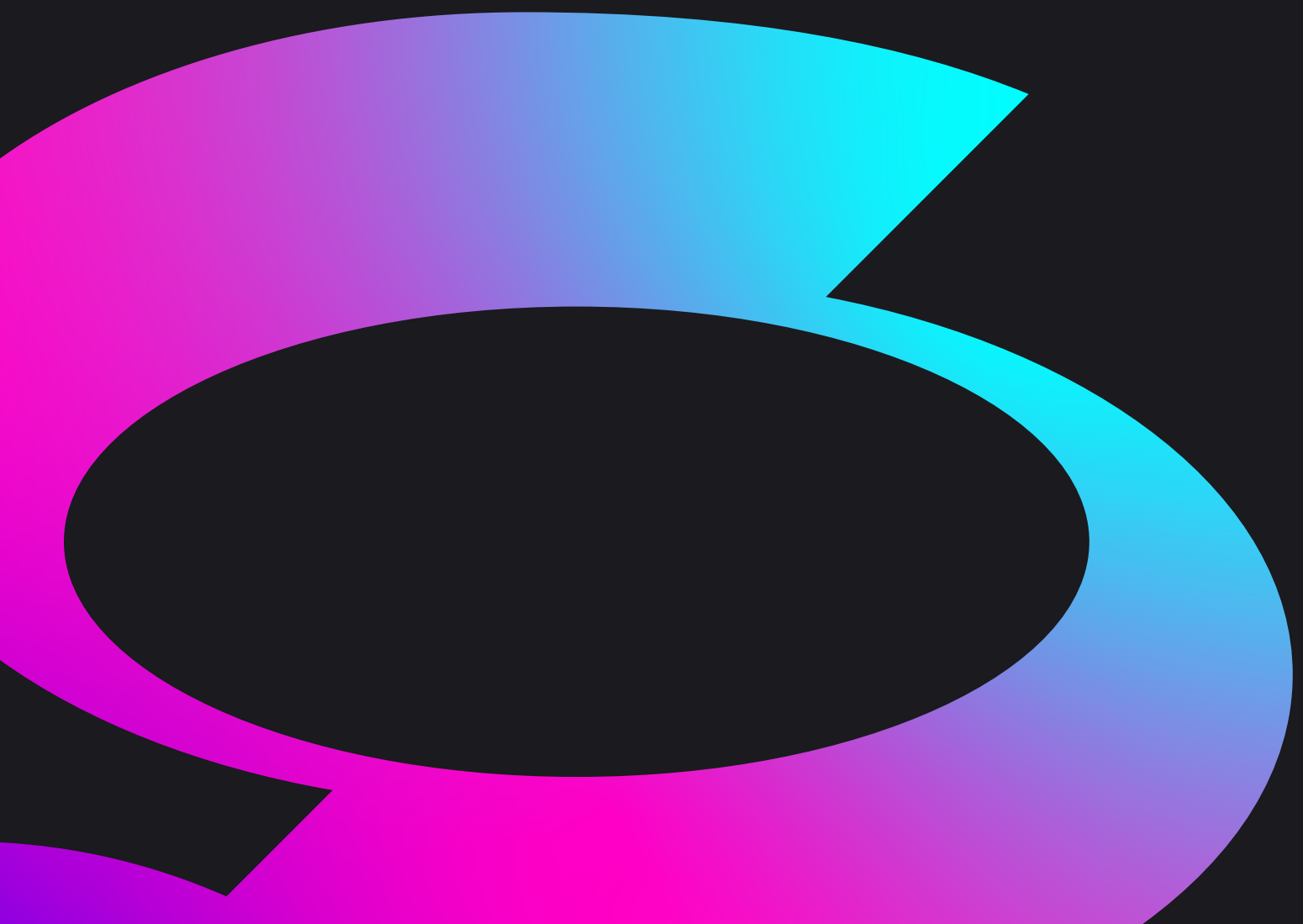




WHITE PAPER

Power under pressure

Regional challenges highlight the way the Middle East and Africa can build grids that work for the next 25 years.





The trajectory of electricity demand across the Middle East and Africa is not a gradual rise, as it is in other regions of the world, but a breakneck acceleration under the combined weight of population growth, rapid urbanization, industrial expansion and a climate that makes cooling loads heavier every year. Electricity consumption in MENA has tripled since 2000 and is projected to rise another 50 percent by 2035, adding the equivalent of Germany and Spain's combined current demand.[1]

Between now and then, governments and utilities must simultaneously expand generation capacity, replace aging infrastructure, integrate unprecedented volumes of renewable energy, manage tighter cybersecurity requirements and do all of it while keeping the lights on for a population that cannot afford outages.

Across the 14 countries examined in this paper, a common set of pressures is emerging with different degrees of urgency. Grid infrastructure built for a stable, centralized power model is now being asked to handle two-way energy flows, fluctuating renewable output, rising peak demand and increasing exposure to cyberattack. In many markets, the financial and institutional frameworks that would normally fund upgrades are strained by debt, subsidy obligations or governance complexity.

The five pressures shaping this landscape are: the physical fragility of aging grid assets; the financial and operational challenge of integrating variable renewable energy at scale; a persistent gap between stated capital investment plans and actual delivery; the growing attack surface that digitalization creates; and the structural tension between fast-rising demand and the slow pace of infrastructure build-out.

Legacy technology, built in siloes and designed for a simpler grid, cannot adequately address any of these pressures on its own. What is needed is a connected approach spanning the full lifecycle of utility assets, from design and construction through operations, maintenance and security.

Software platforms that combine 3D design intelligence, asset performance management, digital twin simulation and OT cybersecurity offer a coherent path forward. The experience of a Gulf-based utility already applying these tools at scale illustrates what is achievable when the technology is deployed with clear objectives and organizational commitment.

The grid of the future in this region will not be built by any single intervention. But it will be shaped by the decision, taken now, to connect fragmented systems into something that can learn, adapt and protect itself.



Five pressures reshaping the regional grid

1. Aging infrastructure and the hidden cost of deferred maintenance

\$44bn

Mena power investment in 2024

Power sector investment in the MENA region reached USD 44 billion in 2024 and is projected to grow by a further 50% by 2035, with nearly 40% earmarked for grids.[20]

Much of the transmission and distribution infrastructure operating across the region was designed for a different era.

In Kuwait, rolling power cuts were introduced in the summer of 2024 for the first time since 2006, after the national grid recorded its highest-ever electrical load during a period when temperatures exceeded 50 degrees Celsius.[5] In Iraq, a near-total national blackout struck in August 2025 when two major transmission lines failed simultaneously under peak heat demand.[7] In both cases, the failure was not caused by an absence of installed capacity. It was caused by infrastructure that could not perform reliably under conditions that are now routine.

Deferred maintenance compounds over time. When utilities lack the systems to track asset condition accurately, maintenance schedules become reactive rather than planned. Work is done when something breaks, not before. The financial consequence of this pattern is severe: in Nigeria, economic losses from grid unreliability are estimated at \$26 billion annually, with businesses spending a further \$22 billion per year on diesel backup generation.[8]

2. The integration challenge of variable renewable energy

130 GW

Saudi Arabia's renewable target by 2030

Saudi Arabia has set itself the target of adding 20 GW of renewable energy capacity annually, reaching 130 GW by 2030 — against an installed base of just 2% renewable in 2024.[21]

Most countries in the region have set ambitious renewable energy targets, but the practical difficulty of meeting them is often underappreciated.

Adding solar panels and wind turbines to a grid is not the same as running a grid powered by them. Variable renewable energy (VRE) introduces supply fluctuations that traditional grids, built around dispatchable thermal generation, are not designed to absorb.

The IEA has classified Kenya, for example, as being in Phase 3 of VRE integration: the stage at which renewable energy begins to materially influence system operations and where grid stability, flexibility and ancillary services become critical constraints.[10] Kenya reached this stage because roughly 90 percent of its electricity already comes from renewables.

Saudi Arabia presents the opposite problem. Renewables account for just 2 percent of the country's power mix as of 2024, against a stated target of 50 percent by 2030.[11] Fossil gas generation grew from 224 TWh in 2019 to 288 TWh in 2024. The grid is configured for large, stable thermal plants. Transitioning to a high-VRE system requires not just new generation assets but an entirely different set of grid management capabilities: frequency regulation, voltage control, storage dispatch and demand response, none of which are yet mature in the current operational environment.

Cooling and desalination together are projected to account for close to 40 percent of the growth in electricity demand in the MENA region between now and 2035.[2] These are largely inflexible loads: they run when heat demands them, not when the grid is convenient. Managing the combination of inflexible demand peaks and variable renewable supply is the central technical challenge of the next decade.

3. The capital execution gap

The scale of infrastructure investment required is not in dispute. Meeting projected 2035 demand requires expanding MENA's power capacity by over 300 GW, the equivalent of three times Saudi Arabia's current total generation capacity.[3] The challenge is not the identification of projects or, in many cases, the availability of financing. It is the ability to deliver projects on time, within budget and to the required performance standard.

McKinsey's analysis of more than 530 global capital projects — of which 62 percent were megaprojects valued at \$1 billion or more — found that average cost overruns exceeded 79 percent of initial budget estimates, with schedule delays averaging 52 percent of planned timelines.[12] Power sector projects are among the most affected, for structural reasons: incomplete scope definition in early engineering phases, supply chain fragmentation, insufficient visibility into contractor performance and a lack of real-time data connecting project planning to execution.

In Pakistan, this dynamic has produced a system with over 45,000 MW of installed generation capacity that nonetheless cannot reliably serve national demand. Circular debt in the power sector reached Rs. 5 trillion before recent reform efforts began to reduce it. Distribution companies with collection rates as low as 60 percent in some regions cannot fund the maintenance their networks require.[13]

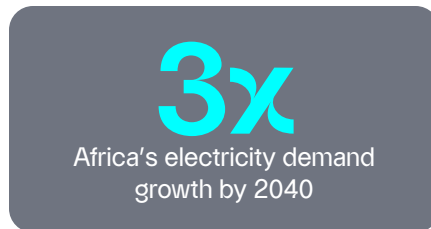
4. Cybersecurity in an era of converged OT and IT

Power infrastructure has always been a strategic target. What has changed today is the attack surface. As utilities digitalize their operations, integrating sensors, communication networks and cloud-connected platforms into their operational technology (OT) environments, the boundary between physical infrastructure and the digital systems that control it becomes more permeable.

This convergence of IT and OT is both the source of operational efficiency gains and the origin of new vulnerabilities. A cyberattack on a utility's control systems is not a data breach in the conventional sense. It is the potential ability to manipulate physical assets: to open or close circuit breakers, alter transformer settings, or disrupt protective relays. The consequences are measured in outages, equipment damage and in extreme cases, cascading grid failures.

As more grid assets become connected and as the number of distributed energy resources grows, the attack surface expands proportionally. Utilities that have invested in digitalization without a corresponding investment in OT-specific security have extended their exposure considerably.

5. Demand growth that outpaces infrastructure



Africa's electricity demand is expected to triple by 2040. Today, over 600 million people on the continent still lack reliable electricity — while holding 60% of the world's best solar resources.[23]

The structural demand pressures in this region are unlike those in mature markets. As of late 2025, Iraq's peak electricity production reached around 28,000 MW while national demand stood at nearly 50,000 MW, leaving a deficit of roughly 22,000 MW bridged by power cuts, expensive imports and private diesel generation.[6]

Lebanon's situation is more acute. On August 17, 2024, the country's only operational power plant shut down after the state electricity company ran out of fuel, producing a complete nationwide blackout for more than 24 hours.[16] In response, citizens installed an estimated 1,200 to 1,300 MW of decentralized rooftop solar, a roughly tenfold increase over four years.[17] This organic DER growth solves an immediate access problem but creates long-term integration challenges when a functional grid is eventually restored.

Nigeria's grid experienced 11 full collapses in 2024 alone.[9] In both Nigeria and Pakistan, demand growth is structural and it will not abate on its own. The question for utilities and governments is not whether to invest in grid capacity but how to do it faster and with more reliable outcomes than the region has historically achieved.

Where legacy technology falls short

Legacy grid management systems were engineered for a different set of assumptions. Generation was centralized and load was largely predictable. Grid topology would change slowly, with maintenance scheduled according to fixed intervals rather than actual asset condition. These assumptions held reasonably well for decades. That is no longer the case.

Fragmentation is the foundational problem



78%

Globally, 78% of power executives see a strong or severe impact on operations from poor data integration and connectivity.

The most pervasive limitation of legacy technology in utility environments is not that any individual system is inadequate: it is that the systems do not talk to each other. A utility operating today typically runs separate platforms for network design, asset management, work order management, geographic information systems, SCADA, protection relay configuration and cybersecurity monitoring. Data generated in one system rarely flows automatically into another.

This means that insights produced in one domain, such as the predicted failure of a transformer based on vibration readings, do not automatically reach the operations center scheduling field crews or the capital planning team deciding whether to replace the asset.

This fragmentation has a direct cost. Decisions made without complete information are less accurate and maintenance that could have prevented the issue becomes reactive firefighting. Capital investments that could be sequenced strategically get allocated based on incomplete asset condition data. Grid incidents that could have been anticipated become surprises.

Static models in a dynamic grid

Traditional network planning tools work with static representations of the grid. They model the network as it exists at a point in time, under a set of assumed load conditions, and they produce outputs valid for those conditions.

A grid increasingly populated by solar, wind, battery storage and distributed generation is not a static system. It changes hour by hour, sometimes minute by minute, as renewable output fluctuates, load profiles shift and prosumers move between drawing from and exporting to the grid.

Running a dynamic grid with static planning tools is like navigating a live traffic system using a paper roadmap. The map is not wrong, it is just not current enough to be useful for real-time decisions.

Asset management without asset visibility

53%

Of power executives globally say the lack of visibility on asset performance is having a negative financial impact on their organization.

Enterprise Asset Management systems in many regional utilities track assets through a combination of manual inspection records, paper-based maintenance logs and periodic condition assessments. Where sensors exist, their data often flows into isolated repositories that are not integrated with the planning and maintenance systems that would act on the information.

The result is that asset condition is known less accurately than it should be and maintenance decisions are driven as much by calendar schedules and institutional memory as by evidence of actual degradation.

In environments where the asset base is aging and maintenance budgets are under pressure, the inability to distinguish reliably between assets approaching failure and those that can safely run for several more years is a significant operational liability. It leads to both under-maintenance, which produces failures, and over-maintenance, which wastes resources on assets that do not yet need intervention.

Security posture built for an earlier era

61%

Of power executives say cybersecurity measures are having a strong detrimental effect on their business

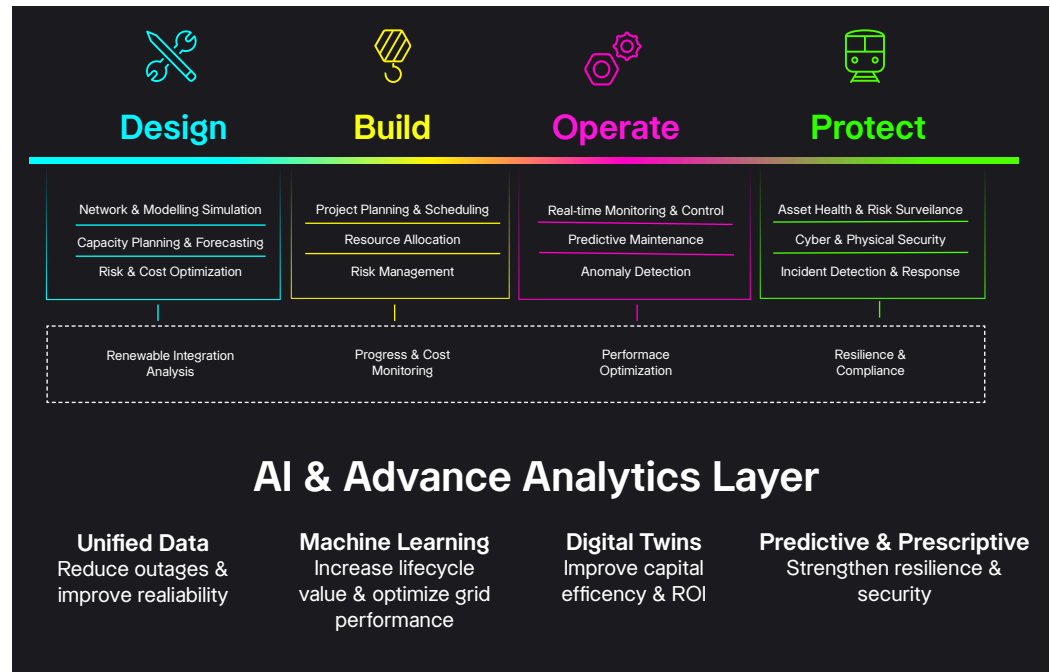
OT security in many utilities was designed when operational technology networks were air-gapped: physically isolated from corporate IT systems and external connections.

Digital transformation has eroded those boundaries. Remote monitoring, cloud-connected platforms and smart metering infrastructure all require network connectivity and that connectivity, if not properly managed, creates entry points for adversaries.

Legacy OT systems were not designed with cybersecurity as a primary concern. Many run on protocols that lack authentication mechanisms. Software updates are infrequent because patching a live operational system carries availability risk. The combination of increasing connectivity and weak inherent security produces an environment where the risk profile has changed substantially but the security infrastructure has not kept pace.

How software and AI support better grid management

The argument for technology in grid management is not abstract. There are specific, mature capabilities that address specific operational gaps and their combined effect when deployed across an integrated platform is substantially greater than the sum of the parts. What follows is a direct account of those capabilities and what they achieve in practice.



3D network design: building the right grid from the start

Grid capital projects consistently overrun on cost and schedule for reasons that begin in the engineering phase. Incomplete or inaccurate models of the physical environment lead to design errors that are expensive to correct once construction begins. Equipment sizing decisions made without full system context produce assets that either exceed what is needed or fall short of what is required. The coordination between civil, electrical and structural engineering streams is frequently managed through disconnected documents rather than a shared model.

Forte 3D and equivalent 3D design platforms replace this fragmented process with a single coordinated model of the network. Design decisions for a new substation, a transmission corridor, or a renewable interconnection are made in the context of the full surrounding infrastructure. Clash detection runs automatically. Changes propagate through the model rather than requiring manual updates across separate documents. The output is a more accurate design that moves into procurement and construction with fewer unknowns.

For a region that needs to expand capacity by over 300 GW in the next decade, reducing design rework and improving procurement accuracy is not a marginal efficiency gain. It is the difference between a capital program that delivers on schedule and one that does not.

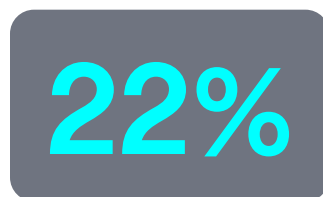
Asset performance and enterprise asset management for utilities

The central proposition of modern APM and EAM platforms is that asset condition should drive maintenance decisions, not the calendar. Sensors embedded in critical assets — transformers, rotating machinery, protection relays — measure parameters including temperature, vibration, partial discharge and load factor continuously. Machine learning models trained on historical failure data identify patterns that precede failures, often weeks or months before the failure itself becomes detectable through manual inspection.

For utilities managing large, geographically dispersed asset bases with constrained maintenance budgets, this capability is practical rather than theoretical. Maintenance resources can be concentrated on the assets that actually need attention. Mean time between failures increases. Unplanned outages decrease. The data accumulated through continuous monitoring also builds a more accurate picture of asset condition across the portfolio, which improves capital planning accuracy.

In South Africa, where the coal fleet's age has been a primary source of loadshedding, the ability to move from time-based to condition-based maintenance would directly improve plant availability. Failures that develop over weeks — detectable through vibration or temperature anomalies well before they cause forced outages — would be addressed on a scheduled basis rather than as emergencies.

Digital twins of networks and generation assets



Adoption of digital twins has historically been slower in the power industry than in other sectors. Today, 22% of power executives globally report the continuous use of a digital twin in their operations, compared to 25% in manufacturing and 30% in oil & gas and chemicals.

A digital twin is a real-time computational model of a physical system, updated continuously with operational data and capable of simulating how that system behaves under conditions that have not yet occurred. For a power network, this means modeling how the grid responds to contingencies: what happens when a transmission line trips, how the system absorbs a sudden drop in solar output, or where voltage deviations occur when a large industrial load connects unexpectedly.

Network digital twins allow grid operators to run these scenarios continuously, identifying potential instabilities before they materialize and testing the effect of proposed operational changes in a safe virtual environment before applying them to the live grid. As renewable penetration increases and grid topology becomes more complex, this capability moves from useful to essential.

Digital twins of generation assets serve a parallel function at the plant level. A combined-cycle gas plant operating with a digital twin of its turbines can identify efficiency degradation early, optimize dispatch decisions based on real-time condition data and simulate the effect of maintenance interventions before scheduling them. Early deployments of digital twins for solar panels and wind power stations in the Gulf region are already demonstrating the value of improved asset and performance monitoring.

AI across the grid lifecycle

Artificial intelligence in the context of grid management is not a single capability. It is a layer of intelligence applicable at multiple points across the asset lifecycle and operations cycle. Predictive maintenance uses machine learning to identify failure precursors in sensor data. Load forecasting models integrate weather data, historical consumption patterns and real-time demand signals to improve the accuracy of generation scheduling. Anomaly detection identifies departures from normal operational parameters that may indicate equipment stress, unauthorized access, or developing faults.

The value of AI increases with the volume and quality of data it can access. This is why the integration of systems matters as much as the AI capability itself. A predictive maintenance model that cannot access both the sensor data from the asset and the work order history from the maintenance system cannot learn as effectively as one that can. An outage prediction model that lacks weather data, historical incident records and real-time SCADA readings will produce less accurate outputs than one built on integrated data.

The utilities that will get the most from AI are those that first address the fragmentation problem — building a common data environment that spans their operational systems. AI is not a substitute for good data infrastructure. It is an amplifier of it.

OT cybersecurity: protecting the infrastructure that runs the grid

Effective OT cybersecurity in utility environments requires a different approach from conventional IT security. Patching operational technology systems on standard IT security schedules is often not feasible because the systems are live and availability is the primary operational requirement. Scanning tools that work well in IT environments can disrupt OT network protocols not designed for high-frequency traffic. The asset base is heterogeneous — spanning equipment from multiple vendors, multiple decades and multiple generations of communications technology.

Purpose-built OT cybersecurity platforms address these constraints. They perform passive network monitoring, building asset inventories and establishing behavioral baselines without generating traffic that could disrupt operations. Anomaly detection identifies changes in communication patterns, unexpected connections, or command sequences that deviate from established operational norms. When threats are detected, the response capability is integrated with both the security operations function and the operational technology teams.

As utilities connect more assets to corporate and cloud networks and as smart metering infrastructure expands the attack surface to include millions of connected endpoints, the case for purpose-built OT security becomes more compelling. The consequences of a successful attack on grid control systems, particularly in countries where grid infrastructure is already under stress, are severe.

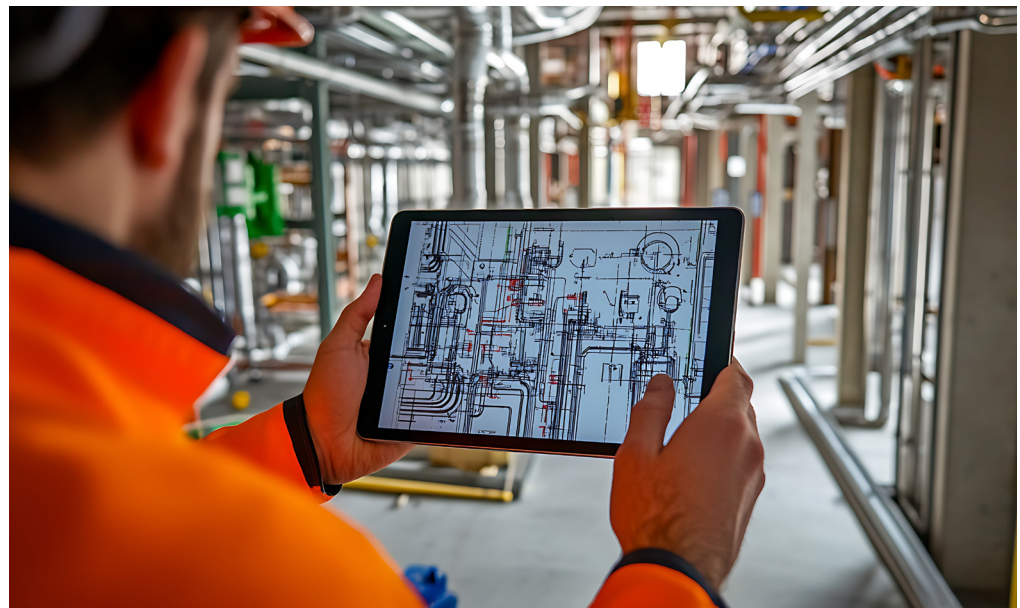
Spotlight: A Gulf utility putting the pieces together

PGEsco, the power generation engineering and services company operating in the Gulf region, provides a concrete example of what integrated digital infrastructure looks like in practice for a utility operating at industrial scale.

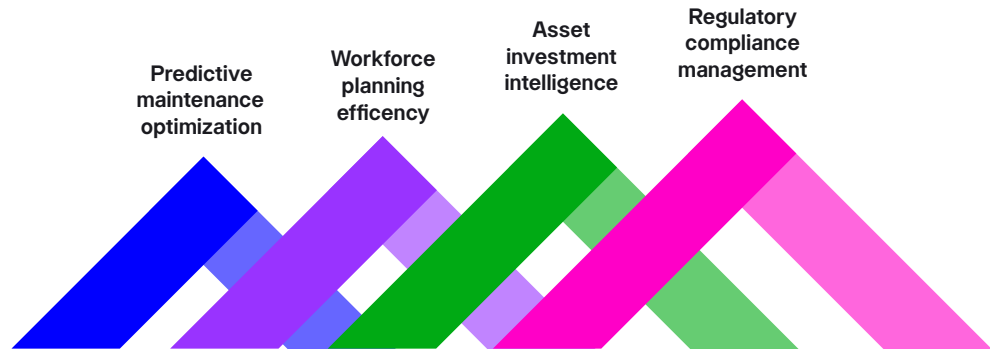
PGEsco manages a large portfolio of generation and transmission assets in an environment where reliability requirements are high, operational complexity is considerable and the demands of both planned and unplanned maintenance allow for limited margin in decision-making. The company's deployment of an integrated asset performance and enterprise asset management platform, connected to real-time operational data, has produced measurable changes in how maintenance decisions are made and how capital is allocated.

What the PGEsco case illustrates is that the technology itself is well understood and available. The capability to move from reactive to predictive maintenance, to connect asset data with operational and planning systems and to build a more accurate picture of the asset portfolio in real time is not experimental. It is proven in industrial environments comparable to those found across the region.

The primary variable is organizational readiness: the willingness to invest in data quality, to train operations teams in new ways of working and to connect systems that have historically been managed in isolation. PGEsco's experience suggests that when those conditions are met, the operational and financial returns are substantial.



Key results



- Moving from time-based to condition-based maintenance has reduced unplanned equipment failures. Maintenance interventions are now scheduled based on actual asset condition data rather than fixed calendar intervals, concentrating resources on assets that genuinely need attention.
- Integration of asset data with work order management has reduced the administrative overhead of maintenance planning and improved the accuracy of resource scheduling. Field crews arrive at job sites with more complete information about the asset they are servicing.
- The connected data environment has improved capital planning. Asset condition data informs replacement and refurbishment decisions more accurately than periodic manual inspection alone, reducing both premature replacement and the cost of failure-driven emergency work.
- The platform has supported compliance with regulatory and contractual reliability obligations by providing a documented evidence base for asset condition and maintenance history.

Conclusion: The power systems of MEA's future

The energy transition in the Middle East and Africa is happening, but it is not happening cleanly. Every country in this study faces some version of the same core tension: the need to build new infrastructure at speed while managing existing infrastructure under stress, in financial environments that constrain investment, against a demand curve that waits for no one.

The path through this tension runs through better information, better connectivity across systems and better use of the analytical capabilities that modern software and AI can provide. These are not aspirational technologies. They are operational tools already deployed, already demonstrating value and already available to utilities in this region.

What integration actually means

When this paper refers to an integrated approach, it means something specific. It means a utility where the 3D design model used to plan a new substation connects to the asset register that will track the substation throughout its operational life. Where the sensors monitoring that substation feed a performance management system that automatically flags degradation. Where the maintenance work orders generated by that system are scheduled against a workforce management platform with visibility into crew availability and spare parts inventory. Where all of this data is protected by a security monitoring layer that distinguishes between authorized operational activity and anomalous behavior that warrants investigation.

This is not a description of what future technology might enable. It is a description of what integrated platforms are capable of today and what utilities that have moved in this direction are already experiencing.

The role of AI in a connected system

Artificial intelligence adds value at every point in this architecture, but its contribution is proportional to the quality of the underlying data and the degree of integration between systems. IRENA estimates that annual grid investment needs to reach \$671 billion between 2025 and 2030 to support the energy transition.[15] The utilities that invest in integration now are building the foundation for AI capability that will continue to improve. Predictive maintenance models become more accurate as they accumulate failure events and near-miss data. Cybersecurity anomaly detection becomes more effective as the system learns what normal operational behavior looks like for each asset type.

Those that continue to manage fragmented, siloed systems will find that even good AI tools cannot compensate for incomplete or disconnected data.

A realistic timeline

The challenges described in this paper will not be resolved in a single procurement cycle or a single deployment. The physical infrastructure deficit, particularly in markets like Iraq, Nigeria and Pakistan, requires sustained investment over decades. The institutional reforms needed in Lebanon and elsewhere require political will and governance capacity that technology alone cannot supply.

But the question of where to start is answerable. The utilities and national energy companies already engaging with digital twin technology, deploying APM platforms to manage aging assets more intelligently and connecting their OT environments to purpose-built security monitoring are not waiting for perfect conditions. They are building the operational capability that will make every subsequent investment more effective.

The decisive factor

The decisive factor in the energy transition of the Middle East and Africa will not be the availability of solar irradiance or wind resources: both are abundant. It will not be the absence of financing or the absence of technology: both are available. The decisive factor will be the ability of utilities and governments to connect fragmented systems into coherent, intelligent networks that can be planned accurately, operated reliably, maintained predictively and protected continuously.

The grids that will power this region in 2050 are being designed and contracted today. The question for every utility executive, every capital program director and every energy minister in the region is the same: at what point does the cost of fragmentation exceed the cost of connecting the grid properly? The evidence from the countries studied here suggests that for most, that point has already arrived.

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