnection Hardware Reduces Capital Costs Due To Economy Of Scale Enabled By The Larger Market of Standardized Parts From Multiple Vendors

➢ Project Information Will Assist DoD In Deploying Technology

- Technology Transfer Advisory Committee Activities Will Continue Via EPRI's Ongoing & Future Technology Transfer Activities (e.g., Via Funding Activities, Workshops and Technology Transfer Awards). Also, EPRI's Support of the IEEE Microgrid Controller/Testing Standard (No. 2030.7/2030.8) Working Groups Will Continue Until Completed (About 4Q, 2020).

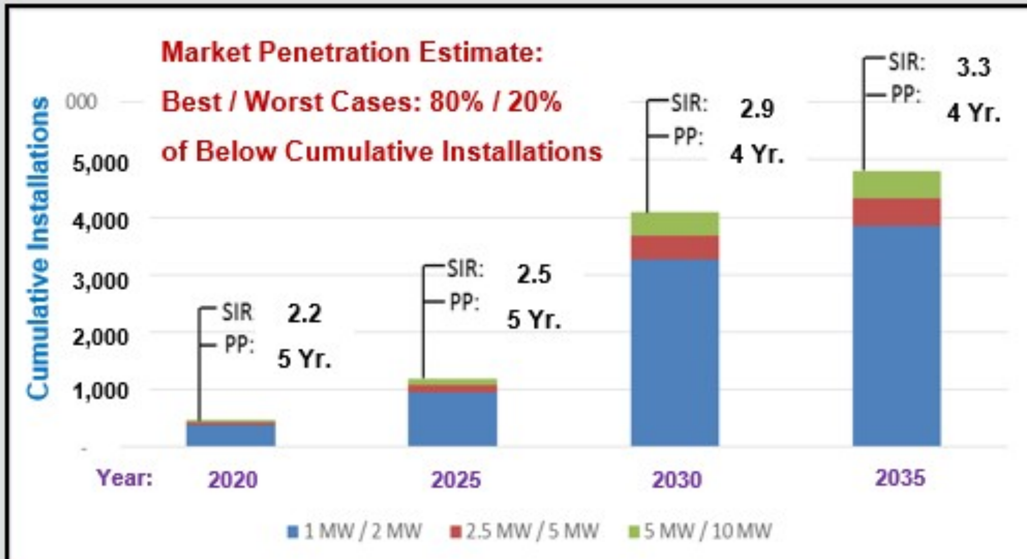
DoD Savings-to-Investment Ratio (SIR) and Payback Period: Preliminary Results



Major Assumptions For Market Penetration Example:

- 80%, 1 to 2 MW Sites; 10%, 2.5 to 5 MW Sites; and 10%, 5 to 10 MW Sites
- Battery & PV Systems Have Reduced Cost (30% over 5 Yrs)
- Battery & PV Sizes & Operations Optimized Via HOMER-Pro
- 4,800 Army, Navy, Marine, Air Force, Coast Guard World-Wide Sites Deployed Over 20 Years
- 100% Penetration Reached by 2035

Note: Other Assumptions Delineated in Appendix 5



Major Assumptions: Example Case:

- Load: 1 MW Average with 2 MW Peak
- Outage:
  - 2 Outages/Year, 120 Hours Each
  - During Islanding, > 1 MW_{avg} Load, and > 4 Consecutive Hrs at > 2 MW_{pk} Load
- 10 Year Study Time Horizon
- Cost Quantified Based On Value Of Lost Load To Be $10/kWh

Example Case Results *(See Figure Above)*

- SIR Ratio: 2.30 to 3.54
- Payback Period: 4 to 5 Years

Lessons-Learned

(As of May 10, 2019)

➢ Permits

- California Environmental Quality Act (CEQA) Permit Took 9 Months To Obtain Rather Than The 4 Month Time Period Originally Planned. **Lesson-Learned:** Next CA Project Needs To Double Or Triple The Expected Time It Will Take To Obtain This Type of Permit.
- Interconnection Agreement Permit To Connect Microgrid To Local Utility's Site Transformer (i.e., Southern California Edison's Building PH1388's 480V, 3 Phase, 4-Wire Wye Configured Transformer). This Permit Was To Take About 3 Months To Obtain; However, The Time Span To Obtain It Is Now Expected To Take 6 to 9 Months. **Lesson-Learned:** Start Process To Obtain This Type of Permit On The First Day Of The Project.

➢ One-Line Electrical Diagram Of PH1388 Building Site

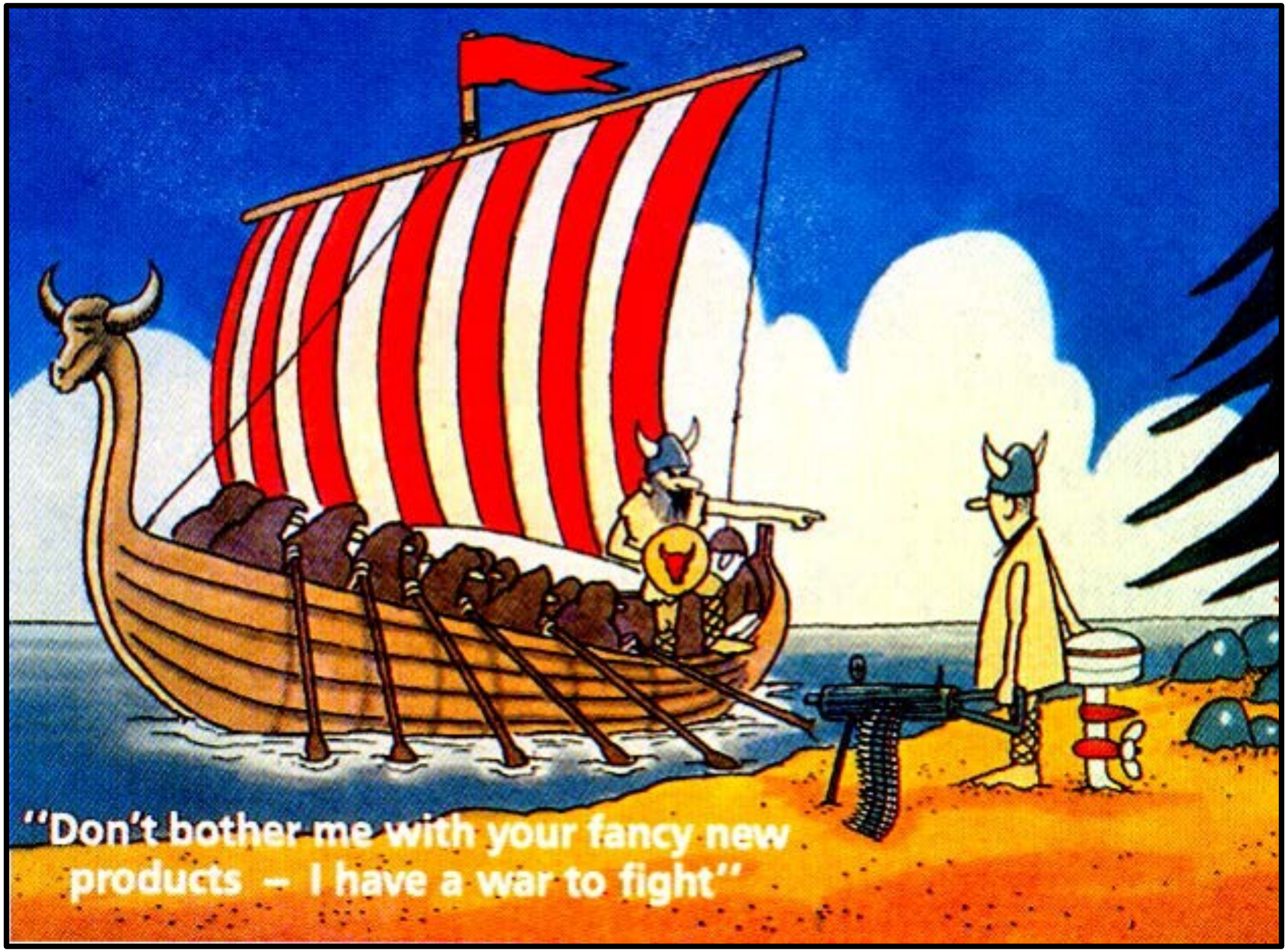
- Navy Base Thought They Had Latest Version Of This Important Electrical 1-Line Diagram; However, Navy and EPRI Found Out That Electrical Upgrades To PH1388 Building Occurred And The Updated 1-Line Diagram Was Not Found. Thus, The Process To Find/Develop This Important 1-Line Diagram Is Still On-Going. **Lesson-Learned:** Get All Electrical Engineers From The Navy Site And From EPRI To Work Together To Develop This 1-Line Diagram Starting On The First Day Of The Project

➢ Transfer Of Property To Navy At End Of Project

- Legal Language To Document This Transfer Was To Occur Via A Memo of Understanding Agreement And/Or Via The Letter of Support The NBVC Provided To EPRI When EPRI Submitted And Won Its Proposals And Got Its Contracts Signed By DoD, CEC, and EPRI. Now, EPRI Has Found Out From The NBVC That A Separate Cooperative Research And Development Agreement (CRADA) Has To Be Developed and Signed By NBVC and EPRI To Get This Transfer Legally Documented To Take Place At The End Of The Project. **Lesson-Learned:** Start Setting Up The CRADA Process On The First Day of The Project.

Cartoon Insight

(Found on a Pentagon Wall)



"We can't solve problems by using the same kind of thinking we used when we created them." *- - Albert Einstein*

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NAVAL BASE VENTURA COUNTY POC

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Open Discussion and Q&A

Together…Shaping the Future of Electricity

How A Synchronous Condenser Works

Synchronous motors have interesting properties, which find applications in power factor correction, to improve the delivery of 'real' power to load to enable real work to occur. The synchronous motor can be run at lagging, unity or leading power factor by controlling its stator field excitation, as described below:

- When the field excitation voltage is decreased, the motor runs in lagging power factor. The power factor by which the motor lags varies directly with the drop in excitation voltage. This condition is called under-excitation.
- When the field excitation voltage is made equal to the rated voltage, the motor runs at unity power factor.
- When the field excitation voltage is increased above the rated voltage, the motor runs at leading power factor. And the power factor by which the motor leads varies directly with the increase in field excitation voltage. This condition is called over-excitation.
- The most basic property of synchro motor is that it can be used both as a capacitor or inductor Hence in turn it improves the power factor of system.

The leading power factor operation of synchronous motor finds application in power factor correction. Normally, all the loads connected to the power supply grid run in lagging power factor, which increases reactive power consumption in the grid, thus contributing to additional losses. In such cases, a synchronous motor with no load is connected to the grid and is run over-excited, so that the leading power factor created by synchronous motor compensates the existing lagging power factor in the grid and the overall power factor is brought close to 1 (unity power factor). If unity power factor is maintained in a grid, reactive power losses diminish to zero, increasing the efficiency of the grid. This operation of synchronous motor in over-excited mode to correct the power factor is sometimes called as synchronous condenser.

When used as part of a mechanical clock, a synchronous motor's timekeeping ability is only as accurate as the average line frequency provided by its power source. Although a small amount of frequency drift may occur throughout the course of a day, power companies actively adjust the line frequency to prevent mechanically driven clocks from gradually gaining or losing time.

Maxi-Cube Load Bank

Resistive: 0 to 2.500 MW Load
Inductive: 0 to 1.875 MVAR Load

480Vac – 3 Phase, 60 Hz

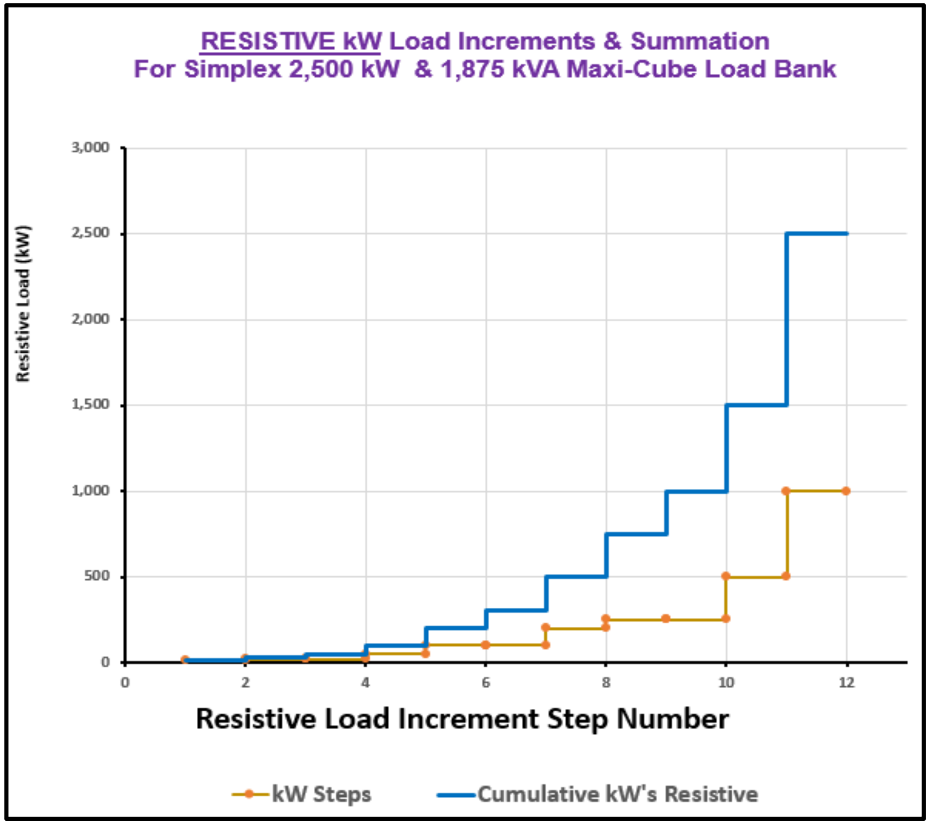
Load Elements Are Field Removable and Replaceable Via Slide-Out Trays

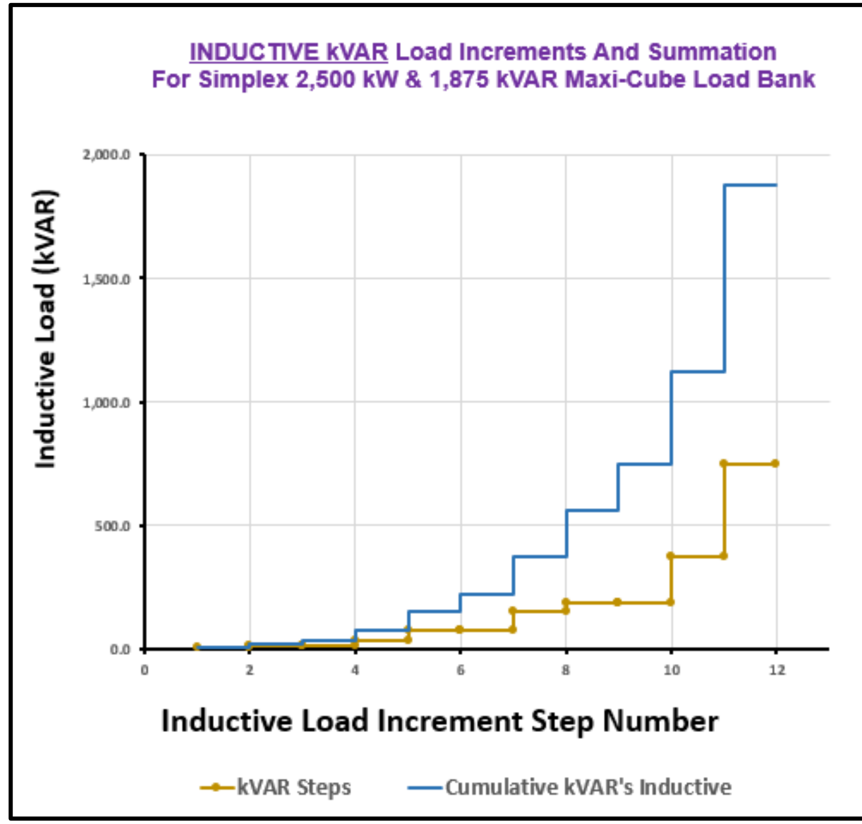
Portable: Crane and/or Flat Bed Truck

Dimensions:

Width:	***96.50”***
Depth:	***130.00”***
Height:	***110.25”***

Maxi-Cube Resistive and Inductive Load Capability Charts (Max: 2.5 MW & 1.875 MVAR)





Note: Resistive kW Testing Will Evaluate Microgrid Performance At Its Maximum Electric Load Threshold Which Will Confirm Design and Hardware Selection of Protection Relays, Switchgear, Cabling, and Short Circuit/Ground Fault Limits That Will Not Cause Microgrid Failures/Outages.

DoD Cybersecurity Risk Management Framework (RMF) Six Step Process

Step 1 CATEGORIZE System

- Categorize the system in accordance with the CNSSI 1253
- Initiate the Security Plan
- Register system with DoD Component Cybersecurity Program
- Assign qualified personnel to RMF roles

Step 2 SELECT Security Controls

- Common Control Identification
- Select security controls
- Develop system-level continuous monitoring strategy
- Review and approve the security plan and continuous monitoring strategy
- Apply overlays and tailor

Step 3 IMPLEMENT Security Controls

- Implement control solutions consistent with DoD Component Cybersecurity architectures
- Document security control implementation in the security plan

Step 4 ASSESS Security Controls

- Develop and approve Security Assessment Plan
- Assess security controls
- SCA prepares Security Assessment Report (SAR)
- Conduct initial remediation actions

Step 5 AUTHORIZE System

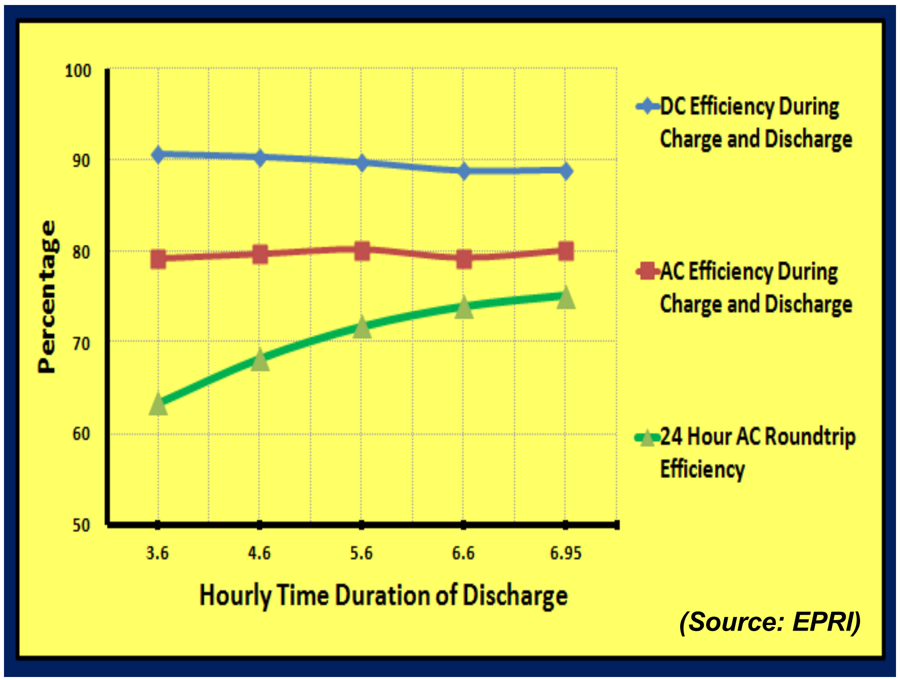
- Prepare the POA&M
- Submit Security Authorization Package (security plan, SAR and POA&M) to AO
- AO conducts final risk determination
- AO makes authorization decision

Step 6 MONITOR Security Controls

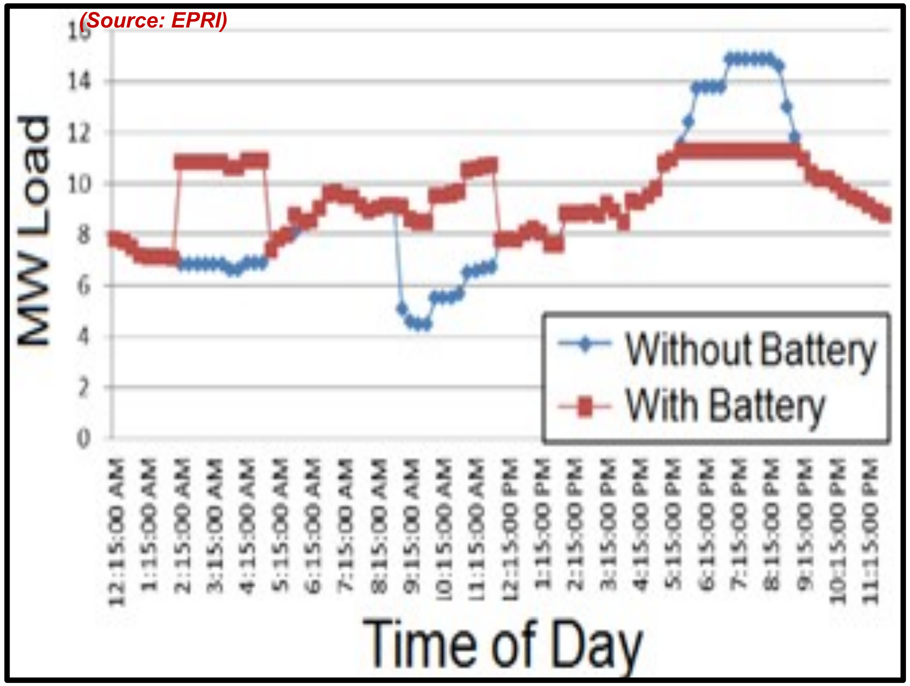
- Determine impact of changes to the system and environment
- Assess selected controls annually
- Conduct needed remediation
- Update security plan, SAR and POA&M
- Report security status to AO
- AO reviews reported status
- Implement system decommissioning strategy

Test Plan
Illustrative Example

Example NaS High Temperature Battery System Round-Trip AC Efficiency Test Results



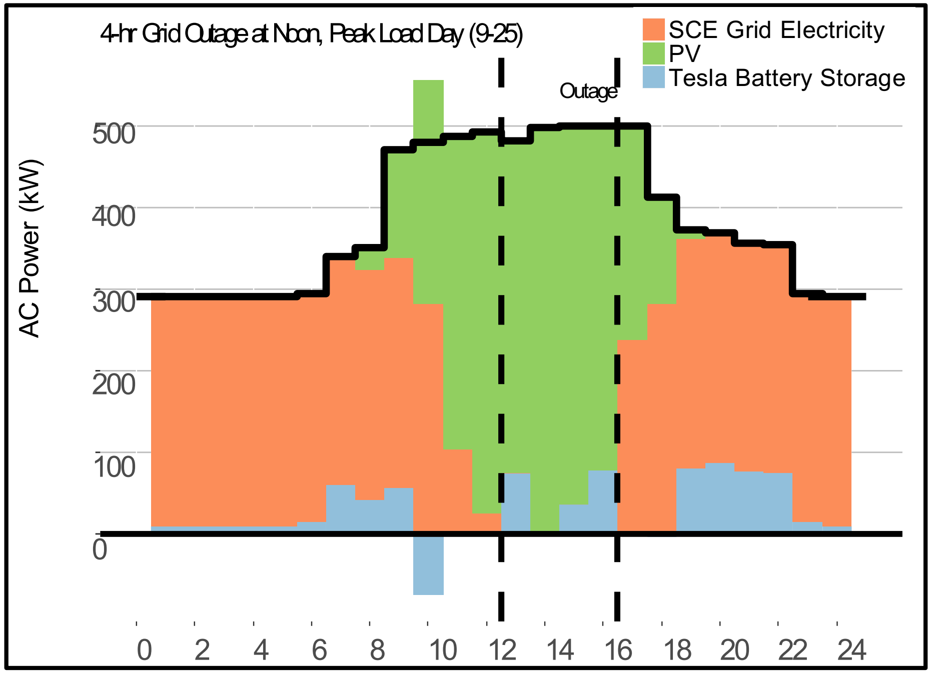
Example Peak Shaving and Load Shaping Duty Cycle Test Results



Expected Emission Benefits When Microgrid Deployed at NAVSEA Database Server Farm Building PH1388

Environmental Benefits

- **280.6 Tons of CO_{2eq}** Saved Per Year From Solar PV System
- Diesels Also Used To **Offset** Local Grid Electricity At CA's Average Of **0.25 Tons $CO_{2,eq}$ / MWh_e** (Specified By California EPA)



Reliability Benefits

- Microgrid's Battery System Reduces Diesel Start-Ups and Use

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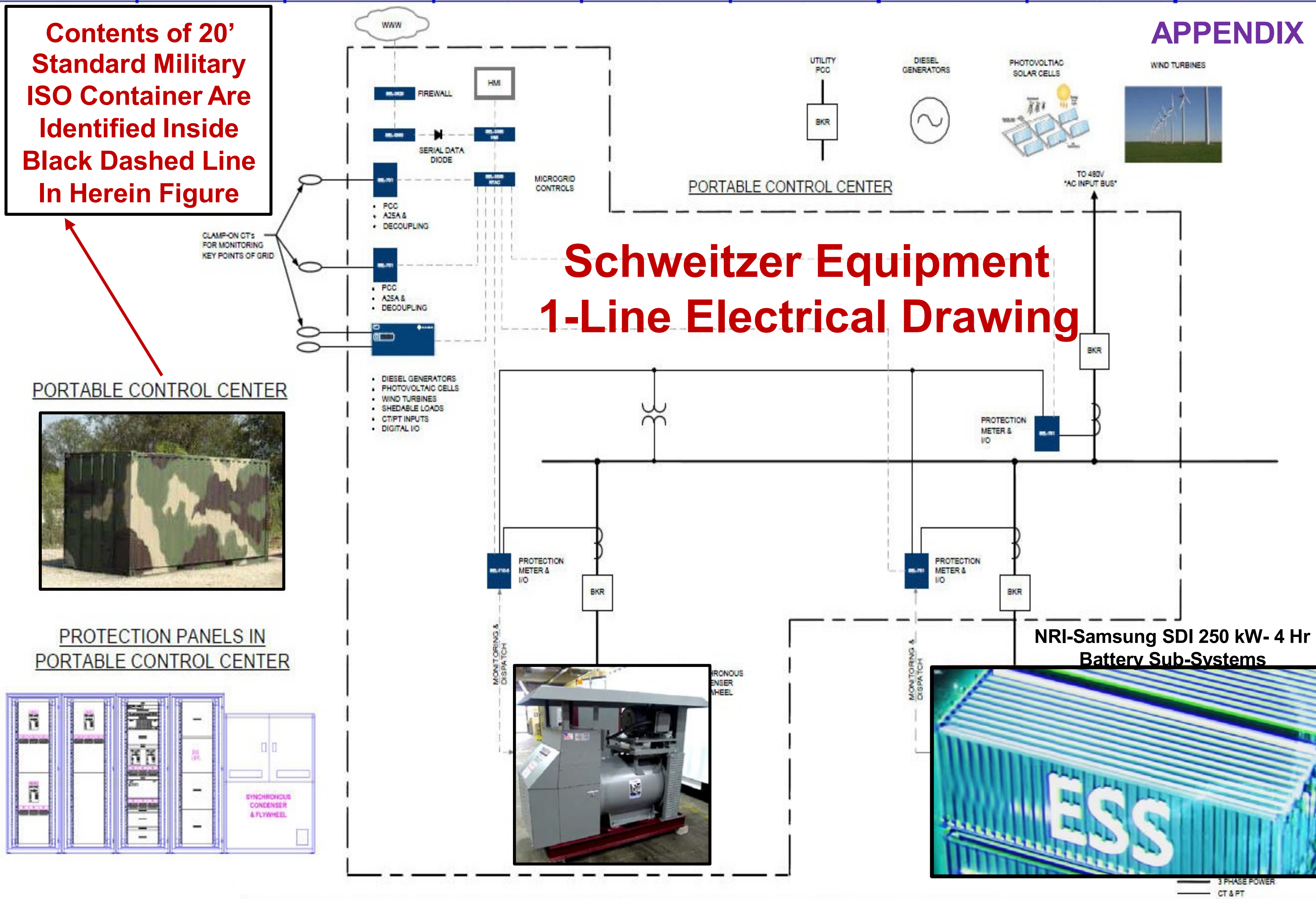
APPENDIX

Contents of 20' Standard Military ISO Container Are Identified Inside Black Dashed Line In Herein Figure

Schweitzer Equipment 1-Line Electrical Drawing



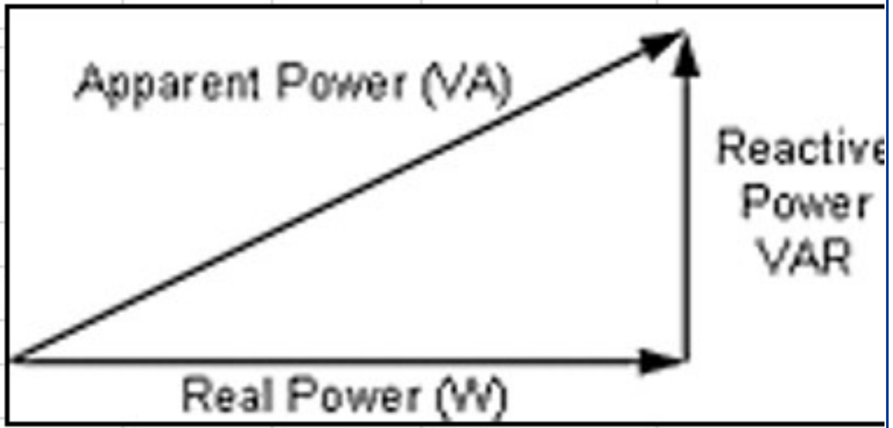
Transportable Microgrid With Energy Storage Schematic Diagram

Power (W) = Volts (V) x Current (A)

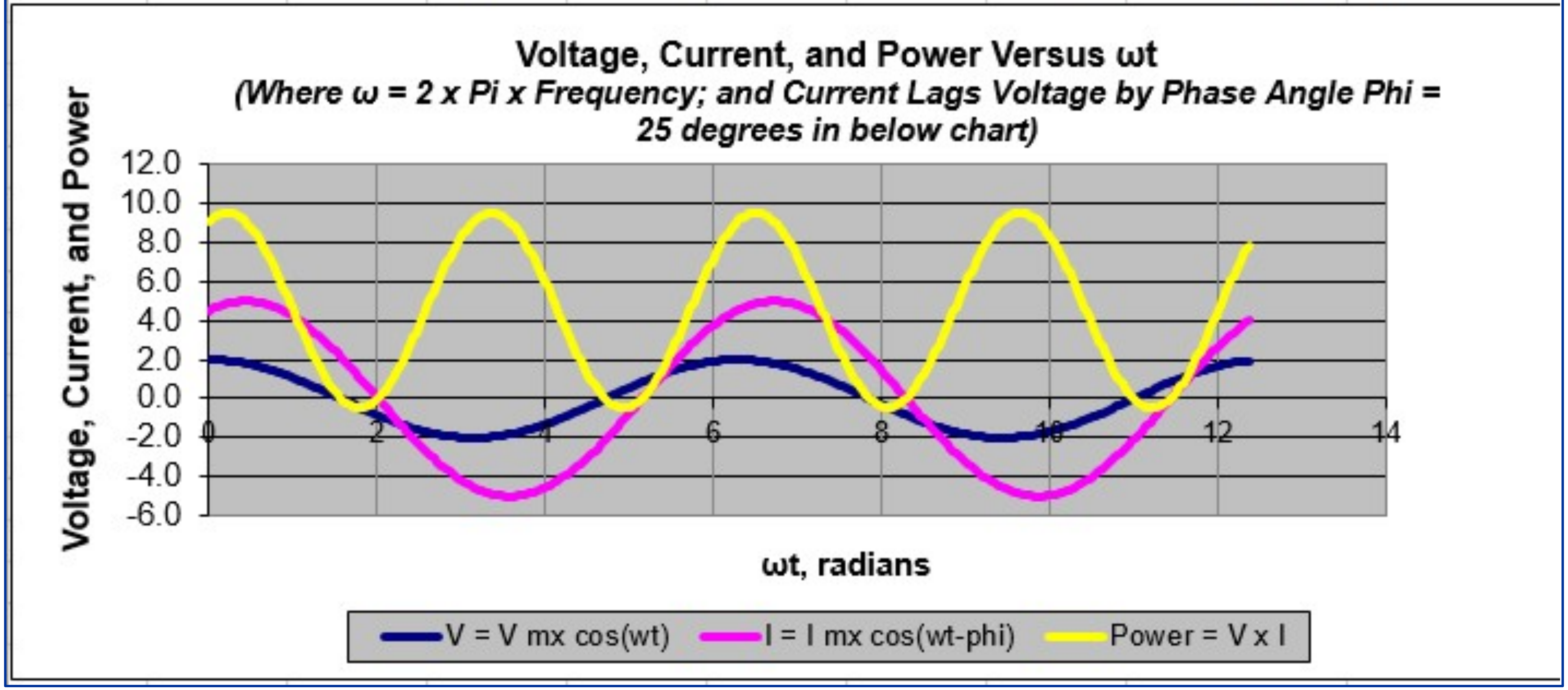
Power (W) in Watts

Volts (V) in Volts

Current (A) in Amperes



Power Factor = Cosine (Phase Angle That Current Lags Voltage, Phi)



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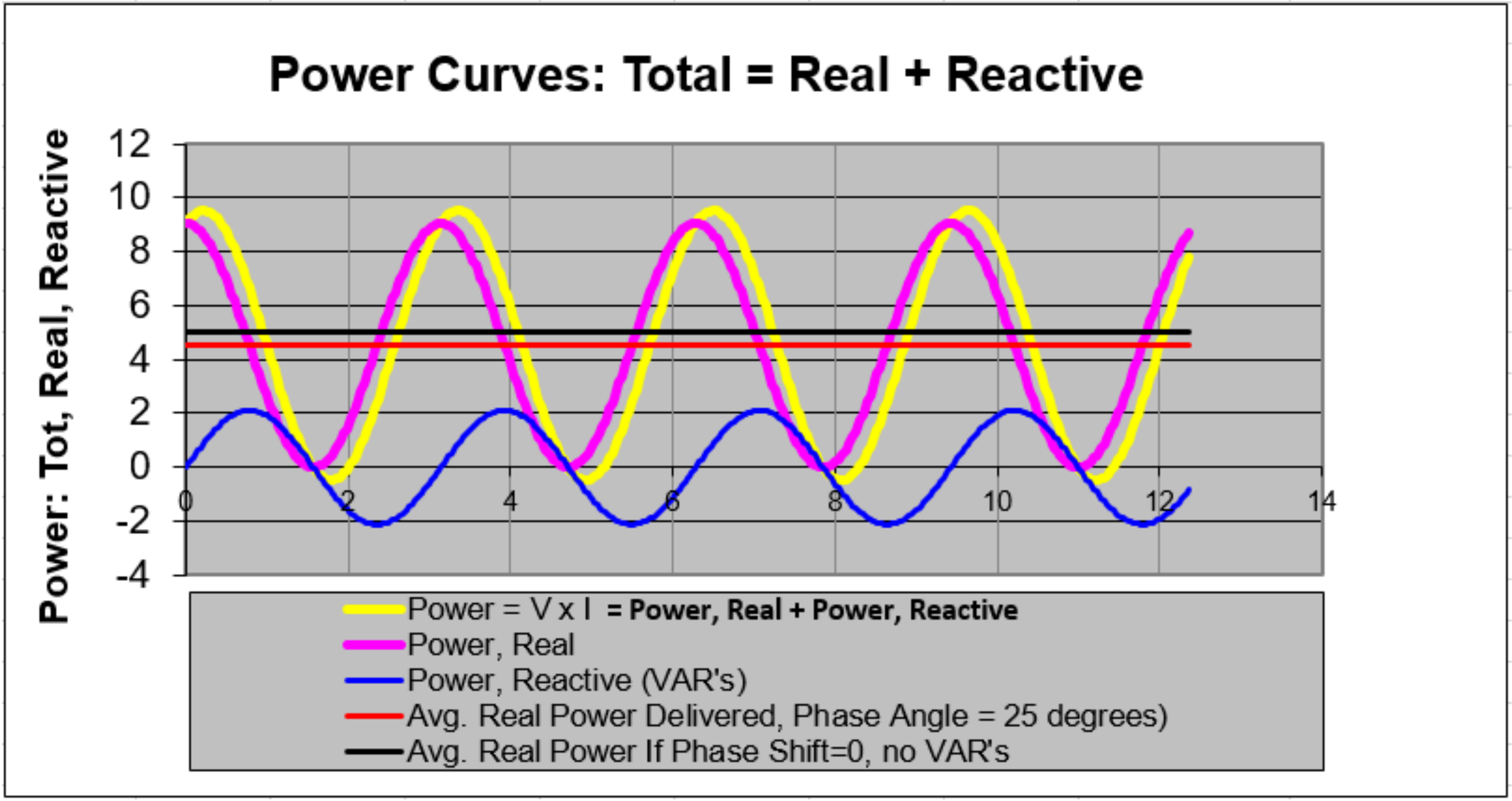
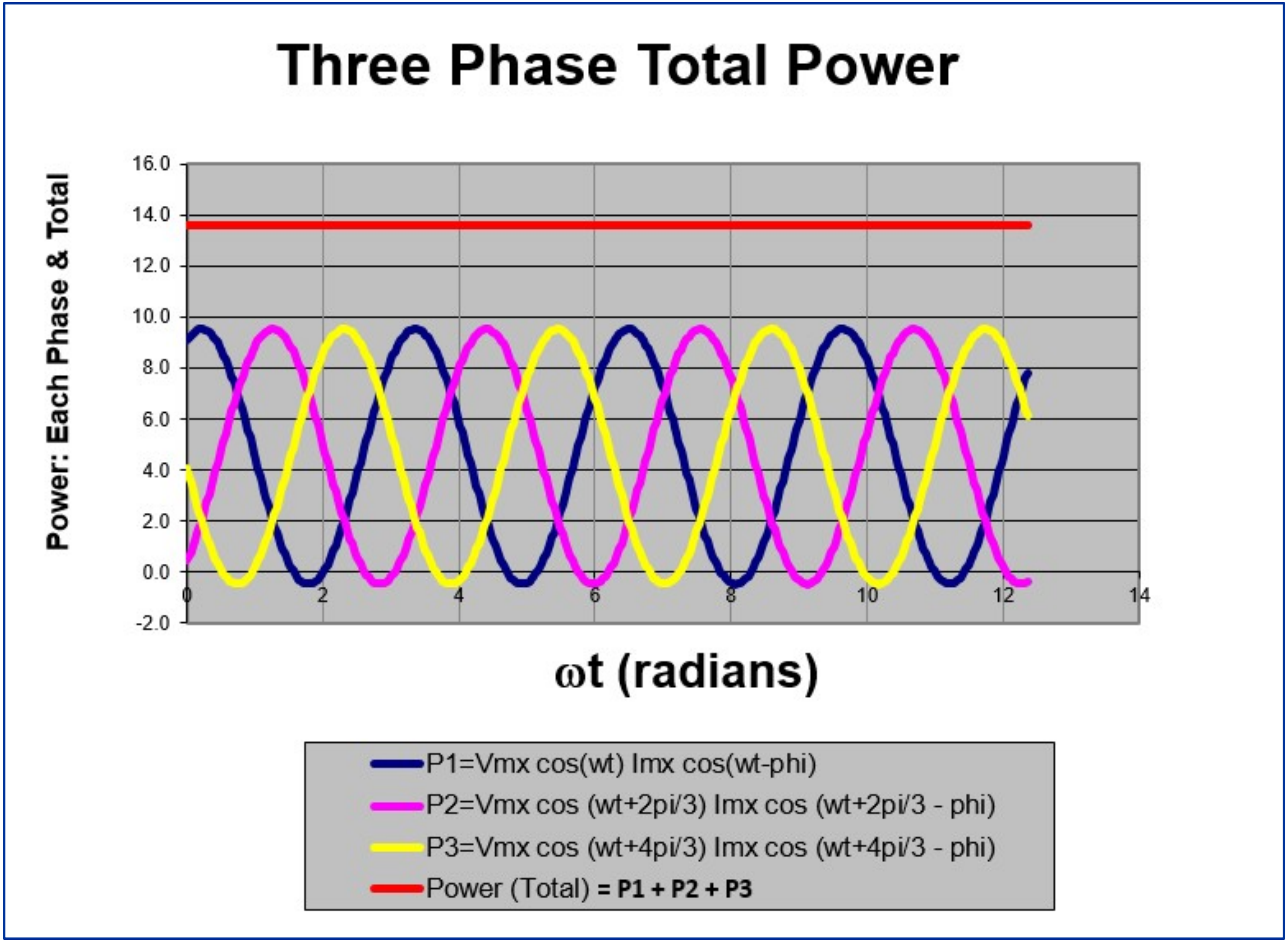


Power Factor (PF) = Cos (Phase Angle) = [Average Power At Phase Angle] / [Average Power If Phase Angle = 0]


Three Phase Total Power
Power: Each Phase & Total
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
0
2
4
6
8
10
12
14
ωt (radians)
P1=Vmx cos(wt) Imx cos(wt-phi)
P2=Vmx cos (wt+2pi/3) Imx cos (wt+2pi/3 - phi)
P3=Vmx cos (wt+4pi/3) Imx cos (wt+4pi/3 - phi)
Power (Total) = P1 + P2 + P3

Glossary

Item	Description
CEC	California Energy Commission
EPRI	Electric Power Research Institute
EXWC	Engineering and Expeditionary Warfare Center
MUSE	Mobile Utilities Support Equipment
NAVSEA	Naval Sea Systems Command
NBVC	Naval Base Ventura County (Previous Name: Port Hueneme Naval Base)
PF	Power Factor (Cosine of Angle Between Voltage and Current Waveforms)
RMF	Risk Management Framework
SC	Synchronous Condenser
SEL	Schweitzer Engineering Laboratories, Inc.
SIR	Savings Investment Ratio
SPIDER	Smart Power Infrastructure Demonstration for Energy Reliability and Security
TMES	Transportable Microgrid with Energy Storage
TTAC	Technology Transfer Advisory Committee