RoleofCloudComputinginSmart Grid

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***Abstract*--Byassimilatingconceptsofadvancedcommunications and future control technologies, Smart Grid hasbecome the nextgeneration power system. Due to its greaterrobustness,efficiencyandflexibilityoverconventionalpower system, its gaining importance. As in modern electrical powersystem, need of resources and storage is increasing which can bedealt with cloud computing. It is a promising technology withfunctionalityofusingcomputingresourcesinscalableandvirtual izedmanner.Cloudcomputingintegratestheelectricalpowersystemr esourcesthroughinternalnetworks,thusimprovementinrobustness, loadbalancingandstoragecapacityisobserved.**

Keywords--Cloudcomputinganditssecurity,SmartGrid

I. INTRODUCTION

Emergingchallengeswiththepowersectorincludeneedofreli ability and sustainability along with its conservation andcarbonfootprints.Manycountriesacrosstheworldcomeacross deficiency in energy which thoroughly impacted developmentand environment through Green House Gas (GHG) emission.The root cause for suchlapses in electric system is lack ofadvancement in electrical transmission and distribution
system[1].Thuscorrectiveactionincludesbestpracticesinitscreati on, management and consumption of electricity with newgridinfrastructure.Thesmartgridisanadvancedelectricpower system with new infrastructure to provide better efficiency,stability and safety, with option of integration with renewableand alternative energy sources, through advanced control andmodercommunicationstechnologies[2]-[3].

Cloudcomputingisgettingpopularwhichisasystemwithconv enient,ondemandfacilitytoaccessnetworkalongwiththevarious integrated computing resources such as servers andstorage that can rapidly be released with least managementeffortorserviceproviderinteraction[4].Asofnow,Po wergridwithdifferentusagehasaspecifiedprocessorandstoragere sources, thus cloud computing helps in maximum utilizationof the storage resources. With the help of cloud computing,variouscontrolalgorithmscanbedevelopedtoimprove robustnessandloadbalancing.

ProviderofcloudservicessuchasGoogle,Microsoftownshigh capacitydatacenterswithlargecomputationalandstoringcapacitie s [5]. Role of cloud computing, data center and smartgrid is depictedinFig1.

Themostimportantconstituentofcloudcomputingisdatacent rewhichaffectsroutingandcongestioncontrolalgorithm
[6].Italsoimpactstheinternet.Secondly,datacenter'saffectedthe smartelectricgridasitconsumesenormousenergyandactsasloadto the grid.

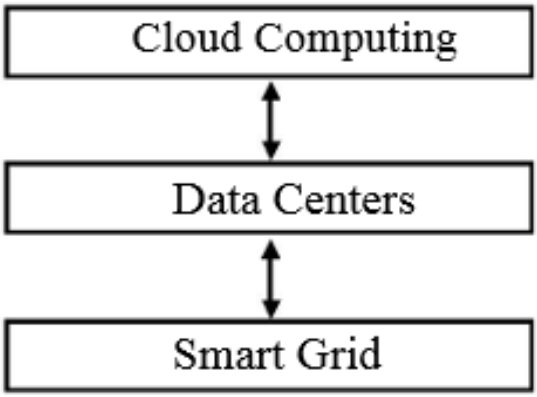

Fig. 1. Relationship between cloud computing systems and smart grid anddistributeddatacenters.

Grid computing is different from cloud computing as gridcomputing uses computing resources as optional. While cloudcomputing provides on-demand resource provisioning, a stepfurther togridcomputing[7].

Thepapercomprisesoffivesections.Firstlywithintroduction, nextsectioncoverstheconceptofcloudcomputing. Moving ahead, the next section comprises of theimplementation of cloud computing in power system followedbyneedofcloudcomputingalongwithsecurityconcerns. Finalsectioncomprisesofconcludingremarks.

II. CONCEPTOFCLOUD COMPUTING

Being an emerging technology, development in field ofvirtualization, storage and connectivity are combined to createa new environment for cloud computing. Cloud computing hasgiven a new definition to IT industry. In the last few years,cloud computing has shown an exponential growth in the ITindustry.Leadingindustrysourcesdefinecloudcomputingasan ew segment of computation in which numerous quantity ofscalableITenabledprocessesaredeliveredtoexternalcustomers usinginternettechnologies[8].Thisleadstorevampthe business of IT industry and will bring changes inmany ofITorganizationintheprocessofdeliveringthebusinessservices that are enabled by IT [9]. By breaking the definition,the first and foremost concept arises of delivering services.Secondconceptprovides insight ofeconomies of scalabilityas

it reduces the cost of service. Third, delivery using internettechnologyimpliesthatspecificstandardthatiseasilyaccessibleandvisibleinglobalsenseareused[10].Attheend,theseservicesareprovidedtomultipleexternalcustomersleveragingsharedresourcestoincreasetheeconomiesofscale.Thereisvastdifferencebetweenscalabilityandelasticity.Scalability isdefinedon parameterof performanceanditsability to fulfill customer needs. While elasticity is the abilityto support those needs at large or small scale at will [11]. Theimportant issue with scalability is its bidirectional movementwithout disrupting the economics of business model associatedwiththecloudservice.Severalflavorsareknownfortheexecutionofmainapplicationavailableonflexibleenvironmentand mainly three systems exist on this which is depicted in theFig2.

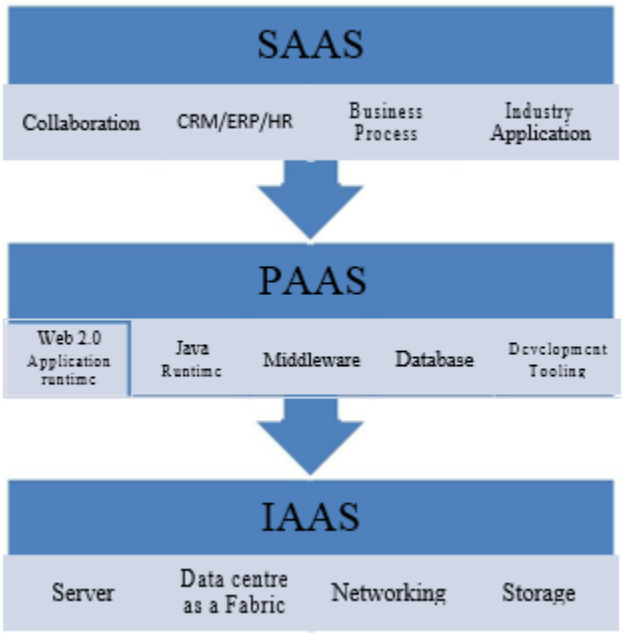

Fig.2.ArchitectureofCloudComputing

Infrastructure as a service is a single surface cloud layerwhere the computing vendors share the dedicated resources onthe 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 startupalongwithmaintenanceandupgradesperformedbythevendor.This model incorporate the capability of provision processing,storage networks and other basic computing accessories whichenable the consumer to examine and run arbitrary software,whichconsistofoperatingsystemandapplication.Thebenefitsrelatedtothismodelarethatitisscalablewithrapidstartupand peak leveling [13]. This model also faces heat from variousrisks such as Pricing of model, ability of lock-in, security andprivacy along with proliferation. Examples which defines theabove said views are Amazon EC2, Rack space. This model ofdelivery is called as IaaS. With offsite hosted software, thecustomerisfree from itsmaintenance.On the otherhand,customerisnothavingauthorityofchangesinthehostingservices. This software can be used out of box and do not needtomakealotofchangesorrequireintegrationtoothersystems.As of now, many types of software that compare themselves tothis model. For Saas, any software that performs a simple taskwithout interaction with other systems make it ideal candidateforSaaS.Differentcustomersbesidefromsoftwaredevelopment but have need of high powered applications canalso benefit from SaaS [14]. Some of these applications areCustomerresourcemanagement,videoconferencing,ITservice management, Accounting, web analytics, web contentmanagement. When SaaS is used as a component of anotherapplication, this is known as a mash up or a plug-in. There arecertain problems which arises during implementation of thisservice is thatwithSaas, any organization that has a veryspecificcomputationalneedmightnotbeabletofindtheapplicationavailableinit.Secondly,availabilityofopensourceapplication and cheaper hardware is another problem with thismodel[15].

CloudPlatformasaService(PAAS)isamodelwithfunctionalitygiventotheconsumertousethecloudinfrastructureconsumercreatedoracquiredapplicationscreated using programming languages and tools supported bythe provider [16]. All the services and application can be usedwithoutdownloadingandinstallingit.Variousvendorsprovideapplicationssuchashosting,developmenttestinganddeployment along with its scalability and maintenance. PaaSisgenerally based on HTML or Java script for creation of humaninterfaces. The advantages related to this model is that it focusonhighvaluenotoninfrastructurealongwithleverageeconomies of scale and provide scalable go to market. PaaSisfound on different systems such as Stand-alone environments,add on development facilities and application delivery whichonly require environments. The hurdle faced by the developersofthismodelcomprisesmainlyofhighercostalongwiththeafraidof being locked into a single provider and upgrade issues are verycommon with this model. Certain examples of this model areforce.com,MicrosoftAzure,webande-mail hosting.

III. IMPLEMENTATIONOFCLOUDCOMPUTINGINPOWER SYSTEM

Theworkingofelectricpowersysteminvolvesgeneration,transmission, distribution and usage of power simultaneously.On the other hand, electric power system has a feature that itcan'tstoreenergyinlargeramount[17].Thus,inproductionofthe electric power, the control should be real-time, reliable andmust consist of hierarchical management, hierarchical control,and distributedprocessing[18].

Theabovementionedcontrolcanbeachievedthroughcloudcomputing.Thecloudcomputing can dividelengthycalculation into small segments with the help of intranet. Afterfragmentation,

it is delivered to a system consisting of manyservers.Serversperformcomputationandanalysisoftheinformation and pass it to the end users [19]. So, due to cloudcomputing, huge information can be handled within a shortspanoftimewhichresemblesittothesupercomputer'sgrade service. As distributed computing is finding place in electricalpower system which make its operation analogous to internet[20]. The cloud computing platform is categorized in to cloudcomputing control center and computing resources integrationplatform. With cloud computing, resource allocation as perapplication can be done and can access to storage resources ondemand. Integration of the running grid nodes or computationon a single computer system is possible. Alternatively, cloudcomputing avoids improving the computational ability of thenode or computer. It automatically gets enhanced through thecloudsat everypointinoverallsystem.

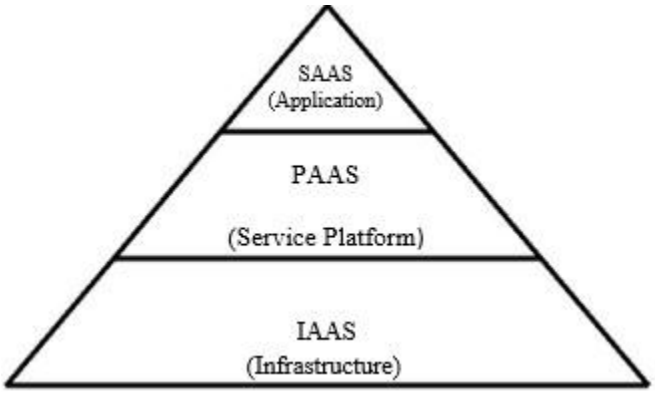

Fig.3.Theservicearchitecturemodelofcloudcomputing.

The various layers of services are depicted in Fig.3. Thelayerwhichisunderlyingiscalledasinfrastructure(infrastructureasaservice,IaaS)withabilitytoprovidecomputer or data center, enabling the execution of arbitraryoperatingsystemsandsoftware.Nexttoitisaserviceplatformlayer(Platformasaservice,PaaS)whichconsistsofinfrastructure and the increased custom software stack for aspecificapplication.Uppermostlayeristheapplication,(Software as a service, SaaS), a measurement service, a systemwhichimplements software onremote computer.

Thecloudcomputingofelectricalpowersystemassimilates all networks with computer application software ofinner network of power system to work unitedly with help ofclusterapplication,distributedcomputersystem[21].Alllevelsof network of electric power system can be reached throughsoftware interfaces. Structure of the hierarchical model of theintelligentcloud ofpower systemisdepictedinFig4.

Basically,instructuralmodel,thebasicstoragelayerbecomes the fundamental element of the Smart power system.As different locations are omnipresent, so storage devices areinterconnected through network in power system. On the otherhand, basic management layers assimilate the integration of allthedevicesinthe cloudatmosphere.

Ontheotherhand,themostflexiblepartofcloudcomputing isapplication interfacewhich providesdifferentinterfaces and services to electric network as per the demand[22].

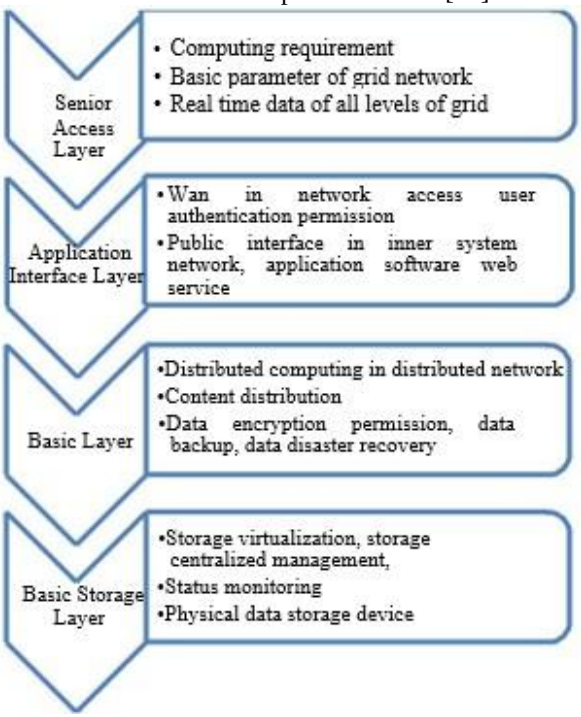

Fig.4.StructuralandhierarchicalmodelofintelligentcloudofPowerSystem

IV. NEED OF CLOUD COMPUTING IN SMART GRID

Variousapplicationsrequiretheneedofcloudcomputing inelectric power system. Primarily,cloudcomputinghelps the power system to recover in the blackout condition. Secondly,monitoringandschedulingofthepowersystemcanbeperformed with the help of cloud computing. It also enables tohave reliability evaluation of the power system. Recovery ofpowersystemafterblackoutprovestobeacomplicatednonlinear optimization problem. Promotion of the informationsharingandcooperationbetweendifferentparticipantsispossiblethroughpowerrestorationprocess[23].Anincreaseincalculation efficiency is observed by distributed computing.Further, an optimal complex interconnected recovery plan canbe put into action due to shared computing platforms. Theseplatforms provide better sharing and cooperation. The variousfunctions of cloud computing in power system are as shown inFig5.

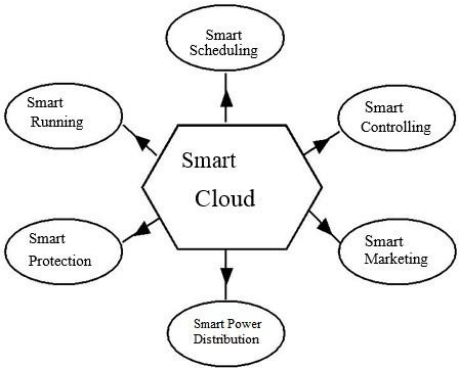

Fig.5.FunctionsofcloudcomputinginPowersystem

Monitoring and scheduling is another application area ofcloud computing in the power system. With the unitary powersystem, cloud platform can upgrade control up to channel levelofinformationdistribution.

As the number of the distributed power can be very largesystem scheduling and operation needs to be maintained. Withthe scalability property therecan be increase in computingpower irrespective of size of power system.Realizationofreal-timemonitoringand informationcollectionbecomesfeasiblewithcloudcomputing.

Further advances can be observed in reliability analysiswith cloud computing. It also provides the unified approach infuturepowersystemcomputingplatforms[24].

V. CLOUDSECURITY

Withsmartgrid,varioussecuritythreatsmustbeovercomeinor dertobenefitfullyfromcloudcomputing.Thisnewdevelopingconc eptfacesseveralsecuritythreats.Incompatibility of storage services provided by one vendor withanother vendor creates a threat to the system. As with cloud,data's transfer, storage and retrieval takesplacesodata integrityisanothersecurityconcern[25].

With further developmentsintheinformationsecurity,cloudsecuritytechnolog iesareadoptingthesenewdevelopments.Protectivemeasuresinclu decommunicationwhichprovidessecuritysoftwarethenecessarye dgeitneedstofightthreats.

VI. CONCLUSIONS

It can be concluded here that through cloud computing fatdeliveryofcomputationalresourceispossible.Cloudcomputing providesanewwaytoachievepowersystemonlineoperationanalys isandoptimalcontrol.

Cloudcomputinginpowersystemanalysisincludesvarious aspects such as power flow calculation, the systemrestores monitoring, scheduling, reliability analysis. As cloudcomputing is still growing with smart grid, so future researchwork needstofocusonitscore.

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