

The Smart grid: adopting new concepts for infrastructure to power Africa's emerging industrial revolution

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ABSTRACT

African economies are emerging among some of the world's best performers and set on course for imminent industrial revolution. This will however require more secure and affordable electricity supplies among other infrastructure. The centrally controlled power utility model as conceived by Nicola Tesla in the 1880's has served the world well for just over a century and a quarter and been pivotal in the evolution of currently developed economies. But with emerging 21st century demands such as efficiency, environmental sustainability and consumer choice the model is reaching its limitations. Towering power lines traversing the countryside have traditionally presented imagery of development and advancement but are very capital intensive and incur massive power losses. A whole range of ecological and biodiversity issues along the routes of large power lines are also well documented.

Solutions for development in the developing world need not follow the same path as the developed world. Instead, relevant technical solutions for advanced applications in the developed world can be used to leapfrog intermediate technologies and applied directly, with benefit to the developing countries.

New trends are emerging both in energy supply economics and power management technologies. The most popular theme is the Smart Grid. The vision is comprised of three key elements namely, consumer empowerment, grid integrated distributed renewable resources and intelligent network logistics. The use of distributed resources particularly aims to reduce the need to invest in transmission infrastructure by positioning power generation closer to the load centers. In this paper the authors show through a case study of Tete province (Mozambique) that rather than taking generators to the load, new industrial centers should instead be built close to energy resources. Savings from the deferred transmission infrastructure could instead be used to construct manufacturing industry. Africa is particularly advantaged because unlike the developed world it does not have old infrastructure backlog. This presents a golden opportunity to plan using modern scientific concepts.

Keywords: Smart grid; renewable energy; distributed generation; power grid planning; infrastructure

1.0 INTRODUCTION

African postcolonial pioneers such as Kwame Nkrumah, Abdel Gamal Nasser and Julius Nyerere initiated the dream of a United States of Africa more than a half a century ago. In recent times the idea gained new momentum, through such initiatives as the New Partnership for African Development (NEPAD) and the African Union (AU). The objective is to create a single African market, now estimated at over a billion people, that is competitive within itself and at

the global level (NEPAD, 2001; Simuyemba, 2000). As a first step, economic integration is already taking shape through regional blocks such as ECOWAS, COMESA, EAC and SADC.

Gradually improving levels of democracy and good governance across the continent offer increased prospects for success.

Lack of infrastructure has, however, been cited as a major stumbling block to growth and development on the continent. Systematic integration, upgrade and modernization of networks such as roads, railways, aviation, telecommunications and fuel lines would clearly offer the required catalyst for economic growth. Some efforts are being made to address this. For example in July 2010, African leaders launched a Programme for Infrastructure Development in Africa (PIDA). Led by the African Union, New Partnership for Africa's Development (NEPAD) and African Development Bank (ADB), the initiative has a budget of several billion dollars (ADB 2010).

Electricity is recognized the world over as a leading catalyst for development and modernization. The extremely low penetration levels of electrification in Africa underscore the current poor state of not just electricity, but infrastructure in general that must be urgently addressed to avoid (among others) stifling the envisaged industrialization drive.

The spectre of large power transmission lines crisscrossing the countryside has historically carried a symbolism of development. These large transmission lines, however, also carry a disproportionately large price tag in terms of capital and recurrent costs. For example, the Uganda Electricity Board (UEB) archives reveal that out of the total capital investment in the generation, transmission and distribution of Owen Falls hydroelectric power system, the dam and power station accounted for only 55 per cent. All but 5 per cent of the remainder had been the cost of creating the distribution network

The distribution of power in Uganda is particularly challenging. The Lake Victoria climatic environment presents unique features that increase power transmission vulnerabilities. For example the region is reported to have one of the highest liabilities to thunderstorms in the world and historical experience has shown that transmission lines and substations were particularly vulnerable to damage by lightning. As a result extra protection, at additional cost, had to be installed. The UEB archives further report that compensation for damage to crops reached a peak of more than £50,000 per annum in 1959. Lines through forests had to be frequently checked to make sure that creepers did not climb the poles and cause short circuits. This inevitably meant higher than normal recurrent and maintenance costs. Added to all these is the nominal line power transmission losses that can range between 10 – 40%.

There is no doubt that electricity must be made available to every corner of the country to support modernization and development in all areas such as health, education, commerce and consumer comfort. However given the above constraints there is need to look for possible alternatives to complement (and at times substitute) the traditional centralized utility power generation and transmission model.

In fact none other than the first chairman of the Uganda Electricity Board (UEB), Sir Charles Westlake had, way back in the 1950's, recommended a more decentralized electric system for Uganda. He had proposed that the Owen falls power station be confined to a more compact network. It would supply industry and consumers in Kampala, Jinja and Entebbe. The Uganda Argus of May 2, 1955, further quoted him, as having suggested that the furthest west that Owen Falls power would go was Masaka. Anything beyond that would have to come from local hydroelectric sources. For the North, Westlake proposed that power would be produced from the numerous potential sources in the region. Table 1 shows some of Uganda's potential hydroelectric power centers. Unfortunately subsequent UEB policy seems to have ignored

this strategy and opted for the costly large grid system centrally supplied from Owen falls. Consequently transmission infrastructure costs have historically emerged as the biggest stumbling block to Uganda's electrification. Any Ugandan consumer who has ever attempted to extend a power line to a location at even one kilometer from the grid can attest to this truth.

Solutions for development and industrialization in Africa need not follow the same path that was followed by the developed world. Instead relevant modern technical concepts for advanced applications in the developed world could be used to leapfrog intermediate technologies and applied directly, with benefit to the developing countries. The telecommunications industry for example has avoided the outdated and expensive landline infrastructure and catapulted into cellular technologies. The resulting explosive growth across the continent has immensely impacted on the growth of economies and increased the quality of lives. Ironically, Africa's traditional lack of telephony infrastructure provided the opportunity for this growth. Likewise the lack of existing industrial cities offers a great opportunity for prudent planning. Rather than generate and transmit power over long distances through expensive infrastructure a prudent strategy should be to locate new industry in close proximity to major energy resources. The capital costs and time resources that would have gone into unnecessary transmission lines would be used to construct industry instead.

In this paper the authors examine an African case study of Tete Province in the Republic of Mozambique. The province is home to a large hydropower resource in the Zambezi basin, and generates large amounts of electricity for export. The authors however observe that there is little evidence that this exported energy has had any tangible impact on the local economy. They then propose that rather than continue to generate power and transmit it to distant places, the local economy of Tete as well as the Southern African economy in general, would be far better served if industries were built in the Zambezi basin itself. Developments in strengthened regional integration should augment such a strategy as broken customs barriers mean that investors and goods can crisscross regions without incurring penalties.

Table 1. Potential hydropower sources in Uganda(Source: Wikipedeadea)

Hydro electric power station	Community	Potential Capacity
Ayago Power Station*		500MW
Bugoye Power Station		13MW
Bujagali Power Station	Bujagali	250MW
Ishasha Power Station	Rukungiri	7MW
Isimba Power Station	Jinja	100MW
Karuma Power Station	Masindi district	750MW
Kiira Power Station	Kiira	200MW
Mpanga Power Station	Kamwenge district	18MW
Nalubaale Power Station	Njeru	180MW
Nyagak Power Station	Nebbi District	3.5MW
Kisiizi Power Station	Rukungiri District	0.3MW
Waki Power Station	Masindi District	5MW

2.0 TETE PROVINCE- REPUBLIC OF MOZAMBIQUE-A case study

The Department of Science and Technology (Tete Province), in Mozambique, through the auspices of the International Council for Science (ICSU_ROA) extended an invitation to a select group of African energy experts, in 2008, to visit and appraise the state of rural electrification in the Province. These authors were part of the invited group. This took several days as daily trips were organised to nearly all the district headquarters in the province and finally

the Governor's office. The 2000MW hydropower station at Cahora Bassa was also visited. An energy workshop, opened by the Provincial Governor, was held at the end of the visit.

Apart from the Cahora Bassa power plant the province is also blessed with multiple hydro-potential resources as illustrated in figure 1. The total hydro-potential is estimated at between 9000 –12000 MW. This has the capacity to support the energy needs of any size of industry that can be envisaged..

There is a thriving agricultural sector as well. Livestock is estimated at some 200 000 head of cattle and over 300 000 goats. Crop agriculture includes tobacco, wheat, soy, sorghum, potatoes and horticulture. There is also bee-keeping and honey production.

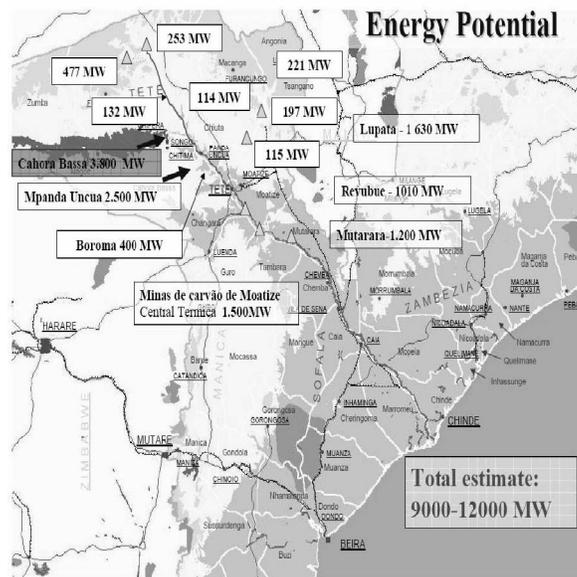


Figure 1: Potential hydropower sources in Mozambique and their estimated capacities (Courtesy: Directorate of Science and Technology, Central Region, Mozambique).

Many of these activities would contribute to the raw materials feedstock if local industries were in place. Moreover Tete is strategically located near the borders of Zimbabwe, Zambia and Malawi, which give it easy access to regional markets, as well as sources of raw materials. There is potential for trans-boundary game parks crossing into neighbouring countries and thus ample scope for investment in tourism and wildlife.

Despite all this potential there is very little industrial activity and the bulk of power generated gets exported. A tobacco leaf processing plant is operational but this yet another product that is exported before being fully processed and thus the local economy does not enjoy the full benefits of their resources.

Mozambique currently uses a traditional power transmission model that delivers bulk power to loads as far away as Johannesburg. The massive capital outlay for the delivery infrastructure as well as the recurrent maintenance is clearly not cost effective. This is without considering the well-documented environmental impact of high-tension lines. Power supplies to Mozambican domestic and commercial centers follow a similar model.

Recent research in energy supply economics (Lovins, A. B. et al, 2002) has shown that this century old centralized power utility model is no longer sustainable. Apart from large capital

outlays the model has been proven to be responsible for massive transmission losses and premature aging of the power delivery infrastructure particularly during peak demand through over heating of the transformers and cables. The new approach is adoption of integrated resource planning.

In the authors' view Tete province presents the ideal setting for the next industrial hub in Southern Africa. This would mean that rather than transmit power away to distant places, industry would instead be taken to Tete.

3.0 INTEGRATED RESOURCE PLANNING

Traditionally, a good utility has always been one that planned capacity expansion to meet anticipated growth in demand. And like any other business most of their communication to consumers was to encourage them to consume as much as possible. Consumers were encouraged to use electricity even for energy requirements that could have been met by more prudent and easily accessible resources. Moreover traditional tariff structures do not charge consumers in proportion to how far they are located from generation source. By contrast, for example, consumers of petrol in Nairobi (an inland located city) normally pay higher prices than those in Mombasa (a port city) as a result of transport cost differentials. Consequently the traditional power utility tariff model does not incentivize consumers to locate in close proximity to generation and thereby save on the huge capital and recurrent expenditure on transmission.

Integrated resource planning is an organizational paradigm that addresses energy resources and consumer demand as a collective. The Institute of Engineering and Technology (IET 2007) has developed an energy hierarchy, which is included in their Primer on Energy Policy. It aims to promote sustainable energy management by following a logical approach.

At the top of the hierarchy is changing of human behaviour. Rather than continue with unfettered utility capacity expansion to meet growing demand one needs to examine consumer usage behavior as well. Thus the consumer becomes an energy resource. Emphasis here must be to reduce consumption but without compromise to consumer standard of living. This requires little or no capital investment by the consumer and defers the need for new capital investment by the utility. Apart from consumer behavior and improved appliance efficiency, prudent resource-to-consumer-need-conversion is vitally important. For example given that solar is available as an energy resource and if the consumer's need is hot water then the most prudent conversion technology is a solar water heater. The electric heater may be retained as a complementary rather than a primary appliance. In the following paragraphs the authors illustrate why the traditional power utility model is particularly unsuitable for Mozambique.

To begin with it was revealed, during the aforementioned authors' visit to Tete, that the current output capacity of the Cahora Bassa plant is 2075 MW. An estimated 10% (200 MW) of this power is lost while being transmitted through a 1414 km line to the Republic of South Africa and other neighbouring states. But the clients can only pay for power that they receive. Secondly Mozambique is geographically stretched out in structure and requires long and costly transmission infrastructure to span the distances.

It is necessary that a power supply system should be made available to all parts of the country for equitable development. The cost of the infrastructure as well as delivery losses would however be minimised if (for starters) prudent integrated resource planning is implemented. While most Mozambican households currently use biomass for cooking, largely as a result of the country's low electrification rate, the preferred modern living model is electric cooking and heating for the electrified urban consumers. In other words if more Mozambicans were to improve their affluence these households would (most probably) switch all their energy requirements to electricity.

Apart from the abundant solar resource Mozambique happens to be also endowed with natural gas resources. These two resources are what ought to be used to meet heating and cooking loads in the place of electricity. (Currently Mozambican gas is mainly exported, as a raw material, to South Africa and converted to liquid fuels by South Africa's giant fuel manufacturer, SASOL, using a very energy inefficient technology). The use of electricity would instead be confined to quality and essential functions such as lighting, refrigeration, infotainment, and communication services for schools, hospitals, households, commerce and public administration. This would also impose less wear and tear on the distribution network, which would also mean less maintenance and increased security of supply. It would also require an infrastructure with much smaller components and cables and thus lead to increased expansion of the national grid to reach more consumers through reduced capital costs and overheads per kilometer.

In the case of industrialized economies the location of industry is already in place and only partial improvements to the traditional power distribution model can be achieved. On the other hand Africans are only beginning to plan and locate their industry and therefore have the opportunity to do it prudently and achieve optimum results. Such precedent has already been made in the cellular telephone industry. There was practically no previous landline telephone infrastructure in sub-Saharan Africa. Now with the emergence of the new wireless technology, Africa has moved to avoid the old, expensive technologies of constructing posts across the countryside. This is without considering the prolonged construction timelines. As a result sub-Saharan Africa has achieved growth rates in cellular telephony that are far higher than the rest of the World. In some countries like Kenya and Cameroon growth rates in excess of 300% per annual have been reported

4.0 CONCLUDING REMARKS

A case study of the Mozambican Province of Tete has been presented to highlight some fundamental anomalies of the traditional centrally operated power transmission system. It has been shown that the province generates enormous amounts of electricity but the sales revenue earned from these un-beneficiated exports has had little impact on the economy of its host country.

Mozambique will only realise value from their electricity production if it is used to run locally based industry. There is already ample agricultural activity to supply the required feedstock to kick start this.

Mozambique does not yet have any industrial centers and therefore has a great opportunity to plan prudently. So rather than continue to construct long and expensive power transmission infrastructure new industries should instead be built in Tete province. This would save both money and time. In addition energy supplies to the rest of the country should be based on an integrated resource model. This would use other distributed energy resources particularly solar, gas to meet mainly heating and cooking loads. Campaigns in consumer awareness and education to effect behavioural change would also realise further energy savings. The drastic reduction in electricity usage per consumer would mean a thinner and more affordable infrastructure per kilometer and the resultant savings would enable more grid coverage around the country.

5.0 REFERENCES

- ADB (2010). Official Launch of PIDA. African Development Bank.
<http://www.afdb.org/en/news-events/article/official-launch-of-pida-7073/>
- IET (2007). The Institution of Engineering and Technology. The IET Energy Principles. *The IET Knowledge Network*. July 2007. See also: 
<http://www.theiet.org/publicaffairs/energy/index.cfm> (Accessed 24 July 2008)

- Lovins, A. B. et al, (2002). "Small Is Profitable: The hidden economic benefits of making electrical resources the right size." Earthscan, Nov 2002. ISBN 971881071075
- NEPAD (2001). The New Partnership for African Development. Abuja Nigeria. October. /<http://www.nepad.org/2005/files/documents/inbrief.pdf>
- Sebitosi A. B., Pillay P. (2005). "Energy Services in Sub-Saharan Africa: How conducive is the environment?" Elsevier Energy Policy, Volume 33 (16) 2044-2051
- Simuyemba S. (2000). Linking Africa through regional infrastructure. African Development Bank, Economic Research paper No.64. USAID Regional Center for Southern Africa Gaborone, Botswana. See also /http://www.afdb.org/pls/po-ral/docs/PAGE/ADB_ADMIN_PG/DOCUMENTS/ECONOMICSANDRESEARCH/ERP-64.PDFS.
- The World Bank, (2004). Skills Development in Mozambique: Issues and Options. Report No. 29492-MZ. Human Development Country Department AFCO2 Africa Region.
- See also: http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2004/09/08/000160016_20040908100717/Rendered/INDEX/294920MZ.txt