Role of Cloud Computing in Smart Grid

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***Abstract*--By assimilating concepts of advanced communications and future control technologies, Smart Grid has become the next generation power system. Due to its greater robustness, efficiency and flexibility over conventional power system, its gaining importance. As in modern electrical power system, need of resources and storage is increasing which can be dealt with cloud computing. It is a promising technology with functionality of using computing resources in scalable and virtualized manner. Cloud computing integrates the electrical power system resources through internal networks, thus improvement in robustness, load balancing and storage capacity is observed.**

Key words--Cloud computing and its security, Smart Grid

I. INTRODUCTION

Emerging challenges with the power sector include need of reliability and sustainability along with its conservation and carbon footprints. Many countries across the world come across deficiency in energy which thoroughly impacted development and environment through Green House Gas (GHG) emission. The root cause for such lapses in electric system is lack of advancement in electrical transmission and distribution system [1]. Thus corrective action includes best practices in its creation, management and consumption of electricity with new grid infrastructure. The smart grid is an advanced electric power system with new infrastructure to provide better efficiency, stability and safety, with option of integration with renewable and alternative energy sources, through advanced control and modern communications technologies [2]-[3].

Cloud computing is getting popular which is a system with convenient, on demand facility to access network along with the various integrated computing resources such as servers and storage that can rapidly be released with least management effort or service provider interaction [4]. As of now, Power grid with different usage has a specified processor and storage resources, thus cloud computing helps in maximum utilization of the storage resources. With the help of cloud computing, various control algorithms can be developed to improve robustness and load balancing.

Provider of cloud services such as Google, Microsoft owns high capacity data centers with large computational and storing capacities [5]. Role of cloud computing, data center and smart grid is depicted in Fig 1.

The most important constituent of cloud computing is data centre which affects routing and congestion control algorithm [6]. It also impacts the internet. Secondly, data center's affected the smart electric grid as it consumes enormous energy and acts as load to the grid.

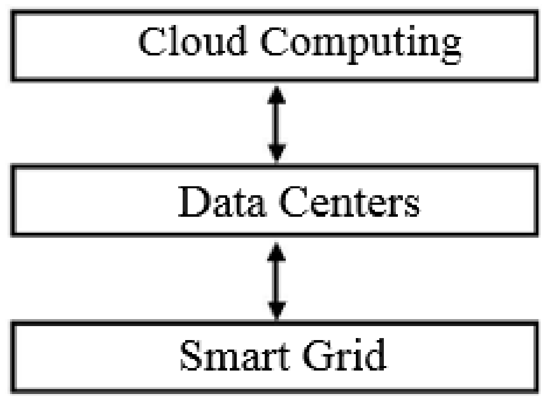

Fig. 1. Relationship between cloud computing systems and smart grid and distributed data centers.

Grid computing is different from cloud computing as grid computing uses computing resources as optional. While cloud computing provides on-demand resource provisioning, a step further to grid computing [7].

The paper comprises of five sections. Firstly with introduction, next section covers the concept of cloud computing. Moving ahead, the next section comprises of the implementation of cloud computing in power system followed by need of cloud computing along with security concerns. Final section comprises of concluding remarks.

II. CONCEPT OF CLOUD COMPUTING

Being an emerging technology, development in field of virtualization, storage and connectivity are combined to create a new environment for cloud computing. Cloud computing has given a new definition to IT industry. In the last few years, cloud computing has shown an exponential growth in the IT industry. Leading industry sources define cloud computing as a new segment of computation in which numerous quantity of scalable IT enabled processes are delivered to external customers using internet technologies [8]. This leads to revamp the business of IT industry and will bring changes in many of IT organization in the process of delivering the business services that are enabled by IT [9]. By breaking the definition, the first and foremost concept arises of delivering services. Second concept provides insight of economies of scalability as it reduces the cost of service. Third, delivery using internet technology implies that specific standard that is easily accessible and visible in global sense are used [10]. At the end, these services are provided to multiple external customers leveraging shared resources to increase the economies of scale. There is vast difference between scalability and elasticity. Scalability is defined on parameter of performance and its ability to fulfill customer needs. While elasticity is the ability to support those needs at large or small scale at will [11]. The important issue with scalability is its bidirectional movement without disrupting the economics of business model associated with the cloud service. Several flavors are known for the execution of main application available on flexible environment and mainly three systems exist on this which is depicted in the Fig 2.

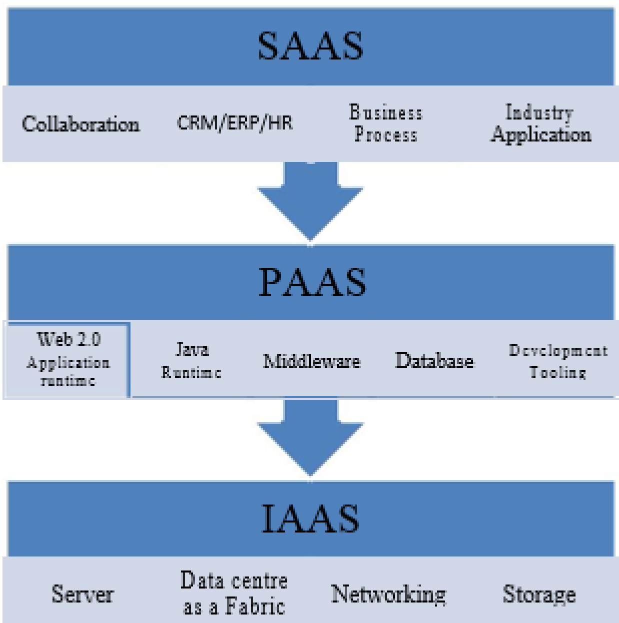

Fig. 2. Architecture of Cloud Computing

Infrastructure as a service is a single surface cloud layer where the computing vendors share the dedicated resources on the basis of pay per use. Client interface such as web browser, various applications are accessible from variant client devices [12]. The advantages associated are that it has a rapid startup along with maintenance and upgrades performed by the vendor. This model incorporate the capability of provision processing, storage networks and other basic computing accessories which enable the consumer to examine and run arbitrary software, which consist of operating system and application. The benefits related to this model are that it is scalable with rapid startup and peak leveling [13]. This model also faces heat from various risks such as Pricing of model, ability of lock-in, security and privacy along with proliferation. Examples which defines the above said views are Amazon EC2, Rack space. This model of delivery is called as IaaS. With offsite hosted software, the customer is free from its maintenance. On the other hand, customer is not having authority of changes in the hosting services. This software can be used out of box and do not need to make a lot of changes or require integration to other systems. As of now, many types of software that compare themselves to this model. For Saas, any software that performs a simple task without interaction with other systems make it ideal candidate for SaaS. Different customers beside from software development but have need of high powered applications can also benefit from SaaS [14]. Some of these applications are Customer resource management, video conferencing, IT service management, Accounting, web analytics, web content management. When SaaS is used as a component of another application, this is known as a mash up or a plug-in. There are certain problems which arises during implementation of this service is that with Saas, any organization that has a very specific computational need might not be able to find the application available in it. Secondly, availability of open source application and cheaper hardware is another problem with this model [15].

Cloud Platform as a Service (PAAS) is a model with functionality given to the consumer to use the cloud infrastructure consumer created or acquired applications created using programming languages and tools supported by the provider [16]. All the services and application can be used without downloading and installing it. Various vendors provide applications such as hosting, development testing and deployment along with its scalability and maintenance. PaaS is generally based on HTML or Java script for creation of human interfaces. The advantages related to this model is that it focus on high value not on infrastructure along with leverage economies of scale and provide scalable go to market. PaaS is found on different systems such as Stand-alone environments, add on development facilities and application delivery which only require environments. The hurdle faced by the developers of this model comprises mainly of higher cost along with the afraid of being locked into a single provider and upgrade issues are very common with this model. Certain examples of this model are force.com, Microsoft Azure, web and e-mail hosting.

III. Implementation of Cloud Computing in Power System

The working of electric power system involves generation, transmission, distribution and usage of power simultaneously. On the other hand, electric power system has a feature that it can't store energy in larger amount [17]. Thus, in production of the electric power, the control should be real-time, reliable and must consist of hierarchical management, hierarchical control, and distributed processing [18].

The abovementioned control can be achieved through cloud computing. The cloud computing can divide lengthy calculation into small segments with the help of intranet. After fragmentation, it is delivered to a system consisting of many servers. Servers perform computation and analysis of the information and pass it to the end users [19]. So, due to cloud computing, huge information can be handled within a short span of time which resembles it to the supercomputer's grade service. As distributed computing is finding place in electrical power system which make its operation analogous to internet [20]. The cloud computing platform is categorized in to cloud computing control center and computing resources integration platform. With cloud computing, resource allocation as per application can be done and can access to storage resources on demand. Integration of the running grid nodes or computation on a single computer system is possible. Alternatively, cloud computing avoids improving the computational ability of the node or computer. It automatically gets enhanced through the clouds at every point in overall system.

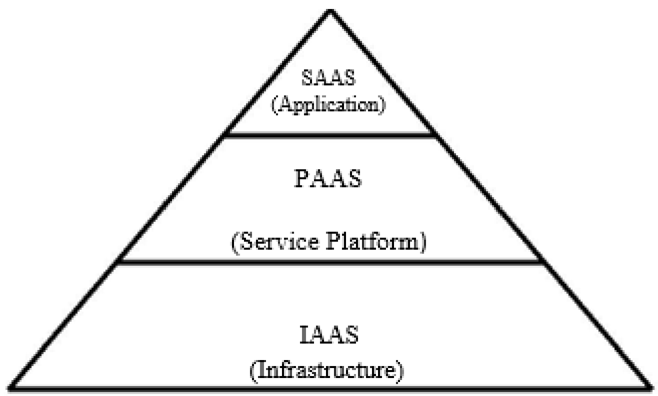

Fig. 3. The service architecture model of cloud computing.

The various layers of services are depicted in Fig.3. The layer which is underlying is called as infrastructure (infrastructure as a service, IaaS) with ability to provide computer or data center, enabling the execution of arbitrary operating systems and software. Next to it is a service platform layer (Platform as a service, PaaS) which consists of infrastructure and the increased custom software stack for a specific application. Upper most layer is the application, (Software as a service, SaaS), a measurement service, a system which implements software on remote computer.

The cloud computing of electrical power system assimilates all networks with computer application software of inner network of power system to work unitedly with help of cluster application, distributed computer system [21]. All levels of network of electric power system can be reached through software interfaces. Structure of the hierarchical model of the intelligent cloud of power system is depicted in Fig 4.

Basically, in structural model, the basic storage layer becomes the fundamental element of the Smart power system. As different locations are omnipresent, so storage devices are interconnected through network in power system. On the other hand, basic management layers assimilate the integration of all the devices in the cloud atmosphere.

On the other hand, the most flexible part of cloud computing is application interface which provides different interfaces and services to electric network as per the demand [22].

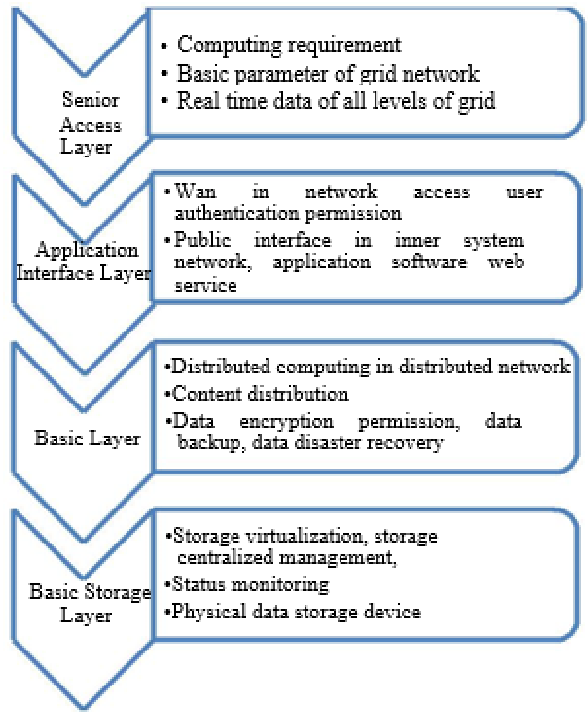

Fig. 4. Structural and hierarchical model of intelligent cloud of Power System

IV. Need of Cloud Computing in Smart Grid

Various applications require the need of cloud computing in electric power system. Primarily, cloud computing helps the power system to recover in the blackout condition. Secondly, monitoring and scheduling of the power system can be performed with the help of cloud computing. It also enables to have reliability evaluation of the power system. Recovery of power system after blackout proves to be a complicated nonlinear optimization problem. Promotion of the information sharing and cooperation between different participants is possible through power restoration process [23]. An increase in calculation efficiency is observed by distributed computing. Further, an optimal complex interconnected recovery plan can be put into action due to shared computing platforms. These platforms provide better sharing and cooperation. The various functions of cloud computing in power system are as shown in Fig 5.

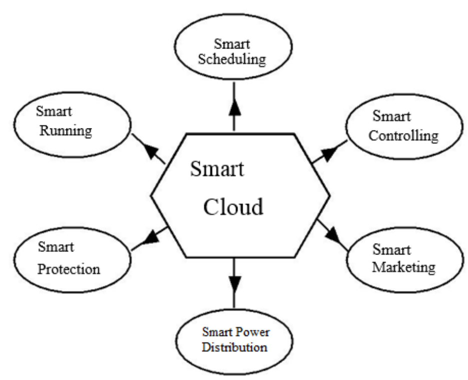

Fig. 5. Functions of cloud computing in Power system

Monitoring and scheduling is another application area of cloud computing in the power system. With the unitary power system, cloud platform can upgrade control up to channel level of information distribution.

As the number of the distributed power can be very large system scheduling and operation needs to be maintained. With the scalability property there can be increase in computing power irrespective of size of power system. Realization of real- time monitoring and information collection becomes feasible with cloud computing.

Further advances can be observed in reliability analysis with cloud computing. It also provides the unified approach in future power system computing platforms [24].

V. CLOUD SECURITY

With smart grid, various security threats must be overcome in order to benefit fully from cloud computing. This new developing concept faces several security threats. Incompatibility of storage services provided by one vendor with another vendor creates a threat to the system. As with cloud, data's transfer, storage and retrieval takes place so data integrity is another security concern [25].

With further developments in the information security, cloud security technologies are adopting these new developments. Protective measures include communication which provides security software the necessary edge it needs to fight threats.

VI. CONCLUSIONS

It can be concluded here that through cloud computing fat delivery of computational resource is possible. Cloud computing provides a new way to achieve power system online operation analysis and optimal control.

Cloud computing in power system analysis includes various aspects such as power flow calculation, the system restores monitoring, scheduling, reliability analysis. As cloud computing is still growing with smart grid, so future research work needs to focus on its core.

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