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Application of Cloud Computing In Smart Grid: A Review

Pradeep Kumar Verma, Himanshu Sharma
Department of Electrical Engineering, Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India

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Abstract

The smart grid refers to electricity transmission and distribution system integrated, sophisticated sensing and monitoring,information and communication technologies to create an automated, intelligent, and widely distributed energy delivery network. Electrical Energy is the linchpin of our economic future.Increasing concern about energy consumption is leading to infrastructure that supports real time, bilateral communication between utilities and consumers, and allows software systems at both ends to control and manage power use.In this paper we propose Cloud Computing (CC) paradigm because of its indispensable benefits of low cost, flexible & redundant architecture with fast response. CC has functionality to provide security, interoperability and best performance required for a large scale & complex Smart grid application.

1. Introduction

Energy is a measure of standard of living & quality of civilization. Social activities of human life are based on production & consumption of energy. Energy is indispensable necessity for existence of Modern era. Smart grid (SG) Intensification of the 20th century electrical grid, is regarded as a system that uses bilateral communication and information technologies, and computational intelligence in an integrated environment across electric energy followed by generation, transmission, distribution and utilization to accomplish an electric power system which is clean, secure, reliable, efficient, and sustainable.SG regarded as the new generation electric grid, will use advanced power, communication, and information technologies to create an automated, intelligent, and widely distributed energy delivery network. With the enhancement of advanced applications and services that can lifting the capability enabled by the advanced information system for smarter grid. However, indefeasible miscellaneous information generated in the SG because of extensively utilized supervising and control devices calls for a powerful and worthwhile information management system (IMS) for data processing, analysis, and storage. Here IT industry will help us to assist in IMS of smarter grid. Especially Cloud Computing paradigms serve the information management system in smart grid. Cloud Computing refers to large data centres with gigantic computation and storage capacities. Cloud Computing paradigm provide facility to share resources, software, information, and storage data. Smart grid information management system achieved by Cloud Computing paradigm. The potential benefits of an enhanced smart grid are enormous. Smart grids have capability of important services for users e.g.; ability to manage electricity use and its costs, along with better support for distributed generation consumption. A scenario prepared by the Electric Power Research Institute (EPRI) suggests that transformation of the power grid over the next 20 years could result in substantial increases in productivity. [1] [2] [3] [4] [5]

2. Smart Grid: An overview

Modernization of the electricity delivery system so that it monitors, protects and automatically optimizes the operation of its interconnected elements – from the central and distributed generator through the high-voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices. The Smart Grid is a combination of hardware, management and reporting software, built atop an intelligent communications infrastructure. In the world of the Smart Grid, consumers and utility companies alike have tools to manage, monitor and respond to energy issues. The flow of electricity from utility to consumer becomes a two-way conversation, saving consumers money, energy, delivering more transparency in terms of end-user use, and reducing carbon emissions. The basic pillars of Smart grid are transmission optimization and demand side management and distribution optimization and asset optimization. To meet the faithful implementation of all these functions of the smart grid, certain techniques have been proposed by the modern researchers. In this paper, a emphasis has been made on the exploration of different control strategies implemented to ensure the fault free and efficient operation of smart grids at all levels. [6]

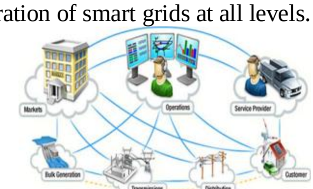

Fig: 1. Concept of a smart grid. [7]

3. Cloud Computing Utility in Smart Grid

Cloud computing paradigm is plays a vital role in power sector for several economic &technical issues. CC can be managed reasonably in highly automated ways, and provide protection against attack more easily than ongoing systems. So finally, cloud computing paradigm offers amazing features .i.e.; capacity and elasticity. Modern cloud computing system is often perform on few data centres which might have more efficient computing than world's supercomputing centres added together. [8] [9]

Corresponding Author,
E-mail address: pradeep.k.verma002@gmail.com

Here we take account of some issues in using the cloud for building the smart grid.

3.1 Scalability

The cloud computing dilemma have resulted in the displacement of previous key IT playersas Intel, IBM, and Microsoft etc. by new as Google, Facebook etc. Technology these new-age companies created is becoming inevitable prevailing for any infrastructure of computing involving scalability: a concept that can be in direct contact with large numbers of advanced sensors, intelligent actuators or customers, but can also assign to the ability of a technical solution to run on large numbers of lightweight systems ,reasonable servers within a data Storage centre. Earlier approaches were often discarded precisely because of their poor scalability. [10]

3.2 Cost

The Smart Grid needs a national-scale, common network that connects coal, gas, nuclear , hydro, solar & Wind power plants to each other including small independent electricity producers with load centre. Cloud computing enable exchange information and control of power production and consumption. The scale of such an undertaking is mind blowing. It is very easy tobuild apps that control appliances, based on power pricing information. Cloud computing paradigm offers strong cost advantage that electrical power community cannot deny them in favour of restricting a private, dedicated system for future smart grid.[11][12]

3.3 High Performance Computing (HPC)

As we all know that SCADA is high performance computing applications .It therefore a question arise that how the cloud perform better than HPC. In 1990s, HPC revolved around special computing hardware with unique processing capabilities in power plants & Industries. These devices were expensive. HPC often requires the availability of a massive number of computers for performing large scale experiments. Traditionally, these needs have been addressed by using high-performance computing solutions and installed facilities, which are having problem to setup, maintain, and operate. Cloud computing provides scientists with a completely new model of utilizing the computing infrastructure. Compute resources, storage resources, as well as applications, can be dynamically provisioned (and integrated within the existing infrastructure) on a pay per use basis. These resources can be released when they are no more needed. The adoption of Cloud computing as a technology and a paradigm for the new era of computing has definitely become popular and appealing within the enterprise and service providers. It has also widely spread among end users, which more and more host their personal data to the cloud. For what concerns scientific computing, this trend is still at an early stage. [13]

3.4 High Assurance Applications

Cloud computing was not designed for high-assurance applications so poses numerous challenges for accommodate a massive infrastructure service like the smart grid. One complicating factor that multiple companies often share the same data centre, so as to keep the servers more evenly loaded and to amortize costs. Multiple applications invariably run in a single data centre. Thus, whereas the Electrical power community has always owned and operated its own proprietary technologies, successful exploitation of the cloud will force the industry to learn to share. This is worrying, because there have been episodes in which unscrupulous competition within the power industry has manifested itself through corporate espionage, attempts to manipulate power pricing, etc. (ENRON being only the most widely known example). Thus, for a shared computing infrastructure to succeed, it will need to have ironclad barriers preventing concurrent users from seeing one-another's data and network traffic. The network, indeed, would be a shared resource even if grid operators were to run private, dedicated data centres. The problem here is that while one might imagine creating some form of separate Internet specifically for power industry use, the costs of doing so appear to be prohibitive.

Meanwhile, the existing Internet has universal reach and is highly cost-effective. Clearly, just as the cloud has inadequacies today, the existing Internet raises concerns because of its own deficiencies. But rather than assuming that these rule out the use of the Internet for smart grid applications, we should first ask if those deficiencies could somehow be fixed. If the Internet can be enhanced to improve robustness (for example, with multiple routing paths), and if data is encrypted to safeguard it against eavesdroppers (using different keys for different grid operators), it is entirely plausible that the shared public Internet could emerge as the cheapest and most effective communication option for the power grid. Indeed, so cost-effective is the public Internet that the grid seems certain to end up using it even in its current inadequate form. Thus, it becomes necessary to undertake the research that would eliminate the technical gaps. [14]

4. Comparison between Exiting & Smart Grid

The smart grid is a complete enterprise-wide information system framework and infrastructure, which can be achieved for electricity customers, continuous monitoring of assets and operations, improve management, efficiency, grid reliability and service levels in comparison to existing grid.[15]

We can comp are both grid on the behalf of some measures which are as follows:-

Measure	Existing Grid	Smart Grid
Communication	One way with time delay	Bilateral in real time
Customerinteraction	Limited	extensive
Metering	Electro-mechanical	digital metering enabled with real time pricing & internet
Operation	Manual	Remote supervising
Generation	centralized	Centralized & distributed
Power Flow control	Limited	Comprehensive & Distributed
Reliability	Prone to	Automate, pro-

	failure , cascading outages , essentially reactive	active, protection ,prevents outage before the start
Restoring following disturbance	Manual	Self-healing
System topology	radial	Multi pathway

5. Evolution of Cloud Computing in Smart Grids

The cloud uses by the smart grid even now the impact of cloud computing paradigm over smart grid is studied almost at theoretical level and also the advantages of this transformation of the power industry are not so well defined. However this is starting to change since both the administration and the industry realize the interaction between these two models and the increasing interest for exploring and understanding .The massive development of the electrical power requires progressively enormous and real-time computing and storage capacity. In smart grid concepts, the amount of these resources will grow in all levels of the grid in a uniform distributed manner. Here, the cloud model comes into the scene and becomes very significant.

Cloud computing is probably the simplest and best fitted way for these kind of application (smart grids) due to its scalable and flexible characteristics, and its capability to manage large amounts of data. The construction of a smart grid necessitates large-scale real-time computing capabilities in order to handle the communication, the transport and the storage of big transferable data. But once the distributed entities are in place, cloud computing will unload the smart grid by offering automatic updates, remote data storage, reduced maintenance of IT systems – saving money, manpower and energy.

In recent times, researchers have studied how to use cloud computing to manage the smart grid.

Yogesh Simmhan et al. analyzed opportunities and challenges of using cloud platform for demand response optimization in the smart grid. [16]

Hongseok Kim et al. proposed a cloud-based demand response architecture for fast reply time in large scale deployments, in contrast to master/slave based demand reply where the customers directly interact with the utility using host address- centric communication. [17]

Mohsenian-Rad et. al. formulated the service request routing problem in cloud computing together with the power flow analysis in the smart grid and explained how this can lead to gridaware cloud computing routing algorithms. [18]

Cristina Alcaraz et. al. described some security mechanisms that will help in a better integration of smart grid and clouds. [19]

Sadia Fayyaz et. al. focuses on security issues for smart grid 60 Cloud Computing and Smart Grids applications using cloud computing framework. [20]

S. Rusitschka et al. presented a model for the smart grid data management based on specific characteristics of cloud computing, such as distributed data management for real-time data gathering, parallel processing for real-time information retrieval, and ubiquitous access. [21]

Nikolopoulos et al. proposed a decision-support system and a cloud computing software methodology that bring together energy consultants, consumers, energy service procedures and modern web interoperable technologies.[22]

Xi Fang et. al. analyzed the benefits and opportunities of using cloud computing to help information management in the smart grid. [23]

Simmhan et al. analyzed the benefit of using Cloud platform for demand response optimization in the SG. [24]

Rusitschka et al. presented a model for the SG data management based on CC, which takes advantage of distributed data management for real-time data gathering, parallel processing for real-time information retrieval, and ubiquitous access. [25]

Nagothu et al. proposed to use CC data centers as the central communication and optimization infrastructure supporting a cognitive radio network of smart meters. [26]

Nikolopoulos et al. presented a decision-support system and a CC software methodology that bring together energy consultants, consumers, energy service procedures and modern web interoperable technologies. [27]

Kim et al. proposed Cloud-based demand response architecture for fast response time in large scale deployments. Our work advances this line of research by minutely analyzing the benefits and opportunities from the perspectives of both the SG domain and the CC domain, further proposing a model connecting these two domains, and presenting some motivating applications. [28]

Abhishek Khanna et.al explains smart controller and home energy automation to create the infrastructure for future. [29]

Dao Viet Nga et.al describe Visualization Techniques in Smart Grid with Google Earth; GIS; QGIS, AMI; SCADA; Spatial; Temporal etc. [30]

Ebisa Negeri et. al analysed Holonic Architecture of the Smart Grid and proposed smart grid holarchy is a suitable architecture to accommodate the foreseeable era of prosumerization. Moreover, the existing developments and the ongoing efforts in various aspects of the smart grids are in line with the requirements for its implementation. [31]

Although smart grids seem fit for using in cloud computing, there are some views against. For example, Cornell University Computer Science Department identified breaches in the cloud computing technology, properties that power control and similar smart grid functionality will need. These include security, consistency, fault tolerant services, real-time assurances and ways to protect the privacy of sensitive data. [32]

Their conclusion is that the cloud is not ready at this time to run the smart grid, but could be in the future if sufficient research is done.

Matt Wakefield et.al explains how administrators achieve Smart Grid Interoperability through Collaboration and get efficient distributed energy network. [33]

6. High Assurance Cloud Computing Requirements of the Future Smart Grid

A real-time service will meet its timing requirements even if some limited number of node (server) failures occurs. Current scenario cloud systems require rapid responses, but their response time can be disrupted by transient Internet congestion events, or even a single server failure. An another term consistency covers a range of cloud-hosted services that support database ACID guarantees, state machine replication behaviour, virtual synchrony, or other strong, formally specified consistency models, up to some limited number of server failures. Today's cloud computing systems often "embrace inconsistency", making it hard to implement a scalable consistency-preserving service Current cloud platform is very poor in protecting private data that most cloud companies must remind their employees to "not be evil". It needs protective mechanisms strong enough so that cloud systems could be entrusted with sensitive data, even when competing power producers or consumers share a single cloud data centre. Highly Assured Internet Routing. In today's Internet, consumers often experience brief periods of loss of connectivity. However, research is underway on mechanisms for providing secured multipath Internet routes from points of access to cloud services. Duplicated, highly available routes will enable critical components of the future smart grid to maintain connectivity with the cloud-hosted services on which they depend. [34][35][36]

7. Benefits of Smart Grid [37] [38] [39]

The smart grid is providing benefits to Utilities, Consumers & society in the following areas:

- Reliability: By reducing the cost of interruptions and power quality disturbances and reducing the probability and consequences of widespread blackouts and provide increased employee safety including increased revenue.
- Economics: By keeping downward prices on electricity prices, reducing the amount paid by consumers as compared to present grid, creating new jobs, and stimulating the country's gross domestic product (GDP).
- Efficiency: By reducing the cost to produce, deliver, and consume electricity and reduction in lines losses on both transmission and distribution, transmission congestion costs, peak load and energy consumption leading to deferral of future capital investments.
- Environmental: By reducing emissions when compared to present grid by enabling a larger penetration of renewable and improving efficiency of generation, delivery and consumption. It reduced frequency of transformer fires and oil spills through the use of advanced equipment failure / prevention technologies, optimize energy-consumption behavior resulting in a positive environmental impact and increased opportunity to purchase energy from clean resources, further creating a demand for the shift from a carbon-based to a "green economy"
- Security: SG dilemma reducing the probability and consequences of manmade attacks and natural Disasters.
- Safety: It reduced injuries and loss of life from grid-related events.
- Flexibility: Next Generation transmission and distribution infrastructure will be better able to handle possible bi-direction energy flows allowing for distributed generation.

8. Global Smart Grid Solution Implemented [39]

- Faroe Islands – Denmark
- Danish Energy Company DONG ENERGY and Faroese Partner SEV demonstrate the "World's First" Smart Grid system on the windy Faroe Island.
- The Faroe Islands are the first place in the world where a virtual power plant is used to recreate balance in an island power system by automatically decoupling large industrial units from the main power system is less Thana second, thereby avoiding systemic block-outs.
- Technically speaking, the virtual power plants delivers so-called fast frequency demands response.

9. Smart Grid Project in India [40] [41]

Puducherry– A Smart Grid project recommended by the Power Ministry's India Smart Grid Task Force will come up on a pilot basis in the union territory, reportedly the first in the country.

Smart Grid Pilot Projects in Power Distribution Sector in India

S.No.	Utility Name	Area Proposed	Functionality Proposed*	Initial Consumer Base
1	CESC, Mysore, Karnataka	Mysore Additional City Area Division	AMI R, AMI I, OM, PLM, MG/ DG	21,824
2	APCPDCL, Andhra Pradesh	Jeedimetla Industrial Area	AMI R, AMI I, PLM, OM, PQM	11,904
3	APDCL, Assam	Guwahati Project Area	PLM, AMI R, AMI I, OM, DG, PQM	15,000
4	UGVCL, Gujarat	Naroda / Deesa	AMI R, AMI I, OM, PLM, PQM	39,422
5	MSEDCL, Maharashtra	Baramati, Pune	AMI R, AMI I, OM	25,629
6	UHBVN, Haryana	Panipat City SubDivision	AMI R, AMI I, PLM	30,544
7	TSECL, Tripura	Electrical Division No. I, Agartala	AMI R, AMI I, PLM	46,071
8	HPSEB, Himachal Pradesh	ESD Kala Amb Under Electrical Division, Nahan	AMI I, OM, PLM, PQM	650
9	Puducherry	Div 1 of Puducherry	AMI R, AMI I	87,031
10	JVVNL, Rajasthan	VKIA Jaipur	AMI R, AMI I, PLM	2,646
11	CSPDCL, Chattisgarh	Siltara, Chattisgarh	AMI I, PLM	508
12	PSPCL, Punjab	Mall Mandi City Sub-Division Amritsar	OM	9,000
13	KSEB, Kerala		AMI I	25,078
14	WBSEDCL, West Bengal	Siliguri town, Darjeeling District	AMI R, AMI I, PLM	4,404

***Legend:**

S.No.	Functionality Abbreviation	Functionality
1	AMI R	Advanced Metering Infrastructure for Residential Consumers
2	AMI I	Advanced Metering Infrastructure for Industrial Consumers
3	OM	Outage Management
4	PLM	Peak Load Management
5	PQM	Power Quality Management
6	MG	Micro Grid
7	DG	Distributed Generation

10. Conclusion

The smart grid challenges us today: creating it could be the first and perhaps most important step towards a future of dramatically improved energy efficiency and flexibility. The Internet and the Cloud Computing model around which it has coalesced appear to be natural partners in this undertaking, representing the culmination of decades of work on high-productivity, low-cost computing in a distributed model. But only if the gap between the needs of the smart grid and the properties of the cloud can be bridged can these apparent opportunities be safely realized.

More than ever, utility operators face challenges posed by a changing marketplace and aging IT infrastructure. New applications offer utilities the promise of answering these industry problems, but these applications require utilities upgrade to a cloud-based IT infrastructure, which comes with it's own set of challenges. Faced with concerns about security, performance, and reliability, utilities have been hesitant to adopt new cloud-based technologies.

We presented a cloud computing model for managing the real-time streams of smart grid data for the near real-time information retrieval needs of the different energy market actors. The Smart Grid Data Cloud would be suitable for liberalized energy markets with a data clearinghouse concept, large vertically integrated utilities, as well as associations of transmission system operators.

We explained the characteristics of cloud computing, which will make the majority of smart grid use cases feasible. Especially the easeof-interfacing with the cloud has the potential to create usable de facto standards whilst enabling interoperability and extensibility.

The scope is to demonstrate a platform for collaboration and information exchange between end users, retailers, virtual power plant operators of highly distributed generation as well as the network operators.

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