The Smart Grid Computing: A Comprehensive View to Power Grid Systems

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Abstract

The development and integration of smart grid technology in current scenario is very crucial and useful. Involving the Smart Grid computing into electricity supply, yields a huge amount of monetary benefits which includes less emissions, better storage and high efficiency. Such grid based system is proving to be highly lucrative for customers using it. The Governments are highly investing in such technology to achieve independence especially into power sector. Deploying Smart Grid technology has been a priority for governments all around the world. It is having a revolutionising effects on existing conventional power grid systems. Smart Grid lies at the confluence or intersection where Computers and Electronics intersect. Both these things have been in their prime and have had far-reaching effects on the innovations off late. Smart Grid is the very new innovation possible with the contribution of former and latter and is proving to be boon not only for developing but developed countries too.

Introduction

The smart grid is an electricity supply system which functions under two-way communication channel. In this channel customer receives the electricity and also returns a feedback. This feedback is vital in cutting down the wastage of power and extra expenditure. It has also been breakthrough technology in reducing the effect of global warming. Consumers, using the smart grid devices, transmit information that is used to customise the supply according to the needs as seen in this information[1]. The presence of internet connection is very much needed to make the presence of smart grid technology possible.

Blackouts and brownouts were a severe headache for any country in its electrical grid system [2]. Normal grid systems are not equipped to handle additional load given the demand is high. It seriously affected the industrial and services sectors. These factors alone account for the need of a system that can handle all the failures effectively. In came the Smart Grid.

Smart grid technology became known in 1990s after drawbacks of its predecessors became prevalent. What makes smart grid smart, is its ability to track the power usage. It can very well identify the amount of power required over a varying time period of a given day. This was not possible in previous available arrangements. Smart grid can also efficiently detect the location and cause of fault. This detection was not possible previously. Smart Grid technology has achieved path breaking results in area of fraud detection. This drawback of previous systems is very well covered by the Smart Grid. The most advantageous and vital aspect of Smart Grid is that it is dominantly customer-driven. This feature helps the beneficiary to manage their consumption and expenditure.

What makes a smartphone smart? It is the in-built computer which makes the phone smart. Similarly, it is the computer which smartens our existing grids to make it Smart Grid. Some very obvious computer technologies involved in implementation of Smart Grid involves Database Management, Cloud Computing, Distributed Computing etc. Since customer preferences are constantly tracked, they are stored in database which are further very much useful to make prediction and track the behaviour. This database is very useful for the distributing company to cater to the needs their customers. Techniques of distributed computing is used at the distribution centre. This helps in switching between different sources of energy available. Smart Grid is equipped with a lot of sensors which are inter-connected in a network. Computer scientists invest huge fraction of their time setting up the sensors in a network.

Basic Elements of Smart Grid

Architecture is very important to manage the complexity and easily manages to achieve goals[4]. Architecture helps visualising the challenges which lie in implementation. Taking precautions prior to implementation helps reducing risks. Building infrastructure of Smart grid is pretty much sophisticated and complex. This also is very costly as compared to conventional electricity distribution systems available. The architecture of Smart Grid as depicted Figure 1 is majorly composed of following: -

- ***Transmission Stations***: Transmission stations is where electric power is generated by different means. The power generated is sent to the distribution centres for further supply. They too make use of smart devices that make supply automatic and need-based.

- ***Distribution Centres***: This is the pace where majority of work takes place. Distribution centres receive power from transmission stations and redirect them to the consumers. Important tasks like fraud detection, load balancing and

distribution according to the need and switching between various transmitting stations of thermal, tidal, hydro-electric power plants.

- ***IoT Devices****:* Smart Grid, simply put, is not possible without IoT devices. These devices are installed at each and every step and part possible in the complete setup. Devices like sensors, actuators, smart meters etc. These devices are used in process of transmission, metering and distribution. It is these devices through which the needs and behaviour of consumption is reflected. The data collected in the devices is precious for future pattern predictions and customisation of supply.

Why do we need Smart Grid?

Smart grid is the utmost need of the currently existing out-of-date and obsolete electrical supply system which vulnerable to frauds and wastage of power. Building Smart Grid is the need of the hour not only because is almost fraud-proof but also cost efficient and eco-friendly. Bringing customer into the picture is what is the most prominent feature of Smart Grid. This technology also deploys renewable sources of energy like wind, tidal, solar etc. and blends it in with other non-renewable sources of energy like thermal. The system is smart enough to switch according to the demand and automatically lowers the load, hence saving money. Smart Grids have been found to save 30% more energy than conventional grids.

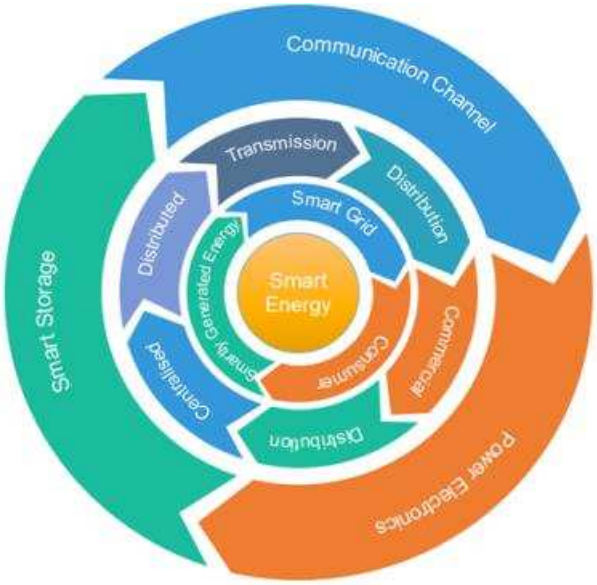

Figure 1: Different Elements of Smart Grid Architecture

Fault detection still remains one the grave area for conventional energy gridsbecause, to the detect the place and kind of fault is a very tedious task which is made pretty easy by Smart Grid. Smart Grid automatically detects the fault and itself tries to handle it with pre-defined measures. Other advantages of Smart grid are as follows [5]: -

- ***Reduced Costs and Expenditure***: Managing and providing the load and power according to the demands lowers the cost and cuts expenditures.
- ***Eco-Friendly****:* Since Smart Grid makes use of both renewable and non-renewable sources, it lowers the harmful emissions and reduces the risk of global warming.
- ***Robustness****:* Smart Grids being more robust means that they are less prone to attacks and can manage themselves. It is also blackout and brownout proof.
- ***Smart Storage****:* If in case, somehow, the power generated is more than what was demanded; it also provides smart facilities, which can be utilised as and when required.
- ***Interoperability****:* The fact that Smart Grid utilises various smart devices and other technologies proves this technology is interoperable [6].
- ***Load Balancing****:* Balancing the load [5] with techniques like switch-configuration [7] and tie-line addition helps save power by storing it when not needed.

The technological revolution, started almost a century ago, has been a bang and is still has great momentum. The number of innovations coming up would never have been possible without electricity. These inventions when combined with the Smart Grid technology would completely revolutionise the way we see the world. As the large cities are growing larger, the challenges which lie ahead are too are becoming much bigger. Integrating the infrastructure according to the digital age is

where the major benefits of Smart Grid lie. This technology can be used to lay foundation of Smart City [8], whose other layers contain remote light monitoring, public safety, water and gas supply, traffic control. Nothing is possible until and unless the electricity distribution system is efficient and robust.

Deploying Smart Grid: From the perspective of Developing Nations

Developing countries like India, Iran, Brazil, Ukraine etc. find satisfaction in the fact that using technologies like Smart Grid would lead them to a path of development and rightly so. Developed countries like United States of America, China, South Korea, Japan and some European giants have proved that Smart Grid is the way to development. What all developing countries have in common is their productive expenditure. Their expenditure in the right direction is paying off. Smart grid is one such area where they must invest to bore fruits in future. Here are some of the techniques employed by some countries to integrate Smart Grid:

- ***Smart Grid in China:*** It is estimated that China may have 233% growth in electricity demands by 2050 [9]. Since its introduction in 2006, the Chinese have very much focused on this technology so much so that, they are investing around RMB 17 billion. They have also laid down separate ministry for power grid technology in Twelfth Five Year Plan. This will help create around 15 million jobs. Induction and realisation of the power of this technology has completely boosted the growth rate of China.
- ***Smart Grid in India****:* Smart Grid is a must inclusion in the Indian electricity system because India tops the list in terms of percentage of production lost to theft, around 26% [10]. India is bereft of poverty and this again is good reason to introduce Smart Grid Technology in India. Indian markets would benefit with this technology, because present distribution systems are weak and fragile. The energy planning and investment would definitely boost the Indian economy [11].
- ***Smart Grid in Brazil:*** Seeing the potential of growing economy, Siemens has invested around $1 billion USD [12]. Brazil is big hydro-electricity producer and making use of it through Smart Grid technology would produce fruitful results. Brazil makes great use of pilot projects to induce this technology in their existing distribution system.

Conclusion

This article provides the broad view towards benefits of smart grid technology which is investing heavily in power enhancement for any country's development. It has been initiated with the efforts related to change in implementing the concept of smart grid computing and would have splendid results for the coming future generations.

References

Zafar, Rehman, Anzar Mahmood, SohailRazzaq, Wamiq Ali, Usman Naeem, and KhurramShehzad. "Prosumer based energy management and sharing in smart grid." *Renewable and Sustainable Energy Reviews* 82 (2018): 1675-1684.

Anantharaman, Prashant, J. Peter Brady, Patrick Flathers, Vijay H. Kothari, Michael C. Millian, Jason Reeves, Nathan Reitinger, William G. Nisen, and Sean W. Smith. "Going Dark: A Retrospective on the North American Blackout of 2038." In *Proceedings of the New Security Paradigms Workshop*, pp. 52-63. ACM, 2018.

http://www.ewh.ieee.org/r6/san_francisco/pes/pes_pdf/Smart_Grid_Architecture.pdf

Zame, Kenneth K., Christopher A. Brehm, Alex T. Nitica, Christopher L. Richard, and Gordon D. Schweitzer III. "Smart grid and energy storage: Policy recommendations." *Renewable and sustainable energy reviews* 82 (2018): 1646-1654.

Lu, Ning. "An evaluation of the HVAC load potential for providing load balancing service." *IEEE Transactions on Smart Grid* 3, no. 3 (2012): 1263-1270.

Greer, Christopher, David A. Wollman, Dean E. Prochaska, Paul A. Boynton, Jeffrey A. Mazer, Cuong T. Nguyen, Gerald J. FitzPatrick et al. *Nist framework and roadmap for smart grid interoperability standards, release 3.0*. No. Special Publication (NIST SP)-1108r3. 2014.

Jiang, Iris Hui-Ru, Gi-Joon Nam, Hua-Yu Chang, Sani R. Nassif, and Jerry Hayes. "Smart grid load balancing techniques via simultaneous switch/tie-line/wire configurations." In *Proceedings of the 2014 IEEE/ACM International Conference on Computer-Aided Design*, pp. 382-388. IEEE Press, 2014.

Washburn, Doug, Usman Sindhu, Stephanie Balaouras, Rachel A. Dines, N. Hayes, and Lauren E. Nelson. "Helping CIOs understand "smart city" initiatives." *Growth* 17, no. 2 (2009): 1-17.

Fadaeenejad, Mohsen, A. M. Saberian, MohdFadaee, M. A. M. Radzi, H. Hizam, and M. Z. A. AbKadir. "The present and future of smart power grid in developing countries." *Renewable and Sustainable Energy Reviews* 29 (2014): 828-834.

Hashmi M, Hanninen S, Maki K. Survey of smart grid concepts, architectures, and technological demonstrations worldwide. In: Proceedings of IEEE PES, innovative smart grid technologies (ISGT). 2011.

Acharjee JGP. Development prospect of smart grid in India. In: Proceedings of IEEE international conference on power and energy. 2010.

Siemens acquiring smart grid company in Brazil, ⟨http://www.metering.com/ node/212192012⟩.

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