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INTRODUCTION: WHERE ARE WE?

An accomplished Russian astrophysicist named Nikolai Kardashev[١] established a way to measure the evolution of a civilization based on its ability to harness energy. Kardashev's system relies on three distinct levels to classify the level of advancement of a given society, as follows:

- Type ١ is the rank for a society that could harness the power from its planet.
- Type ٢ is the classification for a culture that could exploit the power from its solar system.
- Type ٣ is the category for a civilization that could obtain the power from its galaxy.

A different way of thinking about the Kardashev scale is in terms of usable energy a society has at its disposal and the level of space colonization it has been able to achieve, so a Type ١ civilization has reached mastery of the resources of its home planet.

Another famous physicist, Dr. Michio Kaku[٢], labeled us a Type ٠ society, based on the Kardashev scale. According to him, burning fossil fuels to meet a substantial chunk of our energy needs is not sustainable and demonstrates that we can harness only a portion of the energy that is available on Earth.

On the flip side of Dr. Kaku's assessment, we have nowhere to go but up. We are now on the verge of becoming a true Type ١ civilization with the oncoming of the Smart Grid, which will enable utilities to:

- Increase power availability
- Improve energy efficiency
- Accommodate renewable power
- Prepare for growing power load

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1 Nikolai Semenovich Kardashev (born April 25, 1932) is a Russian astrophysicist and the deputy director of the Institute for Cosmic Research of the Russian Academy of Sciences in Moscow. For more information, please see http://www.daviddarling.info/encyclopedia/K/Kardashev.html

2 Michio Kaku (born January 24, 1947) is an American physicist, the Henry Semat Professor of Theoretical Physics in the City College of New York of City University of New York and co-founder of the string field theory. Dr. Kaku is popular in mainstream media due to his knowledge and accessible approach to presenting complex subjects in science. For more information, please see http://mkaku.org/home/?page_id=5

The Current Situation

As the world recovers from the effects of low electricity demand caused by the recent economic recession, the E&U (Energy and Utility) sector is refocusing its efforts in efficiently meeting energy needs globally, while operating in a safe, open and environmentally responsible manner. Concomitantly, the power industry will be undergoing major changes in the upcoming years, as:

- the proportion of electricity generation from alternative sources increases
- the costs for power transmission and distribution facilities rise
- power shortages trigger problems worldwide

Another consideration is the lack of efficiency in generating and transmitting energy. For instance, the U.S. Department of Energy states that the majority of power plants are only ٣٥ percent efficient. Obsolete power systems typically result in a ٦ to ١٠ percent loss of electricity by the average utility grid. The modernization of that power system can be a simple initial step in reducing these system losses that can be eliminated via utility grid optimization.

In addition to these factors, the overarching desire to embrace “green” initiatives to attract and retain customers and employees has resulted in corporations voluntarily agreeing to aggressive carbon reduction targets[٣]. From a government perspective, some jurisdictions within North America (such as the Province of Ontario or the State of California) are mandating the E&U sector to comply with lower CO٢ emissions. For utilities, there is no panacea to curb greenhouse gas emissions, as many of them will still require fossil units to meet the energy demand, so a combination of various technologies will be necessary to meet the green challenge.

Therefore, the power industry is aiming for more efficiency, and that will be a major catalyst for change. A Smart grid is increasingly being regarded as a way to drive this efficiency. Simply put, a smart grid is made up of three basic components: intelligent devices, two-way communications and information management, as shown below:

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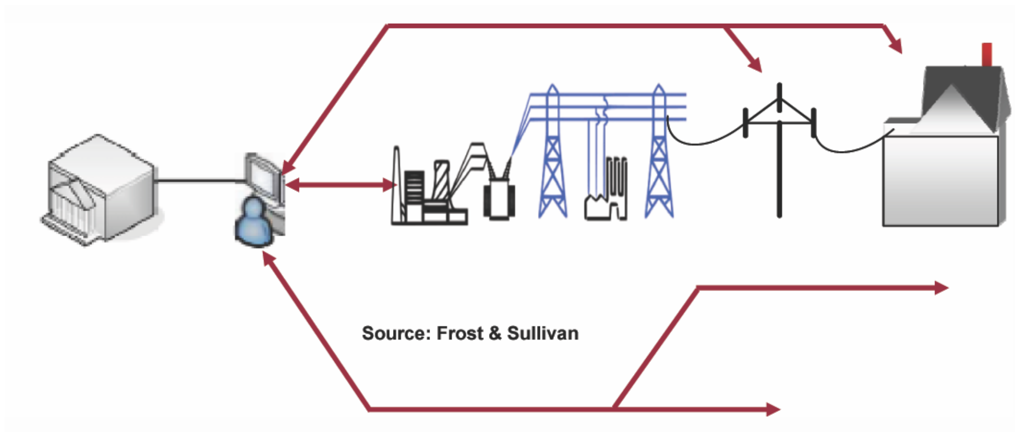
[3] Fifty-one percent of global fortune 500 companies have committed to carbon reduction targets, and the number of companies disclosing carbon emissions has increased from 235 to more than 2,200 in the past five years. (Source: Wall St., Frost & Sullivan estimates 2010)

Figure 1—Smart Grid Example: A Virtual Peaking Plant



More specifically, the " Smart Grid overlays the electricity generation, transmission, and distribution grid infrastructure with communication and information infrastructure to empower data collection and device control for energymanagement, efficiency, and cost control. The major Smart Grid applications that require new broadband communications infrastructure are depicted in the following table:

Figure 2—The Pillars of the Smart Grid

	Function	Component	Description
Real Time Intelligence		SCADA (Supervisory Control And Data Acquisition)	Telemetry data gathered from each grid element, Data Collection sensor and location to monitor and control the generation, transmission and delivery of electricity
	Data Management	AMI (Advanced Metering Infrastructure)	"Smart" meters networked to the utility company that enable time-of-use billing, power quality and outage reports
	Load Management	DR (Demand Response)	Mechanisms to help the utility achieve "demand shaping" (i.e., consumption of electricity in response to supply); DR elements educate and enable customers to make "smart" energy conservation decisions
	Asset Management	DA (Distribution Automation)	DA enables "smart" infrastructure to enhance asset yield by extending the intelligent control of grid functions to the distribution level. The idea is to control equipment in homes, buildings and communities, leading to better management of demand and cost, as well as conservation of resources.

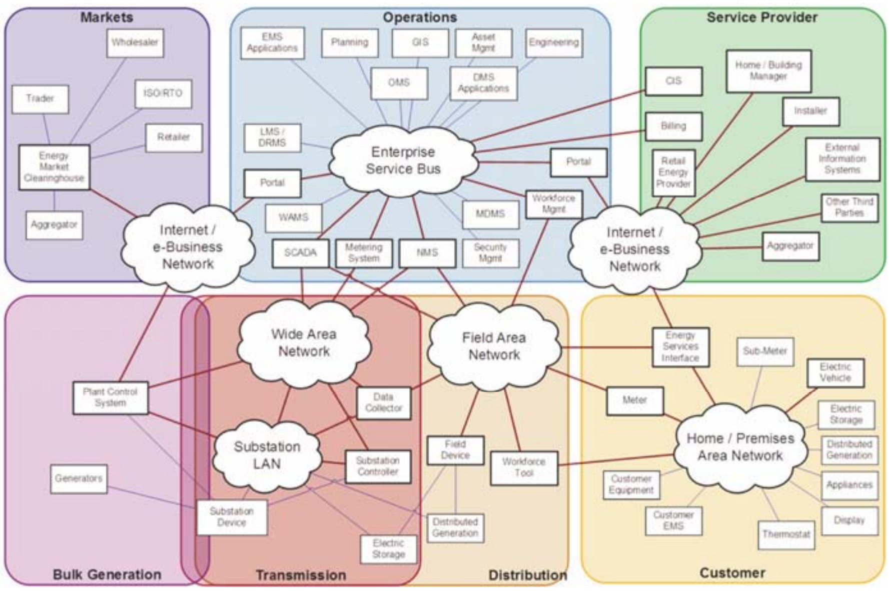
In order to aid the transition to smarter and more efficient networks, the Electric Power Research Institute (EPRI) developed its IntelliGrid Architecture as the basis for Smart Grid deploymenced applications to enable the generation, delivery and consumption of electricity. The main components of the specification include:

- **Broadband Communications:** A secure network deployed to interconnect intelligent grid elements using standards-based IP interfaces and allow communication with field personnel, energy distribution markets, and support staff.
- **Control and Data Management:** Automation necessary to provide a comprehensive view of the grid in order to analyze and respond to variations in load demand and enable a truly "smart" grid.

- **Advanced Applications:** Including load management and a host of value-added services such as home security services or remote control of appliances, air conditioning, alarms, and lighting, via a cell phone or online portal.

The Smart Grid architecture defined by EPRI is illustrated in Figure 3:

Figure 3—Smart Grid Architecture



The advent of the Smart Grid brings together two industries (power systems and telecommunications/IT) whose insular nature has prevented a more substantial crossover to this point. That said, there are signs that utilities are increasingly seeking telecom and IT solutions to help address their challenges associated with the deployment of Smart Grid networks.

Current Challenges Faced by Energy and Utility Companies

Despite the need to embark on Smart Grid strategy, most E&U companies are still considering the best way to proceed. For instance, in the U.S., only ١,٠٠٠ out of a total of more than ٤,٠٠٠ E&U companies have Grid initiatives. From those ١,٠٠٠, only ١٠٠ have received grants to do so, while the other ٩٠٠ are self-funding.

Adoption of Smart Grid technologies is being hampered by a plethora of challenges being faced by utilities, including:

- **Regulation compliance:** Anticipating regulatory changes can be a tricky exercise .For instance, in terms of “green” legislation, in the U.S., states are moving forward irrespective of national policy: ۳۵ states have either Renewable Portfolio Standard (RPS) or Renewable Portfolio Goal (RPG) targets to achieve. E&U companies have to anticipate and then comply with regulatory change.

- **IT infrastructure obsolescence:** Utilities typically are "smart followers" from an IT perspective and tend to be late in adopting newer infrastructure. Consequently, it is not uncommon for them to own a number of legacy IT systems, usually having business logic behind-certain processes that are either embedded in the code or decentralized, residing in various locations. This dramatically increases the complexity of making any changes related to modifications in regulatory or safety conditions, dynamic dispatch of units to match an unforeseen energy peak demand, or embarking on an operational transformation exercise.

- **Security:** The issue of cyber attacks is fairly important in designing and manufacturing Smart Grid technologies. For instance, NERC (North American Electric Reliability Corporation) has developed Critical Infrastructure Protection (CIP) standards for Critical Assets (CA) and utilities had until August 2009 to implement these specifications. The inability to comply with these standards usually leads to penalties.

- **Risk mitigation:** From an organization perspective, in order to mitigate risk, several levels need to be involved. For instance, the AMI sales cycle is typically long and unpredictable due to budgeting, purchasing, and the regulatory approval process that can take up to several years to complete. The project needs to be approved by Independent System Operators (ISO) or Regional Transmission Organizations (RTO). This is followed by vigorous testing and extensive review, including a limited trial of the system prior to full deployment.

- **Generation:** New mandates for increased generation from alternative sources (e.g., wind power) are triggering new requirements for M2M (machine-to-machine) interfaces for two-way communication between grid load management centers and endpoints, sensors and energy management devices that are found in homes and businesses.

- **Organizational issues:** In many utilities, network engineering and operations is part of the power transmission and distribution organization. This separation from and general hostility toward IT can create issues as telecom service providers transform the E&U business. Another problem is "inertia," which is often present in organizations having a concentration of senior staff that is being forced to embrace a new modus operandi and change the old ways of getting things done. Finally, E&U organizations are notoriously inefficient and without changing their business practices, they might not be able to efficiently adopt the Smart Grid.

- **Lengthy decision-making process:** In general, utilities do have a lengthy and complex decision-making process. Utilities generally engage with vendors through requests for proposal (RFPs), direct request, or through a joint bidding process with a third-party vendor. The RFP process can take anywhere between 12 and 16 months.

Why are These Challenges Important?

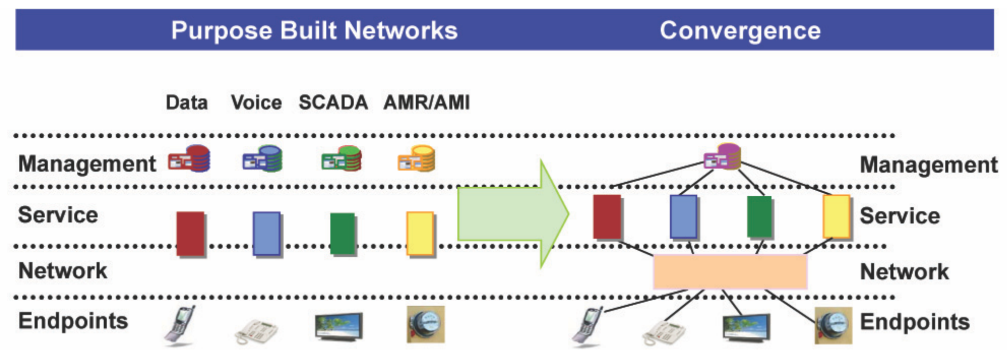
As we enter the second decade of the ٢١st century, E&U companies are expected to do far more than simply generate and transmit and distribute power. Increased grid intelligence is empowering the integration, temporary storage and re-transmission of non-continuous renewable energy, while ensuring system reliability and stability, and optimizing affordability. Furthermore, with added intelligence from sensors and real-time monitoring systems, grids are becoming “self-healing,” enabling power to be re-routed around outage areas through automatically reconfigured power distribution grids.

Smarter grids are enhancing electricity system information exchange, transparency, and real-time power availability, helping to improve asset utilization rates while minimizing the waste of power (due to distribution or temporary storage inefficiencies). Smart grids are now allowing utility generation systems to meet peak demand requirements via load shifting, thereby minimizing incremental investment in new generation capacity.

A FRAMEWORK TO TRANSFORM THE WAY ENERGY AND UTILITY COMPANIES OPERATE

As utilities begin to embark on the path toward the Smart Grid, they will have to migrate from siloed, vertical, purpose-built networks to a converged topology that will bring together power system and communications/IT infrastructure in a more horizontalized-type architecture, as captured by the following figure:

Figure 4—Transitioning to a Smart Grid Architecture



As an initial step toward this transformation, most utilities would rather take an evolutionary (rather than revolutionary) path by incrementally integrating new applications into their transmission and distribution grids rather than ripping and replacing their existing infrastructure . In order to enable the integration and interoperability between new applications and an existing grid infrastructure, these new apps need to be compliant with the Common Information Model (CIM) standard. The CIM specification relies upon the following International Electro technical Commission (IEC) standards:

- **IEC 61850 standard:** Defines the design of electrical substation automation
- **IEC 61968 standard:** Normalizes information exchange between electrical distribution systems
- **IEC 61970 standard:** Articulates the application program interfaces (APIs) for energy management systems

Currently, there is a heavy business process impact to utilities arising from the embracing of these specifications; however, none of them specifically offers a reference Business Process Model (BPM) to successfully adopt these IEC standards. Formal enterprise architecture allows the modeling of business processes and their simulation, so it is very useful to be able to provide BPMN (Business Process Modeling Notation) capabilities to the toolsets in order to model, simulate and streamline business processes though modeling.

Another task as part of the Smart Grid transformation is determining the standards that need to be adhered to. While solutions are likely to vary by utility, there is a debate on improving interoperability of the various devices deployed for the Smart Grid. The choices and implementation of appliances have not been finalized as a result of ongoing interoperability standards efforts. In the past, decisions to deploy technologies were decentralized, which led to equipment with proprietary technologies.

By contrast, in June ٢٠٠٩, the U.S. DOE (Department of Energy) issued ١٦ interoperability standards for Smart Grid technologies needed for the interoperability and security of the Smart Grid and $١٠ million in Recovery Act funds to the National Institute of Standards and Technology (NIST) for support of the standards. These include:

- Advanced Metering Infrastructure Security (AMI-SEC) System Security Requirements— AMI and smart grid end-to-end security

- American National Standards Institute (ANSI) C١٢.١٩/MC١٢١٩—Revenue metering information model

- BACnet ANSI American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) ١٣٥-٢٠٠٨/International Organization for Standardization (ISO) ١٦٤٨٤-٥—Building automation

- Distributed Network Protocol (DNP٣)—Substation and feeder device automation

- International Electrotechnical Commission (IEC) ٦٠٨٧٠-٦/TASE.٢—Inter-control center communications

- IEC ٦١٨٥٠—Substation automation and protection

- IEC ٦١٩٦٨/IEC ٦١٩٧٠—Application-level energy management system interfaces

- IEC ٦٢٣٥١—Parts ١-٨ Information security for power system control operations

- Institute of Electrical and Electronics Engineers (IEEE) C٣٧.١١٨—Phasor measurement unit communications
- IEEE ١٥٤٧—Physical and electrical interconnections between utility and distributed generation
- IEEE ١٦٨٦-٢٠٠٧—Security for intelligent electronic devices

- North American Electric Reliability Corp. (NERC) Critical Infrastructure Protection (CIP) ٠٠٢-٠٠٩—Cyber security standards for the bulk power system

- NIST Special Publication (SP) ٨٠٠-٥٣, NIST SP ٨٠٠-٨٢—Cyber security standards and guidelines for federal information systems, including those for the bulk power system

- Open Automated Demand Response—Price responsive and direct load control

- OpenHAN—Home area network device communication, measurement and control

- ZigBee/HomePlug Smart Energy Profile Home Area Network—Device communications and information model

The regulatory compliance conundrum is likely to continue as timelines for implementing Smart Grid interoperability standards are not yet clear. As a result, utilities have to keep up with changing requirements on this front.

An additional consideration on the journey to a smarter grid is how to enhance the security of the IT infrastructure. The physical and electronic security of facilities, personnel, applications, communications, and data is an imperative. E&U companies operate facilities in numerous, sometimes remote, locations and if any one of them is compromised, the results could be devastating. Similarly, the systems and data used to control the grid elements, used by utility personnel and accessible by partners and customers, must be protected and secured from intrusion.

Utilities have to also devise and implement real-time communication and distribution automation systems that will make their grids smarter. Smart sensors are enabling the distribution grid to become self-monitoring between distribution substations and the end customer. The reconfiguration of feeder transmission lines with automated switchgear is allowing "self-healing" distribution whenever an outage occurs. Moreover, voltage regulation, surge protection, protective relays and capacitor bank controls facilitate the grid to start optimizing the routing of power throughout the grid; this is an important consideration to avoid costly overloading of transmission lines, which can further exacerbate a power outage situation. Linking all this together are automated substations that interconnect "islands" of information within the grid, centralizing access to all grid devices while eliminating redundant communication infrastructure and maximizing system security, integrity and efficiency.

Utility planners transitioning to a next-gen grid also focus on AMI as a means to help achieve end-use (e.g., residential and commercial buildings) efficiency. Buildings represent about ٧٠ percent of electricity usage in the U.S. (commercially, buildings account for roughly ٣٥ percent of the mix). A commercial building energy retrofit encompassing various sub-systems (lightning, controls, chillers, etc.) can yield an average power savings of approximately ٢٥ percent. The potential savings from the deployment of smart meters and AMI networks at large commercial or industrial buildings can trigger a substantial savings opportunity, as these buildings represent about ٥٠ percent of the peak demand in the U.S. Downstream savings (i.e.., those closest to the end-user) are the most crucial and have the largest effect on reducing greenhouse gas emissions. In other words, end-use efficiency has a multiplier effect on potential savings at generation due to the loss of power in generation (~٧٠ percent) and transmission and distribution (~١٠ percent). Hence, a unit of energy saved post-distribution can equate to eight units of savings at generation.

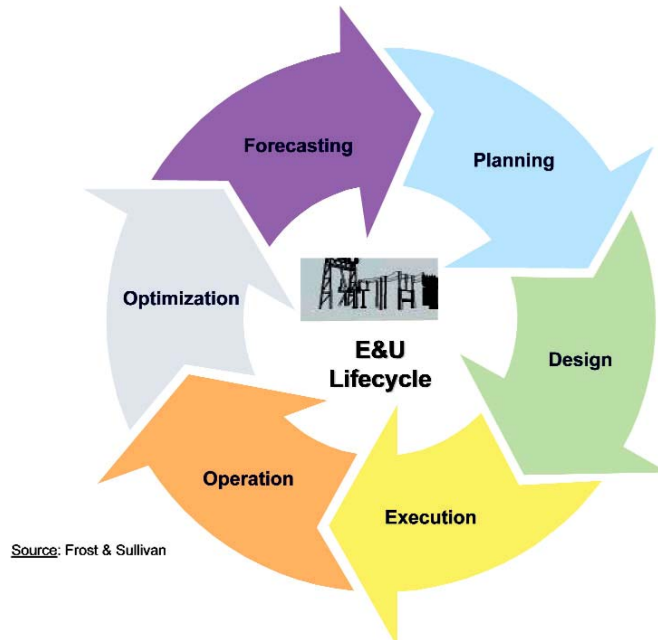
Automated DR programs should also be an important part of the evolution toward the Smart Grid. Even though Demand Response is a relatively new term, the practice of reducing load (manually) is not new. While “energy efficiency” needs no change in the pattern of electric consumption (fewer energy units utilized doing the same task), DR entails changes in electric usage in response to modifications in price or incentive payments. Automated DR programs represent an important way to achieve “demand shaping” and can lead to a more cost-effective and intelligent grid with more energy- efficient commercial buildings. For example, in a ٢٠٠٩ study, FERC (the Federal Energy Regulatory Commission) pegged that DR programs can shave peak loads anywhere from ٥ to ٩ percent.

When planning the transition to a smarter grid, utilities have to also be cognizant of the losses when transmitting and distributing electricity, which typically hover around the ٦.٥ percent mark. These losses represent the discrepancy between energy produced by power plants and energy sold to end customers. As the source of energy diversifies into nuclear power and other alternative sources, from thermal and water power, the distribution and transmission distances have lengthened, which is something that planners have to consider. For instance, solar and wind power need areas with abundant sunshine and wind. As such, the power generation area has no choice but to be far away from power consumption regions.

Putting It All Together

As we can see from the above discussion, the tasks associated with the transition from the older, disparate, purpose-built networks to a newer, converged, more intelligent grid can be quite complex and require a very close coordination between various teams from a given utility. In addition, the processes need to be mapped out and each step needs to be carefully weighed after taking into account all the considerations. In order to achieve these goals, it is important to have an iterative continuous framework in place.Frost & Sullivan has devised an E&U sector lifecycle that captures all the tasks associated with transitioning to the Smart Grid, which is shown in the following illustration:

Figure 5—A Framework to Transform the Way Utilities Operate



The above lifecycle can serve as a foundation for utilities to gradually begin migrating their infrastructure and adding intelligence to their grids.

DELIVERING THE VISION: HOW IBM ANSWERS THE CHALLENGES

The foundation of a framework to help utilities incrementally adopt Smart Grid capabilities revolves around a unified scalable platform that can enhance the application development process, including cutting down the development time frame, improving the system security and reducing the number of bugs.

Such a platform would be designed to address all aspects of a network transformation exercise, including business strategy and objectives, industry standards compliance, environmental aspects, and organizational, hardware and application infrastructures. In addition, the solution set would include other elements that tackle issues, such as configuration management and collaboration effectiveness.

An Example Smart Grid Framework by IBM

IBM is one vendor that has developed a comprehensive solution portfolio in order to help utilities better tackle the gradual transition to a smarter grid. IBM's approach is based on an all-encompassing set of modules that delivers network visibility and control, process automation and business collaboration across E&U companies.

We will now consider an example of a utility (ABC Power) within the context of our E&U lifecycle and use examples of IBM products that illustrate how the company is addressing the pain points of enabling a smarter grid.

As a way to incrementally start adopting Smart Grid capabilities, ABC Power wants to integrate new applications into its transmission and distribution grid rather than embark on a "rip-and-replace" strategy. In the "Planning" stage (light blue arrow in Fig. ٥) of the project, ABC wants to ensure that the new application (e.g., an AMI app) can properly
integrate and interoperate with its existing grid infrastructure and be compliant with the CIM standard. A business analyst can rely on **IBM Rational Requisitepro®** as a single reference source for requirements linking directly to the specific SIM extension model in order to manage all requirements and keep track of any change in them.

In the "Design" stage (green arrow in Fig. ٥), a system engineer is handed these requirements from the business analyst and can leverage the **IBM Rational Software Architect** modeling software to generate the UML for CIM and CIM extensions. A key differentiator for IBM in this case is the tight integration between Requisitepro and Rational Software Architect, which enables the system engineer to stay on top of changing requirements by synchronizing the requirements management tool (Requisitepro in this case, but alternatively also **IBM Rational DOORS**) with Rational Software Architect.

In the "Execution" stage (yellow arrow in Fig. ٥), a key goal for ABC Power is to effectively carry out team development across several locations and manage CIM-based models across multiple project lifecycles via application/data integration and data design and analysis. An efficient change management system is vital to keep track of various change requests and gain a more detailed visibility throughout the delivery effort. The **IBM Rational Team Concert™** platform can play a key role in enhancing team productivity through its integrated configuration, change, and build management systems for large and disparate teams. This is instrumental in managing a complex project, particularly when teams are geographically dispersed, which often happens within the E&U industry. In addition, Team Concert supports ad-hoc collaboration, thereby eliminating contentions, design duplication and other versioning problems that often arise in mid-to-large size projects.

Following that, the “Operation” stage (orange arrow in Fig. ٥) is also very important, as it ensures the ongoing activities are hitting various planned targets, including budget, schedule, risk, and compliance. As part of its Smart Grid exercise, it is crucial for ABC Power to establish a Program Management Office (PMO) to ensure the roadmap is being executed and that projects that were committed to are helping meet the overall strategy and complying with corporate network, IT, and data standards. The **IBM Rational Focal Point** software enables ABC’s PMO to achieve these goals and prioritize pipeline projects based on certain decision criteria, thereby enabling them to be completed in a timely and cost-effective manner. Therefore, Focal Point allows the PMO to gain a better control of

ABC’s budget, change processes whenever necessary and even prevent each operations group from installing point solutions that are incompatible with the architecture, systems, infrastructure, and data defined across ABC’s business.

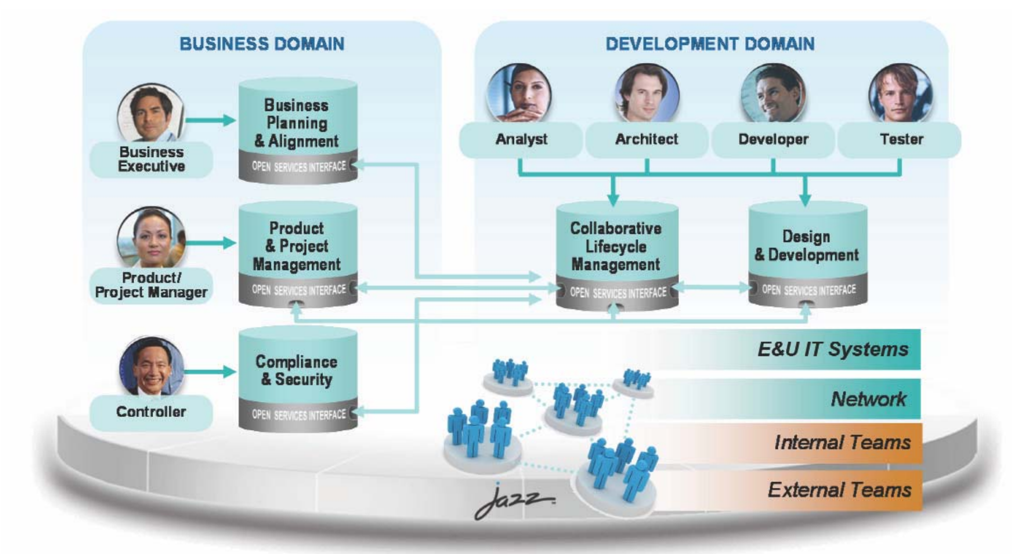
The optimization and forecasting stages (gray and indigo arrows in Fig. ٥) are also important as they represent a continuing effort to optimize the existing grid and have an outward view into the future to meet a key longer-term goal, such as reducing carbon emissions and readjusting the power generation to keep up with demand. This requires a careful planning and orchestration of various groups and further spawns new projects that will entail transformation planning, IT investment and supply chain management, and impact analyses to handle the underlying risks associated with Smart Grids and other large-scale initiatives. IBM can address these challenges via its **Rational System Architect** software, which can assist ABC in reaching better tactical and strategic decisions with validated results. System Architect can further provide visual traceability across various layers, correlating the data to business processes, technology and personnel.

All these tools can contribute to a successful and gradual transition to a smarter grid, but it is essential to have them integrate with each other and to enable changes to be made whenever necessary. An underlying enterprise architecture can help achieve that by furnishing a comprehensive view of how the business and technology resources can support and achieve a utility’s project and business initiatives.

Furthermore, the framework approach that we discussed earlier can also be extremely helpful for E&U firms transforming their grids. In this case, IBM provides its **Solution Architecture for Energy and Utilities Framework (SAFE)**, which is a software platform geared toward offering network visibility and control, process automation and business collaboration for solutions across the Energy Value Chain. SAFE combines IBM's acumen in integration and management of a utility's assets and information, enhancing the network transformation and business agility. This framework formulation is superior to other approaches that usually require either full customer development, which is lengthy and expensive, or "siloed" packaged applications, which are usually stand-alone, inflexible and require a high degree of extra custom work.

In summation, IBM's E&U solution portfolio has solutions that can enable people in each role within a utility to optimize a Smart Grid transformation. This is illustrated in Figure ٦:

Figure 6—IBM E&U Solution Portfolio



CONCLUSIONS

Rather than try to take on a monumental Smart Grid migration exercise by themselves, E&U corporate planners need to find a qualified partner to help them and change their business processes to incorporate software-intensive system integration. We believe the ideal partner should have the right combination of industry subject-matter expertise and technology applications and tools. That partner should also be able to provide a framework that combines middleware capabilities with pre-built extensions and accelerators to deliver speed, flexibility and choice, while reducing cost and risk associated with a Smart Grid transition. More importantly, that partner should also have a keen understanding of the complexities of the E&U industry, being able to tackle the challenges of the future while exploring the technologies that can yield some key competitive differentiation.

This paper examined the IBM E&U Smart Grid approach, which features a solution portfolio that can play a key role in helping utilities achieve operational effectiveness and efficiency quickly, transparently and flexibly, while working with established infrastructure and processes. We believe that IBM's E&U product portfolio can help utilities around the world undertake a successful Smart Grid transformation that will ultimately help us achieve Kardashev's Type ١ ranking for our civilization.