

GE ENERGY CONSULTING

TURNING KNOWLEDGE INTO POWER



ABOUT GE

ENERGY CONSULTING

For nearly a century, a core group of leading GE technical and business experts have focused their energies on solving the electric power industry's most pressing challenges—driving the evolution of electric power systems with greater affordability, reliability, and efficiency by providing techno-economic solutions. Today, GE's Energy Consulting team continues this tradition by providing innovative solutions across the entire spectrum of power generation, delivery, and utilization. With our cross-company resources, GE's Energy Consulting business is able to serve a diverse global client base with a strong local presence.

Our Heritage

Industry Pioneers who literally “wrote the book” on how to engineer and operate the interconnected electrical system we know today...

CHARLES STEINMETZ

- Was One of the first employees of General Electric; started Energy Consulting in 1915 (named “Central Station Engineering”).
- Developed the theories and mathematical equations behind alternating current (AC).

EDITH CLARKE

- Was First woman professionally employed as an electrical engineer in the U.S.
- She was the first person to publish a mathematical examination of power lines longer than 300 miles.
- Invented the math that was the first step leading to the smart grid.

www.gereports.com/edith-clarke-mother-of-invention

CHARLES CONCORDIA

- Joined GE in 1926 and in the 1940's became Energy Consulting & GE's consultant to public utilities.
- Focused on large scale computing devices to model the economic and technical operations of the large-scale grid systems.
- Authored 1944 paper “Steady State Stability of Synchronous Machines as Affected by Voltage-Regulator Characteristics”, one of the most cited papers in the utility industry. The concepts in this paper are now represented and used worldwide as part of EC's PSLF software

www.geenergyconsulting.com/practice-area/software-products

MARKET CHALLENGES DRIVE THE NEED FOR ENERGY CONSULTING

- There are nearly 1 billion people globally without access to reliable, affordable and efficient electric power
- The economics and operations of the electric power systems globally are changing drastically with the increased penetration of low cost, intermittent and variable renewable generation
- New policies and business models are shaping the utility of the future, with more focus on distributed energy resources
- Grid systems that weren't originally designed for this changing landscape need detailed planning and protection to ensure reliable, affordable and efficient energy is available when and where it's needed



ENERGY CONSULTING SERVICES IN A CHANGING ENERGY LANDSCAPE

TURING KNOWLEDGE INTO POWER

RENEWABLES INTEGRATION

Challenge

Clean renewables will account for **38% of the global power generation capacity** by 2025

Solutions

Integration studies leveraging proprietary planning software **identifying economic and technical integration** requirements for grid-scale and distributed renewables

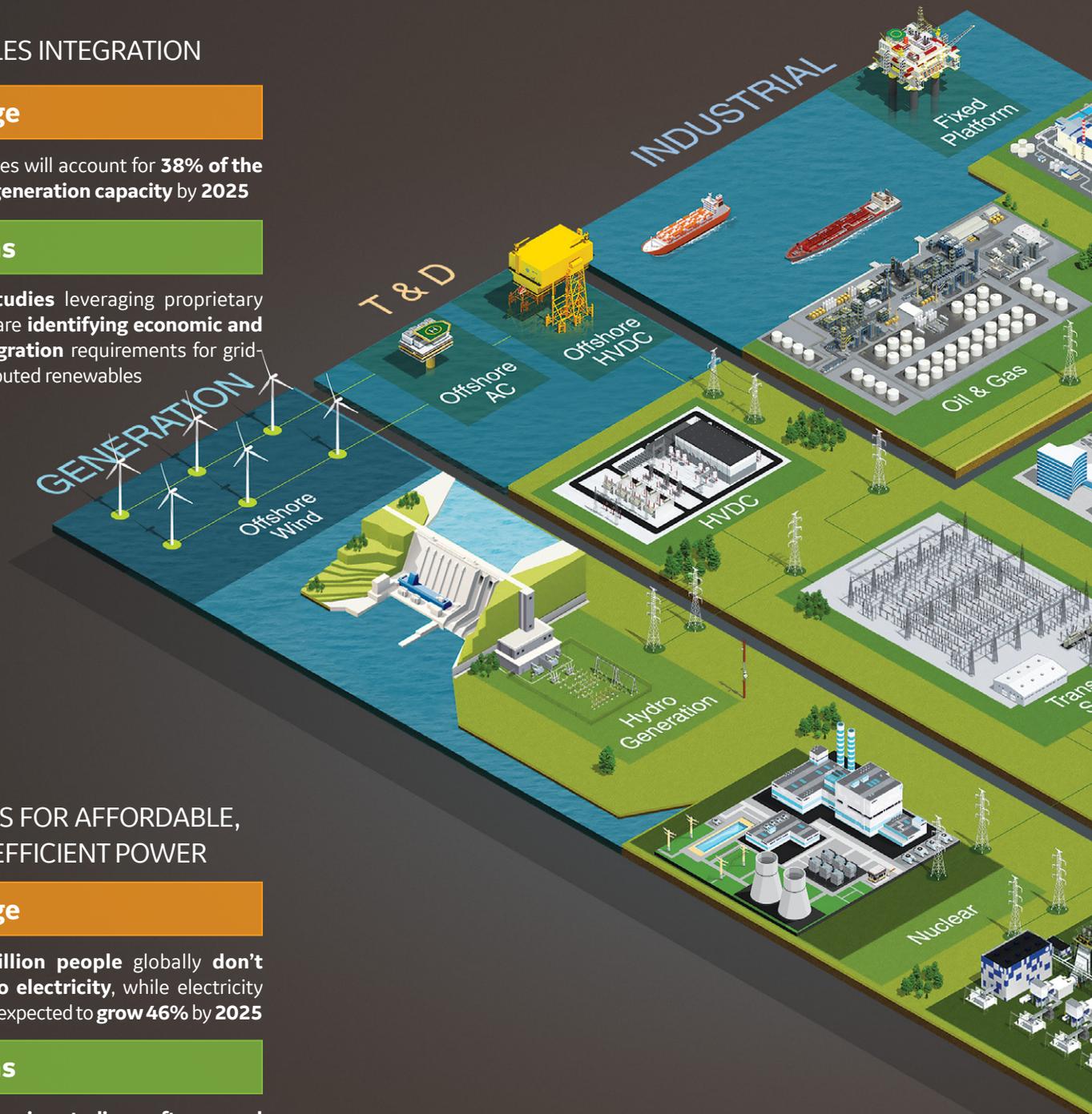
BLUEPRINTS FOR AFFORDABLE, RELIABLE, EFFICIENT POWER

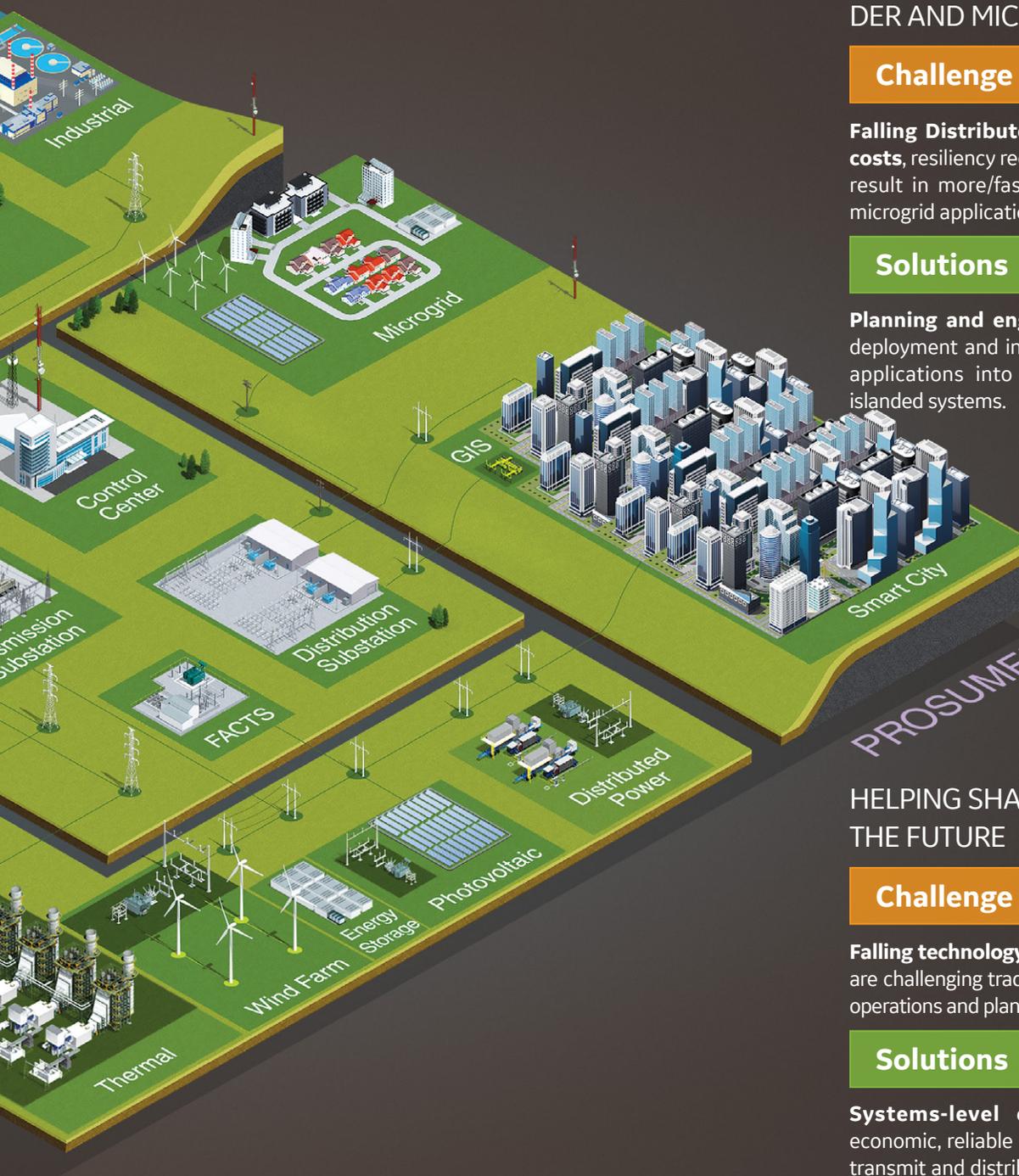
Challenge

Currently **1 billion people** globally **don't have access to electricity**, while electricity consumption is expected to **grow 46% by 2025**

Solutions

Global grid planning studies, software and training help develop electrification roadmaps for emerging countries like Myanmar, Papua New Guinea and many others





BACK TO THE FUTURE: DER AND MICROGRID

Challenge

Falling Distributed Energy Resources (DER) costs, resiliency requirements and policy changes result in more/faster deployments of DER and microgrid applications

Solutions

Planning and engineering studies enable the deployment and integration of DER and microgrid applications into the grid and as stand-alone islanded systems.

HELPING SHAPE THE UTILITY OF THE FUTURE

Challenge

Falling technology costs & global policy changes are challenging traditional electric power business, operations and planning models

Solutions

Systems-level evaluations of the most economic, reliable and efficient ways to generate, transmit and distribute electricity while **engaging emerging “pro-sumers”**

ENERGY CONSULTING ... THE FIRST 100 YEARS



BIRTH OF AN INDUSTRY

Thomson Houston Co. Power & Mining Dept.

April 15, 1892: GE formed by merger of Edison General Electric and Thomson Houston



Combined Electric Utility & Industrial Application Engineering



OIL EMBARGO

Electric Utility Systems Engineering Department



COMPETITION

Energy Consulting

STAGNATION

Systems Development & Engineering Department

The Digital Energy Transformation driven by:

- Digitalization
- Decentralization
- Decarbonization

1880s 1920s 1930s 1950s 1960s 1970s 1980s 1990s 21st Century



Central Station Engineering



INFRASTRUCTURE GROWTH

Central Station Engineering with Analytical Engineering



LARGE CENTRALIZED GEN. STATIONS & EHV REGIONAL GRIDS

Electric Utility Engineering Operation

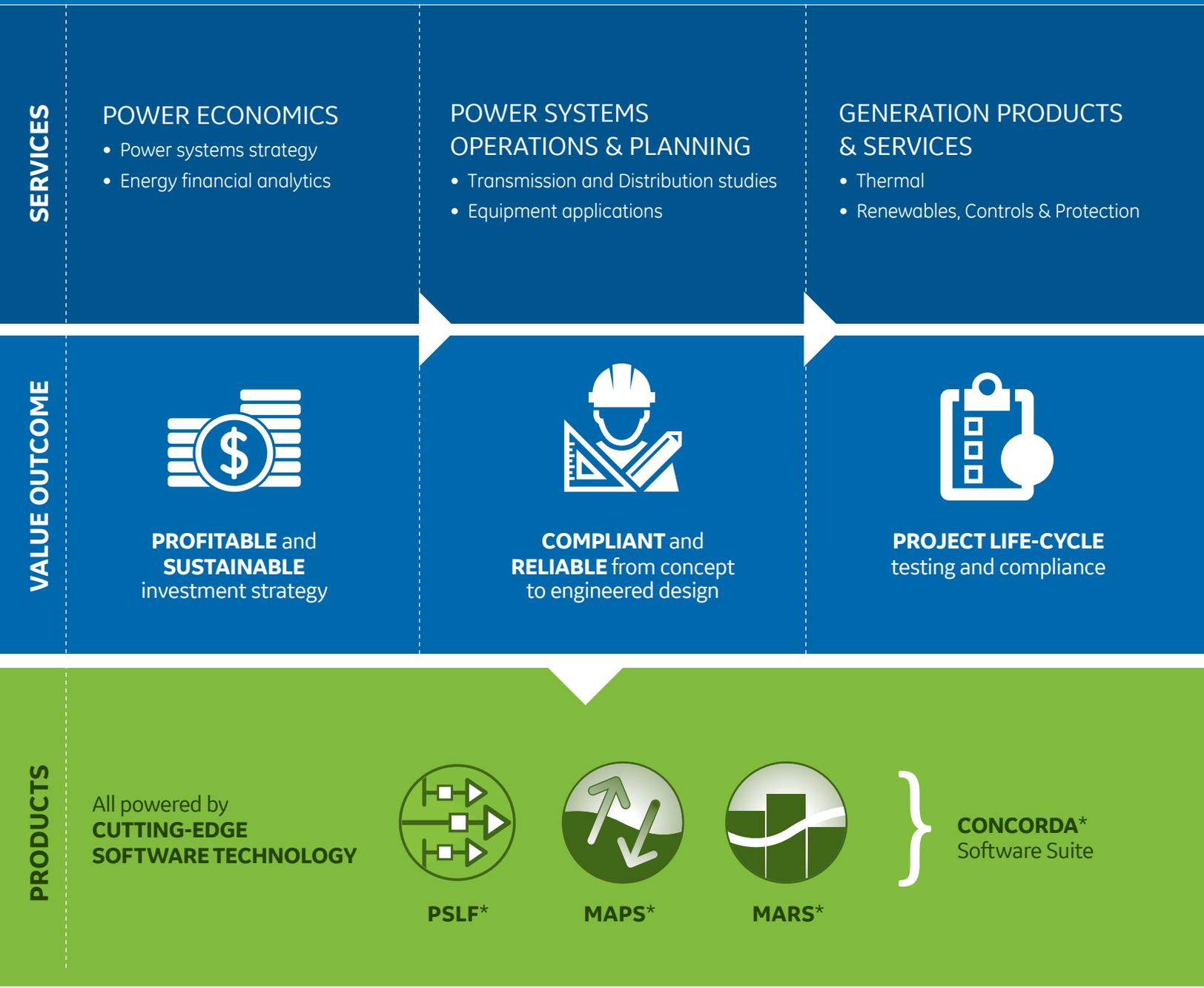


DEREGULATION

Power Systems Energy Consulting



SYSTEMS ENGINEERS SOLVING CHALLENGES THAT DELIVER CUSTOMER VALUE



TAILORED Education and Professional Development Courses from Energy Consulting including **Power Systems and Energy Courses (PSEC)** - Longest running energy executive development program

SERVICES

POWER ECONOMICS

Working with our customers to make difficult energy asset decisions, while helping them reduce potential risks.

POWER MARKET ASSESSMENTS

- Energy and capacity market structures
- Generation dispatch and bidding behavior
- Renewable tariff mechanisms
- Gas (fuel) and transmission availability

INVESTMENT DECISION ANALYSIS

- Cost and revenues projections
- Dispatch and utilization analysis
- New site screening and upgrade value studies
- Transmission interconnection analysis

IMPACT OF ENVIRONMENTAL POLICY & REGULATION

- Current and future scenarios
- Environmentally (SOX, NOX, mercury, carbon) constrained planning models
- Supply side and demand side resource expansion optimization constrained for renewable and environmental policy
- Electric vehicle, storage and demand side program impact

INTEGRATED RESOURCE PLANNING

- System reliability analysis
- Generation and transmission planning
- Demand-side management and participation

VARIABLE GENERATION STUDIES

- Wind and solar integration
- Impact on ancillary services

POWER SYSTEMS OPERATIONS AND PLANNING

Focusing on the planning, design, and operation of interconnected power systems.

- Generator/switchyard protection settings
- Grid reinforcement and expansion planning
- Secure islanding of power plants – system stability analysis
- Reactive power adequacy and voltage stability analysis
- Transmission line protection
- T&D long-range planning
- Equipment, switchgear, and arrester application
- DSTAR – Distribution R&D for today's utility environment (www.dstar.org)
- Distribution automation and smart grid
- Distributed generation impact studies
- Industrial protection and control application, fast load-shed schemes
- End-use power quality and reliability

GENERATION PRODUCTS & SERVICES

Analyzing regulatory and performance requirements through an expert lens to help our customers meet their application needs.

THERMAL

- Power Plant Testing for Grid Code Compliance
- Transient Dynamic Model Development and Validation (e.g. "WECC" and "NERC" Tests)
- Grid Code Compliance Evaluation Studies
- Power System Stabilizer (PSS) Analysis, Tuning & Testing
- Grid Code and Technical Standards Development (e.g. with NERC and IEEE)
- Sub-Synchronous Resonance and Generator Torsional Solutions

RENEWABLES, CONTROLS & PROTECTION

- Electrical Design Review and Performance Analysis
- Interconnection and Plant Coordination Analysis
- NPI/NTI/Certification Support
- Specialty Controls and Hardware Solutions
- Custom Controls Design, Evaluation, and Implementation
- Sub-Synchronous Controls Interaction and Mitigation Design
- Power Plant Protection Settings Coordination



GE SOFTWARE

Planning the Grid of the Future Today

Focused on the planning, design, and operation of interconnected power systems.

See how GE and Energy Consulting are leveraging the power of software, big data and analytics to shape and plan the grid of the future through this interactive experience on www.GEEnergyConsulting.com/insights/grid-planning-software-insights



MAPS*

- Evaluates power system economics and impact of congestion
- Provides locational prices, unit schedules, line flows, emissions
- Used in high wind penetration and standard market design studies
- Supports GE's multi-billion dollar energy investment portfolio



PSLF*

- Simulates physical behavior of the grid and connected equipment
- Provides voltages and line flows, system dynamic behavior
- Extensively used to study 2003 Northeast US blackout
- Mechanism for ensuring that equipment is properly modeled



MARS*

- Assesses reliability of supply in meeting energy demand
- Provides of load expectation (LOLE) and other reliability indices
- Applied for regional reliability and reserve margin studies
- In use at most ISO's in the US



ENERGY CONSULTING EDUCATION AND PROFESSIONAL DEVELOPMENT

Power Systems and Energy Course (PSEC) GE Software Training MAPS, MARS & PSLF

- Respected 65-year history of developing the world's energy leaders
- Nearly 1800 graduates worldwide, representing 177 companies and 55 countries
- Professional experts at PSEC have proven, real-world expertise in a wide range of technologies — from power systems planning and energy economics to power markets and emerging generation solutions.



POWER SYSTEM ENGINEERING



POWER SYSTEM PLANNING AND ADVANCED APPLICATIONS



POWER MARKETS, ENERGY ECONOMICS AND STRATEGIC PLANNING



EMERGING GENERATION TECHNOLOGIES

GE MAPS, MARS and PSLF instructional sessions designed to help you unlock the full power of your investment in GE software products.

For more information about courses, visit: www.GEEnergyConsulting.com/education

All courses will still be eligible for IEEE Continuing Education Units (CEU) and Professional Development Hours (PDH).



SOLVING OUR CUSTOMERS TOUGHEST ELECTRICAL SYSTEMS CHALLENGES

PROTECT CUSTOMER OPERATIONS (Newmont Mining, Nevada, U.S.A)

Saving millions of dollars in potential repairs and down-time

CUSTOMER SITUATION



- Mining customer uses on-site generation to provide efficient, reliable and economical power to the site
- Generation is connected to the local grid, and excess power is sold back to the utility

CHALLENGE



- Utility adds series capacitors to the grid
- These Could expose customer's generators to severe system disruptions
- These disruptions could cause torsional stresses that could result on-site generation to break risking an outage and lost revenue

GE SOLUTIONS



- GE Energy Consulting engineers, designs and installs blocking filter technology to minimize system disruptions from the grid
- The customer's Generation equipment is protected, the outage is avoided, saving time and money

RENEWABLES INTEGRATION (Pan-Canadian Wind Integration Study)

Delivering efficient renewable integration without compromising grid reliability

CUSTOMER SITUATION



- Canada has high quality wind resources nation-wide
- Canadian policy makers and planners are interested in understanding impact of higher penetration of wind energy in their power systems, going from 5% now up to 35% by 2025

CHALLENGE



- Canadian grid is run provincially
- Need to understand how to most effectively integrate large amounts of wind within the provinces
- Identifying the impact of higher wind penetration on power system operations, dispatch of thermal generation, fossil fuel consumption, and carbon emissions

GE SOLUTIONS



- GE Energy Consulting conducts the first-ever nationwide analysis of wind energy integration
- Analysis shows Canada can get more than one-third of its electricity from wind without compromising grid reliability, while reducing greenhouse gas emissions and generating new export opportunities

MICROGRIDS & GRID RESILIENCY (National Grid Potsdam Microgrid Project, Potsdam NY, U.S.A)

Developing resilient microgrids ensuring always-on power availability

CUSTOMER SITUATION



- Mission critical facilities in Potsdam, NY, as well as Clarkson University and SUNY Potsdam get affordable, reliable and efficient power from the traditional interconnected grid
- These facilities traditionally have some back-up generation capabilities

CHALLENGE



- A severe winter storm damaged several parts of the electric grid in the town, putting facilities with critical power needs at risk
- Power was interrupted in some cases for a few hours and the grid was unavailable for several days in some places
- In many cases back-up power wasn't sufficient

GE SOLUTIONS



- Conducted technical and economic studies to assess the feasibility of a microgrid solution
- Developing technology design and cost estimates, as well as an advanced microgrid controller for the project in collaboration with National Grid to provide reliable and efficient power

POWER ISLAND PROTECTION, CONTROLS & COMPLIANCE (Major LNG Export/Import Terminal, Texas, USA)

Enabling plant efficiency while helping to ensure compliance

CUSTOMER SITUATION



- LNG plant customer could potentially draw electricity from the grid
- The customer pays predetermined wholesale rates to utility
- The plant could be out of commission if electric grid is damaged, costing time and money

CHALLENGE



- Customer chose to develop its own islanded power on-site to ensure reliable, efficient and affordable power
- On-site power requires complex electrical systems to serve loads
- The on-site generation is connected to the grid and needs to be grid-code compliant

GE SOLUTIONS



- Conducting electrical systems studies and designing the complex electrical systems for the customer
- Developing and designing protections
- Ensuring power system is grid code compliant

SERVING GLOBAL CUSTOMERS



WORLD - RENOWNED

More than 100 recognized
electric power systems
industry experts

INNOVATING & PIONEERING

More than 100 patents
awarded in the last
30 years

INDUSTRY LEADERSHIP

4 IEEE Life Fellows, and
1 member of the U.S.
National Academy of
Engineering

Nation-Wide
**WIND INTEGRATION
MODELS & Blueprint**
(Canada)

**RESILIENT
MICROGRID**
Engineering Design
& Feasibility Study
(U.S.A.)

**INDUSTRY
LEADERSHIP**

WITH LOCAL EXPERTISE

GRID CODE TESTING Largest Combined-Cycle Plants (U.K.)

Aluminum Smelter: **SECURE ISLANDING & PROTECTION** Study (UAE)

National **ELECTRICITY MASTER PLAN** & Models (Myanmar)

ENERGY ECOSYSTEM STUDY: 30GW Generation & 765kV Super-Grid (Nigeria)

HYBRID WIND, SOLAR, STORAGE Study & Engineering Design (India)

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