Grid Computing Technology Enhances Electrical Power Systems Implementations

R. AL-KHANNAK, B. BITZER
Electrical and Automation Engineering Department
South Westphalia University of Applied Sciences, Campus Soest
Luebecker Ring 2, D-59494 Soest
GERMANY

Abstract: - Modern power systems and their applications are developed rapidly bringing many obstacles to be considered and solved. Complexities and difficulties for handling these applications make scientists looking for better solutions to get efficient, redundant, and clean power generation. This need requires geographically-distributed power systems to be integrated as a single entity where among the main features of this integration are large data base and computing intensive. Hence the current power systems are incapable to handle integration requirements for both computational power and datasets sizes. Grid Computing is a coming innovative solution. This paper describes grid computing as an efficient computational technology, the research work on why grid computing is needed for modern power systems, what are the major challenges that grid computing is forcing to be integrated into power systems, and how grid computing can be utilized to fulfil the requirement for next efficient power generation.

Keywords:- computational grid, idle resource, grid computing, resource broker, job, node, grid middleware.

1 Introduction

Automation in the electrical engineering has a long tradition and is closely connected with used system architecture. After the first use of process computers at the end of the 60s and respectively at the beginning of the 70s, client/server architectures were established in the 80s, and these are still dominant today. With the rise of the Internet in the private as well as in the business sector the used structure was adjusted. But in recent years, instrumentation and controlling systems were introduced, where the architecture of the Internet was already being considered during the development phase. In this case the system is known as the fourth generation.

Modern power systems and electrical energy applications are demanding more and more computational power, which cannot be achieved by the existing computing technology or computers. In order to meet these computational challenges, it is necessary to have a standardized means of connecting disparate resources over high speed networks to build high power virtual supercomputers [4] and the methodology to compute these computational processes with efficient and high quality of services. Computational power refers to processor processing speed, data storage capacity and network performance. Modern electrical grids are computer enabled power networks that provide efficient and smooth management, monitoring and information exchange of distributed power networks with diverse widespread resources of power generation [5]. The electrical grid will be transformed from central generation down to collaborative networks that will incorporate customer appliances and equipment and modern information devices in the distribution. The future electrical grids will consist of large small-scale generation units of renewable energy sources and other disparate energy sources. Highly scalable and decentralized integrated communication, computing and power networks will be necessary to monitor these smart grids of the future [3].

2 Computational and Power Grid

From the basic understanding of power electrical grid that whenever any kind of generator is connected to the grid, means this generator is ready to feed the grid with the required or demanded power. This system is working in a dynamic mode that generators are joining and leaving the grid in a specific scheduling and mechanism.

In the same how, grid computing came analogy following the same scenario that in the computational grid any computing resource once connected to the grid (grid computing network) is ready to support the computational grid with demanded computing power or storage facility.

3 Grid Computing Technology (GC)

Grid computing is a powerful and efficient computational technology which represented as an advanced step for the previous distributing computing. Along with the high network communication speed and high technical specified machines (PC, Desktops, super computers...) distributed computing still suffering from some limitations because of the way and the percentage of using these resources (power gaining)[6,7].

Grid computing as a new computing generation that uses the resources of many separated computers connected by a network for solving such massive computation problems by making use of the underutilized resources or grid shared resources. Grid computing shares the

heterogeneous resources (based on different platforms (operating systems), hardware/software architectures, and computer languages, located in different locations depending on Grid systems architecture using open standards and protocols [8].
Grid computing is solving such large scale of problems which could not be solved within the traditional computing methods due to the limited memory, or computing power. Grid system required a high speed network working under specific or specialized software called grid middleware [6,7,9], which allows the distributed resources to work together in a relatively smooth and transparent manner.
Using or getting benefit from idle computer's lost power make Grid distributed computing work much faster with high accuracy, lead to more progress and increase development curve.

3.1. Grid Middleware

Grid computing software is represented as one of the most important elements which characterizes grid network computational efficiency, and in the same time limits the compatibility for applying specific applications. Many companies and developers are offering variant Grid Computing middleware, which have different facilities, capacities, and capabilities to achieve wide range of electrical engineering applications. Due to the high sensitivity and complexity, electrical energy systems are demanding proficient and reliable GC solutions (middleware).
Any Grid Computing system structure is consisting of three major elements for processing Grid jobs: The submitter (manager), which, apply the job to the Grid network and monitor them, the broker which, detect, and control computational process, and one or more contributor(s) to Process the job and data storing.

3.2. GC and Electrical Energy Engineering

Grid Computing is now seen as a powerful and important tool for the electrical engineering applications. These days the power system operation and control involves large data-intensive, time-intensive applications. Therefore it can get a better solution by using this new technology. Also the power system is moving towards the renewable energy sources. In this case it helps them in providing cheap and efficient electrical energy supply.
The demand for conservation of the current conventional energy has been increased due to the growing concern on the deteriorating condition of our environment. [1]
The control and operations of modern power systems are becoming data-intensive, information-intensive, communication-intensive and computation-intensive due to much of the reliance of these power systems on computerized communications and control. [11]
Therefore, since Grid Computing is considered as an inexpensive means for "super-computing" for dealing with heterogeneous and distributed computing [7], Grid Computing is the best option in providing the necessary storage media for the huge data, intensive computational processes and also the required computing resources.

4 Modern Power Systems

It is estimated that by 2050, the world's electrical energy needs will be somewhere between 30 and 60 Terra Watts (TW) of electric power from the current 12 TW [12]. This kind of electric energy will require efficient and secure distributed, storage, transmission modern grid technologies in order to be delivered globally within high quality. GC technology will be necessary to provide a computational infrastructure to solve the diverse computational problems involved in future envisioned electrical grid operation. Traditional monitoring and control that is employed in the current electrical grids is highly centralized and not scalable enough to include new highly scaled, distributed and embedded renewable energy sources [3]. Monitoring and control of the future power systems will be both highly scalable and universally adoptable because of its distributed nature and use of open standards. The application of GC helps to solve problems that may be too large for the single supercomputer but at the same time retains the flexibility to work on distributed smaller problems [13].
Application of suitable Information Technologies such as GC will enable active and collaborative participation of consumers, utilities and third parties in energy markets. This will help to stabilize the prices and to be a key for shaping future power market [13].
Two instances of massive power failures have highlighted the need and the urgency to develop enveloping, intelligent and reliable smart or modern electrical grids in order to manage with the ever increasing energy demands. The 2003 large scale power failure in North America that affected many parts of US and Canada is one instance. The other more recent power failure occurred in early November, 2006 and affected many parts of Germany, France and Belgium. National or regional modern grid implementations, will allow power utilities to virtually upgrade power lines, substations and other electrical transmission equipment without huge expensive physical replacements [14].
Also in the modern power systems, both power generation side and customers on the other side are reacting to other similarly that both could be in selling mode and later changing to the buying one. The new power organization behave as fully dynamic system which allow all its partners to share and exchange activities and positions. This dynamic system needs a high level of monitoring, controlling and efficiency to ensure accurate and best quality of services. From figure 1, it is illustrating the modern power system environment or organization which include all operators in one cluster due to the dependency and complimentary.

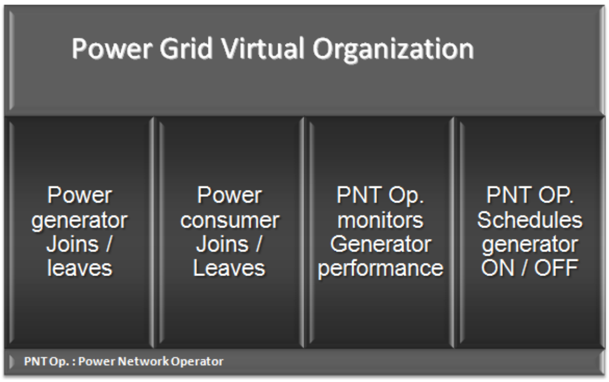

Fig. 1: Power grid virtual organization

5 Power System Conversion

Modern power systems in general are changing into larger numbers of smaller-scale highly dispersed generation's units that use both current generation technologies and renewable energy sources to reduce carbon dioxide emissions [1,3]. These modern systems need to be connected into modern facilitated network to enable transferring, monitoring and controlling their situation within high speed techniques [1, 15]. GC is the technology which is capable to provide such high speed of computations within huge datasets that to be transferred among power systems. While, these generators are connected into the power system it will become necessary to analyze, monitor and control their output level and their on/off schedule. The control technology in use at transmission level is not scalable to very large numbers of generators. GC is the technology which is capable of providing a relatively inexpensive new solution, allowing the output of embedded generators to be analyzed, monitored and when necessary controlled [16].

The advantages of current powerful and high performance computers and network services facilitate and solve many of power engineering problems which may need for such a high technically specified machines and services. In the same time, along with the developments of engineering applications and technologies in general and power systems specifically, a lot of obstacles limit these developments due to two major reasons, either the machines' performance, which may not sufficient and match solutions' requirement or inefficient use of these facilities.

Looking to the modern engineering technologies, which are depending on computers' performance for solving and developing them, make these technologies to be absolutely dependent on the performance of these machines and the way of using or tapping the percentage of these machines' power.

Dealing with huge power load data make this technology always suffering from time and cost difficulties rather than others. The time required to solve any power problem and cost due to needed resources make using more powerful computing technology is the efficient solution to solve these power applications.

6 Why Grid Computing

The development of GC is also motivated by the possible benefits that can be gained by using GC within any organisation [17]. To get the reasons why GC is needed, some GC characteristics and benefits are followed:

a) Utilising Underutilised Resources

   In most organisations, many computing resources are idle and underutilised at most of the times. For example, most desktop computers are idle more than 95% of their time [17]. Realising that these idle times are being wasted and not profitable to the organisation, GC provide the solution for exploiting underutilised resources.

   In addition to processing resources, it is often that computing resources have also large amount of unused storage capacity. And Grid Computing allows these unused capacities to be considered as a single virtual storage media where the need of huge storage capacity within a particular application is resolved. Thus, the performance of this application is improved if compared running this application over a single computer.

b) Parallel CPU Capacity

   The possibility of applying massive parallel CPU activity within an application is one of the main exciting features of GC. While the need for parallel CPU activity may initially pertaining to scientific purposes, this need is now being extended to different fields such as financial modelling, oil exploration and motion picture animation, causing revolutionary working methodology in these fields. Though this idea of parallel CPU activity is chillingly attractive to be implemented, many barriers that exist within GC infrastructure have to be overcome before a perfect parallel CPU utilisation can be realised.

c) Resource Balancing

   GC groups multiple heterogeneous resources into a single virtual resource. Furthermore, the grid also facilitates in balancing these resources depending on the requirements of the tasks. As a result, appropriate resources are selected based on the time of execution and the priority of each task. In larger organisations, unexpected peak load of activity is handled effectively by the grid and therefore ensures the smoothness of load balancing. This invaluable feature of GC is realised through the process of profiling individual resource based on its availability and capacity.

From these individual benefits, the benefits of GC as described above [18], can be categorised into:

a) Business benefits

- Faster time to obtain the results (Faster results guide to best of manage and first in market)
- Increase productivity

b) Technology benefits
- Optimise existing infrastructure
- Increase access to data and collaboration

7 GC Challenges / Problems

Grid services transparently provide access to the entire collection of information processing system that includes computing, data and application resources. While the grid framework has seen great developments in the recent past, the greatest challenge remains the development and deployment of applications. Application development remains a great barrier due to the heterogeneous nature of the underlying resources [19]. This is illustrated by the fact that application libraries are installed differently on different machines. This makes bath jobs, scripts and executables not easily transferable from one system to another.

Grid Web services are partially trying to minimize this problem by abstracting program installation and execution from the users. Universal adoption of programs like java is also helping to minimize this portability problem.

Software compatibility is another factor that affects development of grids. Not all middleware are compatible with available toolkits. Due to this fact, proper choice of toolkits and third party middleware is very important. Successful grid task completion is only possible with correct toolkit and middleware combinations.

8 Power Systems Challenges

In a distributed and integrated power systems, it is vital to ensure that each power source (generator, wind turbine, etc) is working within its allowed parameters. These parameters are normally based on the current power load that are sometimes have been forecasted within regular intervals (weekly, monthly or yearly) [19, 20]. Anyway, these non real-time forecasts have their drawbacks and may not supplying correct information when any of these events occurred:

1) Sudden failure of any of the power sources
2) Unexpected increase or decrease of power demand within a short timeframe

During the occurrence of any of these events, power load balancing within these power sources are required within immediate timeframe in order to ensure that there will be no power interruptions.

From this point it could be recognized that the integration of current power systems and designing modern electrical energy systems are requiring smarter and more intelligent systems to enable reaching a higher level, faster real time monitoring, controlling and scheduling for future electrical power systems.

9 GC Integration into PS Model

The model proposed for integrating GC with power applications as illustrated in Figure 2.

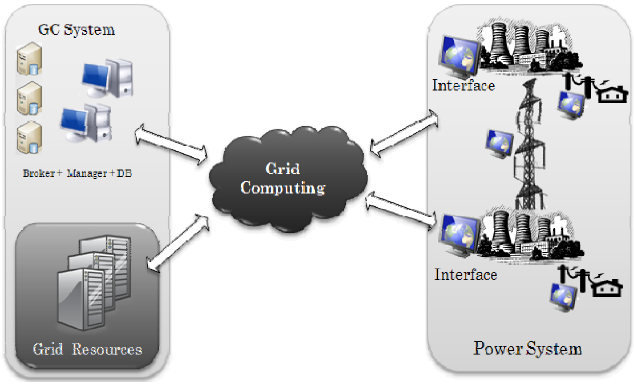

Fig. 2: Grid Computing Model Integrating with Power Applications

From Figure 1, further descriptions of the model are as follows:

a) The model infrastructure is combining power systems via application interface with grid resources connected in a GC system, which share processing power and data storage.
b) The power applications interact with GC system to obtain the current list of all power applications connected to the GC and therefore, these power applications will interact with each other for real-time operations.
c) GC system broker is in charging to find available GC resources meeting certain specifications in order to perform real-time electrical energy application.

10 GC Integration Mechanism

As illustrated in figure 2, electrical grid is a part of the computational grid and vice versa. In other words, both electrical and computational grids are acting as one system, which scientists are still trying to find the most specific name among all given ones, like smart grids, modern power systems, micro grids, virtual power grid, and VPP virtual power plant. So, for any electrical power application, computerized power systems are facilitated with the GC available resources, sharing and handling any application to enhance and speed it up. In figure 3, the architecture of applying or combining GC with electrical power systems, showing that during normal and stable power system running, GC system is sharing power system operations. [1, 2]

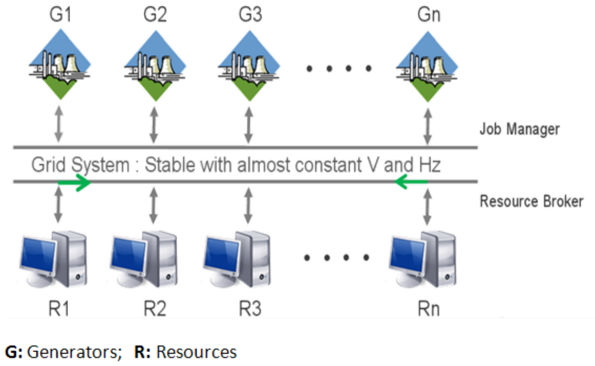

Fig. 3: GC with electrical power system Integration

An example of GC application with electrical power system as illustrated in figure 4, when any fault may happen in any part of power system (power plant generator(s)), compensating lost power due to that fault needs a fast and accurate response that GC system is offering GC resources which are exchanging continuously real time power system information, then it could nominate best compensational part to react to that fault. In the same how for real time power demand which GC system can offer better power generation scheduling, load balancing and controlling due to fast, accurate, and available data or information.

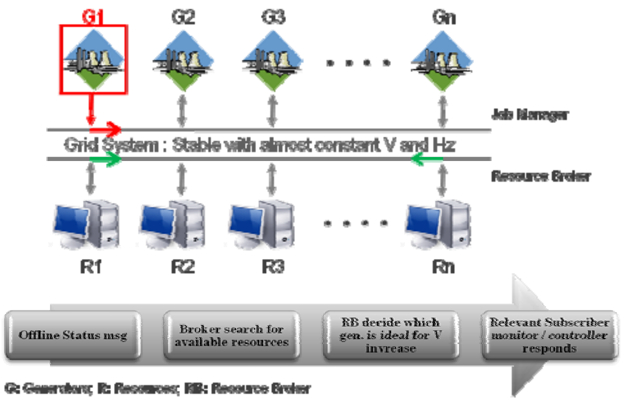

Fig. 4: GC application with electrical power system

11 Grid Power System Applications

GC applications are implemented in the South Westphalia University (SWU), where different GC tools are used; such like DeskGrid, Globus, and SGE (Sun Grid Engine) GC systems which are applied for power systems implementation and applications. Power load forecasting and power load balancing are some of these applications for analyzing the performance GC especially for a real-time data transfer and time consuming. [1, 2]

Power load forecasting computing are Implemented within both technologies traditional and grid to achieve compare and analyze new technology benefits and differences. Traditional method is implemented by using normal unique machine, then job is submitted and time is measured. The same task is submitted into grid system successfully. Time comparison shows that grid system consumed much less time with high efficiency and high accuracy. From figure 5, it is clear that traditional method consumed 260 minutes (blue bar) while grid computational process needed 75 minutes to achieve same job (red bar).

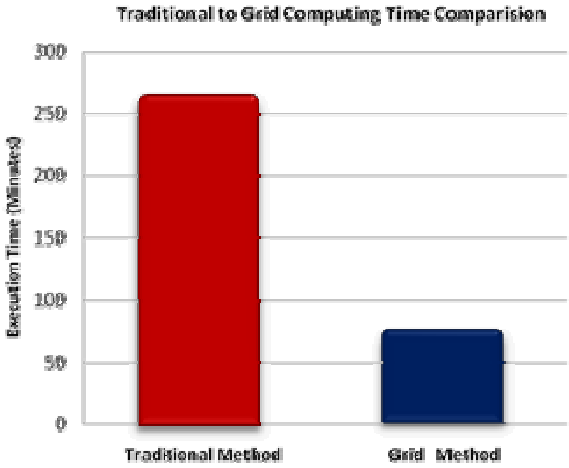

Fig. 5: **Comparison between traditional and GC methods**

For the real-time load balancing operations, It has been successfully by using Globus grid computing system and power world simulator.
Also, utilizing all the available GC resources was successfully done, in order to perform load forecasting operations. The forecast values were then returned to each relevant power systems where, if these values exceed a specific limit, decentralized load balancing operations were then executed. The load forecasting performance on different number of resources calculations are analyzed and the results are as illustrated in Figure 6.

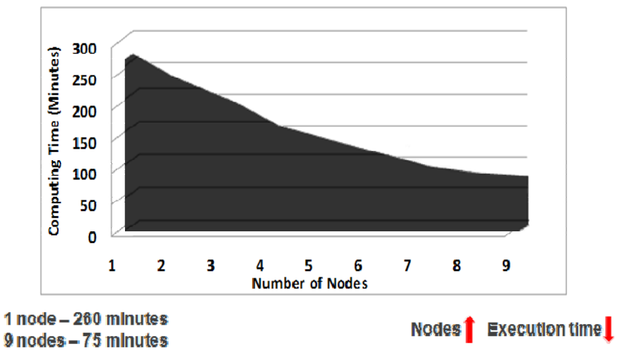

Fig. 6: **GC power load forecasting operation performance**

Figure 6 illustrates that the time taken load forecasting reduces quite significantly when more GC resources were selected. Thus, by having the required resources, hourly load forecasting can be calculated where the forecast value shall be return to each power system for decentralized load balancing operations.

12 Conclusions

Future future power grids will require efficient storage, transmission, distribution systems and intelligent control to enable the grids to deal with massive future energy demands and reliability that will be required. The smart grid will comprise of millions of generation and storage points at local and remote locations. This type of grid will require tight integration of old technologies, many advanced new electrical technologies and information communications infrastructure. Grid Computing as a new distributing computing technology gets benefit of all unused (idle) computers by contributing them into Computational Grid to process such problem needs many computational resources and goals to implement huge and difficult problems which need these resources without owning them, and to speed up computational process. On the other hand Grid Computing is represented as the best Power future tool that new IT solutions are required for supporting trading activities, simulating power marketing decision, power controlling and predictions and major complex power engineering. For power implementations, more small generators and separated controlling power parts with diverging towards renewable energy make Grid Computing on the prior Power Grid solution. Rather more, Grid Computing software developing is the step to make variant engineering applications compatible and suitable to be solves by using Grid techniques.

Reference

[1] R. Al-Khannak, B. Bitzer. "Load Balancing for Distributed and Integrated Power Systems using Grid Computing". ICCEP07, Capri, Italy May 2007. IEEE http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4272368

[2] Taylor, G.A., Hobson, P.R., Huang, C., Kyberd, P. and Taylor, R.J. "Distributed monitoring & control of future power systems via Grid computing." Retrieved August 20, 2006, from

http://people.brunel.ac.uk/~eesrgat/research/pdf_pubs/IEEEPES2006.pdf

[3] Deak.O. (2005). "GRID SERVICE EXECUTION FOR JOPERA." Retrieved October 05, 2006, from http://www.iks.ethz.ch/publications/files/Oliver_Deak_MT.pdf

[4] Cascio, J. (2005). "Smart Grids, Grid Computing, and the New World of Energy." Retrieved October 4, 2006, from http://www.worldchanging.com/archives/002152.html

[5] Rajkumar Buyya and Srikumar Venugopal, CSIC communications, computer society of India' July 2005

[6] Foster, Ian and Carl Kesselman ed.: The Grid: Blueprint for a New Computing Infrastructure; Morgan Kaufmann; San Francisco; 1999.

[7] Grid Computing Info Centre (GRID Infoware), http://www.gridcomputing.com

[8] Joshy Joseph, Craig Fellenstein. Grid Computing, 2004.

[9] Qi Huang, Kaiyu Qin and Wenyong Wang, Development of a Grid Computing platform for electric power system applications. Power Engineering Society General Meeting, 2006. IEEE

[10] "Smart Electric Grid of the Future: A National "Distributed Store-Gen." Test Bed." Retrieved October 04, 2006, from

http://www.ldeo.columbia.edu/4d4/testbeds/Smart-Grid-White-Paper.pdf

[11] "Grid Computing." Retrieved September 05, 2006, from http://en.wikipedia.org/wiki/Grid_computing

[12] Global Environment Fund. (2005). "The Emerging Smart Grid." Retrieved August 29, 2006, from http://www.globalenvironmentfund.com/GEF%20white%20paper_Electric%20Power%20Grid.pdf

[13] Yini Chen, Chen Shen, Wei Zhang and Yonghua Song. Grid computing infrastructure for power systems.

[14] Malcolm Irving and Gareth Taylor' Prospects for Grid-Computing in Future Power Networks, September 2003.

[15] Features of the Java Commodity Grid Kit. Available from: http://aspen.ucs.indiana.edu/gce/C536javacog/c536featuresOfCoG.pdf

[16] Parvin Asadzadeh, Rajkumar Buyya, Chun Ling Kei, Deepa Nayar and Srikumar Venugopal, Global Grids and Software Toolkits: A Study of Four Grid Middleware Technologies. Available from: http://www.gridbus.org/papers/gmchapter.pdf

[17] Gannon, D., Ananthakrishnan, R., Krishnan, S., Govindaraju, M., Ramakrishnan, L. and Slominski, A. "Grid Web Services and Application Factories." Retrieved October 03, 2006, from http://www.extreme.indiana.edu/xcat/publications/AppFactory.pdf

[18] D.Bevc, S.Zarantoneolla, N.Kaushik, I.Musat, " Grid Computing for Energy Exploration," Mini-symposium on Grid Computing for Oil and Gas Industry, SIAM Conference on Parallel Processing for Scientific Computing, San Francisco, February 2004.

[19] S. Sheng, K.K. Li, Z. Xiangjun, "Grid Computing for Load Modeling," IEEE International Conference on Electric Utility Deregulation, Restructuring, and Power Technologies, April 2004.