

Chapter 5

eIoT Transforms the Future Electric Grid



In conclusion, the development of eIoT is an integral part of the transformation to the future electricity grid.

- Chapter 1 discussed five energy-management change drivers that are bringing about this transformation:
 - Rising demand for electricity [34–36]
 - Emergence of renewable energy resources [37–40]
 - Emergence of electrified transportation [41, 42]
 - Deregulation of power markets [43, 44]
 - Innovations in smart grid technology [45, 46]
- Chapter 2 explained that the impact of these energy-management change drivers will appear primarily at the grid’s periphery. Distributed generation in the form of solar photovoltaics (PV) and small-scale wind will be joined by a plethora of internet-enabled appliances and devices to transform the grid’s periphery to one with two-way flows of power and information [45, 46]. The resulting activation of the grid periphery gives rise to an energy internet of things composed of network-enabled physical devices, heterogeneous communication networks, and distributed control and decision-making algorithms.
- Chapter 3 organized the discussion of these elements into an eIoT control loop built upon well-established standards and architectures.
- Chapter 4 showed that such an eIoT control loop is most consonant with the emerging concept of TE and then proceeded to discuss how it may be applied within utilities–distribution system operators and industrial, commercial, and residential customers.

In summary, eIoT is set to transform all aspects of grid operations and control. This transformation spans both technical and economic layers and leads to new applications, stakeholders, and energy system management solutions. This chapter serves to summarize the conclusions of the work: 1. eIoT will become ubiquitous, 2. eIoT will enable new automated energy-management platforms, and 3. eIoT will

enable distributed techno-economic decision making. This chapter also serves to highlight two open challenges and opportunities for future work: the convergence of cyber, physical, and economic performance, and the re-envisioning of the strategic business model for the utility of the future. These conclusions and open challenges are now discussed in turn.

5.1 Conclusions

5.1.1 *eIoT Will Become Ubiquitous*

As discussed previously in Sect. 3, the number of sensors and actuators deployed at all levels of the electric grid is set to dramatically increase. These sensors and actuators will enable the transformation of both the distribution and transmission network aiding in the measurement and actuation of primary and secondary electric power variables. The transformation is going to be characterized by improvement in the quality of data measured and a significant increase in the diversity of measurements taken. The speed and granularity of measured variables in the transmission system will be enhanced through widespread adoption of PMUs, and an upgrade of the SCADA system as addressed in Sect. 3.1.2.1. Monitoring of secondary variables such as wind speed and solar irradiance will significantly improve the forecasting accuracy and capability, and promote the overall reliability of the supply of wind and solar power.

The steady supply of natural gas is critical to ensuring electric power supply reliability especially with major base load retirements. This motivates the need for secondary measurements by eIoT to ensure reliable and cost-effective operation of the electric and natural gas supply systems as covered in Sect. 3.1.3. As for transmission system actuation, the adoption of decentralized or distributed approaches for AGC and AVR applications is imperative to effectively control distributed energy resources. Naturally, current FACTS devices must also become smarter to enable faster, efficient, and accurate measurement and actuation of transmission variables as discussed in Sect. 3.1.2.2.

Advanced metering infrastructure with AMR and AMM capability provides access to consumer data and enables two-way communication between consumer devices and utilities. Smart sensing devices will also motivate consumers to upgrade their homes for faster and efficient energy management. Energy monitors, smart switches, outlets, lights, and HVAC will provide better actuation abilities for consumers while allowing for secondary measurements that would ultimately improve the efficiency of DR programs.

The mere presence of sensors and actuation devices triggers innovations and advancements in the communication networks that connect them. Communication such as SCADA networks and wide area monitoring systems are expected to continue to play an integral role in utility and grid operator communication networks.

Low power wide area networks will allow communication over long ranges while minimizing the energy consumption of devices. Communication devices that go beyond the purview of either utility or grid operators will be needed to enable the inclusion of all interacting parties. Telecommunication networks may need to take on the role previously carried out by utility and grid networks. Local area networks will play a key role in ensuring the full automation of residential, industrial, and commercial premises. Together, these networks will create a web of interacting devices that will work collaboratively to ensure the reliability of the electric power supply system. Furthermore, this network of interacting devices will enable the emergence of TE platforms that will revolutionize the exchange of energy products and services.

5.1.2 eIoT Will Enable New Automated Energy-Management Platforms

eIoT will create a network of interacting devices that measure, store, and actuate data in real-time. These devices also bring about many opportunities for the improvement of current electric power system operations. Most of these opportunities are observed at the grid periphery where millions or even billions of interacting devices will emerge in turn to create numerous control points for the distribution grid. The once passive consumer base will become active participants in their own energy supply and consumption. While some consumers will become prosumers, others will have the opportunity to participate in electricity markets or carry out transactions with their neighbors. In addition, the grid periphery will be characterized by a proliferation of DERs such as rooftop solar and electric vehicles that need management.

The transformation of the grid periphery calls for several changes to status quo. The distribution network will require an upgrade and depending on the issue, non-wire solutions such as engaging consumers through DR may be necessary. This calls for better energy-management platforms that help engage the consumer base. As DERs begin to participate directly in electricity markets, aggregation platforms or companies will be necessary to avoid any reliability issues. A change in the regulatory or market structure may be required to aid in the smooth participation of DERs and efficient DR programs.

Depending on the willingness of utilities to step up to these new challenges, this could result in the transformation of the utilities business model or the emergence of new stakeholders to take on these new roles. Either way, the effective deployment of eIoT will require new energy-management platforms whether they are for managing energy transactions or for managing the large quantities of data collected in real-time. TE and blockchain-powered platforms are starting to emerge as potential energy-management platforms. Additionally, various cloud-based commercial IoT

platforms such as Amazon, Microsoft, SAP, and OpenFog are emerging to support the millions of interacting IoT devices. With time, these platforms will also evolve to specifically cater to the energy industry.

5.1.3 eIoT Will Enable Distributed Techno-Economic Decision Making

In order to control the millions or even billions of interacting devices, scalable and distributed techno-economic decision making will be needed. Whether it is in the transmission system with distributed AGC and AVR or in the control of smart devices at the grid periphery, distributed control will play a key role in the effective deployment of eIoT devices. Through TE, eIoT will enable distributed decision making of physical and economic power supply variables. The eIoT control loop is centered around sensing, communication, actuation, and distributed control algorithms that creates an effective decision-making framework. This framework informs and executes complex decisions that are spawned by distributed technical and economic information from all over the electric power supply and distribution system. The distributed economic decision making will greatly benefit DR applications through peer-to-peer trading platforms and smart energy-management programs.

5.2 Challenges and Opportunities

5.2.1 The Convergence of Cyber, Physical, and Economic Performance

eIoT is not without its challenges. With every challenge, comes an opportunity to advance the electric power system. eIoT causes a convergences of the cyber, physical, and economic performance of the electricity grid.

- Most eIoT devices will have and/or require an internet connection.
- eIoT devices need to work together to perform different functions across the electric supply and demand value chain.
- New market participants such as aggregators, prosumers, DERs, and microgrids will emerge.
- A large quantity of data will be generated and stored or processed in real-time.

Connecting eIoT devices to the internet creates a cybersecurity concern for grid operators and all parties involved. This requires investment in technologies to ensure the integrity and security of all devices in the network.

Additionally, careful vetting of interacting devices may be necessary to prevent infections from spreading through rogue devices or connections. Data sent to the cloud must also be vetted to avoid exposing sensitive data to security issues. This may require equipping devices with enough processing capabilities to carry out some computations without involving the cloud. The electric grid architecture is increasingly transforming, more specifically, to one with two-way flows of power and information. This architecture creates a cyber–physical requirement where both physical devices and informatic components must accommodate this architectural need. With changing architectural requirements, the cyber–physical–economic aspects of the grid must be designed in such a way as to ensure interoperability. This provides an opportunity for the development of standards for ensuring interoperability.

The emergence of new market participants creates the need for more devices, platforms, and economic structures not to mention regulatory changes to manage and control their participation in electricity markets.

A mechanism to store, manage, and secure the data collected in real-time is necessary to protect the interests of all stakeholders. Although the convergence of the cyber, physical, and economic aspects of grid operations poses a challenge, it provides an opportunity for collaboration across various layers of the electricity grid and jurisdictions to enhance system reliability.

5.2.2 Re-envisioning the Strategic Business Model for the Utility of the Future

The biggest transformation will occur on the distribution side at the grid periphery. In addition to the millions of interacting devices, the rise in the number of active consumers and DERs poses a major challenge to the utility business model. Utilities must re-evaluate their approach to how they manage their system. For example, instead of defaulting to network upgrades to accommodate DERs, utilities may consider the potential of non-wire solutions.

In order to engage the active consumer base, utilities must develop proper compensation mechanisms that:

1. Motivate consumers to shift and/or lower consumption
2. Are fair and offer value to the consumer
3. Provide a diversity of options that cater to varying consumer needs.

This may require either a complete transformation of the utility business model or open collaboration with aggregators and emerging stakeholders. The distribution market structure may transform to be similar to that of the wholesale electricity markets observed at the ISO/RTO level. This, in turn, may require regulatory measures that foster fair and competitive markets to equally engage all participants.

The deployment of eIoT poses numerous challenges that span the cyber, physical, economic, and regulatory structure of the electricity supply and demand value chain. A holistic approach is necessary to effectively deal with these challenges. Consequently, stakeholders at various jurisdictional layers must engage with each other to work out a favorable solution that benefits most if not all. The success of this collaboration highly depends on the existence of favorable regulatory and policy structures as well as standards that serve as guidelines for stakeholders.

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