A vibrant energy sector sets the pace for the development of any nation’s economy. For steady economic growth, energy, especially electricity, has to be sufficient, affordable and readily available. According to the African Infrastructure country diagnostic [1], ‘the performance of Africa’s power supply sector on the continent is unsatisfactory. Most of the continent’s power companies are unreliable sources of supply, inefficient users of generating capacity, deficient in maintenance, erratic in the procurement of spare parts, and unable to prevent losses in transmission and distribution. They have also failed to provide adequate electricity services to the majority of the region’s population, especially to rural communities, the urban poor and small and medium enterprises.

With such a dire situation, it is no wonder that the economies of many African countries – like Uganda – are in trouble.

Uganda’s electricity and business sector

In order to promote growth in the energy sector, the Ugandan government implemented a Power Sector Reform and Privatisation Policy under the Electricity Act of 1999. This resulted in the formation of Uganda Electricity Generation Company Limited (UEGCL), Uganda Electricity Transmission Company Limited (UETCL) and Uganda Electricity Distribution Company Limited (UEDCL). These were carved out of the Uganda Electricity Board (UEB) which was a vertically integrated state-owned enterprise that was commissioned during the colonial era, but had chronic operational inefficiencies. UEGCL and UEDCL later leased their assets to Eskom (Uganda) Limited (EUL) and UMEME Ltd (energy distribution network company in Uganda) respectively. In addition, in April 2001, the Electricity Regulatory Authority was formed and given the responsibility of overseeing and regulating all the players in Uganda’s electricity sector.

The electricity grid only covers the urban parts of the country, yet 80% of the population lives in the rural areas. The rural electrification agency was thus formed in 2001 to ensure that rural electrification is improved from 1% in 2001 to 10% by 2012 [2]. In the meantime, at the dawn of 2012, electricity consumers in Uganda were tired of continuous load shedding [3]. Industrial and commercial consumers had to bear the cost of fuel for use in generators to carry on operations. The unreliable power supply which the country had been experiencing for the better part of 2011, accounted for approximately 25% of the processing losses incurred by manufacturers [3]. Fortunately, this did not last for long. Bujagali hydro power dam was supplying 250 MW of power to the grid and there was a sigh of relief as the load shedding stopped.

The celebration however did not last long as at the end of 2012, UMEME Ltd, the main power distribution country, announced an increase in power tariffs and the business community went up in arms again. Manufacturers said expensive power will further make Uganda uncompetitive in regional and global markets, saying the country had already lost its regional market share of manufactured goods owing to Tanzania’s recent institution of a 25% import duty on goods originating from Uganda [3].

In 2009 the Union of Producers and Transporters of Electricity in Africa (UPDEA) revealed that Uganda, at an average of 25 cents USD/kWh, had the highest power tariff in East African region [4]. Kenya and Tanzania had average of 12 cents USD/kWh and 10.5 cents USD/kWh respectively. Ironically, as shown in Figure 1, the power tariff has been steadily increasing since 2009. It is feared that an increase in the tariff will drive the cost of doing business up and eventually drive up the price of the commodities.

Figure 1: End user tariffs [5].
Study approach

The authors conducted a survey to appreciate the challenges faced by commercial users of electricity in Uganda. It was conducted in the areas of Kampala (central), Jinja (Eastern region), Mityana and Mbarara (western region). A total of 100 businesses were part of the survey. Businesses that participated in the survey comprised 6% (industry), workshop (11%), restaurant (12%), shops (71%).

In addition, the researchers carried out site visits and face-to-face interviews with engineers from two of the large hydro power stations and one mini hydro power station. They also interviewed engineers and employees of UETCL and UMEME.

Findings

Commercial consumers

22% of the responses said that their greatest problem with power was that it is expensive while 51% said that the power was unstable. 27% did not respond.

When there is no power, 42% of the businesses use generators while 18% close the business for the day. 32% use lanterns for lighting and 8% use candles. Unstable power can lead to equipment getting spoiled. 29% of the business owners said that their equipment had become spoiled while 70% said that none of their equipment had become spoiled.

Surprisingly 54% of the consumers said they were just satisfied with the distribution company, while 18% were very dissatisfied.

Generation

Currently there are over 20 generation companies in the country [5]. Uganda Electricity Generation Company Limited (UEGCL) owns the Nalubaale and Kiira hydropower generation stations and equipment in Jinja, concessioned to Eskom (Uganda) Limited. Other generation companies include, Bujagali Energy Limited which controls the newly constructed Bujagali hydropower station, Aggreko which owns thermal (diesel) generation plants at Mutundwe and Jinja, Jacobsen which owns a thermal plant at Namavve, Kasese Cobalt Company Ltd (KCCL), Kilembe Mines Ltd (KML), Electromax (thermal) and Bugoye.

Uganda’s energy mix

The electricity generated in the country is from three sources; hydro power, thermal and biomass with hydro power contributing 77%, thermal 20% and biomass 3%.

Abbreviations

ASR – Alkali Silicate Reaction
EUL – Eskom Uganda Limited
FESL – Ferdsult Engineering Services Limited
GPRS – Global Positioning Network System
KCCL – Kasese Cobalt Company Limited
KIL – Kilembe Investment Limited
KML – Kilembe Mines Limited
SCADA – Supervisory Control and Data Acquisition
UEB – Uganda Electricity Board
UEDCL – Uganda Distribution Transmission Company Limited
UEGL – Uganda Electricity Generation Company Limited
UETCL – Uganda Electricity Transmission Company Limited
UMEME Ltd – An energy distribution network company in Uganda
UPDEA – Union of Producers and Transporters of Electricity in Africa
WENREC – West Nile Rural Electrification Company

Victoria Nile River hydropower at sunset - Jinja, Uganda, Eastern Africa.
to resort to load shedding again. For this reason, the government is in the process of setting up more dams such that by 2020 there will be an addition of at least 1 396 MW of power on the grid. Table 1 presents a summary of the hydro power generation projects that are either in planning stages or already under construction and their expected year of completion.

Table 1: Future Hydro power stations [6].

<table>
<thead>
<tr>
<th>Power Station</th>
<th>Capacity (MW)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ayago Power Station</td>
<td>600</td>
<td>2018</td>
</tr>
<tr>
<td>Isimba Power Station</td>
<td>140</td>
<td>2015</td>
</tr>
<tr>
<td>Karuma Power Station</td>
<td>600</td>
<td>2017</td>
</tr>
<tr>
<td>Muzizi Power Station</td>
<td>26</td>
<td>2018</td>
</tr>
<tr>
<td>Nyagak II Power Station</td>
<td>5</td>
<td>2015</td>
</tr>
<tr>
<td>Nyagak III Power Station</td>
<td>4,36</td>
<td>2018</td>
</tr>
<tr>
<td>Waki Power Station</td>
<td>5</td>
<td>2014</td>
</tr>
<tr>
<td>Kikagati Power Station</td>
<td>16</td>
<td>2016</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1 396 MW</strong></td>
<td></td>
</tr>
</tbody>
</table>

In addition to the hydro and biomass, Uganda also has the potential of generating power from other renewable sources like wind, geothermal solar and peat [7]. The potential of all these sources is shown in Table 2.

Table 2: The potential for renewable energy in the country [7].

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Estimated electrical potential (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>200</td>
</tr>
<tr>
<td>Peat</td>
<td>800</td>
</tr>
<tr>
<td>Biomass</td>
<td>1 650</td>
</tr>
<tr>
<td>Geothermal</td>
<td>450</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2 100 MW</strong></td>
</tr>
</tbody>
</table>

Challenges in the generation sector

The following were revealed as the challenges in the generation sector:

- Huge investment costs: In order for the country to reach its potential in electricity generation, heavy financial investment is required. This has limited the exploitation of many renewable energy sources of power.

- Hydro power stations not generating at full capacity: The Nalubaale and Kiira dams are operating below capacity due to old malfunctioning machinery and decreasing water levels. In addition, the Nalubaale dam’s walls are cracking due to significant alkali silicate reaction (ASR) with an expert review in 2010 giving it just another 20 years before it outlives its usefulness [8].

Transmission

**UETCL transmission grid**

All the generated power is transmitted on a 220 kV/132 kV/66 kV grid that is controlled by UETCL. The grid is 1 430,5 km in length, of which 72 km - 220 kV lines, 1 358,5 km - 132 kV lines and 35,2 km - 66 kV lines. It is made up of a combination of wooden and steel structures with wooden structures taking up 54 %. The oldest section of the grid was energised in 1954. There are a number of 15/30/40 MVA substations all over the country. These include Lugazi, Lugogo, Kampala North, Mutundwe, Namanve, Namugongo, kabulasoke, Nkonge, Nkenda, Masaka West, Mbarara West,Tororo, Opuyo, Lira, and Kahungye substations. The power is transmitted at 132 kV, stepped down to 11 kV and 33 kV for distribution and lastly to 415 V/240 V at consumer premises. Since the state of the grid is always changing in terms load and frequency, it is important to keep it stable. UETCL monitors and controls the transmission grid through its Supervisory Control and Data Acquisition (SCADA) system that is situated at the main substation at Lugogo. Using a combination of fibre optic and microwave radio links for communication it also monitors the other substations that are providing power on the grid for example Kakira, Mpanga, and Bugoye power plants.

Challenges in the transmission grid

Interviews with UETCL engineers revealed that the transmission grid is largely stable with most problems being caused by unnatural causes. The problems depend on the type of tower. Steel towers are vandalised as well as having lightening strike the disk insulators while their wooden counterparts experience vandalism of earth wires, rotting of the poles and breaking of the disk insulators. Vandalism is also rampant in substations. Transformer oil, electrical conductors, transformer copper windings, copper and aluminium are vandalised for financial gain. This has negatively impacted on the company since it is always replacing the stolen equipment. In addition, the grid also suffers from way leave encroachment. People set up structures (semi-permanent and permanent) or carry out economic activities under the high voltage lines, endangering their lives. The company has embarked on sensitisation of the public to combat this problem.

Distribution

There are over seven distribution companies in the country. These include UMEME Ltd, Fersduel engineering services (FESL), West Nile Rural Electrification Company (WENRECo), BECs, PACMECs and...
Kilembe Investment Limited (KIL) [3]. This article focuses on UMEME distribution network because it is the largest distributor.

**UMEME distribution network**

UMEME operates under a concession with a structural monopoly on the distribution of electricity across Uganda, distributing 99% of electricity in Uganda through a single buyer model [9]. As of 2012, the UMEME distribution network consisted of 6,394 km of 33 kV lines, 4,809 km of 11 kV and 15,933 km of low voltage (5-0.41 kV) lines. It has 69 substations and over 6000 pole-mounted transformers, low-voltage (less than 1 kV) distribution wiring and meters. The control centre at Lugogo controls 35 out of the 69 substations. It only controls up to the substation level not the feeders. For communication to the control centre, the substations and control centre are connected by a combination of fibre optic and GPRS links. The fibre optic links are used in urban areas, the GPRS links are used for the substations that are far away from Lugogo.

**Challenges in the distribution grid**

The distribution grid suffers from a number of issues that we now focus on.

- **Vandalism:** The distribution grid is plagued by many cases of vandalism. In just one month in 2012, 42 transformers were vandalised from Natete, a Kampala suburb; an average of four transformers every three days. Given that each transformer costs over 10,000 USD, having to spend 420,000 USD per month is quite prohibitive. In addition, since each transformer serves 2,000 customers each case of vandalism affects them directly. Vandalism has also been the cause of a number of deaths. In 2009, there were over 31 deaths countrywide due to vandalism [10]

- **Illegal connections:** Uganda has the highest electricity tariff in East Africa, thus most Uganda’s find the electricity unaffordable. Consumers therefore invent ways of avoiding the electricity bills by making illegal connections or by-passing the electricity meter. When this happens not only does the utility company lose revenue, but also lives are put at stake. In 2012, countrywide there were 65 deaths due to electrocution as a result of illegal connections and vandalism [10]

- **Transformer overloads:** During peak hours, transformers quickly become overloaded, thus the affected areas have to be load shedded

- **Transformer failure:** This is a multifaceted problem that has many causes. These include vandalism, illegal connections which lead to overload, lightening and LV short circuit. From January to April 2013, 345 transformers had failed. 87 of those were due to lightening, 78 due to overload and 70 due to vandalism. Figure 5 shows how much each cause contributes to the problem.

**Figure 5:** Statistics for the reasons for transformer failure.

- **Lengthy sectionalisation:** The grid is ridden with many faults which have to be dealt with. In order to rectify the problem, the source of fault, has to be located. The control engineer remotely opens circuit breakers along the faulty feeder line, while a technician in the field closes the tripped circuit breaker in the substation. If the circuit breaker remains closed then the source of the problem has been identified. Otherwise the circuit breaker trips and the process is repeated. This process, known as sectionalisation is lengthy and can sometimes take a day.

UMEME is implementing number of measures to deal with the challenges, these are summarised in Table 3.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vandalism</td>
<td>Public sensitisation through the media.</td>
</tr>
</tbody>
</table>
| Illegal connection to the grid | o Use of aerial bundle conductors which are tamper proof but increase capital costs  
                                | o Installation of prepaid meters                                         |
| Transformer overload        | Load shedding to relieve the over-loaded transformer                     |
| Lengthy sectionalisation    | Implementing sectionalises along the feeders between the substation and the transformer |

**Smart grid made in Uganda**

A smart grid (also known as the future grid) is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources so as to meet the varying electricity demands of end-users [11]. Through bidirectional flow of electricity and communication, the smart grid intelligently integrates the actions of all users connected to it in order
to efficiently deliver sustainable, economic, and secure electricity [12]. Upon comparing information from the generation and transmission sector with that of the distribution sector, we find there is enough power being generated and the transmission network is fairly reliable but the bottleneck is in the distribution network. We therefore propose the following smart grid applications for Uganda:

- **Automatic Metering Infrastructure (AMI) and Demand Side Management (DSM):** Consumers are suffering from the effects of high tariffs, unstable and inadequate power. With AMI and DSM, the price of power would be varied basing on demand such that power during peak hours electricity is more expensive than at off peak hours. Consumers would control their consumption during peak hours thus reduce transformer overload. Consumers would also be empowered to control their consumption so as to avoid the high power tariff. Lastly if smart appliances and sockets are used in the consumer premises, direct load control would be possible [13]

- **Distribution automation:** The distribution network suffers a lot of faults which sometimes take long to sectionalise. Distribution automation would ease fault management and possibly control vandalism

- **Distributed generation:** There is a need to have distributed generation in order to relieve the load on the transformers in the distribution network

- **Energy storage:** The country relies 70% on hydro power, which varies with water levels. It would be good if in the rain season, electricity would be stored

### Conclusion

The future for any electrical grid is in converting to a smarter grid. However before this can happen it is important for countries to clearly articulate the specifications of the smart grid that address their problems and thus propose smart solutions to them. This paper has explored the status of Uganda’s electrical power grid and identified critical problem areas that will require custom designed smart solutions. The next stage of this research will be to study documented cases from elsewhere in the world and identify similar aspects and the emerging technology options that could be adapted to address the Ugandan power grid issues.

### References


