Application of Smart Grid and Edge Computing Technologies to Improve The Operational Efficiency of The Supply Chain and Logistics Processes

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Abstract
Energy demand is growing at a very rapid pace worldwide. Conventional energy sources are being replaced steadily by non-conventional sources such as renewable energy sources like wind, solar, geothermal, hydroelectric etc. This rapid growth in demand for energy compounded by the depletion of conventional, non-renewable energy sources in recent years has brought about a transformation in the energy sector. Households, manufacturers and other consumers of energy can now both produce and consume energy. The flow of energy is bidirectional. They can also either store the surplus power for future use or send it to the grid for sharing with other users of energy. As a result of this transformation, the smart grid came into existence where the producers and the consumers of energy can be the same person and contribute to the supply of energy to the grid.
Keywords: Smart grid, IoT, Supply chains, Industry 4.0, Energy sources, Edge computing

Introduction

More than ever, companies are under pressure to provide as much information as possible with minimal delay, lower overhead and exacting specificity. Smart companies are aware that to overcome and be at the forefront, beating the competition, it is imperative to invest in data-driven intelligence. Companies need to know the most important components needed to develop a next-generation, data-driven transportation and logistics ecosystem. They must understand and be aware of the technologies—and support that is required to ascertain that their company can achieve efficient deliveries with transparency and responsiveness that modern supply chains demand.

Companies thinking of investing in a competitive, future-proofed infrastructure need to understand where supply chain technology is going—and where it's going is "the edge."

Review of the Literature

Supply chain management is basically organising the various flows such as the good flow, financial flow and information flow from the supplier to the manufacturer and the end customer to achieve the best possible customer service and also at the lowest cost Cooper et al. (1997). There is also a reverse flow in the supply chain, like product returns. To make the best use of the return flows. The concept of reverse logistics has been coined. Reverse logistics consists of flows in the opposite direction of the forward supply chains Rogers and Tibben-Lembke (1998).

The objective is to recover as much economic value as possible and several steps like repair, refurbish, remanufacturing. Recycling, as well as direct resale, has been practised Fleischmann et al. (2000). Hence, to meet the challenges of these fundamental changes taking place, closed-loop supply chains have come into existence, Guide et al. (2003). The main ingredients of the concept of closed-loop supply chains are forward and reverse flows. This concept is unique in that both forward and reverses flows are considered simultaneously. They are also organised to maximise the total supply chain benefits. Smart grids are networks that are robust and self-healing (Eunice, 2018). They allow the bidirectional transmission of energy and information inside the utility grid. This gives rise to a new class of energy user who consumes, produces, stores and shares energy with other grid users. Such a user is called a "prosumer" and refers to user of energy who will be able to generate renewable energy within their home environment. This generated energy can either be stored for future use or traded with other users who need the energy, both domestic and industrial users in smart grid Rathnayaka et al. (2015). Therefore, the prosumers' aim is to both produce as well as consume energy and also to share and distribute the surplus energy among the other users in the grid Zafar et al. (2018), Parag & Sovacool (2016)

Prosumers' participation in the smart grid is critical for the sustainability and long-term efficiency of the energy sharing process. Thus, prosumer management has attracted increasing attention among researchers in recent years.

Another important concept is a group of prosumers who participate in energy provisioning. PCG is defined as a network of prosumers, who have nearly identical energy sharing tendencies, and attempt to follow a joint objective of collaboratively compete in the energy market Rathnayaka et al. (2014). Electricity Prosumer Communities (EPCs) is one more concept associated with prosumer concept. They are "groups of people who produce, share, and consume power locally, Oliver et al. (2017). There are other publications that have utilised similar terms like Integrated Community Energy Systems (ICESs) Koirala et al. (2016, 2017), Xu et al. (2015), Mendes et al. (2011) and Clean Energy Communities (CECs)

Gui & MacGill (2018) and also mean the same concept.

The difference between traditional users who consume energy from the grid, prosumers are involved in generating, consuming and also transferring or storing excess energy Rathnayaka et al. (2012), Pal et al. (2016). Prosumers are also able to store surplus energy by making use of Energy Storage Systems for future use or trade the excess energy to the consumers in the grid, Mahmood et al. (2017)

In the smart grid, energy subscribers will be able to do generation, storage, and sell the generated energy to other subscribers in the grid Rathnayaka et al. (2015). The smart grids are supposed to be self-healing and must support for controlling it from remotely and also for remote monitoring Farhangi, (2010).

Electric power is generated by using multiple sources of energy, which is converted into electricity and then, transmission and distribution of the electricity take place Alanne and Saari (2006).

The world's demand for energy is increasing rapidly. The International Energy Outlook 2017 (EIA, IEO2017) is projected a 28% increase in world energy consumption between 2015 and 2040 (EIA, IEO2017). The present demand for energy is mostly fulfilled using petroleum, coal, and natural gas. Nevertheless, the exploitation of the above mentioned non-renewable sources of energy will result in environmental pollution, generate more heat leading to global warming, resulting in the emission of greenhouse gases, and lead to health hazards and other negative impacts on the environment and humans and animals. As a result, energy consumption is rapidly changing from non-renewable to renewable sources of energy.

Furthermore, to manage the fast-growing demand, the provider-consumer unidirectional model is now being transformed into a bidirectional energy and information model. To enable this transformation, digital communication technology in the energy network is rapidly on the rise, resulting in the smart grid concept. The smart grid is defined as "an electric system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated

fashion across electricity generation, transmission, substations, distribution and consumption to achieve a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable (Gharavi & Ghafurian, 2011)" It is rapidly gaining acceptance because of its many advantageous features and holds potential benefits such as self-healing, enhanced consistency and reliability, better power quality, moderated peak demand, increased asset utilisation, reduced transmission congestion costs, increased security, and improved resistance to malicious attacks or unfavourable natural events (El-hawary, 2014).

Understanding the Edge

While the Internet of Things, or IoT, has been a buzzword for a decade or more, the term commonly referred to a centralised system where simple networked sensors shared data back to a server which could be used to better understand and control complex processes. The above technological evolution is followed by the decentralisation of the computing process and shifting the computation and analysis from a centralised hub to the multitude of devices that gather data such as different types of sensors on machines, telemetrics systems used in fleets of vehicles, In warehouses and retail facilities, data is collected using RFID scanners, and also by the use of mobile computing devices used by workers. This has been driven by the development of smaller, more affordable and more power-efficient chips designed to meet the needs of an increasingly mobile world.

This shift to the edge will enable IoT devices to increase processing capabilities significantly, allowing machines to talk to each other directly, tracking solutions that make real-time updates to inventory systems, employees who can do real, substantive analysis on mobile devices—and all of this can help constantly streamline workflows and identify potential challenges before they erupt into something more costly. Moving to "the edge" enables technologies like machine learning and AI that can understand data better and faster than a human operator, generating deep insights into complex processes that help keep pace with the demands of today's market. Figure 3 shows the various IoT application domains where IoT is currently used extensively.

As expectations grow, the organisations that are successful will be those that are best able to capture data across their organisation and translate it into actionable intelligence for their workforces. But what do you need to ensure your organisation can compete?

Choosing the Right Connected Technology to Keep the Industry Efficient and Competitive

In a highly volatile and fast-changing industry with very small profit margins, a technology that is embraced and used by organisations in an industry is only as worth and priced as its ability to perform on the organisation's most difficult day—this means the systems must be capable of achieving the entire supply chain visibility and transparency globally, through seamless integration and connectivity of the entire supply chain starting from the suppliers, the manufacturers and the distributors. Also, it has to be made that the organisations have the appropriate computing hardware, equipment for communication, connectivity and network devices and software applications that can be easily modified to suit the requirements, have high security and be managed efficiently to achieve the short-term and long-term objectives of the organisation. Organisations planning on investing in this kind of next-generation edge computing technologies will have to ensure that each component of their technology chain meets enterprise-grade requirements. The devices, software and services that come together to enable "the edge" need to be reliable, robust and designed at their core to handle large amounts of data from disparate sources.

To summarise, the most important components of an edge ecosystem are:

- A network of smart, connected devices constantly generate valuable and real-time data on all activity within the organisation's supply chain with minimal downtime.
- Reliable and dependable connectivity among the supply chain partners allows the most widespread supply chains to remain connected, regardless of their geographical location.
- Smart software can accept diverse, complex data and convert it into actionable intelligence for the organisation and its employees to make useful decisions.

They are looking at the first component the devices that will gather and analyse the data from the supply chain and convert the data into actionable and useful intelligence at the source of capture. For the logistics industry such as in the warehouse, transportation and other logistics activities, a lot of real-time streaming data will need to be generated using automated devices with many kinds of in-built sensors and large computing capabilities. For instance, RFID scanners can keep track of where an inventory item is and instantly share that information with devices throughout a network. Also, material handling equipment such as conveyors, sortation systems, automated guided vehicles such as guided forklifts or stretch or shrink wrappers nowadays have smart sensors attached to them so that they can identify maintenance requirements, inefficiencies in the storage and transportation processes or order accuracy issues instantaneously.

Edge IoT not only uses automated sensors but is also about providing warehouse associates and vehicle drivers with devices that enable them to become part of the data capture process at their places of work.

For example, as truck drivers must perform electronic logging to comply with the United States introduced ELD (electronic logging devices) mandate, they can also become data generators. These devices are intended to record data about the operation of the vehicle and the activities of the driver. The driver information mostly consists of the hours of service (HoS). Commercial vehicle drivers have a restriction as to the maximum number of hours they are g on-duty hours were in drivers are working but not driving) and rest time over the entire period of the trip.

Manual logbooks using paper were initially used, with the information entry done by handwriting.

The ELD mandate paper logs and an earlier recorder called an Automatic On-Board Recording Device (AOBRD) must be replaced by the automated ELD technology.

Several handheld computing devices fulfil the requirements of the ELD mandate. They can deliver even more valuable data that can make fleet management more efficient than ever, information like the status of loading docks, the need for refrigerated or other speciality trucks, when a customer is available to accept delivery, and more. So, in addition to a safety benefit, an enterprise mobile tablet or handheld used for electronic logging can also provide valuable insights into where shipments are and when they can be expected to be delivered.

In the warehouse, equipping workers with rugged handheld devices offer them a window into the edge IoT network to better monitor and understand data as it is being generated. This means a workforce can spend more time addressing inefficiencies and heading off challenges before they become problems.

Second, connectivity issues determine how good a modern connected ecosystem is. As demands on real-time data collection increase and as supply chains are becoming increasingly global, the connected technology must have the ability to match this scope of becoming global and the scale of data required. A truly powerful edge network is not about connecting one facility or one fleet of trucks; it's about a global network of devices and workers sharing insightful data as fast as possible, with as much computation done at the source of the data as possible. This means you must have reliable and high-speed data connectivity across a network, no matter where a job might take you. A factory in Mumbai, India, needs to "speak" with a rail car container carrying goods in Penang, Malaysia, which needs to be able to share data with a warehouse in Stuttgart, Germany, which needs to talk to a distribution centre in Allentown, USA—and for the end-user, all of this needs to happen seamlessly and on-demand.

Third, organisations require suitable software that can analyse and make sense of all of this data captured from various sources and can be used for automated business intelligence. Even with much of the computation being done at the edge, end-users need to have a view into these complex systems that empower them to understand and act on the data being collected. Irrespective of whether the data is accessed through the network from a desktop terminal, a laptop, a tablet, or a handheld device, they must be able to view, interrelate with, and modify processes wherever, whenever. This requires the organisation to work with a technology partner who can guide the organisation and make sure that

they have the right software for their needs, as well as the ability to access the data using a variety of devices and operating systems.

Lastly, investing in "the edge" and depending on it to achieve an edge over the competitors requires that the organisation need to ensure that as any technical issue arises or whether maintenance and be able to quickly respond to the need for servicing and repair of the organisation's mobile workforce devices. The best supply chain is only as good as its ability to be resilient in the face of unexpected downtime.

And for each of these critical components, it is important that an organisation's resources are protected by enterprise-grade security. As more capital is invested in connected systems, maintaining their integrity becomes a paramount concern. This means that you should be certain that you're protected at all three levels: hardware (handheld devices or automated machines), the network level, and at software level.

Smart Solutions for the Edge Ecosystem

The growing demands on supply chain and logistics organisations are linked with often downsizing IT departments. This means that organisations that want to stay ahead of the competition are outsourcing their IT activities by turning increasingly towards external service providers and vendors who have the expertise and can assist them in tackling the modern technology challenges. The deployment of an intelligent, data-generating network is a major, large-scale challenge that requires immense expertise in deploying, installing, training and servicing a network made up of multiple kinds of devices and software across many geographies.

Identifying a vendor who can provide a full-scale solution—versus just a device or piece of software— alleviates pressures on already stretched IT staff and reduces the complexity involved in maintaining a system over its life. For today's organisations looking to maximise efficiency through a connected ecosystem, finding the right partner is key to ensuring success.

The Smart Grid

The Smart Grid is highly essential to develop a safe, reliable, efficient, secure, less polluted future,

as per the International Energy Agency (IEA). The IoT framework includes the Smart Grid as one of its parts. This can be utilised to remotely oversee and control and manage efficiently many things such as company lighting, traffic lights, vehicular congestions on roads, availability of parking spaces, road warnings, and also act as an early detection and warning system for power influxes as the result of natural disasters like earthquakes and extreme weather. The smart grid technology can be of great benefit in the entire supply chain, where energy is consumed at the supplier's manufacturing operations, storage, distribution, etc. At the manufacturer's site also, the smart grid is useful for their manufacturing operations, storage and distribution and finally at the distributors also at the wholesalers and retailers, where energy is consumed in their various activities. The Smart Grid achieves this by using a network of power transmission towers and lines, meters that have smart sensors, automating the power distribution function, substations, transformers, sensors, software and more that are given to organisations and private residences all over the city (Dauxerre, 2018)

Smart Grid technologies lead to efficient IoT-based energy management solutions which are not present in the framework being used currently. The advantage of IoT Smart Grid is the presence of two-way communication between various devices which are connected and the hardware that can identify and send a suitable response to the customers' requirements. The usage of such technologies indicates that a Smart Grid is more robust and resilient and less expensive than the presently used infrastructure.

The infrastructure of Smart Grid Technology is given in Figure 1 below:

Figure 1: Infrastructure of Smart Grid Technology

Several manufacturing firms utilise diverse sources of power in order use them for different applications. The common source of energy which is used is the current electricity. The other source of energy that is used equally is natural gas. These energy sources are usually supplied by electricity boards of states or other private electricity suppliers who use their energy resources. Alternatively, energy can also be generated in the firm's premises by making use of solar panels, wind turbines, as well as geothermal technologies. Of course, the most popular source is obtained by using fossil fuels that undergo combustion. The most popular applications of energy among the industries are lighting and HVAC systems, manufacturing applications, transportation, as well as different types of process equipment.

The cost incurred due to utilising energy is not very evident or obvious to the top management of the organisations since several firms classify them as overheads rather than their applicable processes. Normally, the commonest method of documenting energy or power usage is the electricity bill, which charges the company based on the electricity utilisation during the billing cycle.

Procuring Green Power

The term "green power" is used to describe multiple ideas and concepts. Still, in the most common usage, it refers to environmentally-friendly and preferable energy and energy technologies. Electricity boards and utility providers allow their customers to purchase a part of their electricity usage from renewable energy sources. These electricity and energy providers' sources of renewable energy come from sources such as hydroelectric, solar, wind, biomass, and geothermal and other sources of renewable energy. Figure 7 shows how renewable energy sources can be used along with smart grid technology to supply power to houses efficiently.

The price of electricity generated utilising non-renewable sources such as fossil fuels is never constant. It changes frequently and most of the time the price only increases as its price depends on the international fuel prices. But the power that is generated from green energy sources does not show similar price variations and the development of more modern technologies make the green more affordable and more cost-efficient, thereby encouraging organisations and governments to invest in such renewable energy resources. The most prominent environmental benefits of green power procurement include less pollution, zero or minimal emissions, no large emissions of greenhouse gases, and finally and importantly, protecting human health and a cleaner environment. . It is necessary that organisations also realise the potential financial benefits through the use of green power. Procuring power from renewable energy sources provides stability in the electricity costs and are not subject to the frequent variations of fuel costs. In the market, the usage of renewable sources of energy may be able to distinguish the organisation's products and services from that of competitors and also becoming a preferred green supply chain partner.

Monitoring and Controlling Energy Use

Techniques used for monitoring energy usage at the facilities level should be from the viewpoint of total energy utilisation processes. This includes the manufacturing processes of the facility and the other supporting energy sources and the impact on the environment due to those sources. Exhaustive energy usage monitoring consists of measuring in regular periods, performing documentation and reporting the important energy flows and also attempt to identify the energy savings as shown in Figure 2. Proper forecasting of energy requirements must be made and hence energy consumption can be monitored and controlled efficiently.
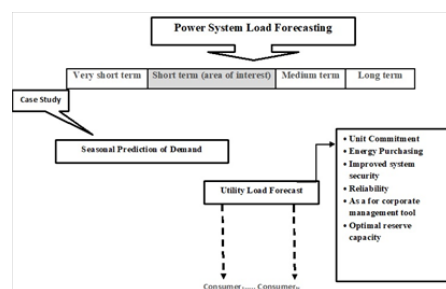

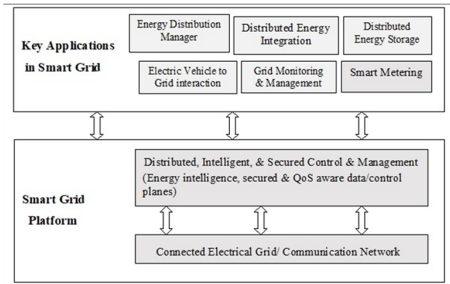**Figure 2: Forecasting Power Requirements**

Figure 3: Key Applications and Platform in a Distributed Smart Power Grid Applications

Development of plans of action and measuring the progress in attaining the targets related to energy performance must be done against these action plans. Energy improvement opportunities must be identified by comparing the monitoring data with several operational factors, such as work shifts, equipment maintenance procedures, operators and other standard operating procedures. Ensure that targets are reasonable by comparing the monitoring data against the benchmark data. The future of power generation and distribution will be in a distributed framework, with applications and the platforms in a distributed system architecture, as shown in Figure 3 below.

Conclusion

Microgrid model can be used along with renewable energy sources to provide power to houses and industries more economically and efficiently. Smart grid technology uses the Internet of Things to gather power usage data from various equipment and be able to predict future power usage. Based on these predictions, an accurate amount of power can be generated and supplied to the various customers of the power grids.

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