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Assesing The Feasibility of Smart Grid Technology on Electrical Distribution Grids

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Abstract

This paper gives a critical analysis framework on the impact of smart grids on electrical distribution grids. It highlights the discrepancies between the developed and developing countries on the adoption of this technology. The concept of smart grids is gaining appreciable recognition in the developed world's electricity networks. The need to assess the impact of this new technology is critical as the laws of infrastructural clearly show that this is the direction to go if speedy and efficient development is going to be achieved in the developing world. A case study of developing countries was cited as a reference base and compared against developed countries. As developing countries still have the majority of their people still without access to power, the paper shows that the capacity for the implementation of smart grid technologies is ripe for implementation, albeit at a rather high fiscal cost.

Keywords: developing country, developed country, smart grids.

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1. Introduction

As the technology advances and the demand for electricity increases, it has become imperative to implement methods that address the generation, distribution and storage of electrical power. The development of electrical grids globally has been very slow over the years especially in Africa and with the ever-increasing energy demands it has led to economic, environmental and political unrest. Due to these concerns, there has been an ongoing global discussion on implementation of smart grids with first world countries showing a great deal of commitment. Smart grids offer a great deal of benefits when it comes to revamping and making strides in the electric network structure and most work carried out in this area has been centred on developed countries. To comprehend smart grids one has to know its perceived characteristics which include facilitation in the generation, distribution and storage, optimizing asset utilization and real time monitoring. [1]

Smart grids synchronize across the value chain from end users to investors all the way to shareholder by significantly reducing the associated costs that come with environmental impacts and at the same time manipulating high system performances, consequently this a critical piece of infrastructure in the big data matrix. [2]

Recent studies have shown that developing countries have the highest urban growth population which has seen power needs showing a positive correlation as well. This urban migration is also ironically in the population following the more developed urban areas with electricity. Statistically is has been shown that the majority of the world experience the scourge of power outages or lack of power therefor, with 17% of the global population without electricity and 40% still using non-renewable sources for cooking and space heating. A global survey has also shown that by 2050, seven out of ten people are expected to live in cities. However the repercussions of this newfound access are frequent blackouts that will leave many people in the developing countries with at least 20 hours per day with the average urbanite Zimbabwean already going through long period per day of power outage. These effects are already evident as the power grid is burdened with cities overpopulated and infrastructure development of the grid only at 30% of potential development.

India which has one of the largest population in the world faced the largest blackout in history when the electrical grid crushed. This caused a cease in many operations that supported the economy and as a result the economy experienced the effects of the blackout. This is another example of how the energy grid suffers when it is over-powered by the population and there are no backup structures to curb the effects. As developing countries evolve into modern metropolises, it is clear that the best solution for developing countries hinges on the development of efficient and reliable generation and distribution systems for the advantage of the general populace. [3]

In this light, the timing is perfect as the band wagon of data manipulation (big data) has officially turned its stare of intent towards energy generators and distributors to make them more viable and reliable. What this means is that, smart meters in every household that allow energy measurements and control energy consumptions. For developing countries that have an exponential city growth and an unbalanced mix of energy supply and demand and theft, the changes could be transformational. India loses 25% of its electricity during distribution, USA loses 8% and Zimbabwe loses 14% which translates to $40 billion, $25 billion and $250million respectively in monetary terms. The smart grid is still very much in its infancy stage but a lot of capital is being invested each year into the industry and is expected to reach higher figures globally by 2030. The South American number one player Brazil alone will invest $36 billion in smart grids to substitute 63 million energy readers with smart meters. India is expected to pump $10 billion and one of the biggest economies in the form of China outmatched the United States in 2013 with $4 billion investment. These are however very high figures for the developing countries of Africa. This then sets up an intriguing paradox for the developing nations. [4] Smart grids need to be monitored meticulously in developing countries and guesstimated delicately especially when it comes to financials to safeguard the narrow equity available in these countries. Expense recovery for smart grids investment is challenging in developing countries due to the limit on the figures by which tariffs can be surged and still remain in an affordable range. When synergistically mixed with renewable energy capacity and enforced efficaciously, smart grids result in a plethora of advantages such as reduction of power outages and transmission losses. [5]

Table 1. Associated betterment for investing smart grid technology in developed and developing countries.

Advantage	**Beneficiary**
Downsized outages	End users
Scaled down electricity losses	Energy distributor
Lessened carbon dioxide emissions	Surrounding community
Decreased additional service costs	Energy distributor
Delayed investments for distribution	Energy distributor
Minimized equipment failure	Energy distributor

Extensive research and studies have indicated the area of interest has been exhausted even though the technology has been in its infancy in terms of implementation. However the current studies be they similar in nature or dissimilar do not clarify and highlight a visible plan for both developed and developing countries. Most studies either focus on one of the two, either developed or developing countries. The question remains are the conditions for implementation still the same for the different areas. What are the areas of focus, what are the cost benefits for each area, what are the challenges to be faced in each area amongst other questions? The novelty of this article hinges on critically giving an insight and answers these questions in a meticulous manner. The article or research is based on recent findings from both developed and developing countries so that a clearer conclusion could be reached on the feasibility of this technology without a one sided view.

The article commences by analysing the types of smart grid technologies available and then goes on critically compare the issues faced in developing and developed countries in trying to adopt this technology. A roadmap to expedite and facilitate the adoption of smart grids is then highlighted and the article concludes by explaining the challenges experienced by both developed and developing countries.

2. Objectives/ Rationale of the study

- To analyse the stages of development and research of smart grid systems in developing and developed countries.
- T conduct quantitative and qualitative research on smart grids.
- To study the roadmap or future of smart grids.

3. Smart Grid Technologies Wide area monitoring

Responsible for assessing performance in real time and subsequently showing the result of system elements crosswise the linkage and throughout the massive geographical areas. These state of the art operations scale down on blackouts and merges with a mix of renewables. Progressive technologies generate data which informs decision makers mitigate disturbances and improve transmission capacity.

3.1 Renewable and distributed generation integration

A synthesis of renewable and various energy sources which are distributed encapsulate all the scale levels from large to medium to small scale. This means we are looking at commercial and residential buildings which pose different challenges when it comes to quickness and manageability.

3.2 Advanced metering structures

Allows the dispatch ability of a mix of technologies to already existing modern smart systems which permits an exchange of data in two directions, giving end users and distributors information on pricing and usage as well the timeline of power used and the quantity.

3.3 Customer side systems

Probably the most improved and sophisticated system which aids in power usage at all levels. The information is generally shown on a dashboard and usually it comes in the form of power peak demand and power or efficiency gains. This kind of system synergizes manual responses from the end user and the automated responses on pricing. [6]

4. Smart Grids and Renewables

The ultimate goal of every nation is to run on sustainable energy sources and in particular we will mention renewables. The increase of renewable energy is a fundamental ingredient in accomplishing the global power mix and such an action will require an upgrade from old grid systems to new robust energy systems, case in point smart grid systems. Smart grid systems when incorporated with renewables need to possess some of the following characteristics;

4.1 Distributed Generation

Smart grids facilitate the precise pricing and valuation of renewables as appropriated energy generation has several effects on distribution systems. Smart grids provide comprehensive data on related output and performance and aid the operators in putting accurate figures on the cost of generated renewables. It should also be noted that the information and control is useful in several ways which include but are not limited to reducing output or disconnecting distributed energy.

4.2 Variability

The principal challenge in electricity systems is always maintain the match for demand with supply be it non-renewables or renewables. Traditional fuel powered plants operate on set points and operators rely on them to produce a steady output with less fluctuations. However with renewables such solar or wind which are intermittent in nature, there is always going to be variations in output resulting in an unmatched demand and supply. When smart grids are incorporated they make it achievable to combine a broad spectrum of renewables.

4.3 Capital Investment

Smart grids diffusely highlight on the issue of equity required for renewables by supporting private financing in power systems. In past times the power generators were responsible for enacting power plants. With the ever changing times policies and governments have given support to private investors to finance their power plants along the regulated guidelines. [7]

5. Developed versus Developing countries

Smart grid technologies present a premium of chances for both developed and developing countries. A study shows that the pushing elements for the approval of smart grid technologies in developing economies revealed that these often vary in analogy to the drivers in developed countries. As indicated by *Figure 1,* the comparison indicates that while bettering system efficiency is crucial for both developed and developing countries, increasing system reliability and achieving secure revenue collection has a higher priority. It can be clearly seen from *Figure 1* that developing countries need to focus more on reliability and system improvements and they focus more revenue collection whilst developed countries have improved their supporting policies to enable renewable energy generation and new products introduction in conjunction with system efficiency improvements. [8]

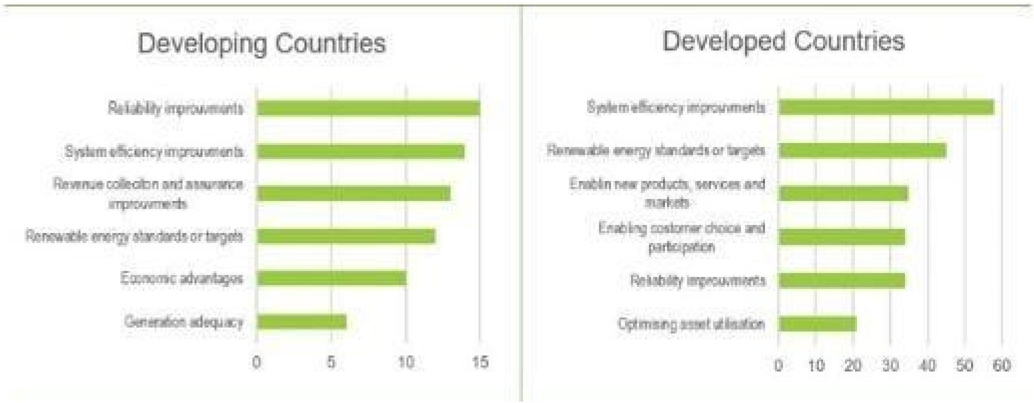

Figure 1. An analogy of the main drivers for investments in smart grids (developing and developed countries)

Due to these different contrast drivers for smart grid investment, developing countries also have different technological priorities when it comes to smart grids. *Figure 2,* indicates the contrast in the technological priorities for smart grid installation for developing and developed countries. *Figure 2* highlights how developed and developing countries prioritizes technological improvements and this can be attributed to the differences in economical advantages between the two.

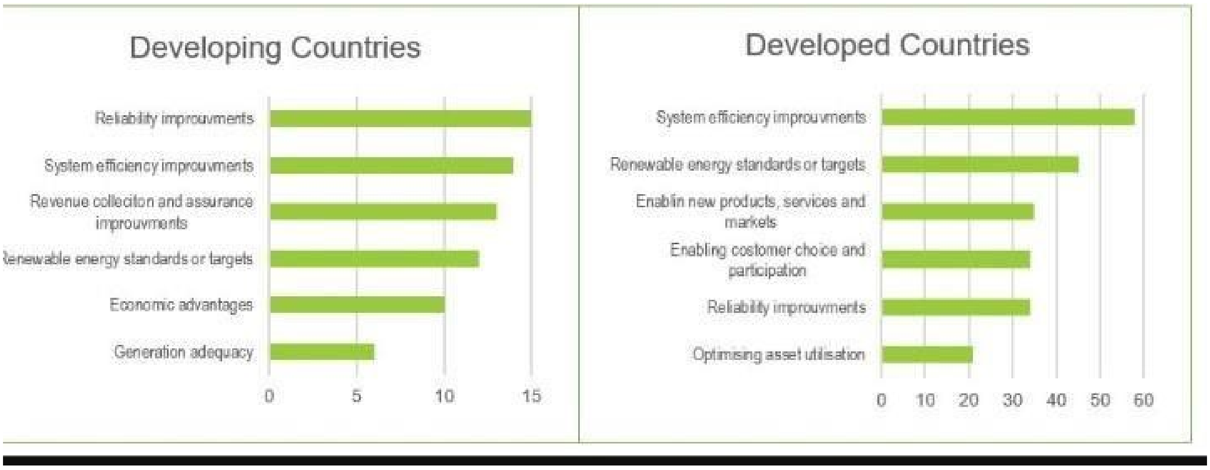

Figure 2. An analogy of the technological preferences for installations of smart grids (developing and developed countries)

Moreover, Table 2 also indicates some of the problems experienced by the electricity network in many developing countries and their corresponding quick fixes which can be used to address these issues. The problems are similar in nature for both developed and developing countries which means an action to implement would also mean these issues have to be tackled. Distributed generation from renewables, limited generation capacity, costs and ageing infrastructure are some of the challenges which can be resolved by balancing demand and supply, load management and efficient generation among other solutions. [8]

Table 2. Problems that are faced in the electricity network and the complementary solutions

Existing problems in the energy system	Solutions for smart grid
Renewable and distributed generations	Matching supply and demand with existing business models
Restrained output capacity	Managing load and minimizing on peak loads and times
Ageing infrastructure	Implementation of automatic systems that avoid power outages
Value and emissions of energy supply	Reliable output levels in terms of supply and demand
Revenue losses	Accountability of all power generated and distributed via automated systems

6. Methodology

The authors work is purely a research article which focused on the impact of smart grids on electrical distribution grid for both developed and developing countries. The research approach was a combination of both qualitative and quantitative data gathering to understand the differences and similarities between the developed and developing countries.

For quantitative data gathering it was purely based on recent studies of research papers and journals on the subject area. The research stemmed from the need to understand the challenges experienced in implementing smart grids. Recent research studies and supporting journals were guidelines for the quantitative data for both developed and developing countries. As for qualitative data, a few interactions with management in energy sectors aided in formulating some of the conclusions. It was a constraint though in this section as the authors were dealing with people who have not yet implemented the technology but with a roadmap.

The analysis of the gathered data was however a success as it was near accurate and a mixture of current studies, implementation and near implementation.

7. Success of Smart Grids Implementation

7.1 Distribution of a mix of generation technology

In a bid to minimize the carbon footprint correlated to power supply, a plethora of variable generation technologies have been deployed. The escalation is expected to expedite in the distant future with most countries incorporating these technologies in their electricity systems; Zimbabwe included. The Zimbabwean government has encouraged the development of independent power generation companies with an emphasis on renewables. As the growth accelerates, it will become challenging to establish a steady and decent management of energy systems supply depending on conventional grid architectures and limited flexibility. Smart grids will however will give strength to deployment of a mix of generation technologies by providing operators with real time information that enables management of generation, demand and power quality thus increasing system flexibility and maintaining stability and balance. Spain initiated a global pioneering to monitor and control these variable renewable energy resources by allowing the maximum amount of production to be integrated under secure conditions. [9]

7.2 Electrification of transport

A statistical survey indicates that due to the increase of electric vehicles and hybrid vehicles, the transport sector will consume 10% of electricity consumption. Charging of electric needs meticulous monitoring or it may result in a surge of peak loading on the electricity infrastructure which consequently leads to current peak demands. Smart grid technology allows prioritized charging in cases of low demand exploiting the use of both low cost generation and extra system capacity. In the long term there is a possibility that vehicles could give stored electricity in the batteries back into the system when needed. The Netherlands engaged in a project that established a network of electric car recharging sites using smart communication and communication technology applications to enable distributors to deal with additional power demands. [10]

7.3 Hurdles to Overcome in Smart Grid Adoption

The electrification of developed countries has spanned over a couple of years and continued financial support is required to maintain a consistent power supply. With growing energy requirements and changes, ageing distribution and transmission infrastructure will need replacement and updating. The downside of this action is that technology investment will be obstructed by current market and regulatory policies which have been enacted for long periods and overlooking the perks of new innovative technologies. Smart grids offer a way to maximize existing infrastructure through better monitoring and management. Fast emerging economies like China have a different assortment of smart grids infrastructure needs from developed countries and its response to its high growth in demand will result in newer distribution and transmission infrastructure. Europe and America have the highest number of ageing infrastructure especially at the transmission level. Japan has been successful in deploying the smart grids which operate at high reliability levels and now focusing on distribution levels. [11]

7.4 Peak Demand

The variation in energy demand is high across the day periods and throughout the seasons. The distribution systems are tailored to cater for high demand periods and during non-peak hours the system is under-utilized. Enacting systems which meet erratic peak demand requires huge investments that would not be needed if the demand curves were flatter. Smart grids can reduce peak demand by providing information and incentives to consumers to allow them to shift consumption away from peak demand periods. The management of peak demand enables improved system planning throughout the entire electricity system, increasing options for new loads. These benefits are essential for new systems where demand growth is very high and for existing and ageing systems that need maintenance. [12]

7.5 Capital Expenditure

All types of smart grid will require major investment and the actors investing will face investment risk accordingly. The more advance types that promise greater benefit require investors with different interests to join forces and to at least coordinate their investments. Three factors which determine investment include; dealing with new risks and uncertainties, dealing with new decision making arenas in which investment plans need to be defended and dealing with the new power position of the electricity consumer and prosumer. Each factor need to be analysed with respect to the market forces. [13]

7.6 Tailoring smart grids to developing countries and emerging economies

First world countries have advanced contemporary systems for smart grids whilst the majority of existing grids that do not operate constantly over a lengthy period, and other have no infrastructure at all. Developing countries and upcoming economies are classified by steep expansion in energy demand, high commercial and technical losses in a context of rapid economic growth and development. Such areas often present important issues and probabilities concerning the subject area. Smart grids play a crucial role in the distribution of new electricity infrastructure in developing countries by allowing more competent action and minimized costs. Minor peripheral systems not networked to a centralized electricity asset and initially employed as a price effective approach to rural electrification might be later connected easily to a national or regional infrastructure. As a means to access to electricity in sparsely populated areas, smart grids could enable a transition from simple, one off approaches to electrification to community grids that can then connect to national and regional grids. The deployment stages go from battery based and single household electrification to micro, mini or standalone grids to national grid and regional interconnection. These stages require standardisation and interoperability to be scaled up to the next level with higher amounts of supply and demand. Each successive step can increase reliability and the amount of power available if managed in a way that allows seamless variation from the community. Ultimately the end point of smart grid deployment is expected to be similar across the globe but the routes and time to get there could be different.

8. Recommendations

- Cultivate research to enhance smart grid programs where the general objective is to achieve dependable and effective grids to cope with the ever changing outlook.
- Foster dissemination and knowledge initiatives with the end objective of allowing grid operators to have a central role and allow them to providing the largest number of security requisites.
- Improve the regulatory and policy framework in which this legal framework would aid in harmonizing existing policies which would be considered as a reference with which to align policies and regulations on other aspects.

- A key element is to allow the revamp of the existing infrastructure which is of old age. The result in to enact systems which will have a long life span and provide efficient output and robustness
- Development of roadmaps for standardisation and interoperability which allows for devices to communicate and operate seamlessly across all levels of the grid.
- Initiate innovation in business models where the government, regulators and utilities should define roles and operational boundaries. Government should collaborate with manufacturers, network owners and operators to create sandbox environments in which new distributed energy business models can be operated in real world conditions to identify least cost integration options.

9. The Future

Current market systems are coupled with hurdles that hinder the proper implementation of smart grids. It is imperative that regulatory and market models that address investments, prices and end user involvement advance as new technologies offer new options. Most typical markets offer vertically integrated utilities which own and operate infrastructure assets across the generation, distribution and transmission.

Therefore roadmap for the developing countries to achieving the feat of smart grids is divided into seven actions and these actions are sequential in their implementation. The first action is the challenge faced with grids and the associated advantages that grids offer. Second action explains the trending status of smart grids coupled with combined expenses and profits. Third action is a future perception for smart grid distribution. The fourth and fifth action examine smart grid technologies and policies and milestones. The sixth action analyses current trends and the outlook of international collaboration and the seventh presents an action plan and identifies future steps. These steps will encompass the full system from generation, transmission, distribution and management for the system. [15]

10. Conclusion

This research article has articulated the adoption of smart grids and the constraints to be faced by both developed and developing nations. In advanced countries, strides have been made in adoption and implementation of these systems with developing countries still lagging behind. The major achievements have been efficiency, reliability and productivity through the use of smart grids. Power generation is not limited to engineering problems, it is multi-dimensional and affects the infrastructure and exchange of information between systems. The following points can be drawn from the study;

- Smart grids can be seen as a basal asset that give the capability to replace adequate use of data to form more effective investments in the electricity systems.
- Smart grids have the potential to change the outlook of how energy generation devising is carried out and how large scale electricity markets are planned. The data gathered will give users the liberty to control their energy use as well as allow utility companies to better comprehend customer needs.
- Smart grid technologies clearly come at a high investment cost and fiscal cost especially to the developing nations which are inherently poorer. However it can also be argued that going for outdated infrastructure in trying to reduce costs may inherently cost a higher running cost, as well as a cost to upgrade. It can also be seen that the cost upgrading old infrastructure to smart systems is evidently higher as many components become redundant and new components are needed altogether, a position which puts developing countries at an advantage as the grid expansion projects and capital power projects can be planned with the smart grid in mind and thereby working efficiently to make the design of the new grid less capital intensive to a point of affordability.

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