MODELLING AND CONTROL OF THE LOW VOLTAGE NETWORK WITH SMART-METERS TO IMPROVE THE RELIABILITY OF SUPPLY IN BURKINA FASO, THE AFRICIT-E PROJECT

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Abstract

The reliability of the electricity supply is of major importance to enhance economic development. With a steady supply, there is no need for private owned backup solutions such as gensets, which have high capital and operational expenditures (CAPEX and OPEX). Therefore, it lowers the cost barrier for new businesses creation and fosters local economical dynamic. Environmentally wise, the improvement of the quality of supply can reduce the emissions due to genset use and improve the profitability of renewable energy facilities enabling a longer feeding period.

The Africit-e project tackles this subject by deploying a smart metering infrastructure and analytic services in Azimmo Ouaga 2000, a neighbourhood of Ouagadougou, Burkina Faso. This paper describes the use cases designed, developed, and experimented within the project. They aim at the reduction of outages' frequency due to local overloads. This project is funded by the "Direction Générale du Trésor" which belongs to the French Ministry of the Economy and Finance. A consortium of three French SME and one association leads the project in collaboration with Sonabel, the national electricity company of Burkina Faso.

1. Introduction

1.1. African context

Africa is a dynamic continent where cities are experiencing an unprecedented demographic and urban growth. They are expected to host twice more people by 2050. The challenges to overcome regarding assets and network infrastructures (water, electricity, road) as well as social inclusion are significant.

When it comes to electrical networks, their development and resilience are essential to:

- Improve the electricity supply in order to foster dynamism and economic attractiveness by facilitating trade and business development,
- Limit urban and social exclusion of their inhabitants through an affordable electricity supply,
- Combine the management of the energy consumption with the increase of renewable energy penetration to enable the energy transition.

However, Africa currently suffers from a low access to energy. Around 600 million of people, i.e. more than half of its population, do not have access to electricity [1]. While North Africa electrification rate is close to 100%, it is of 32% in 2015 and 47% in 2018 in sub-Saharan Africa [2]. As it concentrates 70 % of the worldwide population without access to electricity, many international initiatives are settling in this part of the continent.

1.2. Burkina Faso case

This project focuses on Burkina Faso. Among the 20 million of inhabitants, 24.4 % have access to electricity, 19.2% are connected to the national network [3]. In cities, where the network is more developed, the electrification rate reaches 66%.

Sonabel's mission is to produce, transport, distribute and sell electricity everywhere in its service area. In 2019, Sonabel was supplying 731 000 consumers across the country [4]. The quality of supply is increasing, as stated in [5] the equivalent outage time decreased from 233 to

153 hours between 2018 and 2019. As a comparison, in European countries this KPI is between 50 minutes and 1 hour.

The reason of those outages and their magnitude is available in Fig. 1. The outages caused by load shedding fluctuates according to the demand and supply balancing, for instance a new thermal power plant of 50 MW and the increase of the imported power from Ghana allowed in 2019 an important decrease of it. The one linked with network works remains, over the period, quite stable. However, the level of outages due to network incidents is increasing.

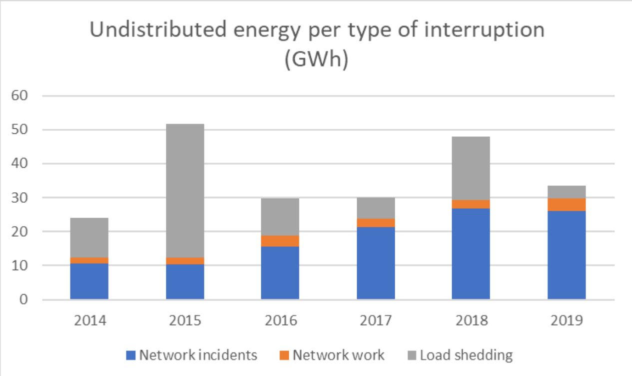

Fig. 1 Undistributed energy per year and type of interruption (in GWh) from analysis of [4]

1.3. Focus on the low voltage networks

Those incidents are occurring on each parts of the network, low voltage (LV), medium voltage (MV) and high voltage (HV). The project Africit-e addresses the ones which take place on the LV network. They are mainly related to assets' overload operating condition:

- Difficulties to supply the requested power during peak hours on some feeders,
- Limited recovery schemes due to the overload of the "emergency feeders",
- The fastened ageing of equipment due to overloads,
- Fraudsters and resellers who connect to the grid and cause unpredicted loads and breakdowns.

To work around with this situation, more than 80% of the households use alternatives sources like gensets, battery-powered torches, or rechargeable lamps, which contribute to the urban pollution and reduce the DSO's incomes.

2. Approach used in the Africit-e project

To deal with the previously raised issues, a consortium of three French companies [6] [7] [8], coordinated by the association "Institut Smart Grids" [9] carries out the Africit-e project. It aims at increasing the reliability of the electrical supply in the neighbourhood of Azimmo in Ouagadougou and giving a proof of concept that the project can be deployed on a bigger scale.

2.1. Use cases

The general use cases developed are depicted in Fig. 2. They consist in making the most of a smart metering infrastructure while using it to enable the reduction of outages on the LV through a modelling and forecasting of the grid and a **fair distribution of the available power**. Two other aspects are added, the **customer experience improvement** through smart metering services and the **promotion of solar facility connection** through a PV hosting capacity map.

Fair distribution of the available power

The objective of the optimization solution for urban low voltage networks is to prevent outages due to local overloads by sharing amongst the consumers the power the grid can really supply throughout the day. The deployment of a smart metering infrastructure allows the collection of new data from the LV network. The Meter Data Management System (MDMS) has been adapted to collect both load curves and voltage profiles from each metering point in order to feed the grid modelling and management system.

Thanks to this data, three analysis are performed:

- The identification of the network's topology with the smart meter – phase – feeder connection [10],
- The estimation of the missing metered power,
- The estimation and forecast at D+1 of the LV network load profile.

Considering the network characteristics, this system can anticipate when and where power cuts are more likely to occur. The mitigation action is realised through a demand response program, which involve the consumer, so they engage a reduction of its consumption during the predicted congestions. This program is twofold:

- The available power the network can actually supply within nominal operation conditions is shared between each consumer. The sharing is implemented through the modulation of the maximum power admissible by each smart meter.
- This modulation is notified to the consumer through an application stating there is a forecasted congestion, and a reduction of the consumption is expected to avoid the outage due to the congestion.

As a result, the integrated solution can automatically warn concerned people and encourage them to reduce their consumption in order to avoid an outage. If consumers do not reduce their consumption, they might exceed their maximum power, and, instead of experiencing an overall power cut on the substations or the feeder, only said consumers will be disconnected from the grid.

In addition, the implemented technology provides a moderate and graduated incentive to ensure the payment of bills. This solution is therefore a tool to help the utility to proceed with the debt recovery.

Fig. 2 Illustration of project use cases

Customer experience improvement

Services based on the smart metering infrastructure have been identified to make the most of it when it comes to customers benefits:

- A smartphone application "Africit-e", available on Android and Apple phones, allows clients to monitor their daily consumption, have access to a billing estimate and receive advice about energy savings.
- As the smart meters allow remote reading, Sonabel employees do not need to visit every customer monthly anymore to read the consumption. Therefore, clients are not required to be home at a defined time to allow the reading and are less disturbed.
- This new process of remote reading allows to bill customer regularly, on the first of each month. This creates steadier bills and secures financially the customers.

Promotion of solar facility connection

The collected data is used as well to process a digital modelling, which assesses the photovoltaic hosting capacity. The output of such analysis is an interactive map which provides, for each metering point, the maximum peak power which can be connected without any expensive reinforcement.

This is a tool to both promote the consumption of local renewable energy and help Sonabel to prepare itself to the forthcoming integration of distributed energy resources on its network. More details on this process are available in [11].

2.2. Perimeter of the project

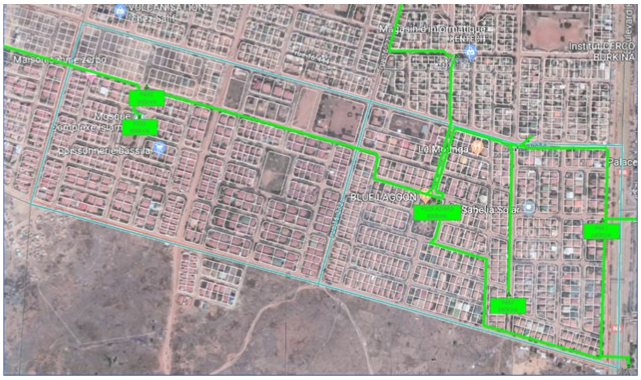

Fig. 3 Azimmo Ouaga 2000 neighbourhood and its MV electrical network

The neighbourhood Azimmo Ouaga 2000 includes different power grid sections, the selected perimeter for the implementation of the project is the right-hand side of Fig.3. It includes approximately 500 consumers supplied by 3 different substations. The neighbourhood is mainly residential, with some restaurants, shops, and offices.

2.3. Replicability

This demonstrator is a small-scale pilot, which ambition is to adapt the potential of smart metering to Sonabel's context. Its operation will provide key insights into the practicality and profitability of the use cases described above. To assess such aspects, a Cost-Benefits Analysis (CBA) is being prepared with collected data about electrical grid and its operation and with the forthcoming results from the demonstration site. The method used is inspired from big-scaled CBA already performed in Europe on smart meters roll out [12]. The main costs of the project are CAPEX due to the investments in the smart metering infrastructure and R&D and engineering time for the software development and project management whereas benefits mostly relate to the power cuts and technician interventions decrease, which are OPEX.

The deployed hardware has been provided by industrial partners, which belong to the partners club. In total, 17 entities surround the Africit-e project. They have been supporting the project since its beginning and are involved in the analysis of its final results. Their industrial point of view is necessary to challenge and improve the CBA as well as to take into consideration the potential adaptation to envision a broader deployment.

2.4. Capacity building

The implemented technologies require specific knowledge to ensure local appropriation. The consortium provides trainings to Sonabel employees on the MDMS solution SmartEnergyCore (SEC) and Odit-e software.

The inhabitants' involvement is crucial for such energy transition project. Thus, the consortium and Sonabel organised a dedicated local assignment for 2 experts from "Electriciens Sans Frontiere" to explain the objectives of the project to Azimmo's inhabitants and to define the most suitable energy savings advices to integrate within the application.

3. Results

3.1. Deployed solutions

The different deployed solutions are represented below, in this order:

- the remote data collection software SEC,
- the modelling and forecasting software,
- the smartphone application for customers use.

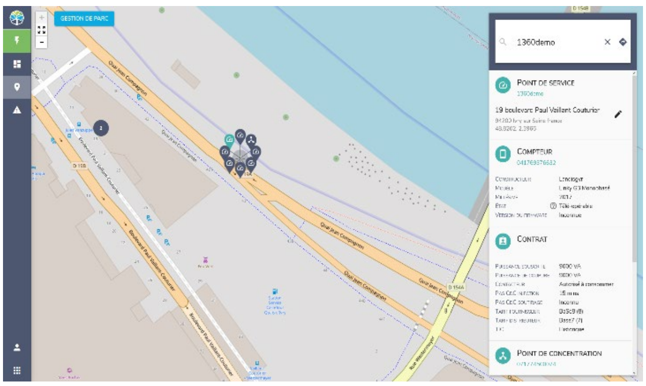

Fig. 4 Smartside SEC screen example

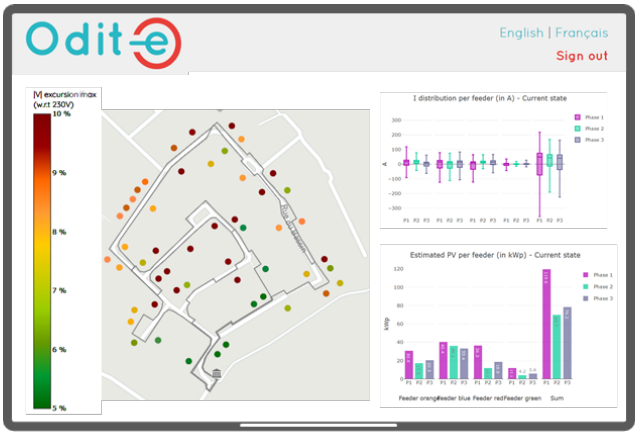

Fig. 5 Odit-e Software screen example

Fig. 6 GridPocket smartphone application screen example

Smart meters from Landis+Gyr and Data Concentrator Unit from Cahors, along with installation tools and 3 ad hoc sensors have been provided to Sonabel to equip the perimeter defined in 2.2.

3.2. Specifics work around

Activ'Linky

To initialize the Smart Meters, Sonabel employees need a device and a software that can communicate with the meters. The device, provided by the company Michaud, consists in a Bluetooth gateway which allow any smartphone or tablet to communicate with the meter. Then, the company INCOM provided Activ'Linky, a software which allows to parameter the smart meters in situ.

Data collection tool

A bunch of information from the installation site is necessary to carry out the project such as GPS coordinates, details contact of the consumers to invite them to download the application, a robust table stating the metering point along with the reference of the meter. Professional tools are available on the market to carry out this task in the case of an industrial roll out. Here, a simple and effective solution of online survey is used to request all this information on the installation day.

Three phase data collection constraints
Most of three-phase smart meters provide aggregated curves and do not give details for each phase. This more detailed information would improve the accuracy of the modelling and forecasting software and would therefore bring more added value by making forecasted outages for each phase more likely to be true. Two actions have been considered to mitigate this issue, the addition of three ad hoc sensors to be installed in the substations and the development of an algorithm able to estimate each phase load curve from the aggregated one. Another solution would be to upgrade the smart meter's firmware, it is possible to do so for a wider roll-out.

4. Next steps and opening

A reliable access to energy is crucial for a city to develop rapidly. Unfortunately, most African cities and particularly Ouagadougou face frequent incidents on the low voltage network such as voltage drops, power cuts or illegal connections.

The digitalization of the distribution grids with such advanced services enables the energy transition, both in Western country and in developing country like Burkina Faso. Africit-e's use cases are adapted to Sonabel's goals: increase clients' satisfaction with reliable, clean, sustainable, and cheap electricity, through Smart Grids solutions adapted to the local context. Moreover, many additional services are already identified.

For instance, Control Centers could use this architecture to manage load flexibility to ensure the supply and demand balancing (SDB), which represents 17% of power cuts in Ouagadougou.

Also, the remote reading system gives to Sonabel all the data necessary to issue invoices. Furthermore, the application already gives a billing estimate. The next step could be to automate the billing in order to lighten the workload of invoicing department, and also to include possibility for clients to pay through the integrated system. Moreover, Africit-e 's architecture in Azimmo will be used to bring further use cases in the "Long-Term Joint EU-AU Research and Innovation Partnership on Renewable Energy", an African and European joint program.

The Africit-e's CBA give a technical and economic analysis of this project but is also a tool to assess costs and benefits for others countries with others operation KPI, to analyse whether a large-scale deployment is profitable or not. Utilities of other countries and development banks are interested to be involved in a wider roll out.

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This paper reflects only the authors' view and none of the previously cited partners are responsible for any use that may be made of the information it contains.

6. References

[1] ADEA, 'L'énergie en Afrique à l'horizon 2050' (2015), pp. 1-17
[2] 'Ensure access to affordable, reliable, sustainable and modern energy for all', https://sdgs.un.org/goals/goal7, 20 January 2021
[3] Unité de Coordination de la Formulation du second compact du Burkina Faso (UCF), Premier Ministère, 'Projet Réseaux et Accès à l'électricité (PRAEL)' (Juin 2018), pp. 3-24
[4] Rapport d'activités 2019, ARSE, p. 8
[5] Sonabel: 'Les chiffres-clés de la Sonabel 2019' (2020)
[6] Odit-e, https://odit-e.com/
[7] Smartside, http://www.smart-side.com/fr/,
[8] GridPocket, https://www.gridpocket.com/fr/
[9] Institut Smart Grids, https://institutsmartgrids.com
[10] Debontride, C., 'Low voltage network topology identification for better flexibility planning – Portugal experiment' CIRED 2020, Paper n° 0383
[11] Pellerej, R., 'Impact of flexibility on low voltage networks' hosting capacity – Belgium experimentation' CIRED 2020, Paper n° 0405
[12] UK Department for Business, Energy & Industrial Strategy, 'Smart meter roll-out, Cost-benefit analysis' (2019)