GE VERNOVA

2024 CONSULTING SERVICES PRODUCT CATALOG

THE ENERGY TO CHANGE THE WORLD

gevernova.com

A MESSAGE FROM JIM WALSH

It is a thrilling time to be part of the Power Industry as we work together to redefine a new future focused on Electrification and Decarbonization. The challenges are profound: Close to a billion people around the world that don't have access to reliable energy, upticks in catastrophic weather events caused by climate change are impacting us all, and ongoing challenges to reliability of the Grid based on a changing generation mix requires new solutions to keep the lights on. Each of these challenges are worth taking on individually; when you look at them collectively, it creates a true call to action for all of us. Working together, we can positively impact all of these challenges, and that is precisely the bedrock that GE Vernova was founded on… a purpose built company focused on the Energy Transition and helping our customers solve for the energy trilemma; Sustainability, affordability, and reliability.

Within Consulting Services, our mandate is to view the world through a "Systems" lens. The Power system is just that, a complex yet intricate system. By delivering this systems level perspective and capabilities, we believe we are unique in the Industry. We have been in and around the world's power systems for more then 100 years, and for that period of time, we have been working with customers to ensure that they have been able to deliver the necessary outcomes required to power the world. As the landscape has evolved, we have evolved as well… and stand ready to meet the emerging challenges of today and tomorrow with an incredible and deep staff of experts. Our people work shoulder to shoulder with the teams who build incredible technology everyday, and our access to them helps us serve you in ways that will deliver real outcomes to your toughest challenges. Our focus is on Electrification and Decarbonization, and working with you as partners to help navigate the challenges that you are faced with is why we exist.

The attached catalog describes our offerings, and some of the successes our customers have had in working with us. It really only scratches the surface in terms of what is possible, and we invite you to bring us your toughest challenges. We will listen, form a plan of action, and leverage the entirety of our company to help you achieve the breakthroughs that you seek.

Our mindset is simple… we win when you win.

Jim Walsh

Vice President
Consulting Services
GE Vernova

SOLVING FOR THE CHALLENGES OF THE ENERGY TRANSITION

Addressing the climate crisis is an urgent global priority and we take our responsibility seriously. That is our singular mission at GE Vernova: continuing to electrify the world while simultaneously working to help decarbonize it.

Transition to a low-carbon – and eventually a net-zero – energy landscape, presents unique challenges in form of significant changes to the economics, energy generation profiles that will need increased penetration of renewable generation, velocity of demand, consumption patterns and operations of power systems as a whole while ensuring that energy supply remains reliable, affordable and secure. For instance, our grid systems that weren't originally designed for this rapidly changing landscape need detailed planning, systems assessments, and protection to provide the backbone that energy transition needs for electricity with adequate grid performance, capacity, flexibility, and system stability.

Evolving policy frameworks, regulations and accelerated support by governments to lower greenhouse gas emissions require systems level decisions. These decisions cannot be taken from a singular perspective, they need a holistic approach that incorporates technology, fiscal impact, financing need and business models, to prepare for the future. Global and governmental decarbonization targets are in place, evolving clarity is offered on how to reach them – key is path to implementation. The execution of the projects hence requires tools and assessments that can forecast capacity additions that will meet those policy goals, efficiently and reliably, while examining both the economic and physical aspects of proposed projects and systems.

"We are united by a single, urgent purpose to electrify and decarbonize the planet, and together, we have the energy to change the world."

Scott Strazik, CEO, GE Vernova

WE ENABLE RELIABLE, ECONOMIC AND SUSTAINABLE ENERGY SYSTEMS THAT POWER THE WORLD

GLOBAL FOOTPRINT LOCAL REACH

Consulting Services in North America:

New and increasing regulations mandate the addition of renewable and carbon-neutral energy sources to grids already at capacity.

Consulting Services in South America:

From hydro and coal to wind and nuclear, South America's energy production portfolio is as diverse as its topography—and we have the resources to meet its challenges.

Consulting Services in Europe:

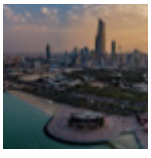
Providing customers with insights, planning tools, and analysis to meet decarbonization targets, power system integration and stability.

Consulting Services in Great Britain:

Enabling our customers to identify and assess the Implications of constraints across the electricity transmission network on plant operations and to the system as a whole towards the credible least cost pathways of future generation and transmission systems required to meet decarbonisation goal.

Consulting Services in Asia:

In Asia's emerging energy market, new technologies must seamlessly integrate with legacy systems. The region stands to play a pivotal role in growth of reliable, affordable and sustainable energy mix. Our experts work closely with customers to bring energy to some of the world's remotest geographies to providing support for new energy portfolio of Hydrogen, Round the clock power and Hybrid power solutions.



Consulting Services in Africa and the Middle East:

With its diverse ecosystems and political climates, Africa presents unique and varied challenges to generating and transmitting power to the people who demand it. In the Middle East, cutting-edge carbon-neutral energy sources are being employed to bring this cradle of civilization into the twenty-first century.

THE VALUE WE PROVIDE

GE Vernova's Consulting Services business is leading the power systems transformation toward decarbonization and driving the necessary changes to the grid around the world.

For more than 100 years, GE Vernova's Consulting Services have been trusted power system experts, solving the world's toughest technical and economic problems, enabling technology integration and serving a diverse global client base with a strong local presence.

Our expertise spans from policy, grid planning, investment decisions analysis to system engineering, equipment and grid code compliance. As industry pioneers, our expertise built over the last 100 years positions us as a sole entity leading the formulation of engineering and operations of the interconnected electrical systems that we know today.

Our holistic approach delivers for our customers thought leadership, electrification and decarbonization playbooks, integrated software platform, grid stability and integration expertise, and deep experience across the breadth of the GE Vernova portfolio.

ENABLING THE TRANSITION TO NET ZERO

The Challenge: Great Britain needed to quantify credible least-cost pathways for future generation and transmission systems to meet its decarbonization goal. The implications of constraints across the electricity transmission network on plant operations and on the system as a whole needed to be assessed.

The Solution: Consulting Services explored alternative generation and transmission investment pathways, considering the economic buildout of renewables, nuclear, storage, and lower carbon thermal generation across Great Britain. This quantified the cost and impact to the system of ensuring energy security while respecting the physical constraints of the grid on a 'zonal' basis and recognizing the potential locations of electricity generation resources.

The Result: Our analysis revealed that there is no silver bullet that will fast forward the Great Britain electricity system to 2050 and deliver the net-zero target. We believe a combination of various electricity generation, transmission, and system control/management technologies with underlying supportive policy and regulatory measures, coupled with reformed markets, will be essential. We built our recommendations to highlight that more than a £50 billion investment is required in generation and storage capacity alone by 2030. Expedite the implementation of market reforms that are technology agnostic, remunerate all system services (energy, capacity, flexibility, and stability) and provide adequate signals for investment in generation and grid assets 'when and where' needed. Adapt energy policy and regulation that bring clarity to the uptake of lower carbon generation (in particular for SMR, CCS, and hydrogen) as well as grid technologies.

CREATING A BLUEPRINT FOR HYBRID GRID-SCALE RENEWABLE ENERGY

The Challenge: With India's ambitious renewable capacity goals, Consulting Services was called on to determine the technical and commercial feasibility of an integrated wind, solar, and energy storage (IWSES) plant with combined generation capacity of more than 1,200 MW.

The Solution/Result: We provided a blueprint for developing the financial and technical elements of an IWSES plant that addressed challenges by connecting and siting wind, solar, and battery storage in the same place, and laid out the business case to make it economically viable.

EFFECTIVELY INTEGRATING RENEWABLES

The Challenge: Canadian policymakers and planners needed to understand the impact of higher penetration of wind energy—from 5% today to 35% by 2025—and to determine how to most effectively integrate large amounts of wind within the provinces.

The Solution: In collaboration with the Canadian Renewable Energy Association, Consulting Services conducted the first-ever nationwide analysis of wind energy integration.

The Result: 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.

DETERMINING INTERREGIONAL TRANSMISSION REQUIREMENTS

The Challenge: How can the Federal Energy Regulatory Commission (FERC) determine the minimum interregional transmission requirement?

The Solution: Consulting Services simulated the Eastern Interconnection (EI) with our integrated software platform under two transmission conditions of constrained flows and unconstrained flows and for three different weather conditions of heat wave, polar vortex, and normal weather. Additionally, we performed an analysis on a subset of EI to assess potential stability qualifications.

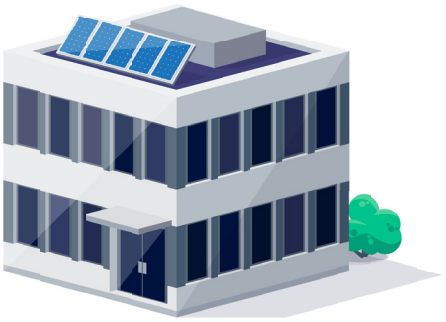
The Result: We identified $3 billion to $4 billion per year in production cost savings, enabled by unconstraining interregional transmission under normal weather conditions and load shedding avoided during simulated heat wave and polar vortex events via unconstrained transmission. Consulting Services proposed methodology for quantifying the incremental interregional transmission requirement via an increase in average power flows enabled by constraining transmission across weather events. FERC can consider this methodology to enable the definition of an incremental transmission requirement between each pool in its jurisdiction. Cost allocation could follow the importing region.

Best fit site services...for Data Centers and Power Generation

Access grid capacity and generate power to maximize the value and reliability.

Grid connectivity is constrained and expensive. Clean-energy developers are seeking opportunity to optimize existing grid and find which parts of the grid have room for new projects

Data centers are integral to the way we live our lives every day. With rising demand also come challenges of power systems rising costs, idetification of sites with power (MW) relaibility, power procurement design



Our experts work across the practice areas of Power Economics, Grid Integration and Stability and Carbon management to deliver innovative solutions to select best sites and minimize grid connection risk, optimizing site integration, identify best options with minimal congestion and stability constraints, minimizing curtailment and grid constraints, provide visibility to act first on prime locations; manage complex queue dynamics while maximizing output, consumption and revenues for the project.

Solutions & Capability

1. INJECTION ANALYSIS
2. COGESTION & CURTAILMENT ANALYSIS
3. INTERCONNECTION FEASIBILITY & APPLICATION
4. REVENUE & SYSTEM BENEFIT ANALYSIS
5. SYSTEM STABILITY ANALYSIS
6. TRANSMISSION SYSTEM ANALYSIS
7. POWER SYSTEM CONFIGURATION & SIZING
8. CARBON INTENSITY ASSESSMEMT
9. POWER SYSTEM CAPACITY & RESILIENCE

THE CONSULTING SERVICES PRODUCT PORTFOLIO

Our experts provide holistic studies that include power economics assessments for the energy transition and software tools to determine whether your project is economically feasible; grid stability and integration studies that evaluate the grid, transmission and distribution, and pathways to integrate conventional, renewable, and emerging power sources; and carbon management consulting that informs your strategies to lower your greenhouse gas and carbon footprint.

Power economics and software
Is a project worth building?

Grid stability and integration
Can a project safely interconnect and reliably operate?

Carbon management consulting
Can you operate sustainably for the future?

~140
ENERGY EXPERTS

100+
PATENTS

12
COUNTRIES

1
MEMBER OF THE U.S. NATIONAL ACADEMY OF ENGINEERING

POWER ECONOMICS & SOFTWARE

Helping you make challenging energy asset decisions while reducing potential risks

You can't base your decisions on technical considerations alone. Instead, you also must look to a range of economic, policy, and regulatory drivers. Consulting Services' cross-functional teams weave stability and adequacy power system analysis into technical and economic recommendations and solutions.

We combine policy, planning, and investment decision expertise to help you make complex energy decisions while reducing potential risks. We analyze electric power market conditions, system dispatch and operations, and energy policy implications so you can make strategic planning decisions in today's often uncertain world.

DEVELOPING COUNTRYWIDE INFRASTRUCTURE

The Challenge: Consulting Services was challenged to review generation, transmission, and distribution planning, including production simulation, load flow, short-circuit, and contingency analysis of a developing country in Asia.

The Solution: The study highlights the need to focus on all fuel types being considered in planning, like gas combined cycle near load centers while reducing dependence on hydro power generation, especially during the dry season.

The Result: Consulting Services trained the engineers on how to conduct detailed generation, transmission, and distribution planning and analysis. Our experts worked with the country's grid operator and other key stakeholders to model and plan the country's future grid, helping to ensure that more people can get access to more reliable, affordable, and efficient energy.

We shared best practices for developing electric power markets as well as the regulations that could govern them with the country's key stakeholders based on our decades of experience consulting around the world.

OUR EXPERTISE

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 and 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
- Gas (fuel) and transmission availability

CREATING AN ASEAN INTERCONNECTION MASTER PLAN

The Challenge: An ASEAN Interconnection Master Plan could enhance the energy connectivity and market integration for the 10-country ASEAN grid to achieve energy security, accessibility, affordability, and sustainability for all. In addition, such a multilateral power trading setup in the region could enable these countries to achieve desirable renewable utilization in the energy mix.

The Solution: Consulting Services worked with ASEAN Center for Energy (ACE), Jakarta, to perform a renewable energy resource assessment, generation planning, and production simulation to maximize the variable renewable energy integration in the Asian power grid. The solution also incorporated a grid study to validate adequacy of interconnection and update the master plan to reflect changes and projections.

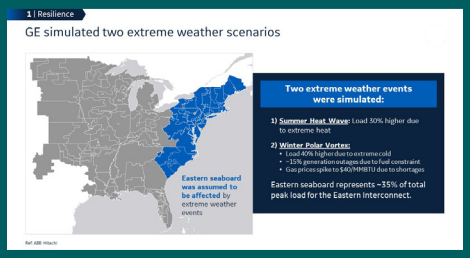
The Result: We delivered the models to demonstrate that increased regional interconnection enables renewables to be sited optimally, leveraging diversity in demand patterns and renewable generation across time zones and improving energy security via lower fossil fuel dependence (lower emission intensity). Our work resulted resulting in newly prioritized transmission investments.

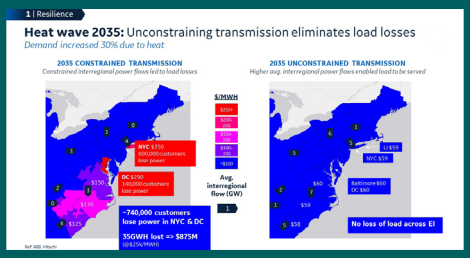
INTERREGIONAL TRANSMISSION: ENABLING AFFORDABLE & RELIABLE DECARBONIZATION

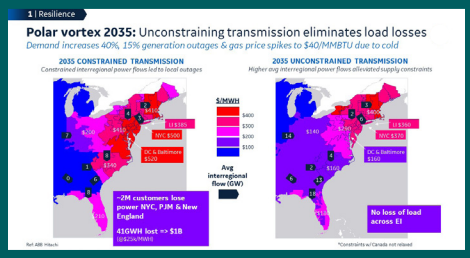
Case study focusing on the Eastern United States in 2035

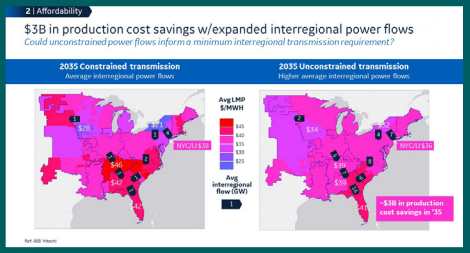
Recently, GE Vernova Energy Consulting completed a study to demonstrate the consumer benefits of greater interregional transmission given more frequent extreme weather events and the shift to lower carbon resources.

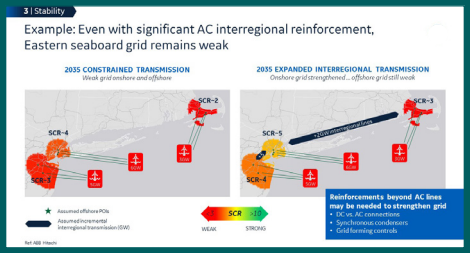
- GE Vernova illustrated that greater interregional transmission provides affordability, reliability and resiliency benefits while also proposing a methodology that regulators could consider, to quantify the amount of incremental transmission required.
- GE Vernova simulated electric generation across the US Eastern Interconnection for a number of weather conditions in the 2035-2040 timeframe in order to quantify the benefits of greater interregional transmission to resiliency, affordability and stability.
- During a simulated heat wave in August 2035, greater transmission prevented ~740,000 customers losing power across New York City and Washington, DC saving $875M.
- During a simulated polar vortex in February 2035, greater transmission prevented ~2 million customers losing power across Boston, New York City, Baltimore and Washington, DC saving $1B.
- Under normal weather conditions, greater transmission saved $3B/year in 2035 increasing to $4B in 2040 via greater access to lower cost generation.
- Example cost benefit analysis shows $12B in net benefits from 87GW of incremental interregional transmission.
- Grid stability is also increasingly a risk during extreme weather events. Alternate interregional transmission technologies (e.g. DC vs AC connections) should be considered to maintain stability especially with high inverter-based resource penetrations.

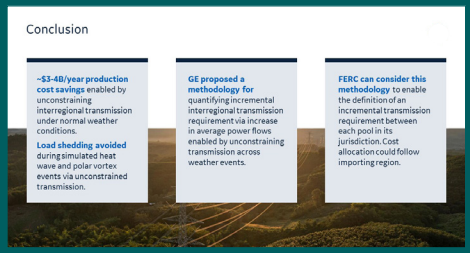












CONSULTING SERVICES SOFTWARE SUITE

Planning the grid of the future today

Our integrated software platform delivers the ability for our customers to address the need for rapidly evolving power systems - leveraging the power of software, big data, and analytics for planning, design, expansion, and reliable operation of interconnected power systems.

INTEGRATED WIND, SOLAR, AND ENERGY PROJECT

The Challenge: Working with a group of stakeholders in the national grid, Consulting Services developed an assessment to determine whether country's power grid could remain stable and meet load requirements while integrating additional renewable power sources.

The Solution: In our assessment process, we developed a production simulation model to examine the hourly and annual impact on system operations and economics, evaluated operational issues, and used our platform to assess the reliability of country's grid system and analyze additional generation capacity requirements to meet target loss of load expectation (LOLE) level.

The Result: Consulting Services answered the following questions:

- Given planned renewable energy (175 GW) and non-renewable energy capacity additions by 2022, will the system succeed in integrating new renewable energy while meeting load (i.e., 24×7 affordable power for all)
- What are the technical/infrastructure options (e.g., flexible generation, advanced grid operation protocols, expanded control areas, demand-side management, optimized transmission, etc.) for minimizing the cost of integrating renewable energy while meeting load.

Our software suite is evolving to provide an integrated platform, designed to help you tackle complexity of power systems reliability, resilience and energy transition

Sharper insights through modular solutions

Modular design promotes seamless data transfer between applications, linking all power system studies and evaluations in lightning speed.

Technology that grows with your team

A platform that expands to additional applications as your team, expertise, or needs require.

Your planning system for the energy transition

Platform offers a holistic analysis of the entire power system to conduct the necessary studies required to keep the grid balanced and affordable while keeping the system reliable.

Accelerated workflows at a reduced cost

Built on lighter, more nimble IT infrastructure and easy API integration, our solution reduces testing and maintenance costs associated with many platforms, improving overall capital and operations and maintenance expenses.

Advanced grid applications and solutions

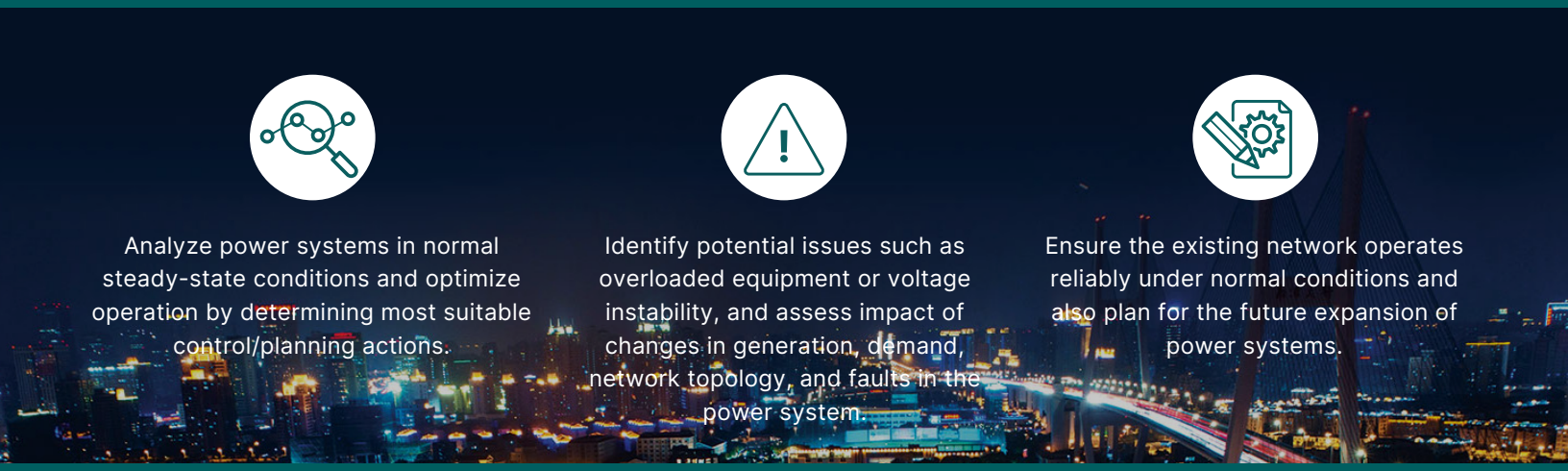
Leverage a unified dataset across modular applications that together provide cohesive integrated planning, and evaluation of your power system.

A blueprint of future energy markets

Create a dynamic blueprint for the future energy transition with expansion planning capabilities, driving intelligent decisions that achieve lowest cost without sacrificing reliability or policy goals.

UNDERSTAND THE TOPOLOGY

Accurately describe and simulate physical behavior of the grid and connected equipment under stable operating conditions, identify potential vulnerabilities, and ensure reliable operation.



Analyze power systems in normal steady-state conditions and optimize operation by determining most suitable control/planning actions.

Identify potential issues such as overloaded equipment or voltage instability, and assess impact of changes in generation, demand, network topology, and faults in the power system.

Ensure the existing network operates reliably under normal conditions and also plan for the future expansion of power systems.

FUNCTIONALITY

- Transmission powerflow and contingency analysis. Advanced steady-state analysis and inspection tools
- Dynamic simulation of large transmission systems.
- Geomagnetic disturbances
- Optimal powerflow
- Sub-synchronous resonance and controls simulation
  - Data models generally cover an entire interconnection (Eastern Interconnection, Western Electricity Coordinating Council, ERCOT)
  - Built-in tabular reports, plotting, export to text

APPLICATIONS

- Dynamic and steady-state transmission planning studies
- Operations planning
- Machine model development/ standard setting, including user-written models
- Sub-synchronous resonance, harmonic analysis, equipment coordination and protection
- Frequency response studies
- Generation siting
- Renewable integration studies
- Co-simulation with other modeling tools

FEATURES

- Powerful scripting in Python or proprietary EPCL language.
- Simulation of systems up to 125,000 nodes
- Modern, easy-to-use user interface for managing all aspects of data management simulation, reporting
- Rich library of dynamic models, especially compound load modeling
- Best-in-class and fastest dynamic simulations
- Automated creation of N-1/N-2 contingencies

ASSESSMENT AND OPTIMIZATION

System operators can assess and optimize power system stability amidst unexpected events while enhancing power transfer efficiency, streamline renewable energy integration by identifying optimal projects through an interconnection queue, and evaluate potential facilities to ensure grid reliability and safety

Performs thermal and voltage analysis

N-1-1 & N-2 double outage combinations based on severity ranking of N-1 contingency sets

ProvisoHD tool to sort, rank, plot, and report violations and critical contingencies

FUNCTIONALITY

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ADEQUATELY SATISFY LOAD REQUIREMENTS

PlanOS enables electric utility planners to more quickly and accurately assess the ability of a power system to help adequately satisfy customer load requirements.

Full Sequential Monte Carlo simulation that goes beyond loss of load expectation and expected unserved energy.

Gather insights into the duration, frequency, and causes of events.

Simulate renewable contributions preserving load correlation.

Access ready-to-use datasets for faster model creation.

FUNCTIONALITY

- Chronological Markov Chain Monte Carlo simulation of generation and transmission availability/capacity
- Routinely used to look 10+ years into the future
- Typically looking at an ISO and surrounding ISOs (or balancing authorities), thousands of annual simulations
- Calculates loss-of-load-expectation (LOLE), loss of-energy-expectation / expected unserved energy (LOEE/ EUE), frequency and duration of events, etc.
- Ability to automate reports and plotting

APPLICATIONS

- ISO/balancing authority reliability evaluation
- Renewable integration planning
- Regulatory compliance
- Evaluation of reliability effects of new generation and transmission
- Used to set reserve margin requirements for several North American capacity markets

FEATURES

- Multi-Area Resource Simulation (MARS) is ready-made for high-performance computing (HPC) clusters
- Markov Chain Monte Carlo as opposed to recursive convolution to simulate complex operating conditions
- Model emergency operating procedures and their effect on resouce adequacy
- Industry-accepted best practices for modeling renewable generation. MARS supports unlimited years of renewable generation data while preserving correlation to load
- Brand new energy storage modeling methods
- Calculation results go beyond LOLE and LOEE. MARS' transparent output shows why these results are what they are
- Pre-made datasets are available for use

INVESTMENTS UNDER UNCERTAINTY

Forecast capacity additions considering uncertain (stochastic) variables and generate adaptable plans that minimize costs across many possible future outcomes.

Develop robust plans acknowledging the uncertainties in the energy transition and optimize across a wide range of possible futures.

Forecast reliable and efficient strategies to meet policy goals.

Interoperable with production cost, resource adequacy, and powerflow simulation modules for a more detailed plan verification.

FUNCTIONALITY

- Hourly chronological simulation of secure, least cost, grid commitment and dispatch
- Respects constraints on transmission, generation (e.g. min-up, ramp rate), energy/fuel limitations
- Routinely used to look 20+ years into the future
- Used in modeling the Eastern Interconnection, Western Electricity Coordinating Council, ERCOT, and over 50 countries globally.
- Numerous reports on nodal LMPs, fuels usage, emissions, production, starts, costs, flows, etc.
- Ability to automate reports, simulations, data management

APPLICATIONS

- Wide range of uses
- Renewable integration studies
- Generation asset valuation
- Energy storage valuation
- Emissions analysis
- Operations and maintenance forecasts
- Regulatory policy evaluation
- Transmission asset valuation
- ISO expansion/merger
- Market rule evaluation, etc.

FEATURES

- Calculation speed. Run a large case in hours instead of days. Multi-Area Production Simulation (MAPS) is ready-made for high-performance computing (HPC) clusters by supporting task
- Sub-hourly modeling for better estimation of intra-hour dispatch and reserve needs
- Graphical user interface for editing and validating data and easy interaction with Excel to export and import data
- A Python API that lets users manage runs across multiple cores, inspect and change data automatically between runs for iterative simulations, and automate the creation of plots at the end of simulations. The API is a massive productivity enhancer and gives users improved control over runs and reporting
- Modeling of energy storage and renewables
- Pre-made databases available for EI/WI/ERCOT and several countries

ECONOMIC OPERATION

Analyze generation system operations to meet load requirements while respecting the operating limits of the transmission network.

A proprietary heuristic linear program for an efficient and scalable nodal security constrained commitment... for even the largest networks.

Flexible detail in modelling inputs and outputs

Chronological hourly or sub-hourly simulation for better estimation of intra-hour dispatch and reserve needs.

Access ready-to-use datasets available for faster model creation.

Software Solutions in Action

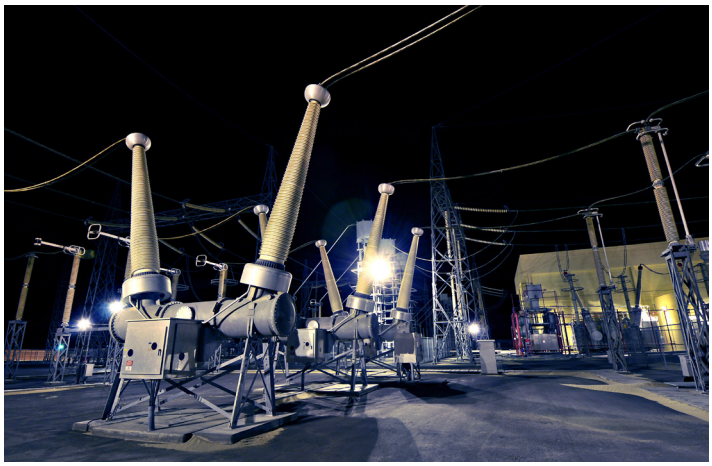
NYPA FINDS A FASTER PATH TOWARDS DECARBONIZATION WITH MAPS

The Challenge: With New York State's goal of achieving a zero-emission power system by 2040, and its own 2035 decarbonization targets, NYPA was seeking to replace its New York City peaker generation with battery storage, a significant challenge based on their historical operation.

The Solution: NYPA leveraged MAPS to model the New York electrical system over the next decade, including state renewable targets, offshore wind and storage resources in NYC as well increased delivery of clean energy into the city. The study showed that NYPA can replace its peakers with 4-hour battery storage at each site when studied individually.

The Result:

- 20% decline in fossil generation by 2030
- 5 years ahead of NYPA's decarbonization goals
- 10 years ahead of New York's statewide decarbonization goal
- 100% peaker plant generation in New York City replaced by battery storage by 2030



REDUCING BLACKOUTS AND BROWNOUTS WITH PUMPED HYDRO STORAGE

The Challenge: With an increase in demand for renewable generation, engineers are searching for the most economical methods of storing wind and solar energy to access when demand is low. A common solution is through battery storage, but the available supply doesn't always meet the demand, leading to blackouts and brownouts. Clearly, a new solution was needed.

The Solution: To address the shortfall of energy during peak times in California, the U.S. Department of Energy leveraged GE Vernova's MARS software to study the effects of an additional 500 MW of hydro storage on the grid, replacing the thermal generation the state often needs to currently meet demand

The Result:

- 1.8 million estimated CO2 emissions reduction, in tons
- Nearly 100% storage capacity value, even with short duration

INTEGRATED WIND, SOLAR AND ENERGY STORAGE PROJECT

The Challenge: Working with Shakti Foundation, CEA, POSOCO, and MNRE, Consulting Services wanted to determine whether India's power grid could remain stable and meet load requirements while integrating additional renewable power sources

The Solution: In their assessment process, Consulting Services developed a production simulation model in MAPS to examine the hourly and annual impact on system operations and economics, evaluated operational issues, and used MARS to assess the reliability of India's grid system and analyze additional generation capacity requirements to meet target LOLE levels.

The Result:

- 24/7 affordable power for all residents
- 175 GW additional renewable power on the grid

GRID STABILITY AND INTEGRATION

Helping you evaluate the grid, transmission and distribution, as well as the pathways to integrate conventional, renewable, and emerging power sources

As the types and sophistication of devices connected to the power grid continue to change, Consulting Services can help you plan and execute graceful technology migration while you deploy new business processes and advanced control operations. Our comprehensive global experience in power system studies and in-depth experience analyzing all aspects of power plant and transmission system dynamic controls can help you successfully integrate conventional, renewable, and emerging power sources for a stable grid with lower carbon intensity.

STUDYING THE FEASIBILITY OF ESTABLISHING A MICROGRID

The Challenge: Mission-critical facilities in Potsdam, N.Y., as well as Clarkson University and SUNY Potsdam get affordable, reliable, and efficient power from the traditional interconnected grid. These facilities traditionally have some backup generation capabilities. However, a severe winter storm damaged several parts of the town's grid, putting facilities with critical power needs at risk. In many cases, backup power wasn't sufficient, and power was interrupted for a few hours and, in some places, for several days.

The Solution: Consulting Services conducted technical and economic studies to assess the feasibility of a microgrid solution.

The Result: We developed technology design and cost estimates as well as a first-of-its-kind microgrid-specific controller, in collaboration with National Grid, to provide reliable and efficient power to Potsdam.

PLANNING THE FUTURE OF ELECTRIC GRID

The Challenge: Bangladesh needed to avoid blackouts and plan for a more stable grid.

The Solution: Our work included:

- Grid model development and validation
- Simulation and validation of future grid operation
- Stability study
- Islanding study
- Grid code review
- Generation and transmission planning review

The Result: Consulting Services recommended code improvements and mitigation strategies to help Bangladesh avoid future blackouts, and worked with the country's grid to simulate, model, and plan a more stable grid that can support future electricity needs.

PREPARING FOR OFFSHORE WIND PROJECT CONNECTION

The Challenge: Great Britain faced numerous complexities with its offshore wind project, mainly due to the utilization of long AC power cable circuits used to transfer power to the onshore grid. Detailed technical system studies were needed to design the system that would meet the planned megawatt capacity.

The Solution: Consulting Services was tasked with calculating power equipment ratings to achieve required system performance and reliability and meet the Natural Gas Grid Code for interconnection. The variability of wind power creates the need for dynamic reactive power compensation to manage reactive power and system voltage. The project had to meet the grid code dynamically as well as in steady state.

The Result: The following studies were executed to enable project interconnection to the grid:

- Equipment Ratings
- Short Circuits Study
- Power Flow Study
- Reactive Power Compensation Study
- Harmonics Study and Filter Design
- Dynamics Study
- Fault Ride Through Study

BRINGING POWER TO THE PEOPLE

The Challenge: Papua New Guinea is aiming to increase access to electricity from 13% to 70% by 2030 through the government's Power to the People initiative.

The Solution: Consulting Services has been working with the government to design an electrification plan to bring power to people who need it most, especially in rural parts of the country. Consulting Services researched and assessed:

- The amount of electricity needed
- Technologies that could meet the need
  - Solar PV
  - Micro hydro
  - Gas engine with integrated LNG infrastructure
  - Diesel engine
- Microgrid solutions for village centers

The Result: We focused our work around a "hub and spoke" approach, which involves identifying a hub—such as a city, village, or town—to serve as a focal point of electricity generation for spokes (schools, clinics, and other community facilities) for the benefit of a larger rural area.

DEVELOPING MODELS FOR FUTURE GRID

The Challenge: Cambodia's grid is interconnected with the grids in Vietnam and Laos. Interconnected grids provide support in the event something happens on a neighbor's system. Consulting Services was contracted by the grid operator in Cambodia to evaluate what would happen if Cambodia's grid was disconnected unexpectedly from Vietnam's.

The Solution: Our work included:

- Developing and validating grid models
- Analyzing the transmission of the country's grid network
- Providing transmission planning software and training
- Offering world-renowned Power Systems & Energy Courses (PSEC)

The Result: In addition to developing and validating Cambodia's grid models, we deployed our expertise to train the country's grid operators on best practices for planning and grid operations.

PERFORMING ROOT CAUSE ANALYSIS ON OFFSHOREWIND PROJECT

The Challenge: An offshore wind project in Great Britain experienced a shunt reactor failure for no apparent reason. The resolution was urgently needed due to penalties for undelivered power.

The Solution: Consulting Services was called in to perform a detailed technical system study prior to performing root cause analysis (RCA) on the equipment failure.

The Result: The study assumed understanding of the offshore and onshore electrical systems as well as the details of shunt reactor design and the operational events that may have potential impact. Close cooperation with the reactor design experts also was required.

OUR EXPERTISE

Engineering studies for the integration of technologies/equipment:

- Renewable generation (offshore/onshore wind/solar)
- Energy storage (BESS, flexible pump hydro, flywheel)
- Hydrogen electrolyzers
- Electrification of offshore oil and gas platforms
- Industrial plants (aluminum smelters, steel mills, refineries)
- Conventional power plants (thermal/hydro)
- Power transmission (HVDC/AC)
- FACTS (for maintaining voltage/power flow/reliability)
  - Transmission system planning
  - System operation analysis to enable reliability and stability

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
- Distribution automation and smart grid
- Distributed generation impact studies
- Industrial protection and control application, fast load shed schemes
- End-use power quality and reliability

EQUIPMENT AND GRID CODE COMPLIANCE

Delivering system modeling and testing to customers around the world

Consulting Services' expertise, experience, and efficiency supports effective planning and execution, helping to keep you well-positioned to respond to regulatory requirements, evaluate upgrade options, and understand your equipment's capabilities. Our offerings include:

- Test planning/grid code testing. A cost-effective approach for generator owners to meet regional and national model validation requirements.
- North American Electric Reliability Corporation (NERC) protection and control standard compliance services. We offer convenient and cost-effective NERC standards implementation services and solutions.
- Generator protection study and relay settings. These include relay settings for generators, bus, step-up transformer, and additional auxiliary equipment for new and existing power plants.
- Power System Stabilizers (PSS). These tuning and testing studies help you achieve the best practical performance.
- Renewable energy consulting. We provide advanced systems engineering analyses for renewable energy sources.

PROVIDING POWER ISLAND PROTECTION AND GRID COMPLIANCE

The Challenge: Because it could be out of commission should the electricity grid be damaged, a major LNG import/export terminal in Texas, U.S., decided to develop its own islanded power on site to ensure reliable, efficient, and affordable power. It turned to Consulting Services in recognition of the complex electrical systems required for on-site power.

The Solution: Consulting Services conducted electrical systems studies and designed the complex electrical systems to ensure the power system could be connected to the grid and is grid code compliant.

The Result: Our engineers helped enhance plant efficiency while enabling grid code compliance.

PROTECTING CUSTOMER OPERATIONS

The Challenge: A mining company was using on-site generation to provide efficient, reliable, and economical power to the site. Its power source was connected to the local grid, with excess power sold back to the utility. However, when the utility added series capacitors to the grid, the company's generators could be exposed to severe system disruptions that could cause torsional stresses, resulting in a possible broken system, outages, and lost revenue.

The Solution: Consulting Services engineers designed and installed blocking filter technology to minimize system disruptions from the grid.

The Result: The company's generation equipment is protected and the outage was avoided, saving time and money.

TESTING POWER PLANTS TO MEET RELIABILITY STANDARDS

The Challenge: FERC Order No. 796 approved NERC Reliability Standards MOD-025-2, MOD-026-1, MOD-027-1, PRC-019-1, and PRC-024-1 on March 20, 2014. As a result, most generating units in the U.S. and Canada are required to perform protection coordination and model validation. Testing is required periodically or whenever the equipment is commissioned or modified. Equipment of various types, manufacturers, and installed dates must be tested. In addition, challenges include equipment OEM data, simulation platforms, model accuracy, and test equipment.

The Solution/Result: Consulting Services has more than 20 years of experience testing power plants around the world. We have tested more than 3,000 units, ranging in size from small diesel generating sets to large nuclear steam turbines. We are experienced with both GE and non-GE equipment, from conventional to renewable power plants.

PROVIDING TORSIONAL PROTECTION SOLUTIONS

The Challenge: Some power system equipment can interact with turbine-generator torsional vibrations at the shaft. If the vibration amplitude is large enough, the turbine-generator's shaft components can sustain cumulative fatigue, including severe damage (such as cracks) to rotors or couplings.

Sub-synchronous resonance (SSR) due to series capacitors is by far the most usual situation that may require torsional protection. Large rated power electronic converters (HVDC, motor drives, and SVC) near the turbine-generators also can be of concern.

The Solution: Experts from Consulting Services have provided torsional protection solutions and analysis services for nearly 50 years. GE Vernova's first Torsional Stress Relay (TSR) was introduced in 1997 as an updated version of the proven single mode fiber (SMF) relay.

The Result: With more than 100 TSR units in service today, we have extensive fleet experience in providing torsional protection solutions.

OUR EXPERTISE

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)

Renewables, controls, and protection:

- Electrical Design Review and Performance Analysis
- Interconnection and Plant Coordination Analysis
- Specialty Controls and Hardware Solutions
- Custom Controls Design, Evaluation, and Implementation
- Sub-Synchronous Resonance & Controls Interaction and Mitigation Design
- Torsional Solutions
- Power Plant Protection Settings Coordination

CARBON MANAGEMENT CONSULTING

Providing you with a pathway to lower your greenhouse gas and carbon footprint

Consulting Services will work with you to develop a strategic roadmap to meet your net-zero targets for a cleaner energy future. By assessing your current greenhouse gas (GHG) emissions, we provide tailored analytics and processes to help you track and understand your CO2 impact. Our studies can help you unlock opportunities to reduce and remove GHG and CO2 emissions, building the foundation for future energy systems.

Carbon Markets

Enable customers, through the full value chain, to identify and implement economically viable pathways for decarbonization technologies in power generation.

GHG Inventory Management

Support customers to design sustainability and decarbonization strategies that align with business goals and complies with applicable regulations and/or reporting standards, levereging our digital platform CERius.

Energy Transition Planning

Drive identification of emission abatement technologies and techno-economic scenario planning leveraging Consulting Services integrated software platform for grid stability, reliability and resilience assessments.

Sustainability Planning

Provide customers an ability to manage sustainability planning and analysis.

STUDYING THE FEASIBILITY OF CCS-BASED CARBON OFFSETS ACROSS 11 U.S. STATES

The Challenge: The utility has an aggressive target of GHG reduction by 2030 and Net-Zero by 2045. However, the financial viability of such targets might still present challenges, despite the IRA's tax benefits for carbon capture and storage projects.

The Solution: Consulting Services developed a baseline and an emissions reduction accounting calculation model. MAPS was used to produce an accurate dispatch profile of the abated CCGT over the entire project lifetime of 25 years. The results then were fed into a project specific financial pro forma developed with support of GE Vernova's Financial services to assess the financial gap at the expiration of tax credits. Consulting Services leveraged GE Vernova's technology expertise to validate the economics of carbon capture at the CCGT plant under existing incentive mechanisms. In addition, Consulting Services relied on its own internal markets expertise to validate and design a revenue stream through carbon monetization instruments.

The Result: Consulting Services identified a potential to leverage carbon market mechanisms to mitigate the financial gap for the economic viability of project, along with an alternative emission reduction monetization pathway.

OUR EXPERTISE

Carbon Management

- Carbon Markets
- Carbon Project Development - Voluntary Carbon Market
- Carbon Project Development - Independent Crediting
- Carbon Credits Monetization
- GHG Inventory Management
- Climate Reporting Strategy
- Scope 1, 2, 3 Carbon Accounting Framework
- Digital Monitoring & Reporting
- Life Cycle Analysis
- Energy Transition Planning
- Power Sector Net-Zero Planning
- Heavy Industry Sector Net-Zero Planning

EDUCATION

Giving you the training and tools around power systems fundamentals, policy, to manage your software, your carbon usage, and more.

What we do:

The longest running energy executive development program, Power Systems Energy Course (PSEC) develops the world's energy leaders with proven, real-world expertise in a wide range of technologies – from power systems planning and energy economics to power markets and emerging generation solutions.

Courses include:

- Policy leadership
- Power Systems Fundamentals and Integration
- Software solutions for planning and operation simulation of power systems
- Custom On-site or online training

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

65
YEAR HISTORY

1,800
GRADUATES

177
COMPANIES

55
COUNTRIES REPRESENTED

WHAT SETS US APART

Serving Customers Globally with Deep Power System Expertise

We are not your typical “consulting” company. We live the Power System every day and have for over 100 years. We are about innovation, efficiency, and helping keep the lights on while enabling electrification and decarbonization. Engage us, we can help!

To succeed in the energy transition, your decisions must be based on a range of economic, policy, and regulatory drivers, not just technical considerations. That’s why Consulting Services’ cross-functional teams address your specific challenges in a holistic way, with power studies that explore the economic and physical aspects of your proposed projects at both the project and system level. With Consulting Services, you benefit from:

- Fact-based analysis and in-house expertise and testing
- More than 50 investment-grade global models with regional and technology expertise
- Access to GE Vernova technologies and grid archives
- An installed base that spans the globe
- Experts in every region

... All enabled by our suite of software tools and backed by our educational and training offerings

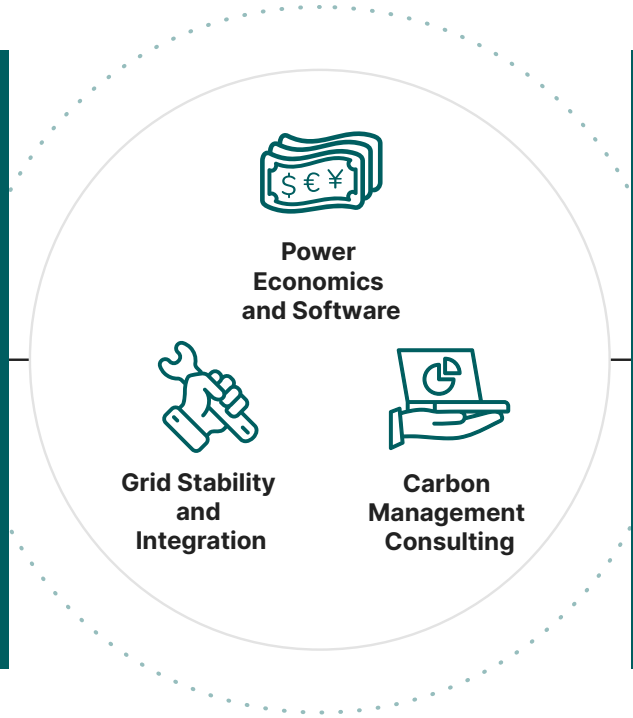
PROJECT LEVEL STUDIES

Is it worth building?

Can it safely interconnect?

Does the investment justify upgrades?

What is the right technology?



SYSTEM LEVEL STUDIES

Can the system operate with new projects?

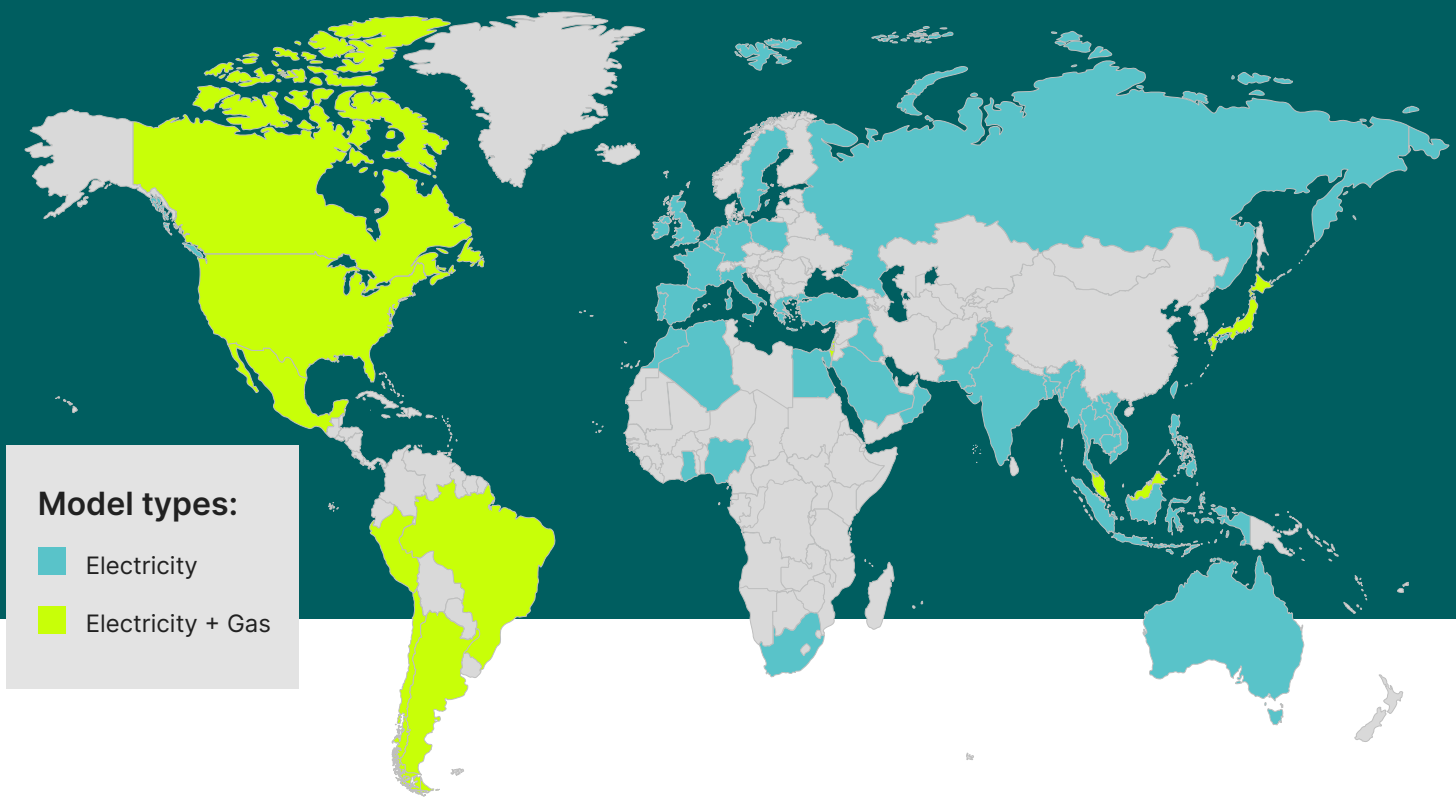
Can frequency and voltage stay stable?

What technology is needed?

What market rules to consider?

Detailed Power System Modelling - Data Coverage

50+ countries, 5 continents



ECONOMICS + PHYSICS

Transmission constrained + least cost dispatch to serve load

HIGH RESOLUTION

Every generator, every OEM, every hour, every year… nodal/zonal

ELECTRICITY + GAS

Global supply-demand balance informs natural gas price forecast

FORWARD-LOOKING

20-year forecast … transmission, generation + historical validation

North America: Canada, US, Mexico • **Europe:** UK, Ireland, Spain, Portugal, France, Italy, Luxemburg, Belgium, Netherlands, Germany, Poland, Sweden, Greece, Turkey • **South America:** Chile, Argentina, Peru, Brazil • **Africa:** Morocco, Algeria, Tunisia, Egypt, Nigeria, Ghana • **Middle East:** Saudi Arabia, Bahrain, Qatar, UAE, Kuwait, Iraq, Israel • **Asia:** India, Bangladesh, Pakistan, Myanmar, Thailand, Vietnam, Laos, Cambodia, Philippines, Malaysia, Singapore, Taiwan, Japan, Indonesia, Brunei, S. Korea

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