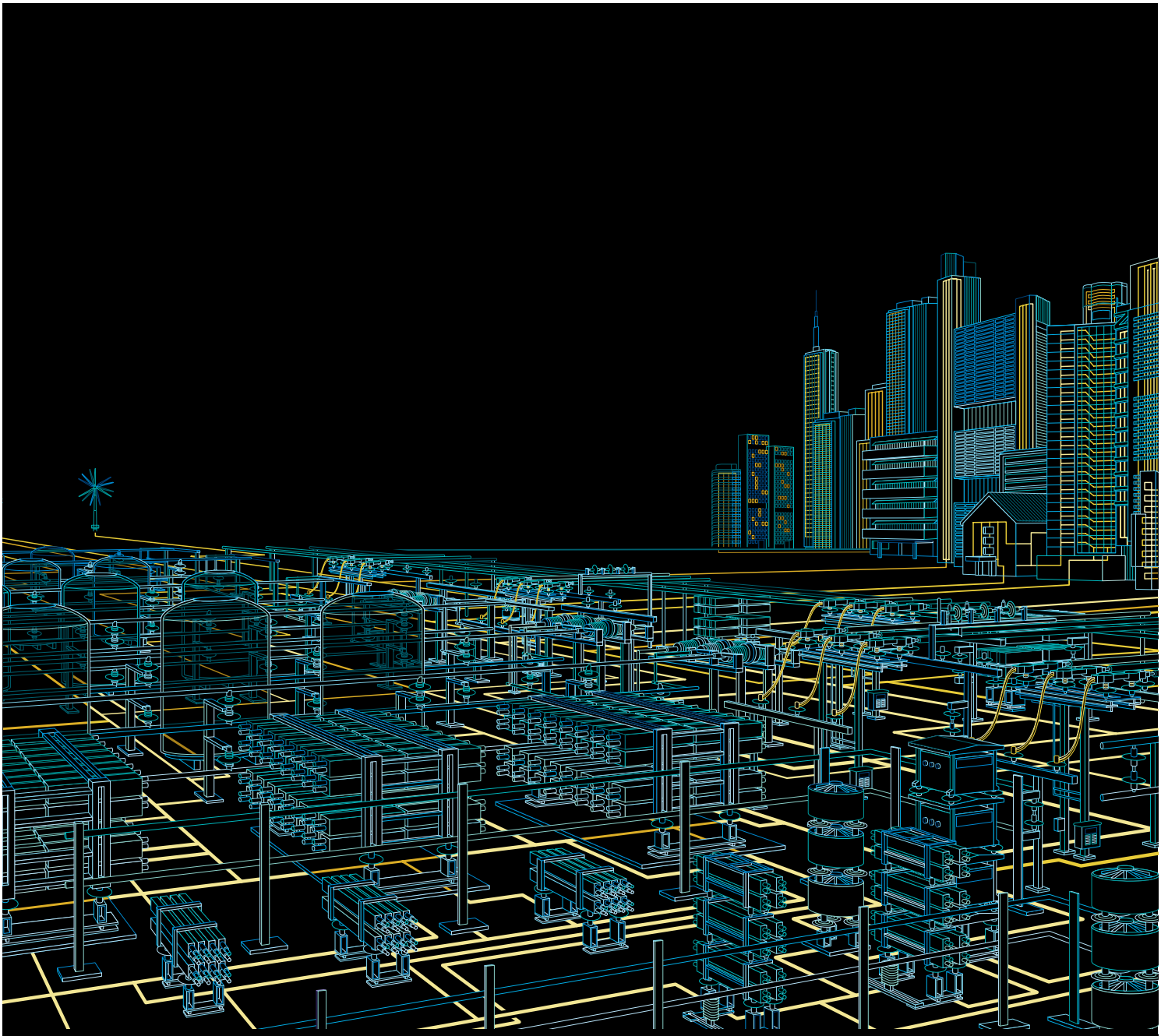


Power Consulting
Solving tomorrow’s challenges today

Power and productivity
for a better world™

From generation to consumption
Power Consulting understands your electric power challenges

Safe, reliable, clean, and cost-effective electricity is top of mind for everyone, from executives to engineers. Whether you lead a company consuming electric power, are responsible for generating, transmitting or distributing it, or head up a government entity that bears the responsibility of regulating it, mitigating the risk of power failures and optimizing safe power operations is paramount to your bottom-line success.

Power Consulting understands the challenges of today's grid, from every point of view. Our consultants aren't just engineers and analysts. We gather the best talent from all across the industry—people with years of experience putting power solutions into action, who can help you avoid project pitfalls from conception to implementation.

Power Consulting also has extensive digital simulation expertise, develops specialized software and uses a variety of commercially available power system software modeling packages. In addition, we utilize proprietary ABB developed software for specialized analysis of power systems and associated economic and financial analyses.

1. Generation
2. Transmission
3. Distribution
4. Industry
5. Microgrids
6. Infrastructure
7. Asset Management

From generation to consumption
Mitigate risks. Maximize performance. Optimize operations.

Unique challenges call for unique solutions, and the first part of problem solving is knowing what you're up against. System studies allow you to analyze and better understand the challenges, paving the way for effective and efficient solutions.

Power Consulting operates as an independent organization that is product and system-agnostic with deeply embedded knowledge of technologies, standards, and local grid codes worldwide. We can help identify the challenges and recommend solutions for your specific needs.

Here are a few of the areas in which we specialize:

- Feasibility and system impact studies
- Economic analysis and project justification
- Business model impact analyses
- Analysis of upgrade vs. replacement strategies
- Transmission capability and utilization analysis
- HVDC and FACTS applications
- AC/DC interactions
- Economic and stability impact of increased penetration of variable renewable energy, centralized and distributed
- Industrial systems reliability analysis and improvements
- Asset life cycle management
- Distribution systems planning
- Grid modernization planning and investment
- Power quality studies
- Rail and transportation studies
- Cyber security
- Electric railway transaction assessments
- Maintenance operations assessments
- Earthing studies
- Technical training
- Smart cities planning

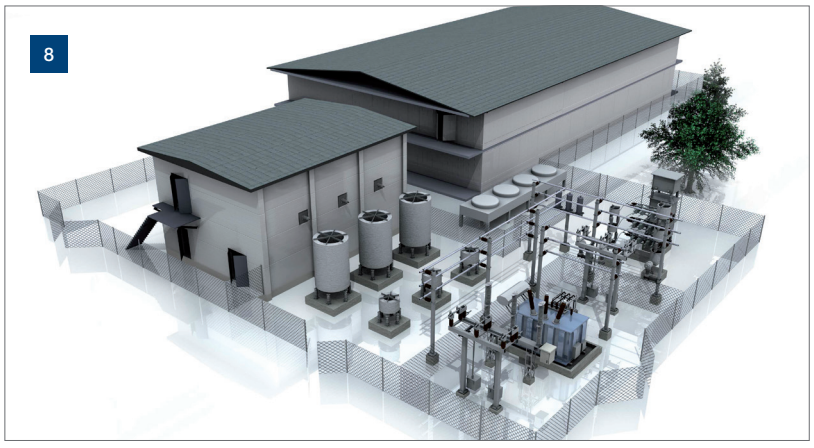
Meeting the challenges of the modern grid

Many of the technologies on the grid were deployed more than a half-century ago, at a time when concepts like renewable energy or the widespread use of air conditioning were only vague dreams. The demands of today's power systems require judicious use of new technologies integrated with old.

Who could imagine the physical and cyber security challenges organizations would face in our modern world? Or the opportunity to improve operational efficiency through increased grid intelligence? Or the types of business models that open up when technologies like distributed energy resources blur the line between producer and consumer?

In the following pages, we'll explore eight areas where Power Consulting is helping organizations address these unique challenges to capitalize on great opportunities.

1. Grid modernization
2. Regulations and policies
3. Physical and cyber security
4. Climate change



“Modernizing the U.S. electrical grid is essential to reducing carbon emissions, creating safeguards against attacks on our infrastructure, and keeping the lights on.”

Ernest Moniz,
U.S. Secretary of Energy[1]

5. Evolving business models
6. Emerging economies
7. Asset manangement
8. Disruptive technologies

Grid modernization
Integrating the old with the new

Aging assets. Increased penetration of renewables. Shifting power usage demands. Distributed energy resources. New regulations. The increasing stresses on the grid seem almost endless. While the goals of the grid, such as operational efficiency and grid resiliency, haven't changed, meeting performance targets is becoming more challenging.

Reliability

Even a momentary interruption of power can endanger lives and impact local economies. Yet, as demand goes up in developing regions and the nature of loads becomes more challenging, avoiding blackouts and brownouts, even in countries with advanced grid technologies, becomes more difficult.

Efficiency

Improving grid efficiency by just 5% would eliminate the fuel and greenhouse gas emissions from 53 million cars[2]. In addition, the best sites for new renewable generation are often far from the load centers for which they are intended. New, high-efficiency lines are needed to reach these population centers.

Stability

Renewable sources of energy, such as wind and solar, can create potentially destabilizing power fluctuations on the grid. Even so, as more traditional sources reach end of life, renewables are vital to meeting the world's future energy needs. Even the nature of stability concerns are shifting, from the traditional concerns of stability between power plants, to the stability of loads, the stability of generation lacking inertia, and the stability concerns arising from various power electronic devices controlling nearby voltages.

Resiliency

Whether man-made or natural, disasters happen around the globe—and with seemingly increasing frequency. Many regional grids need to be modernized to minimize outages and ensure uninterrupted access to high-quality electrical power.

Laying a strong foundation

The best way to prepare for an exciting, but unpredictable future is by laying a strong foundation. Power Consulting offers studies to analyze challenges and prioritize investments:

- Capital project planning
- Grid modernization planning and investment analyses
- Enterprise budget optimization analyses
- Generation and transmission systems adequacy assessments and planning
- System stability studies
- Root-cause analyses and disturbance simulations
- Energy market simulation, planning, and analyses
- Economic studies
- Feasibility studies

The Smart Grid can reduce emissions by 60 to 211 million metric tons of CO_2 a year by 2030.[3]

Power Consulting helps oil refinery reduce unplanned downtime

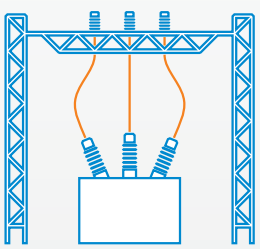
Unplanned downtime is a major issue for many types of businesses, especially manufacturers. When the reliability of their power supply started affecting productivity, Petroplus Coryton Refinery in the UK called on Power Consulting to help.

Power Consulting conducted a number of systems studies to identify the root causes of the power supply issues:

- Load-flow and short-circuit calculations
- Protection co-ordination
- Isolation co-ordination
- Transient stability study
- System reliability analysis
- Asset assessment

Power Consulting identified a number of potential issues. Operational changes and changes to the configuration of the network were proposed as well as the updating of key protection devices. These recommendations would significantly decrease production time lost due to unplanned outages.

By 2030, **6.8 trillion** (USD)



will need to be spent on grid transmission and distribution to keep up with demand.[4]

Where will you invest?

Regulations and policies
All eyes are on the grid

As the number and complexity of industry regulations and policies goes up—both locally and regionally—the costs and risk of non-compliance rises as well.

Around the globe, generation, transmission, distribution, and use of energy are under intense scrutiny. As some have learned the hard way, the downside of compliance failure can be expensive and disruptive. Executives must mitigate both monetary risks, (e.g., fines and lawsuits), and even personal repercussions (e.g., career disruption and personal liability) in a constantly changing regulatory environment.

Maintaining compliance while managing operational costs is a tough challenge for any organization. Because our consultants live and work in the geographies they serve, they understand the local challenges. Here are some of the services we offer:

- Violation resolution and mitigation
- Asset management
- Compliance assessments and remediation
- Impact assessment
- Compliance project planning

In 2005, 3% of the world was covered by mandatory power efficiency regulations. Today, it is more than one third and growing.[5]

Power Consulting helps Brazil optimize investments in wind farm energy while ensuring grid code compliance

As of 2014, Brazil ranked 4th in the amount of newly installed wind capacity.[6] However, Brazil's wind market is a young market with unique challenges that make it difficult to comply with Brazil's grid code requirements for stability and reliability and increase the risks associated with new wind farms.

Power Consulting ran a number of system studies for the customer, Galvão Dreen, to help the organization understand potential grid code compliance challenges. These studies included feasibility studies, system layout and dimensioning of equipment, grid integration and system stability studies, compensation definition, and power quality evaluation. Power Consulting also recommended a solution for reactive power optimization and defined the need for the harmonic filters.

Power Consulting was able to show how system performance could be optimized while complying with grid codes. ABB also helped Galvão Dreen improve ROI for the project by showing them how they could avoid unnecessary investments along with lowering lifetime maintenance costs.

86% of global power executives

are concerned or very concerned about the unpredictability of power regulations and policies.[7]

Are you in compliance?

Physical and cyber security
Now is the time to prepare

Around the globe, there are millions of intelligent electronic devices on the grid, and the number is growing exponentially as new devices are introduced to the market. While these devices are a vital component of future energy distribution models, such as transactive energy, each of them represents a potential security loophole.

However, it's not just cyber security that keeps grid operators up at night. Threat actors are starting to attack substations and other potential weak spots on the grid. Whether malicious or just a prank, their actions could cause cascading failures.

There may not be much that can be done to stop those with malevolent intent, but Power Consulting can help you be better prepared. Our studies help organizations find ways to limit the damage and restore power as quickly as possible.

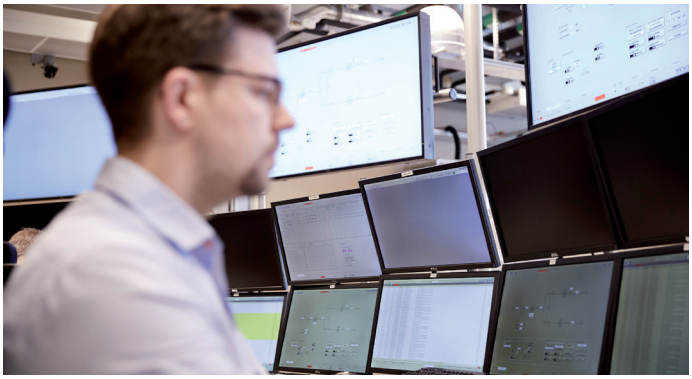
- System restoration studies
- Contingency simulations
- Analysis of interconnections and alternate power sources
- Communications infrastructure analysis

Globally, the cost of cyber crime in the energy sector is second only to the financial services sector.[8]

Power Consulting helps transmission operator comply with cyber security compliance and minimize risks

In 2014, the North American Electric Reliability Corporation (NERC), the regulatory body in the US responsible for overseeing the reliability of the nation's supply of electric power, filed a petition for the approval of reliability standard NERC CIP-014. This standard was approved in 2014, creating a host of new physical and cyber security mandates with which grid operators needed to comply.

Power Consulting helped a major North America transmission system operator with 500 substations implement a NERC CIP management system to manage its cyber asset life cycle workflow operation processes. Since the project's inception, additional services were completed to update the program to address new NERC compliance requirements. With the success of this system, this large transmission system operator can fully meet the latest NERC CIP compliance requirement and minimize cyber security risks.



More than 40%
of cyber attacks

investigated by the U.S. Dept. of Homeland Security

in 2013 were in the **energy sector.**[9]

Are your systems secure?

Climate change
A clean energy future requires strategic thinking—today

Around the globe, governments are mandating the increased use of renewables to combat CO_2 emissions. Germany is one country leading the way. In 2015, renewables contributed to a 20% reduction in German energy-sector emissions over 1990 levels.[10]

While good for the environment, increasing renewable penetration creates a number of challenges for utilities and industry including:

- Determining the best sites for renewable generation
- Evaluating the economic impact of site construction and power transmission
- Predicting output from sources like solar and wind
- Controlling power fluctuations and protecting grid stability
- Managing the decommissioning of traditional generation sources

To help utilities and grid operators meet renewable mandates while maintaining grid reliability. Power Consulting offers the following studies:

- Renewable site selection
- Assessment of potential impact on system reliability
- Generation replacement studies
- Analyses of potential reductions in NOX, CO_2, and other emissions
- Retirement planning for traditional generation sources
- Renewable integration studies
- Load studies
- Powerflow studies
- Voltage stability studies
- Dynamic stability studies
- Transfer limit studies
- Economic cost/benefit analyses
- Economic market simulation forecasting analyses

In 2015, renewables contributed to a 20% reduction in German energy-sector emissions over 1990 levels.[11]

Power Consulting helps EU reach "Twenties" targets

The European Union has set aggressive targets for increasing wind power penetration in existing networks: 20% reduction of CO_2 emissions, 20% improvement of energy efficiency, and 20% energy consumption from renewable sources. Between 2010 and 2013, Power Consulting was engaged by the 7th Framework Programme of the European Commission to help meet these goals.

Power Consulting was dedicated to the specific task of assessing a region of the Spanish transmission grid and designing a new solution to improve the efficiency of power flow control, optimize network capacity and allow increasing wind integration. The project was performed in collaboration with the Spanish TSO and the ABB FACTS team.

One aspect of Power Consulting's recommendations was to install a new FACTS design, the Overload Line Controller, in one of the main 220 kV transmission corridors in Spain. Under certain conditions, the selected region can experience limitations in its transmission capacity due to overload of the corridor. To avoid the bottleneck, the TSO had previously been forced to curtail neighboring wind producers, but by integrating the OLC, this is often no longer necessary.

The Paris Climate Agreement is expected to go into force as early as 2020.[12]

Are you ready?

Evolving business models
New markets. New opportunities. New challenges.

A number of technologies have the potential to change the way power is sold and consumed around the world. Distributed energy resources, such as rooftop solar, small wind farms, and microgrids, allow consumers to generate their own power as well as sell it back to the utility. This has given rise to concepts like transactive energy, which IEEE Xplore magazine editor, Mel Olken, describes as "an enabling environment for any number of users to partner with traditional providers to produce, buy, and sell electricity using automated control."[13]

For example, energy storage helps during peak consumption periods. Advancements in energy storage are causing regulators to take a fresh look at how they can allow utilities to charge for the service they provide. For example, the U.S.'s Federal Energy Regulatory Commission issued FERC 755, a ruling that implements a "pay for performance" plan where suppliers can charge more for power supplied by fast-responding sources like battery energy storage.

Technology challenges are one thing. Business model challenges can be even harder to solve. You need business-savvy consultants who understand the technologies that contribute to viable economic roadmaps.

Power Consulting offers a number of systems studies to help you weigh options and anticipate potential hurdles:

- Distributed generation modeling
- Reliability analyses
- Substation and sub-network modeling
- Secondary grid network analyses
- Economic and technical feasibility assessments
- Power systems simulations
- Valuation models
- Market simulation forecasting

In a recent survey, 94% of respondents said they anticipate a complete transformation or at least important changes to the power utility business model.[14]

Power Consulting lays the foundation for the utility of the future

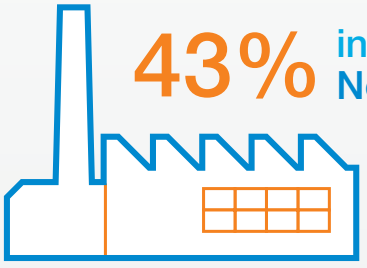
Emerging business models, new regulatory frameworks, and advancements in power technologies (both performance and cost reductions) fundamentally affect how power grids are designed and operated. The utility of the future must address these technical challenges, such as the variability of wind and solar, and manage evolving customer expectations.

To study the challenge and prepare the way, Power Consulting modeled and simulated several regional grids at different time horizons (from transient and short circuit analysis in the millisecond range up to hourly unit commitment type of studies as well as a long term 10-20 years ahead investment planning) and different levels of variable renewables proliferation. In addition, during the scheduling studies, a sensitivity analysis across different economic parameters (technology cost, tariffs, interest rates) was also performed.

The results from these studies equip Power Consulting to help organizations in the power industry adapt quickly and efficiently to new business models.

35% of power industry executives **in Europe**

43% **in North America**



say current **business models are broken.**[15]

How will you adapt?

Emerging economies
Fulfilling the needs of an energy-hungry world

For growing populations, a safe, reliable power source is key to a prosperous future. However, because of location or other geopolitical factors, remote communities often don't have easy or stable access to a central grid. In addition, rapidly growing urban centers often have outdated grids that cannot handle the higher level of demand and increasingly complex loads.

More than 1.3 billion people have no access to electricity at all or only have access to limited or unreliable sources.[16]

Power Consulting has participated in resolving challenges for countries that are quickly surpassing the capabilities of their current grid as well as remote island communities, and industrial sites such as mining and defense operations. We offer power systems studies and solutions that can be instrumental in developing effective holistic business solutions.

- Microgrid feasibility studies
- Grid simulation modeling
- Load flow and system protection analyses
- Optimal equipment selection and placement
- HVDC & FACTS planning
- Network planning and operation guidelines development

Power Consulting helps Saudi Arabia keep up with demand and get ready for the future

Saudi Arabia has seen demand for electricity grow by about 8% annually for the last two decades.[17] The country also has some of the most challenging load characteristics in the world, with air conditioners estimated to comprise up to 80% of the load during summer months and large differences between peak and light load levels. In addition, generation is connected to load centers over long distances with few intermediate stations.

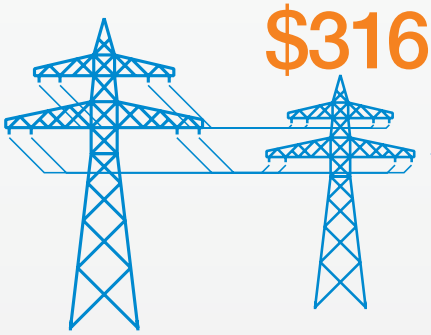
In the early 2000's, Power Consulting was engaged to examine the behavior of the western part of the system, which was experiencing frequent blackouts. Systems studies demonstrated how the blackouts could be traced to the nature of their loads served by long distances. Recommendations included deployment of multiple Static VAR Compensators (SVCs)—some of the largest in the world. Implementation led to significant improvements in network performance. Further studies extended the deployment of FACTS devices to the remaining regions in the Saudi system with similar positive results.

Since the early phases of the project, Power Consulting has been working on an almost continuous basis with the Saudi Electric Company's planning and operations engineers, helping planners visualize their network of the future while assisting operators in the challenge of quickly adapting to the numerous network reinforcements coming into service.

The Gulf Cooperation Council (GCC) countries will require as much as

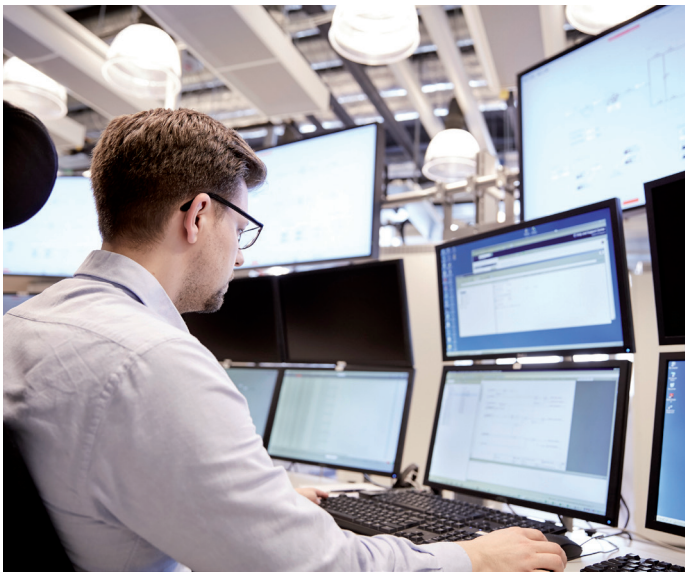
$316 billion

by 2020 to meet their growing power needs.[18]



How will you prepare?

Asset management
Turn information into actionable insights



To make the right investments, grid operators, utilities, and industry leaders need visibility into the health and operational performance of current assets. Monitoring can keep everything operating at peak efficiency as well as alert operators to problems that could lead to unplanned outages.

Comprehensive asset management can also help organizations decide what to do with assets reaching end of life. Sometimes, modernizing the grid requires replacing an aging or failing asset with more modern equipment, but often, asset life can be extended and capital budgets conserved with repair or refurbishment services.

Power Consulting offers a number of software applications to help grid operators and industry ensure their assets are operating at peak efficiency. In addition, Power Consulting studies can identify improvement opportunities and help map an implementation plan that addresses key objectives.

Here are just a few examples of the types of grid studies Power Consulting offers:

- Centralization and integration of asset data
- Monitoring and control of system health
- System planning and risk analyses
- Condition management and maintenance prioritization
- Advice on investment decisions

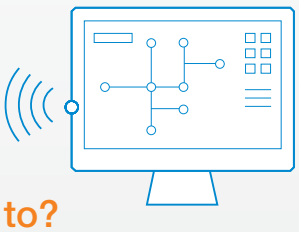
Power Consulting condition monitoring services helps Indian chemical company keep the power flowing

A chemical company has to maintain a lot of essential equipment, including the equipment that ensures a reliable source of power to the plant. Indo Rama Synthetics in Butibori, Nagpur, India relies on Power Consulting to monitor the condition of its 220KV switchyard equipment.

Power Consulting ran a number of diagnostic tests that identified a couple of key issues: an increasing trend of % Tan Delta observed in a 245 kV CT and a higher resistive leakage current in a 198 kV LA. To avoid serious unplanned outages, both pieces of equipment were recommended for replacement.

Not only does condition-based maintenance reduce unplanned downtime, but it also helps the organization focus its maintenance budget and preserve capital budgets for higher priority investments.

38% of manufacturers delayed investments in capital equipment with Asset Management.[19]



Are you spending more than you need to?

Disruptive technologies
No matter what the future holds

It's an exciting time for the power industry. With advancements in technologies like energy storage, renewables, HVDC, and intelligent devices, the dream of providing safe, clean, reliable power is within reach. Power Consulting can help customers resolve the challenges and be ready for new opportunities.

Renewables

When Falcon Ma'an Solar Power needed to ensure grid code compliance for a proposed 23 MW solar power plant in Jordan, they contacted Power Consulting. The team simulated the potential impact under steady-state and dynamic conditions and recommended a 10MVAR STATCOM to meet the grid code's dynamic stability criteria.

Energy storage

To improve reliability of service to its members, The Golden Valley Electric Association of Fairbanks, Alaska, needed an energy storage solution that would produce up to 27 MW for 15 minutes. Power Consulting developed a specialized model of battery energy storage system controls and performed dynamic analyses to confirm the solution could support their power system during a contingency event. Our studies confirmed that the BESS would be effective in improving the reliability of the GVEA system and help it ride through critical outages. It was determined after successful commissioning that the number of power supply type outages decreased by more than 60%.

Supergrid

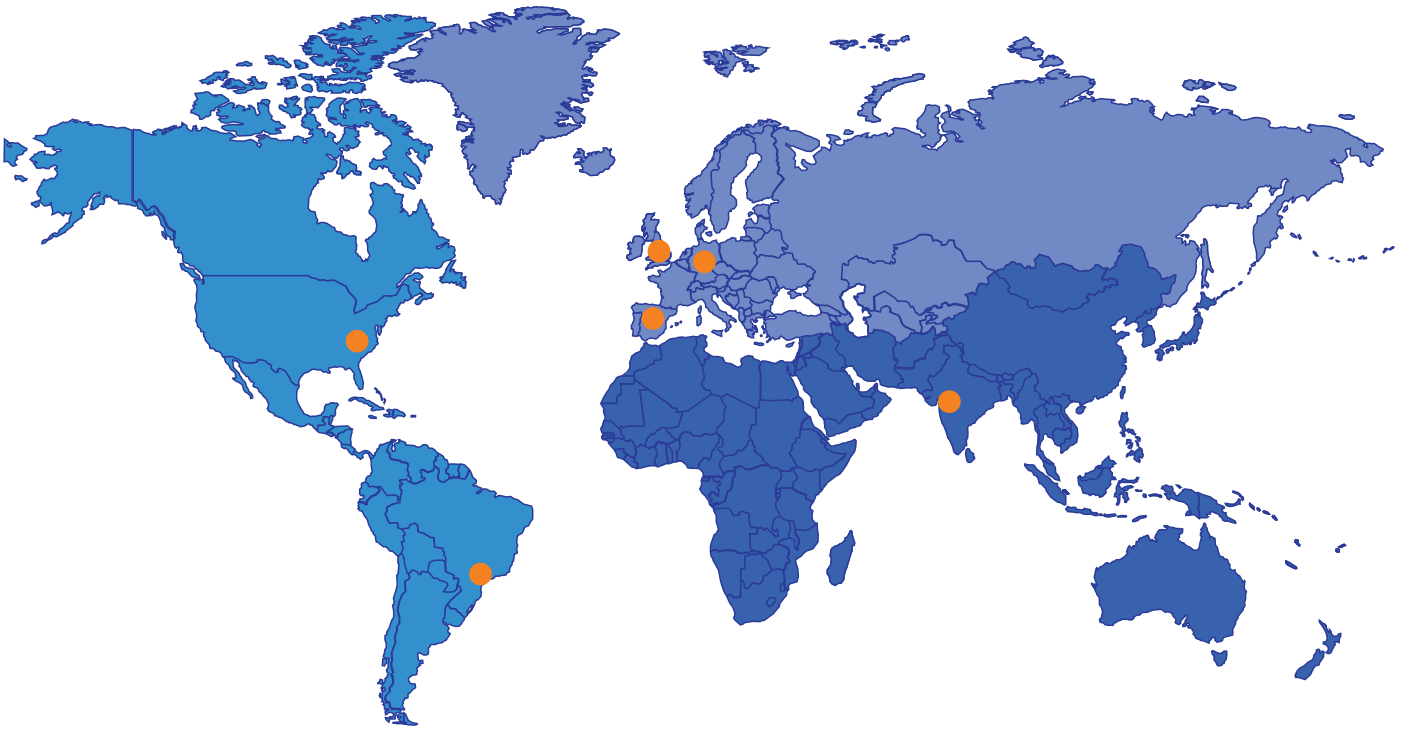
Seeing an opportunity to export power to the UK market, Ireland decided to expand its wind power generation. Power Consulting conducted a number of studies to assess the feasibility and impact of integrating a dual-flow, long-distance HVDC transmission system into the AC network. With the system now in place, Ireland can sell and buy power not only from the UK National Grid, but also from the European mainland.

Big data

Power Consulting is leveraging analytics technology to mine data from past storms to analyze how the grid might be impacted, estimate restoration times, and predict the type of equipment inventory and crew resources that will be needed to handle grid restoration. Combined with other services like contingency simulations and an analysis of network connections and alternate sources, Power Consulting can help decrease restoration times even further.

Electric vehicles

When Chancellor Angela Merkel set the ambitious goal of having one million electrical cars on Germany's roads by 2020, Power Consulting was called in to study the effect of charging stations on the low voltage grid. Among other conclusions, Power Consulting recommended ways to make the grid more economical as well as reduce the frequency and duration of interruptions.



Power Consulting: your local expert worldwide
Your success is our business

For nearly a century, Power Consulting has staked its business on the principle that we must measure success by what matters to customers. Our consultants combine global industry expertise with a commitment to helping clients achieve electrification objectives safely and efficiently. We help address issues of network strategy, planning, operations, capacity, efficiency, stability, security, reliability, and resiliency.

Power Consulting has deployed solutions across six continents, so we have a unique, first-hand perspective on the complex political and regulatory environments our customers face. We have helped every type of business— from large, multinational utilities to small and medium sized municipals and cooperatives to businesses like manufacturers and hospitals—solve their toughest power challenges.

> The convergence of innovations such as distributed energy resources, demand-side management and information technology has introduced a pace of change unimaginable in this historically slow-moving industry.
> GreenTech Media[20]

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