Intelligent Smart Grid Based Fully Automated AI System

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***Abstract*—The conventional smart grid is based on large, centralized power stations that supply end-users via long-established, transmission and distribution systems. Over the years it has performed very well in delivering secure and reliable power. But in this time consumers have different demand profiles and generators have different volatilities. So these traditional power grids have no. of challenges. These challenges will require research within the artificial intelligence (AI) communities to make smart grid intelligent. We need an intelligent smart grid that can receive power of all qualities from all sources – both centralized and distributed – and deliver reliable supplies, on demand, to consumers of all kinds. Intelligent Smart grids will grow through evolution rather than revolution. We expect to see a gradual transformation of the systems that have served us for many years into a more intelligent, more effective and environmentally sensitive network to provide for future needs. This paper presents a vision of the smart grid in transmission and distribution system, which will be fully automated based on artificial intelligence (AI).**

***Keywords*— Distribution system management (DSM), electric vehicles (EV), the emergence of prosumers, and self-healing networks (SAN).**

I. Introduction

This key challenge for grid computing is creating large-scale, end-to-end scientific applications that draw from pools of specialized scientific components to derive elaborate new results. Given a user's high level specification of desired results, the Pegasus system can generate executable grid workflows using AI planning techniques. A fully automated power delivery network is that monitors and controls every customer and node, ensuring a two-way flow of electricity and information between the power plant and the appliance, and all points in between [12]. Its distributed intelligence, coupled with broadband communications and automated control systems, enables real-time market transactions and seamless interfaces among people, buildings, industrial plants, generation facilities, and the electric network [12].

In this time reduction of carbon in environment is a bigger problem for various countries. Achieving this aim requires that the direct use of fossil fuels that we are familiar with today is almost entirely eliminated. Thus, the use of electric vehicles and high speed electric trains will have to become widespread in order to reduce use of petroleum oil for transportation. Likewise, our homes and offices will have to be heated by efficient ground and air source heat pumps powered by electricity rather than existing natural gas and oil fired boilers [22]. As a result, electricity demand across the world is increasing by approx 76%, or 4800 gigawatts (GW), by 2030 (compared to 2007 levels) [20]. Crucially, much of the electricity needed to meet this demand will have to be generated from renewable wind, solar, and tidal sources rather than the coal and natural gas power plants that we use today.

It is this increased demand for electricity, and the requirements for its generation, that present perhaps the greatest challenge. In various countries there have been no changes in electric grid since decades in the infrastructure concerning T&D of electricity leading to significant inefficiencies arising from losses within the transmission (on a national level) and distribution (on a local level) networks [12].

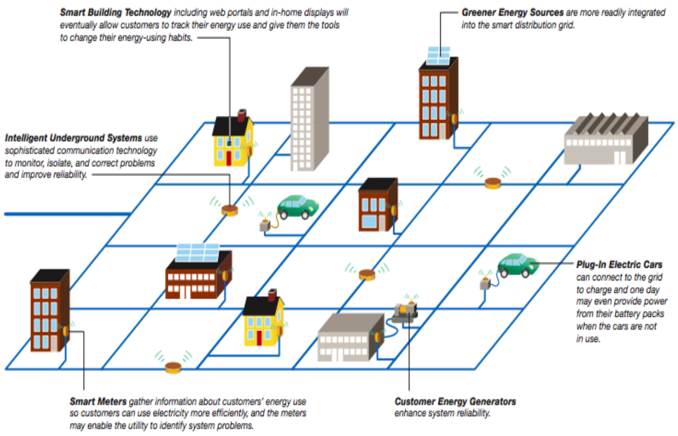

Fig. 1- Physical View of Power supply with smart grid

The vision of an electricity grid that makes extensive use of renewable generation challenges this current situation. But renewable generated energy cannot be possible for longer continuously supply due to vary significantly over minutes and hours. Thus, in this situation smart grid in the demand-side will have to be managed to ensure that demand for electricity is matched against the available supply. Electric vehicles will provide a distributed form of energy storage which may allow the grid to smooth out this variable supply.

Furthermore, Renewable generators may work as virtual power plants, or may be located on every building across the grid, resulting in a distributed network of prosumers, who both produce and consume electricity depending on their local requirements. Thus, unlike existing grids where electricity generally flows one-way from generators to consumers, this will result in flows of electricity that vary in magnitude and direction continuously. To diagnose potential problems and self-heal in the number and variability of generators will require that the grid is able to act autonomously under human supervision but not necessarily under human control.

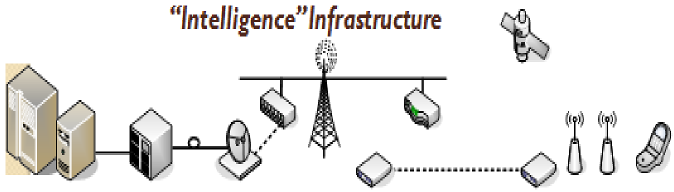

Fig. 2 intelligent grid

Grids should provide automated workflow generation techniques that would incorporate the necessary knowledge and expertise to access grids while making more appropriate and efficient choices than the users themselves would. The challenge of usability is a key because it is insurmountable for many potential users who currently shy away from intelligent grid.

II. DISTRIBUTION SYSTEM MANAGEMENT

For years, strategic planning in many electric utilities has centered on electric generation and transmission. But as paradigms in the energy industry evolve, distribution is getting a lot more focus. The people managing the smart grid of the future face the daunting challenge of managing a distribution network that is more complex and multi-dimensional than what was conceived in its original design and engineering. Now it must plan not only for utility's generation, but also increasing use of decentralized sources on the grid.

New grid should have addition of monitoring equipment, like syncrophasers, to offer voltage measurements by the microsecond to allow operators to see the constant state transmission system feedback. DMS is a real-time solution that provides complete functionality for the planning, operation and analysis of distribution system. Its open architecture is designed for easy integration with other key Smart Grid applications, like SCADA, GIS, and OMS products. It's also highly scalable, making it ideal for utilities of any size. It comes with a highly visual and intuitive GUI, and it's supported by the world's strongest talent in power engineering and computer science.

Features and Benefits of DMS

• Network View combines dynamic power system equipment model and geospatial data into an intelligent, real-time electronic map-board for individual screens and large scale displays

• Fully integrated with SCADA

• On-Line Network Analysis Tools: Bus load allocation, load flow, limit monitoring, restoration plans, loss Reduction

• Performance Indices

• Proactive tools: look ahead analysis, contingency studies, advisory plans with protection validation

• Combined dynamic connectivity and customer characteristics/ profiles provide accurate bottom-up demand model that lead to better nodal-point load forecasts for short term planning and market checks and balances

• Integration with Transmission EMS: provide more realistic security analysis

• Network View presents transmission as well as distribution assets

• Model updates from GIS go on-line without interruption to users

• Integration of unplanned outages with planned switching activity and crew monitoring in one graphical UI

• Integration of FISR and other distribution network analysis functions in one graphical UI

• Integration of automated notices of grid occurrences, like meters without power from AMI

Thus, in summary, we believe the key AI challenges in demand side management are:

Distribution management systems (DMS) – or integrated DMS – are terms as electric utilities find that integrated systems will allow them to realize greater value from smart grid technologies. In many cases, distribution management systems are the command and control centers that run these technologies. For instance, DMS will enable utilities to maintain more control over things like distributed renewable generation. DMS will help them analyze outages for fault detection, isolation and restoration. Improvement in grid efficiency is another DMS benefit. There are also synergies between DMS and distribution automation. Scroll through the content below to learn more about distribution management systems and their role in a smarter electric grid.

III. ELECTRIC VEHICLES

The smart grid is typically thought of a system designed to alleviate stress on the electric grid. The vast majority of smart grid technologies are produced with this concept in mind – with the exception of electric vehicles. These are touted as part of the smart infrastructure, yet putting a strain on the grid rather than lighten the load. Today electric vehicles (EV) and plug-in hybrid EVs (PHEVs) don't claim a significant share of the automotive market, but that will change rapidly. Every utility needs to begin understanding how it will handle the opportunities and challenges EVs will create.

The impact of electric cars on power supply systems can be huge. Massive numbers of electric cars can have a devastating effect on the power grid when plugged in almost simultaneously. Nevertheless, the large numbers of electric cars have their benefits. Until now, the power supply systems have not had electricity storage. Because of the batteries of electric cars, the power supply system now has a potential backup power supply, the size of which depends on the number of electric cars. The potential of electric cars as a part of the power grid have been subject in many studies [4, 18,20].

Electrical vehicles (EVs) are a radical shift not only in how a vehicle is build but also how it is integrated into the power supply infrastructure. For instance, with fixed mounted batteries the vehicle will no longer be fueled during a stopover at a gas station but be charged at home, at work, during shopping on a parking place or even fast charged during a stopover. Vehicle-to-grid (V2G) describes a system in which plug-in electric vehicles, such as electric cars (BEVs) and plug-in hybrids (PHEVs), communicate with the power grid to sell demand response services by either delivering electricity into the grid or by throttling their charging rate.

Electric vehicles charging points will be part of smart grids. Utilities can see the electric vehicle as part of the new smart grid, allowing them to have real time energy demand data, thus enabling its energy grid to be more efficient, reliable, distributed, and interoperable. Our goal is to help electric utilities to be more efficient in the distribution of electric power. Intelligent smart grid helps to accelerate the adoption of plug-in electric vehicles, by significantly decreasing the time needed for vehicle charging through the use of smart grid technology, allowing utility companies to manage the impact of electric vehicles on the demand side.

IV. BENEFITS

Electric vehicle application provides a comprehensive utility and consumer solution that reduces the need for costly upgrades to the existing utility´s infrastructure.

Electric Vehicles charging stations at home are connected to the utility´s in-home portals so that demand requirements are available and decisions can be made or automated to best manage this load.

Thus, we identify in the deployment of EVs in the smart grid as follows:

• Predicting an individual user's EV charging needs based on data about her daily activities and travel needs.

• Predicting aggregate EV charging demands at different points in the network given the continuous movement of EVs, the available charge in their batteries, and the social activities their users engage in.

• Designing decentralized control mechanisms that coordinate the movement of EVs (each with different battery capacities and charging speeds) to different charge points by providing incentives to consumers to do so.

• Designing algorithms to optimize the charging cycles of EVs to satisfy the predicted needs of the user (to shift loads or to travel) while maximizing the profits generated from participating in V2G sessions.

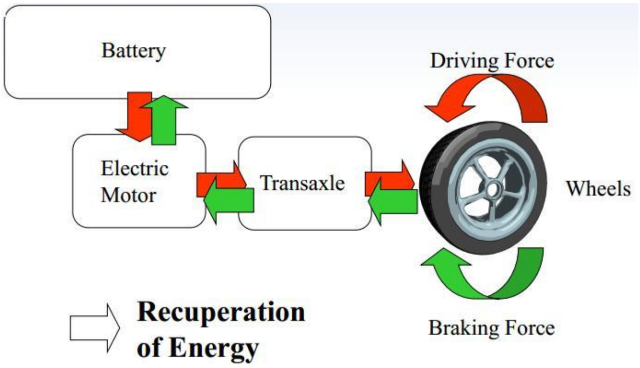

Fig. 3 electric vehicle

V. ENERGY PROSUMERS

In a SmartGrid a prosumer can be a new and active participant in balancing the electricity system. ―Prosumer‖ is an emerging concept in the power market that applies to consumers of energy that can also be producers. A prosumer can be characterized by distributed generation technologies, energy storing equipment, smart meters and equipment to monitor, control and operate. The Smart Grid creates the basis for intelligent integration of user-actions in securing a continuing high supply security while integrating more fluctuating renewable energy into the electricity supply system. An important requirement is acceptance and active adoption of the new possibility by the prosumer.

Smart Grids will become more of a reality as the network of distributed electricity producers increases. Smart Grids will accommodate the connection of new energy sources, such as windmill parks, and give end consumers the possibility to participate actively in electricity distribution. Logically, this includes not only consuming electricity, but using solar cells or small windmills to generate and send back electricity to the smart grid, creating a unified network of energy prosumers. In short, Smart Grid technologies will revolutionize our entire electricity systems and give residential end customers the chance to manage their energy consumption optimally.

In particular, this is set against the current operation of the grid where, in many countries (e.g., the US, UK, and in many parts of the EU), the electricity market is deregulated, such that large generators (located far from the point of use) trade directly with retailers who then sell the electricity on to consumers through fixed contracts and tariffs [19, 35]. An intelligent smart grid is very different energy marketplace where utilities are buying and injecting energy into the distribution grid (the low voltage side) in addition to the bulk or high voltage supplies. Whether utilities are investor-owned utilities (IOUs), municipals, or rural cooperatives, they can work proactively to recast energy buying and selling with more participants, including producing consumers or prosumers.

With the emergence of the SmartGrid and distributed small-scale energy production we may also see the rise of the prosumer in the energy market too. That will of course imply that consumers of energy can also be producers. This could be a household, a plant, an office or similar. Interestingly this also means that a prosumer can be a new and active participant in balancing the electricity system.

In summary, with the intelligence smart grid to trade in electricity markets whilst ensuring safe network flows include:

• Developing computationally efficient learning algorithms that can accurately predict both the prosumers' consumption and generation profiles (instead of only the usage profile for a consumer) as well as the price of electricity in real-time in order to inform profitable trading decisions.

• Developing autonomous trading agents that can use such predictions to maximize their profit in the electricity market, and efficient algorithms to marry congestion management with market operation in distribution networks while guaranteeing good equilibrium conditions in the system.

• Developing human-agent interaction mechanisms, to allow prosumers to guide their agents trading decisions, that take into account the prosumers' daily constraints and preferences to consume or produce energy.

VI. SELF-HEALING NETWORKS

Beyond the real-time monitoring a Smart grid provides, a self-healing network automates decision-making about outage events and extends it into the field. Systems will allow for the outage to be localized by opening and closing switches to reroute electricity—thereby minimizing the impact to customers as well as the degree of revenue lost due to an outage.

when faults causes loss of power to parts of the network, it must self-reconfigure to isolate the faulty areas and resupply power to the healthy ones, taking into account a range of constraints (e.g. capacity constraints) and optimization criteria (e.g. as load balancing).

Intelligent smart grid challenges the mechanism of self healing networks i.e. designing computationally efficient state estimation algorithms that can predict voltage and phase information at different nodes in the (partially observable) distribution network, in real-time, given the prosumers' current and predicted energy demand and supply, enabling distributed coordination of automatic voltage regulators and energy providers and consumers for voltage control and balancing demand and supply during recovery from faults and automating distributed active network management strategies given the uncertainty (either because they cannot be accurately measured or there is incomplete information about certain nodes) about demand and supply at different points in the network.

VII. CONCLUSION

Smart grid needs some automation, information exchange, and distributed intelligence. In this paper, the role of smart grid with AI is discussed. Our claims build upon an extensive survey of the state of the art that goes beyond the papers cited and includes a large number of references (spanning technical papers, books, and policy documents relating to the deployment of specific smart grid technologies and evaluations of these) provided in the online appendix. In particular, we have highlighted the key issues in learning and predicting demand or supply at various points in the network given the variety of demand control mechanisms (e.g., demand-side management and EV charging) and energy sources, each with different degrees of uncertainty in their production capability (e.g., VPPs or renewable energy sources). Moreover, we showed thatthe automated decentralized coordination between such entities (to balance demand and supply while ensuring flows on the network are always secure) will need to factor in both the individual properties of all actors (e.g., EVs with different batteries, different types of renewable energy sources, users with their own understandings of trading decisions and their agents' decisions) involved and the incentives given to them to behave in certain ways (e.g., consumers shifting demand due to real-time pricing, or VPPs sharing profits equitably). Building upon this, we also discussed some initial attempts at solving them within the various sub-areas of the smart grid. Cutting across these various challenges are the issues of human-computer interaction, heterogeneity, dynamism, and uncertainty that are an intrinsic part of decision making and acting in the smart grid. By dealing effectively with these factors, we believe it will be possible for future generations to rely on their energy systems to deliver electricity efficiently, safely, and reliably. Finally, we note that many of the issues present within the smart grid also arise within other domains such as water distribution, transportation, and telecommunication networks where large numbers of heterogeneous entities act and interact in a similar fashion to those within the grid. Hence, there is potential to transfer technologies across these domains and also address broader issues that affect the sustainability of such systems in a unified manner, such as cyber-security and the ethics of delegating human decision making to intelligent systems.

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