Smart Grids In Developing Countries

Abstract:

The current scenario of the power market indicates the importance of continual improvement in the grid network and especially in developing countries where numerous issues continue to surface which affect reliability. The need for optimizing the utilization of power generation and distribution at this present time has become more relevant than it has ever been. In addition, as most developing countries have a need to introduce an economic solution as a large change in infrastructure might not be feasible especially if it requires large scale implementation. This paper discusses the prospect of Smart Grids being used to resolve the issues present in the grid and analyse to find a suitable strategy or method of implementation that will make it an ideal solution with minimal budgetary impact. The objective of this proposal is to tackle the issues present in the current climate of the grid by identifying the predominant issues that compromise reliability and quality of the network. This is will entail doing a study on the power market and dive into the concepts and possible solutions under the Smart Gird bracket and test the applicability for an expedient and pragmatic solution. The idea is to identify and channel the broad scope of the Smart Grid technology to focus on the predominant problems and analyse the data to narrow down a solution that is practical and can be implemented.

Background:

The constant need for development and advancement has led to an increased demand for power and it’s infrastructure to support it. With the global market tilting towards renewable generation and the need to sustain this increased power demand, the job for the energy industry to move into the future is no easy task, especially in developing countries. The power market still has a huge dependency on fossil fuel based generation in order to sustain demand and furthermore developing countries have additional problems where they fall short in providing consistent power to the community. Improvement of infrastructure has been one of the biggest challenges in the power sector which stunts development and application of latest technology, they require large initial costs in capital and a vision for the future as well in order to attract investors from private sectors[Schramm 1990, sec. 1, par. 2][Victor 2007][Gupta 1998, sec. 1]. Data from the 1990’s shows that about 5 billion US dollars was needed annually for financing the power sector gives a glimpse of the level of capital and economic factors that are to be considered when implementing change in the network [Schramm 1990, sec. 2, par. 13][Victor 2007]. Furthermore, due to modern-day issues with the grid like congestion of the grid, increased complexity of the grid due to a more intricate distribution network and operating the grid on the peak of its performance has called for improvement in the current system[Moslehi 2012, sec 2]. Thus, the need to improvise and modify the current system to further accommodate other forms of generation and more importantly optimise the utilization of the power already generated is vital.

A technology that has recently come about whose objective is to provide optimization and improved reliability of Grid performance is the Smart Grid. However, although the idea may be an effective one but whether it can be considered as a practical solution that can be implemented on a large scale especially in developing countries where increasing infrastructure

is not that simple or affordable in such a large scale and therefore it has not yet progressed as an implemented solution. The main challenge encountered in non-OECD countries is trying to create a perfect market rather than address the more relevant issues based on the actual conditions [Williams 2006, sec. 9.1 par. 1]. Considering that US has started a Smart Grid assessment in 2009 to begin an assessment of the technology with set parameters on the performance requirements it must come as no surprise that developing countries are still trying to find their feet with the use of Smart Grids[Sun 2011, sec. 2.2, par. 1]. In this study, various examples across the world both in developed and developing countries are considered and the real struggle experienced in the implementation of this system gives an indicator of a need to provide an optimal solution. The objective of this paper is to analyse the market and identify the major issues currently present in countries that are still growing/developing and to study the vast ocean of suggested solutions under the bracket of Smart grid technology and propose a practical solution that can possibly be implemented to resolve major issues in the system and take the energy industry into the future.

Literature Review:

Since objective of the Smart Grid is to improve grid performance it is important to know review the technology in terms of what it can do and how it can do it. A Smart Grid is a system that allows the grid to flow di-directionally with electricity and information flowing simultaneously between the gird and the consumer [Fang 2011, sec. 1 par. 2][Yan 2012, sec. 1, par. 5]. It is a system which in a nutshell is capable of getting real time information from the grid and utilise it to improve the grid performance. The gird is a sophisticated and complicated network thus SG's in itself is further sub-divided based on the aspect of grid performance it focuses on. They are essentially classified into three types: 1) Smart infrastructure system 2) Smart management system and 3) Smart protection system[Fang 2011, sec. 1]. These subtypes are used to tackle different problems and challenges in the grid suited to its title. These sub-divisions encapsulate almost all the aspects that are involved for the effective functioning of the grid and segregated based on its purpose. When the system deals with an advanced methodology for generation, distribution and consumption of power or even deals with the improved performance of the metering/monitoring and communication system it deals with the infrastructure of the grid. When the Smart Grid revolves around the grid reliability, protection from possible failure/faults or even dealing with possible security threats it falls under the bracket of a protection based system. If the system deals with improving the efficiency or optimization of the grid, provide better rates for customers or manage the balance between the supply and demand comes under the Smart Grid management system.

On further diving into the complexity of this technology there are a few aspects that have a lot of influence on the system which will have a significant role towards its performance, communication for example is an important aspect which is integral for monitoring and effective running of the system. A lot of research has been done on this topic in analysing various methodologies that can be implemented as communication systems for a Smart Grid. These studies give a detailed account on the benefits of using various communication technologies ranging from Power Line Communication(PLC) and Optical Fibres to WiFi and 3G/4G networks along with their respective drawbacks[Ancillotti 2013, sec. 5.2,tab. 2][Gao 2012, sec. 3.1, tab. 1][Gungor 2011, sec. 2]. With forms of wireless communication on the rise, it is also an effective prospect which may save on cost in infrastructure but it does not come with its challenges such as interference and availability in remote locations and so on[Kenneth 2015, sec. 3]. When it

comes to it all the researchers suggest with any form of implementation it will result in a compromise, whether it be the interoperability, metering system, scalability to name a few. Thus, a need to effectively evaluate these various methods of communication with an in depth analysis to recognise the impact both in terms of their benefits and disadvantages. On the management perspective, Demand Response is used to deal with co-ordinating electricity usage in the market. Demand response is basically altering electricity consumption by the customers from the usual pattern by adjusting tariff and thus provides an incentive to consume less power especially during peak demand[Siano 2014, sec. 2, par. 1,2]. Moreover, the idea of demand response is to prioritise renewable generation despite its fluctuating nature by managing the demand with maximum utilization of renewable sources and uses conventional generation as a support system to compensate for any shortage in demand[Maharjan 2012, sec. 3]. It promotes interaction with the customers and gets them involved in the manner in which power can be consumed. This tariff adjustment provides an incentive to the end users to alter power consumption in time segments containing lower tariffs which positively impacts the utility owners by being able to control the market. On doing so, the utilities can better manage the grid, especially during peak demands periods by controlling the market and providing more incentive on saving power. By achieving this, it improves power system reliability and provides future scope to inevitably reduce the demand during peak consumption periods thus saving on plant and capital costs as well as reduces the need for immediate improvement in infrastructure with network upgrades and so on[Murthy 2011, sec. 3]. In essence power reliability and efficiency is achieved by encouraging minimal consumption methodologies, manipulating market to utilize power in different parts of the day and limiting dependency on the grid [Siano 2014, sec. 2][Murthy 2011, sec. 2, par 3]. The implementation of Demand Response does not come without challenges however, an improved infrastructure (need for smart meters and back end software) to support this system is needed for execution of this system to be possible. As the region of implementation grows larger the infrastructure cost goes up and thus will require high expenditure at the start, way before the system benefit shows any return in investment. Security and Protection of the system is also vital as it allows the system to monitor of possible faults in the grid and provide protection thus consequently improving reliability. Security is an important facet needed in the system depending on flow of communication and the necessary measures must be taken to avoid interference. The key here is to find a balance on how the gird must be isolated as well as a requirement for interconnectivity, reason being with more sub-grids the complexity of the system will reduce and in addition, the level of permissible information access to the customer must be discussed [Fan 2013, sec. 3][Fang 2011, sec. 8]. As SG technology is used, it leaves a gap for possible security threats that need to be accounted for eg: considering the level of communication and methodologies for Demand Response involved if any of the data is manipulated it will cause significant changes through the grid[Hu 2012, sec. 1, par. 2,3,4].Similar to the requirement of DR, in order to provide effective protection and security, an improved infrastructure is required with Smart meters capable of analysing the grid conditions and other parameters to ensure a healthy grid network. This concludes the overview on Smart Grid technology and it gives an idea on its function and capability.

Research gap: All these studies have provided a wide scope for Smart Grid technology in terms its capability and function which if implemented well and accurately will solve many of the issues as listed in the review. However, they fall short in terms of providing an effective solution that can be implemented and used in the real world to improve the present grid conditions. With case studies done in China, India and in Kentucky US, it shows that this technology has merely started but is yet to be implemented and make an impact[5][3][10]. With these regions still

getting a grip over the technology and forming road maps to achieve this feat, it is clear that despite the immense potential the execution is not as straightforward especially when large scale development is required.

As discussed, despite a wide range of options in communication or with demand response a useful methodology to improve power reliability, with communication there is no real conclusion as to which method is most effective or pragmatic and for demand response, considering it requires an improvement in infrastructure and a detailed survey of the region to actually narrow done and understand how to tackle these issues, these is a lot of aspects that need to be considered in the implementation of this solution. In addition, building infrastructure over an entire region is no easy task, thus making it much harder in a developing country and requires a solution that is practical and targets the major issues hindering the performance of the grid with scope for upgrades rather than building an ideal system which makes it much harder to execute. Thus, it is proposed that a detailed study of a region's power market and consumption patterns to be done followed by testing out various methodologies in a mission to find a solution that can be implemented.

Experimental Plan:

The focus of this study will be to develop a solution that will resolve the major underlying issues in the grid network by identifying the key problems and applying the relevant aspects of Smart Grid technology. The aim is to provide a solution that can improve the performance of the network and take an optimal toll on the economic conditions of the region. The methodology is as follows with an expected time frame for three-four months for each section:

1) Survey on Power market:

The execution and analysis of this survey is an important aspect of this research as it will provide the data and information needed to develop a solution targeted to tackle relevant issues. The data to be collected in this survey will be on analysing factors such as (a) Consumption patterns by residences, industries and commercial buildings, (b) Generation patterns of conventional and renewable generation along with a comparison and (c) Study on the health of the grid and identify frequency of faults and power outages. The data gathered from this survey will give the legs to the research for directing on identifying appropriate methods to resolve the underlying issues.

2) Performance comparison and testing:

This aspect of the experimental plan will deal with performing different experiments on the various aspects that need to be implemented which will include the following: (a)For the communication required for the system, a comparison needs to be done between the various modes of communication-based on performance though simulation and testing. Agilent Advanced Design System is an effective software that will be able to simulate various signals and wireless systems. (b) Based on the results of the survey and identifying the issues present, an effective methodology must be developed as the alternate hypothesis and compared with the current performance of the grid which is assumed as the null hypothesis. The proving and disproving of the null hypothesis must be implemented by simulating the proposed alternate hypothesis and compare it with the data collected from the survey conducted and compare.

MatLab can be used for the simulation of the proposed alternate hypothesis.

3) Design a model simulation or prototype:

As Smart Grids have a wide range of applications that come under this bracket, the objective will not be to simulate a perfect smart grid but based on the experimental results on the null and alternate hypothesis an effective simulation at least with a possible model prototype to show how the model will implement selective aspects of Smart Grids based on the requirement as well as to show a visible performance of the expected output of the system.

Data Analysis Plan:

The plan for analysing the data of this proposed research will defer based on the experiments and methodologies being executed. (1) Survey: With regards to the survey, the data is expected to be collected and stored in data sheets on excels. In order to avoid the biased collection of data, the collection of data from different regions can be randomized and multiple samples of data must be collected from each sub-station being considered taken at different days. These must be done repeatedly not just in different regions but at closely located sub-stations in each region at different time periods in order to ensure the conclusions from the results must be dependent on the repetition of patterns in the data collected. The data collected can be analysed using graphs to analyse the data in the following ways: a) Patterns in consumption of power by residential, commercial and industrial consumers segregated by time of day, b) Patterns in conventional and renewable generation based on the time of day in different regions c) Analysing the repeated recurrence of faults & maintenance issues being tended to on a regular basis.

In terms of analysing data in the performance and design stage, the decisions on the results will be based on two aspects, a) Performance and b) Expediency with the scope for future development of infrastructure. On considering the communication performance, the data will be evaluated based on Range, Quality of output, Interoperability but a significant weightage of it will also be based on how well it will utilize current infrastructure or if not, analyse if the level of economic backing it requires is plausible.

Conclusion:

In conclusion, in today’s day and age with the need for constant development and improvement is needed but it comes with a major investment required for execution and with the technology being researched there is no limit to the solutions that can be applied to solve numerous issues present in the grid network. The focus of this paper will be to identify the problems that hampers the performance of the grid and has the biggest impact on gird reliability and quality, then apply a methodology to apply only the relevant and required technology to solve with optimal investment requirement and more importantly, optimal for future development in order to ensure the implementation of new and improved technology as it advances.

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