5-2012

Distributed Computing As Business Model within Smart Grids

Timo von der Dovenmühle
University of Oldenburg, Timo.von.der.dovenmuehle@uni-oldenburg.de

Distributed Computing As Business Model within Smart Grids

Timo von der Dovenmühle
University of Oldenburg
Timo.von.der.dovenmuehle@uni-oldenburg.de

Abstract

Some types of renewable energy resources like wind energy or solar cells are bonded to problems such as the energy providing pattern that does not fulfill the needs of the electric energy consumers. This situation leads the provider to the problem that an electric network always has to be balanced – the amount of provided energy must be the same as the consumed one. In a worst case scenario this leads to a situation where providing electric energy will not be service – instead it will be invoice able by the consumer. The energy consumption of modern computer systems is increased based on the higher performance available for consumers. This trend will increase based on the spread of personal computer systems to individuals. In context to the problem of controllable network load provider within a power grid, this development could be a chance: data centers are acting as cloud providers and even personal computers are capable to provide great amounts of processing power as well as network load capabilities. The major difference between these computers and other network load devices is the already existing infrastructure connectivity to control the behavior externally. This paper provides a concept of a business model and associated controlling software which presents an economic added-value to both electric power providers and consumers.

Keywords

Power Grid Optimization, Distributed Power Computing, Green IT, SOA.

1. Introduction

From the distribution of renewable energy sources through existing electric supply networks perspective systems follow new challenges. Nowadays, the network infrastructure is designed to fulfill the needs of highly centralized electric energy sources. The way to produce electric energy is changing. Instead of using fossil energy resources or nuclear power plants, a significant part of newly installed power plants based on renewable energy sources like windmills or solar cells. As a result, the amount of waste and pollution can be reduced. But new challenges come with these changes. The availability of energy is regulated by the weather circumstances. An energy provider cannot produce energy like it is requested. This request pattern is a problem we have to work on. One way to do this is the storage of unused energy. There are different ways to store unused electric energy. The problems are that either there are only very limited resources, the efficiency is not good or the storage is very expensive. Another way is to control the power consumption of the consumer. Technologies like the Smart Grid are dealing with this approach (Müller-Schloer, Karl, Yehia, Becker, Allerding, & Reiner, 2010). The main idea is to adjust the energy consumption to the productivity of specific power plant types. However, there are situations in which the amount of available electric energy to be consumed is higher than the requested amount. This is a critical situation, because the reaction time of power plants is often greater than the needed response time besides the fact that different providers are involved in the situation. Another problem can be legal issues, because some power plant types have to be preferred by law while the other power plants types cannot react in time based on technical limitations (Deutsche Energie-Agentur GmbH, 2010).

Despite the control of power plants the utilization of the existing power grid is another problem. Power grids were designed to distribute electric energy from centralized power plants to the consumers. These great power plants are positioned nearby main consumers in order to reduce delivery losses. The supergrid within a country's infrastructure was planned to serve energy within a well-defined sector and to provide redundant power plant resources in case of technical failures. The increasing spread of power plant types like solar cells or windmills results in a much higher number of small power plant within the power grid. Typically, these power plants are connected to the power grid at low topology levels like the medium voltage power grid [compare Figure 1: Power Distribution Grid]. The supergrid is now used to transmit the energy from areas with great production rate to areas with high energy consumption rates. For example, in Germany windmill power plants mainly installed in the northern parts of the country while the main consumption is located in its southern parts. As a result, the supergrid connection within Germany has to process a much greater load.

The medium voltage power grid-level was designed to distribute the electric energy to the consumer, not to be used as an entry point for decentralized energy injection. The capacity of these grids was planned to handle typical consumer needs. An additional load by utilizing these grids to inject energy could resolve into capacity problems. A way to handle this problem is to consume the injected energy at the same network topology level. This would reduce the amount of supplied energy at higher power grid layers.

Another technical aspect is the need to have a balance between injected and consumed energy. Phase-synchronous injection is a pre-condition for binding multiple power plants to one alternating current voltage network. This pre-condition can only be reached, if the amount of energy injected to the network system is the same as the consumed one. Otherwise, the injecting power plants would not be able to be synchronized via this connection. One way to guarantee the balance within the network is to store unneeded energy in storages. A typical storage type is the hydroelectric power plant. While this is a successfully used technology approach, some main problems cannot be solved following this concept. One problem is that the regional availability of hydroelectric power plants depends on geographic factors like altitude difference. As example, in Germany predominant areas endowed with utilizable altitude differences are located in the south. Wind power plants mainly installed in the northern parts of Germany. As a result, there is the need to transport great amounts of energy from the north to the southern located storage power stations. The resulting problem is the utilization of the existing super grid capabilities between these areas.

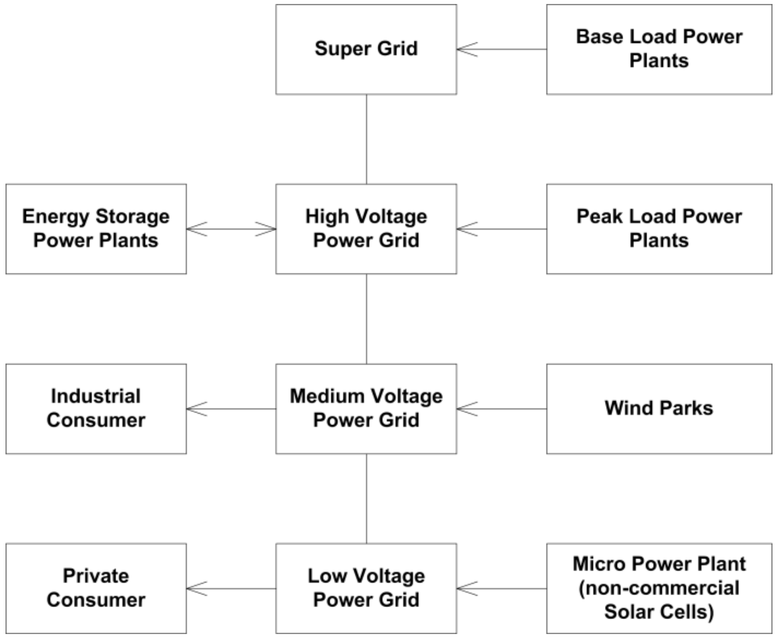

Figure 1: Power Distribution Grid

From an economic viewpoint the electric energy market has some very interesting specifications. As we had seen, the amount of injected and consumed energy has to be balanced in order to activate the power network. This means, there is no explicit provider of a resource and an explicit consumer, as well. If more energy is injected as used by consumers, providing electric energy is not a service any more. The consumer slips into the role of a provider. His ability to consume the injected energy is now a service. This situation results into scenarios, where energy providers are losing money through a negative price for injected energy. Nowadays, operators of hydroelectric power plants are using market situations like that to store energy in order to inject electric energy when the market situation is switched. From the perspective of local energy providers this means losses of money. Additionally, the utilization of the carrier grids is higher than the actual energy demands.

2. Approach

A promising approach to solve these problems is the smart grid. One goal behind using such approach is that the energy consumption of a single consumer can be controlled by the energy distributor in order to utilize provided electric energy more efficiently. A second goal is the lower peaks in the demand curve. Constrained to weather conditions, probably there is the need to increase the actual consumption rate in order to utilize renewable energy sources in an optimal way. Typically white goods like washing machines, dryers or dishwashers are targeted by this approach. Using white goods as controlled loads within the power network is bounded to some practical problems: for example, it is problematic if a consumer accepts the fact, that his washing machine starts running at 3am. The real problem is like follows: the infrastructure within households is not designed to control specific machines remotely. As a result, changes in domestic installations must be done to solve this problem. Firstly, added active control devices to solve this issue is aligned with additional costs and power consumption. Secondly, the efficiency of white goods is increasing rapidly. The average energy consumption of washing machines of the last ten years is about 1 kW/h for a load. Even if a washing machine runs three times a week, this means that yearly this machine is only good for about 150 kW/h of controlled electric energy consumption. Speaking about white goods: another problem is the resulting timeframe adjustment of the peaks. It is not acceptable, that a machine stops and re-starts within a cycle. As a result, the network load exists until the cycle is finished. The maximum timeframe adjustment of a Smart Grid-enabled washing machine is the number of runs. In this example, the machine can provide three load peaks of a length of one run per week. This behavior does not fit into the needs of renewable energy sources like windmill power plants: the power distribution pattern of this type of power plants can change within minutes. This means, to have suitable load capacities, these capacities must be able to react within the same time frame as the injecting power plant.

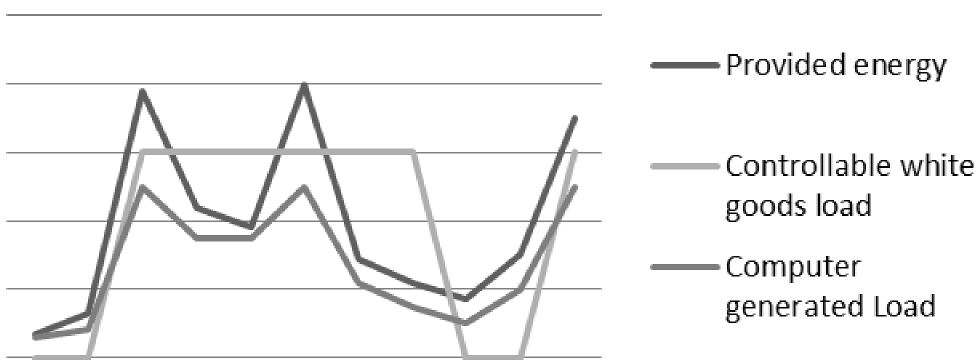

Figure 2: Load and consumption pattern

Using white goods as controllable load is bounded to two problems: the lack of control logic and the low timeframe adjustment of the resulting load pattern. The lack of control logic can be solved, but the timeframe adjustment problem cannot be solved. Anyway, utilizing white good loads is not as easy and effective as it seems.

Within households, there are other types of energy devices, which do not have these problems. By utilizing personal computers, the control logic issue and the timeframe adjustment problem can be solved. At a first view, a computer does not fulfill the requirements of a controllable load in the network. The load capacity is weak and therefore the effect would be unnoticed. This is not right anymore. Actual hardware is able to consume 500 Wh and more. Compared to a washing machine, in less than two hours a computer consumes the same amount of energy like running a washing machine load. Even notebooks can produce a load of 70 Wh. This maximum power consumption is not the load a computer produces at daily usage. Modern energy saving technologies helps to decrease this consumption by 75% or more. When we want to have this higher energy consumption, each running computer is a potential load item with a controllable load-capacity higher than its average power consumption. Another important point is that computers already fulfill the requirements of control logic. There is no need to install new hardware to control the computer or make changes in household's infrastructure (Fechner, 2007). As a typical example, washing machines are planned to be used as work load within smart grids.

The impact of utilizing computers in this approach is the next step. In this paper, we take a look on three different operating scenarios: a daily computer usage of four hours, a daily usage of eight hours and an availability of 24 hours a day. In the first two cases, we assume that the computer is used by its owner. In the last scenario, the computer is available in a network, even if it is not used by the owner.

The first two scenarios are related to computers utilized at a workspace or at home. The utilization of these computers is typically less than the maximum load they can handle. There are several projects regarding the question of how to use these resources. An example is distributed computing, where personal computers solve parts of simulations within their idle times and send the results back to a server. This way, projects like Folding@Home from the Stanford University (Beberg & Pande, 2009) are able to use massive amounts of computation power. There is no direct disadvantage for the users, because the software only uses resources at the computer's idle time.

The next step is to combine the problem of controllable loads within a power grid and the approach of distributed computing. A computer that is working on a problem like the one presented at Folding@Home has network access, it provides the computer location using its IP address and finally there is no disadvantage from the user's perspective, if a task is not finished within a specific time frame (Barker & Chrisochoides, 2003). If the tasks provided to the distributed computing network are controlled by the energy provider, there is the possibility to match the additional load to the energy injected to the power grid. In this paper, we define this concept as Distributed Power Computing (DPC). The advantage of this approach is that the needed infrastructure already exists and therefore the preparation to use such a concept is easier to handle than the other approaches.

Despite the technical questions there is the problem of gaining added value for the customer. If an energy provider wants, using any solution regarding the load problem, to attract its customers, there must be a measurable advantage for them. Using machines to create additional load to the power grid will increase the overall power consumption. From the provider's perspective, this is a desired fact in order to reduce negative price situations. The problem is that the customer will not be willing to pay for the additional consumption, because there is no need or advantage from his point of view (Aote & Kharat, 2009). The first step will be to ensure, that the customer will not be billed for the additional load. Running benchmark tests on a targeted machine allows calculating the amount of idle computer time served by a customer machine solving a problem. Hardware information like processor types can be accessed automatically. As a result, it is easy to calculate, how much energy was consumed by running the distribution computing software. If the customer registers a machine to his household, the consumed energy can be subtracted from the bill. Depending on the economic impact, there is even the possibility to pay the customer via discounts to his overall bill.

In other words, this approach will decrease the risk of negative price situations, but the operational efficiency is low because the energy is not used in a good way. To improve both the ecological and economic efficiency, we need a way to utilize the computing time in a reasonable way. Distributed computer grids show us which types of problems can be solved at such infrastructures . From an energy provider's viewpoint, there are a lot of similar problems to work on.

In this way, a customer can get a measurable advantage by participating at a distributed network. As a non-monetary return, the customer could get information of how its contribution helped to improve the power grid stability and quality of service. Detailed information about how this influences the penetration of the market by renewable energy sources can improve the non-monetary reward, as well.

With the numerous emerge of the fast network capabilities to navigate the internet, new architecture models like Web Service enabled Serviced Oriented Architectures (WS-SOA) becomes more and more popular (Weerawarana, Curbera, Leymann, & Ferguson, 2005). The main difference between this model and the other models is that the software architect is not thinking in processes or methods any more, rather all communications are seen as sets of requests and responses messages. A service provider can provide a certain kind of functionality in its service (Web Services) and an architect is able to use that functionality without having so much information about its implementation. As a future step, there will be the question of how to expose power offerings and demands as market using WS-SOA concept in context of DPC for business purposes (Desrochers & Sautet, 2004).

3. Conclusion

The main difference between Distributed Power Computing and the existing Smart Grid technologies is that additional load will be added to a power grid instead of normalizing the consumer's requests to fit into the actual energy providing scenario. At a first glance, there is no advantage to consume additional energy. But in a market, where the production cannot follow the consumer needs within a reasonable time span, this additional load allows to increase the participation of renewable energy sources without risking the power grid stability. Additionally, the utilization of grid connections can be optimized to enhance the lifetime of existing infrastructure.

Although the validation of this approach's fundamental assumptions is still ongoing work, it is anticipated that the concept of providing remotely controllable power loads within a power grid based on distributed computing will allow implementing Smart Grid functionalities within running power grids without the need to change it at physical level. The resulting effect reduces the provider's economic risk of negative price situations within the energy market. Recent research discovers that the motivation of participating consumers will not only be based on monetary interest rather than on social aspects (Beberg & Pande, 2009). Future interdisciplinary work has to focus on a solution that will give the user the freedom of having measurable advantages. Adopting the concept of Distributed Power Computing in the energy market can be done after some necessary prototypical implementation (von der Dovenmühle & Marx Gómez, Leistungsbewertung zu adaptierender Web Services in serviceorientierten Architekturen, 2011) (von der Dovenmühle, Mahmoud, & Marx Gómez, Energy Saving Through User Scheduled Load Balancing Within Service Oriented Architectures, 2010).

References

Aote, S. S., & Kharat, M. U. (2009). A game-theoretic model for dynamic load balancing in distributed systems. *ICAC3 '09: Proceedings of the International Conference on Advances in Computing, Communication and Control* (S. 235-238). Mumbai, India: ACM.

Barker, K. J., & Chrisochoides, N. P. (2003). An Evaluation of a Framework for the Dynamic Load Balancing of Highly Adaptive and Irregular Parallel Applications. *SC '03: Proceedings of the 2003 ACM/IEEE conference on Supercomputing* (S. 45). Washington, USA: IEEE Computer Society.

Beberg, A., & Pande, V. (2009). Folding@home: lessons from eight years of distributed computing. In IEEE (Hrsg.), *IEEE International Symposium on Parallel&Distributed Processing*, (S. 1-8).
Desrochers, P., & Sautet, F. (2004). Cluster-Based Economic Strategy, Facilitation Policy and the Market Process. *The Review of Austrian Economics*, *17*(2-3), S. 233-245.
Deutsche Energie-Agentur GmbH. (2010). *DENA Netzstudie II.* Abgerufen am 12 2010 von DENA: http://www.dena.de/fileadmin/user_upload/Download/Dokumente/Studien___Umfragen/Endbericht_dena-Netzstudie_II.PDF
Fechner, H. (2007). Internationale Forschung für eine sichere Stromversorgung. *Energietechnik & Informationstechnik*(9), S. 307-308.
Müller-Schloer, C., Karl, W., Yehia, S., Becker, B., Allerding, F., & Reiner, U. (2010). Decentralized Energy-Management to Control Smart-Home Architectures. In *Architecture of Computing Systems - ARCS 2010* (S. 150--161). Heidelberg: Springer.
von der Dovenmühle, T., & Marx Gómez, J. (2011). Leistungsbewertung zu adaptierender Web Services in serviceorientierten Architekturen. In A. Bernstein, & G. Schwabe (Hrsg.), *WI 2011: Proceedings of the 10th International Conference on Wirtschaftsinformatik*, *I*, S. 618-624. Zurich, Switzerland.
von der Dovenmühle, T., Mahmoud, T., & Marx Gómez, J. (2010). Energy Saving Through User Scheduled Load Balancing Within Service Oriented Architectures. *Proceedings of the International Society for Ecological Economics (ISEE) : 11th Biennial Conference: Advancing Sustainability in a Time of Crisis*, (S. 147). Oldenburg Bremen.
Weerawarana, S., Curbera, F., Leymann, F., & Ferguson, D. F. (2005). *Web Services Platform Architecture: SOAP, WSDL, WS-Policy, WS-Addressing, WS-BPEL, WS-Reliable Messaging and More.* NJ: Prentice Hall.