The Low-Cost Transition Towards Smart Grids in Low-Income Countries: The Case Study of Togo

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***Abstract*—Power grids must integrate information and communication technologies to become intelligent. This integration will enable power grids to be reliable, resilient, and environmentally friendly. The smart grid would help low-income countries to have a more stable power system to boost their development. However, implementing a smart grid is costly and requires specialized skills. This article aims to outline a low-cost transition from conventional power grids to smart grids in low-income countries. It examines the possibility of telecommunications networks participating in implementing smart grids in these countries, to minimize costs. A combination of quantitative and qualitative methods was used. Using Togo as an example, a conceptual scheme for a low-cost smart grid is proposed, with Togo's telecom operators as the telecoms network support. A transition plan to the smart grid is proposed, based on feedback from developed countries.**

Keywords—Smart grid; telecommunications network; low cost; low-income countries

I. Introduction

The smart grid encompasses ICT tools for more efficient management of the electrical grid, extensive integration of renewable sources, bidirectional management of the grid, and enhanced reliability of the entire electrical system [1], [2]. According to the European Union (EU) technological platform, a smart grid is an electrical grid capable of intelligently integrating actions from all connected users-producers, consumers, and prosumers. It incorporates intelligent technologies for monitoring, communication control, and self-healing to efficiently supply electrical energy [3]. Household appliances will communicate with smart meters and network equipment to ensure efficient infrastructure usage, responsive demand, and energy management.

Implementing smart grids contributes to improving the reliability, stability, and resilience of electrical systems, fostering economic and ecological benefits [4]. However, the deployment poses technical challenges, security concerns, interoperability issues, and significant costs [5], [6]. Technically, communication technologies for smart grids also present challenges but are surmountable.

To harness the advantages of the smart grid, numerous countries are pursuing this advanced network. As indicated in study [7] several key factors have driven most countries towards adopting a smart grid: energy efficiency, the integration of renewable energies such as solar, the reliability issues of the existing electrical grid, financial incentives from governments, policy mandates, environmental concerns, increasing demand, energy security, reduction of energy theft, and management control. Each country worldwide has a specific plan for its implementation. The development of a smart grid in developed countries often begins with the creation of a decision-making body to establish rules, hold meetings, and accelerate progress [7]. Nevertheless, the initial investment remains high [8]. For example, implementing a Smart City in India cost $7.4 billion in 2020 [9]. Unfortunately, private investment remains low, limiting the capacity of low-income countries to transition to a smart grid, as shown in study [10]. The authors present a global overview of the transition from conventional to smart electrical grids, highlighting issues such as the lack of private investment enthusiasm, cybersecurity, the low market penetration of electric vehicles with vehicle-to-grid functionality, and technical challenges in implementing microgrids.

In low-income countries, the state of the art on smart grid implementation shows conceptual proposals and incentives from stakeholders in the energy sector to transition to smart grids. In study [11], it has been shown that in Nepal's current electrical system, the fragility of the transmission and distribution network, aging infrastructure, high transmission and distribution losses, electricity theft, low renewable energy penetration, and heavy reliance on fossil fuels are significant concerns that need to be addressed promptly. Therefore, even with smart meters installed in the network, transitioning to a smart grid is necessary to solve Nepal's electrical system issues. According to [12], the reasons compelling Gulf countries to transition to smart grids include aging assets, lack of network coverage, and the need for new construction, network stability maintenance, network security, and the necessity of conserving petroleum resources. In study [13], the current and potential capacities of technologies, regulations, and policies for smart grid implementation in Brazil are evaluated. These capacities include significant renewable energy potential (hydropower), existing national laws, and tariff regulations, identified as potential sources for smart grid development in Brazil. In Nigeria, the potential improvements in reliability and efficiency that the Nigerian electrical grid could achieve through smart grid adoption are examined in study [14]. In Uzbekistan, [15] developed smart grid development concepts based on five essential points: developing new solutions and technologies, establishing interaction and control systems, regulatory reform, creating and implementing pilot projects, and finally, replicating results, though the implementation method is not specified.

In recent years, Information and Communication Technologies (ICT) have rapidly evolved in developing countries [16]. Given that smart grid technology is costly and not matured in developing countries, a thorough feasibility study is essential before implementation [17]. Therefore, an analysis of energy and telecommunication resources in low-income countries would provide valuable insights for smart grid deployment. However, no study has explored telecommunications network operators in these countries as a cost-effective avenue for smart grid implementation. It is believed that cost-minimization strategies for smart grid deployment would encourage stakeholders in the electrical field of low-income countries to transition. This article evaluates this approach, using Togo as a case study.

Togo, a low-income country in West Africa, imports 44% of its electrical energy. The remainder comprises 45% from thermal power plants and 11% from renewable sources such as solar and a hydroelectric dam. With primary renewable sources, the country could meet its growing energy demand and achieve energy independence through green energies. However, existing installations suffer from reliability and resilience issues [18]. Despite efforts including network expansions and integrating renewable sources, the grid faces reliability challenges exacerbated by intermittent sources. The solution for an efficient and sustainable electrical grid lies in implementing a smart grid. Yet, initial implementation costs in Togo are high, estimated at $1,054,167,660 for 2,919,000 users [19]. At lower costs, a gradual transition from conventional to smart grid infrastructure would enable Togo to attain reliable and resilient electrical energy.

Transitioning from conventional to smart grids, leveraging the energy potential and telecommunications networks of Togo's operators, and drawing on the experiences of other countries are central to this article. This study aims to serve as a benchmark, encouraging developing countries to transition their electrical grids towards smart grids.

Section II describes the method used in this article. It describes the data source and data processing. Section III shows the results obtained, Discussion is given in Section IV and finally, Section V concludes the paper.

II. METHOD

This study employed a mixed-methods approach combining quantitative and qualitative methods.

A. Quantitative Method

A comprehensive literature review was conducted using search engines such as Google Scholar and IEEE Explore. Key search indicators included "communication networks in smart grids,"; "smart grid development,"; "transition from conventional grid to smart grid," and "electric grid and Togo." Information specific to Togo was gathered from energy and telecommunication regulatory bodies' websites. The quantitative analysis focused on identifying communication network technologies in smart grids and drawing insights from successful smart grid implementation projects in developed countries.

B. Qualitative Method

The study data were collected from Togo's electric power distribution operator. They cover the periods from January 2014 to November 2019. Two days, corresponding to working days, weekends and, public holidays in 2019, were identified. Electricity consumption profiles for these days were plotted. To obtain the trend in the evolution of electrical energy consumption and imports, hourly consumption and imports are summed to find their annual values. Consumption from 2014 to 2018 was then represented. A consumption trend generated in Microsoft Excel 2019.

The overall objective of this methodology was to address the following research questions:

- Can telecommunication networks serve as a foundation for implementing smart grids in low-income countries at lower costs?
- How was the smart grid implemented in developed countries?
- What are the challenges and opportunities for low-income countries in integrating smart grids?

This methodological approach allowed for a comprehensive analysis combining theoretical insights from literature with practical data from Togo, aiming to provide valuable insights for smart grid implementation strategies in similar contexts.

III. RESULTS

A. Communication Network Technologies in Smart Grids

In the development of smart grids, various communication network technologies have been proposed in the literature for smart grid management. Different types of networks such as home area networks (HAN), Neighborhood Area Networks (NAN), and Field Area Networks (FAN) have been identified. Technologies like ZigBee, Wifi, Z-wave, Power Line Communication (PLC), Bluetooth, and Ethernet are suitable for short-range networks like Home Area Network (HAN) and market networks.

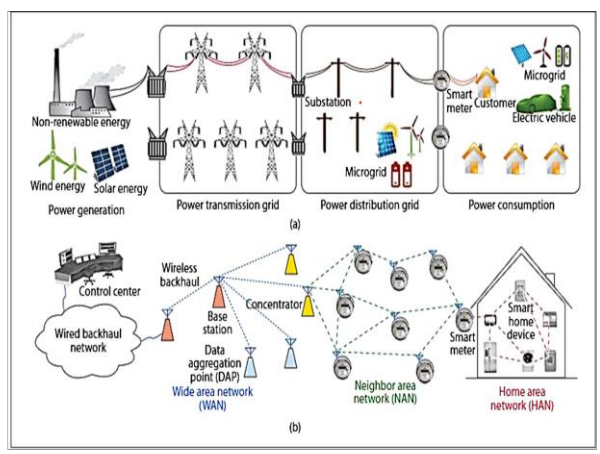

Fig. 1. Telecommunication technologies in smart grid [24].

For connecting smart meters to distribution networks (NAN/FAN), technologies such as ZigBee, WiFi, WiMax, cellular networks (LTE, GSM, 2G, 3G, 4G, and 5G), DSL, and coaxial cable are commonly used. For managing wide area networks (WAN) including transmission and distribution networks, cellular technologies, WiMax, and fiber optics are viable options [20], [21], [22], [23], [24], [25]. Fig. 1 illustrates the architecture integrating communication technologies in the smart grid.

B. Retrospective on the Implementation of Smart Grids in Developed Countries

Pilot projects have been implemented by private entities or state bodies to gain experience in smart grid implementation [26]. This section provides a retrospective on the implementation of smart grids in some developed countries.

1) Smart grid in Canada: The government launched a national law mandating the deployment of smart meters for businesses and households in Ontario from 2006 to 2010 as a pilot project to promote the integration of smart meters nationwide. Renewable energy management was a key concern for the government, leading to a $32 million investment in research for innovative solutions in this area. Additional funds were allocated for clean energy and eco-energy innovation initiatives. Furthermore, think tanks comprising universities and stakeholders were initiated to conduct research and develop policies related to smart grid development [19], [27].

2) Smart grid in China: China prioritizes energy independence. Efforts focus on storage, energy efficiency in transportation, and integration of renewable sources to minimize the carbon impact of the electrical energy sector [19], [28]. As early as 2011, a comprehensive project was launched to integrate Phasor Measurement Units (PMU) across power plants exceeding 300 MW and substations exceeding 500 kV. In 2009, China initiated a framework for smart grids focused on the transmission network [28].

3) Smart grid in Portugal: Portugal's distribution network is managed by a single enterprise. Renewable penetration in primary energy consumption is 21%, with renewables comprising 44% of the country's electricity mix. This high penetration is largely due to incentivized feed-in tariffs, encouraging efficiency through programs such as solar thermal sensor incentives. In 2011, thermal contributions were twice those of photovoltaic sources. Portugal uses a policy of price regulation ceilings to protect consumers from supplier losses due to operational quality issues. The regulator encourages the distribution operator to implement smart grids, allowing customer participation in innovative solutions to ensure energy quality. Conversely, gains from these innovations must benefit customer billing. Network expansion is not considered an innovation policy. These policies encourage the distribution operator to collaborate with entities including universities, technology firms, and metering equipment suppliers to create the InovGrid project. In 2009, InovGrid's initial investment enabled the implementation of a distribution transformer controller. In 2008, a project was initiated for integrating electric vehicles with over 1300 standard charging stations and 50 fast charging stations across 25 cities in the country. Many other projects have been implemented for the evolution of InovGrid [29].

4) Smart grid in India: Power outages in 2006 in India were the precursor to the beginning of smart grid implementation. A phasor measurement unit (PMU)--based monitoring system for network stability control was developed [30]. Smart grid implementation in India has been a state priority with the introduction of pilot projects. The investment cost was $7.4 billion in 2020, primarily driven by the Smart City initiative. A total of $480 billion has been allocated for Smart City development. Improvement of existing electrical network infrastructure has also been accomplished through projects. These include electrification projects, large-scale integration of renewable energies into the country's energy mix, and energy storage projects [31], [9].

C. Case Study of Togo

1) Electrical energy demand: Electrification rates are predominantly dominated by urban areas and their peripheries with access to 88.8% compared to only 8% for rural areas. However, thanks to electrification policies, access rates increased from 17% in 2000 to 45% in 2018 [32]. Between 2014 and 2018, there was a 29.51% growth rate in consumption, with a slight decline of 0.1% in imports, indicating the impact of energy source construction projects in Togo. This evolution is shown in Fig. 2.

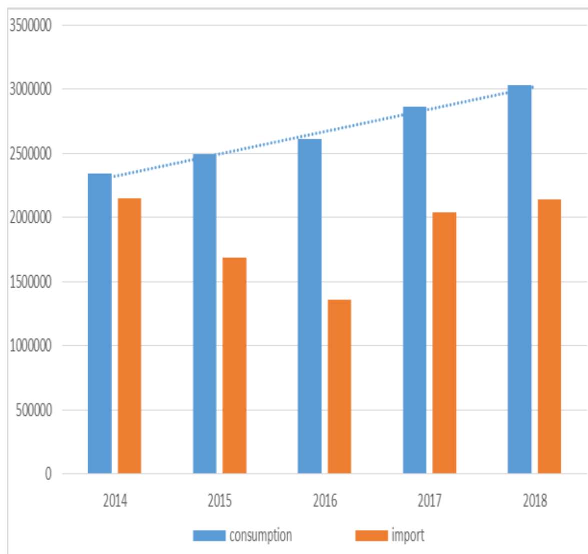

Fig. 2. Electricity consumption evolution.

The analysis of daily consumption, taking random dates (two holidays, two weekdays, and two weekends) as examples, reveals three major levels of electricity consumption in Togo, as indicated in Fig. 3.

- From 0 to 7 AM, consumption drops significantly, reflecting the sleeping hours of the population and the gradual shutdown of certain businesses whose activities are primarily or exclusively at night.

- From 7 AM to 6 PM, there is a bell-shaped consumption pattern, with peaks around 11 AM and noon, indicating increased usage due to rising temperatures. There is a slight relaxation between 12 PM and 2:30 PM, considered as break hours in Togo's services sector. During this time range, weekdays show higher consumption followed by weekends and holidays. It can be noted that consumption on weekdays is higher than on other days during this period.
- From 6:30 PM to 12 PM, consumption increases again, reaching peak levels for all days studied. This timeframe records the highest energy consumption in the country, as it corresponds to the time when almost the entire population is at home, using various electrical appliances.

This consumption pattern illustrates the daily fluctuations in electricity demand in Togo, influenced by societal and economic activities throughout the day.

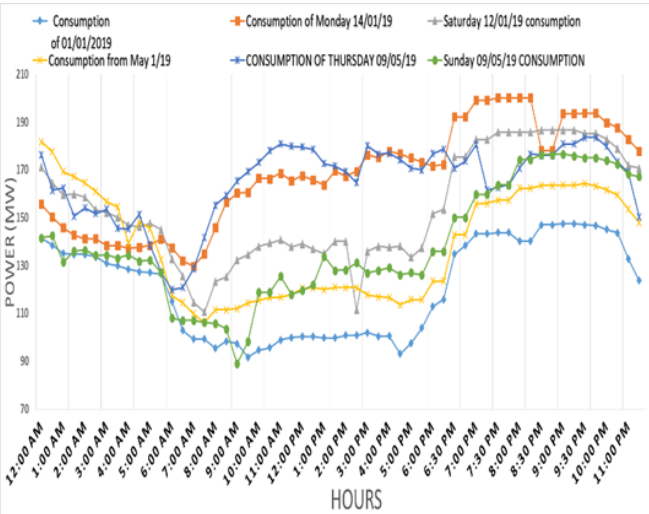

Fig. 3. Daily electricity consumption.

2) Regulatory framework: The energy sector in Togo is under the supervision of the Ministry delegated to the President of the Republic, responsible for energy and mines. This ministry implements state policy in the fields of mining, hydrocarbons, and energy, ensuring its follow-up. Within this ministry are the following entities:

- The General Directorate of Energy (DGE): It proposes development policies for the sector, particularly in research and the development of renewable energies. It drafts and proposes legislation, regulations, and standards related to energy. This directorate aims to stimulate public and private initiatives to promote the sector, ensure resource reliability, and guarantee security across the entire supply chain.
- The Energy Sector Regulatory Authority (ARSE): It oversees regulatory activities in the electricity sub-sector and potable water and sanitation.
- The Togolese Agency for Rural Electrification and Renewable Energies (AT2ER): This agency is responsible for implementing the country's rural electrification policy and promoting and valorizing renewable energies.
- The Togolese Agency for Standardization (ATN): It aims to achieve the objectives of harmonization and mutual recognition of technical standards and approval procedures in force within member states as stipulated by community treaties.

3) Electrical energy situation in the country:

a) Energy challenges: The total energy consumption was evaluated at 2042 Ktep in 2019, with electricity accounting for only 5% of this consumption [33]. Consequently, the country's electrification rate has continuously increased, rising from 44.6% in 2015 to 54% in 2020, marking a 9.4% increase in just five years [34].

The National Renewable Energy Action Plan (PANER) aims to increase the total capacity of renewable energies connected to the grid from 41% in 2010 to 41.9% in 2020 and 43.3% in 2030. This translates to capacities of 66.6 GWh in 2010, 131.635 GWh in 2020, and 131.635 GWh in 2030. This growth pertains to hydroelectric and intermittent renewable sources, particularly solar energy [35].

The integration of new sources into the grid and the increased load will exacerbate the issues currently faced by dispatching. These include synchronization problems, managing intermittent renewable sources, network failures, and load management.

The year 2030 is set as the target for universal access to electricity in Togo [36]. Achieving this will require $142 million annually, four times the national budget for electrification [37]. One of the strategic plans involves providing electricity access to over 300 households, requiring an investment of $251 million. Additionally, 555,000 solar kits need to be installed, and the electric grid needs expansion, including:

- Installing at least 108 MW of additional production capacity,
- Connecting 960 new localities to the grid,
- Electrifying 400,000 homes currently on the grid but not yet electrified.

4) Electrical grid: The electrical grid comprises the transmission network shared between Togo and Benin, transporting electrical energy from imports to each country's distribution networks [18]. This network integrates SCADA/EMS for supervision and operation and includes protection tools. However, it faces reliability issues that significantly impact the socio-economic and technical plans of both countries. The distribution of electrical energy in Togo is managed by Electric Power Company of Togo (CEET), under ARSEE's regulatory authority. CEET lacks supervision tools for its network. Regarding customers, there are two types of meters: post-paid meters with an analog display and pre-paid meters with an electronic display. The meters are not smart, contributing to energy loss problems due to theft and management, estimated at 16.04% in 2020 [38].

a) The architecture of Togo's electrical grid: Since 2006, Togo's energy situation has led to the revision of the energy policies of both countries. Consequently, CEET is now the sole entity authorized to purchase and sell electricity in Togo. Only projects like Nangbeto and Adjrala are shared by both countries. The Electrical Community of Benin (CEB) serves as the transmission network for both countries, with progressive integration into the ECOWAS transmission network. An independent transmission network regulatory body, separate from the policies of both countries, will be established. Each High Voltage and Medium Voltage customer can choose their supplier [39]. The current electrical grid architecture of both countries is shown in Fig. 4.

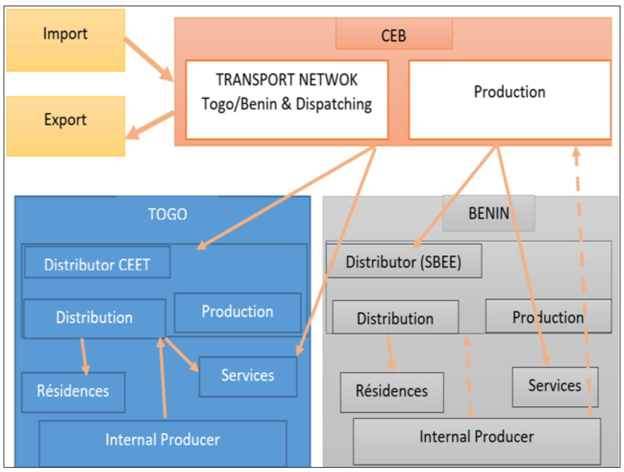

Fig. 4. Electricity grid distribution in Togo and Benin.

5) Milestones for the development of smart grids in Togo: The aim is to conduct an energy assessment to highlight the requirements that make a smart grid a viable energy solution for Togo. It is necessary to outline pathways for an affordable smart grid in Togo.

a) Togo's Energy Potential: Without oil and uranium resources, Togo's electrical energy potential is largely focused on renewable sources such as hydroelectricity, wind, and solar energy.

- Solar Potential: The average daily solar photovoltaic energy potential between 1994 and 2018 ranges from 3.8 kWh to 4.4 kWh from the south to the north of Togo. Annual totals range from 1387 kWh to 1607 kWh [40]. The average global irradiance of the country is around 4.4 kWh/m²/day for Lomé, 4.3 kWh/m²/day in Atakpamé, and 4.5 kWh/m²/day in Mango. During the dry season with clear skies, the irradiance can exceed 700 W/m². Studies by [35] confirm that Togo has renewable energy potential in hydroelectric and solar power. Regarding solar energy, studies by [41] have shown a variation in solar irradiation across the country depending on the month and altitude, proving the intermittent nature of solar energy in Togo. Climate change effects are expected to make solar energy a predominant source of renewable energy production by 2050 due to rising temperatures across the territory. Climate scenarios with projections for 2025, 2050, 2075, and 2100 reveal a trend of increasing rainfall concurrent with global warming. Simulations for 2025 and 2100 show an increase in maximum temperatures ranging from 0.63 to 4.5°C [42]. Fig. 5 illustrates Togo's solar potential.

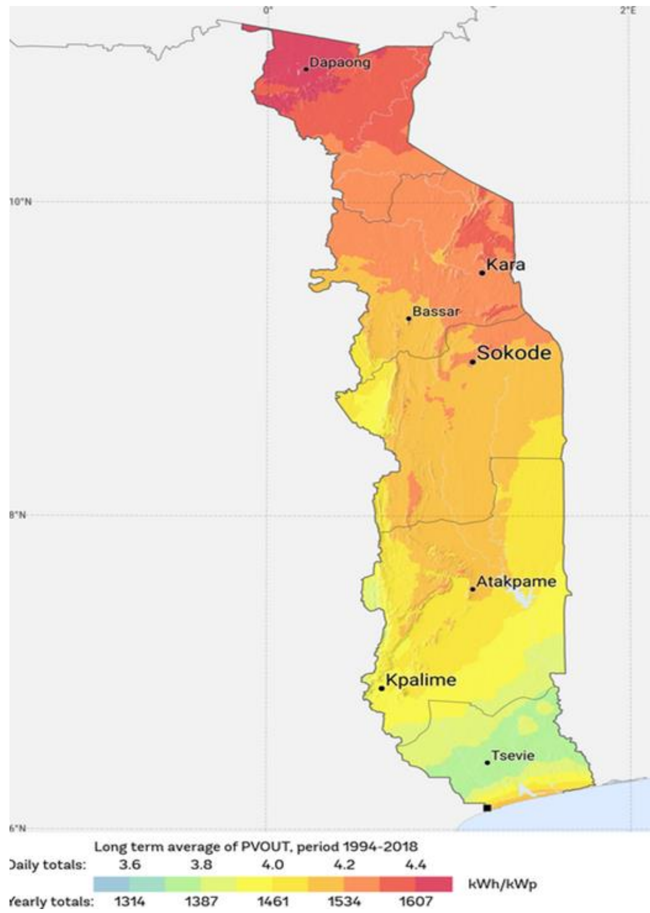

Fig. 5. Togo photovoltaîc potential.

- Hydroelectric Potential: The currently installed hydroelectric capacity in Togo includes the Nangbeto Dam with a capacity of 2x32.8 MW and the Kpimé Dam with a capacity of 1.6 MW. Studies conducted in 1984 by Tractionnel Cabinet identified a hydroelectric potential at approximately forty sites on the Mono and Oti rivers, with 23 sites expected to generate more than 2 MW each. The total anticipated production from these sites is estimated at nearly 850,000 MWh, with an installed capacity of 224 MW [43]. It is important to note that this potential may be affected by climate change around 2050 and 2100. Besides this national potential, the presence of rivers throughout the territory could facilitate the establishment of micro-grids for local electrification.

- Wind Potential: According to the latest studies, the wind potential in Togo is relatively low. Wind potential is primarily around the coast and in the mountains, with the wind resource estimated at 20 MW [42]. Given that an average wind speed of 4.5 m/s can operate a small wind turbine, turbines can be installed on the coasts where average wind speeds are 4 m/s at a height of 10 meters. A planned wind energy project, awarded to Delta Wind Togo, the wind energy subsidiary of the ECO DELTA group, covers the Zio floodplain around Kagomé-Abobo and Djagblé-Agbata, spanning approximately 42 km² for the installation of a wind farm to produce electricity for Lomé. According to Global Atlas, wind speeds can peak at 5.5 m/s in the Oti plain and along the coasts, with an average of around 4 m/s. Fig. 6 illustrates the wind potential of Togo. Research by [44] indicates that using the E-53 turbine, an average annual energy output of 77.53 MW can be achieved at an altitude of 73 meters, 65.67 MW for the E-48 model at 76 meters, and 49.69 MW for the E-44 at 60 meters.

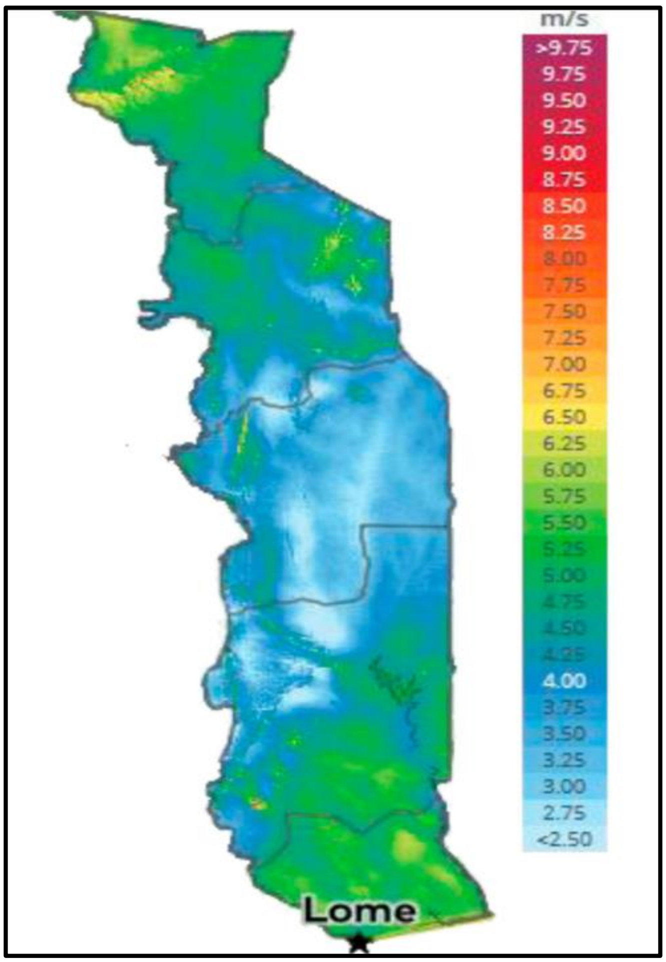

Fig. 6. Togo wind energy potential.

6) ICT in Togo: A foundation for smart grid development: In this section, an overview of Togo's communication networks will be conducted first. This assessment will highlight the strengths needed for a successful transition to a smart grid in Togo. Togo has several internet service providers, mobile phone operators, a data center, and an internet exchange point. Togocom, the state-owned operator, holds the rights to provide internet services and manage both fixed and mobile networks. This makes it a potential key player in the development of the smart grid in Togo through a public-public partnership.

a) Fixed Operators: Togocom is the leading operator with the most comprehensive and efficient core network. Its core network primarily consists of fiber optics covering the entire length of the country. This network is connected to the WACS (West Africa Cable System) submarine cable, of which the operator is the owner. It provides Internet through DSL, WiMAX, Specialized Line (RTC), and Fiber Optic Link (LFH) technologies. Thanks to the provision of aerial fiber optic Internet, Togocom has reached all neighborhoods of the Togolese capital. Its backbone is present in all Togolese cities with available fiber optic strands, allowing for the interconnection of intelligent elements from any part of the country.

There are other operators such as "Technologies Operations Liberté Services" (TEOLIS), "Centre d'Assistance, de Formation et d'Etude" (CAFE), which offer Internet through microwave links, and "Group Vivendi Africa" (GVA), which provides Internet to its subscribers through aerial fiber optics. These latter three are widely represented in the capital of Togo.

b) Mobile network operators: These are operators whose distribution network is a mobile phone network that provides access to the Internet. There are two historical operators: Togocom and Atlantique Télécom (Moov Africa).

Togocom has a network covering almost the entire Togolese national territory. Using Base Transceiver Stations (BTS), Base Station Controllers (BSC), and Mobile Switching Centers (MSC) as distribution points, it offers its subscribers technologies ranging from the first to the fifth generation of mobile telephony (2G, 3G, 4G, and 5G). Fig. 7 represents the network architecture of Togo Cellulaire, the mobile network entity of Togocom. It has a national backbone consisting of a fiber optic network and microwave links with a bandwidth of up to 10 Gbps [45]. The core network of Togo Cellulaire spans the entire territory. Its cellular network covers almost the entire country. The Togocom group has more than four million subscribers.

The Atlantique Télécom group announced a 400 km fiber network between Lomé and Kara by the end of July 2016 [46]. It has a network ranging from the first to the fourth generation, thus utilizing BTS, BSC, and MSC towers. For international connectivity, the Atlantique Télécom group subscribes to the WACS and satellites, enabling communication with other offices in Africa. Like its competitor, it has a fiber optic and microwave link backbone with a capacity of up to 10 Gbps. The installed fibers have up to 96 strands available, offering the possibility of smart grid interconnection throughout the Togolese territory. It has more than 3 million subscribers.

c) *Government network (e-Gov):* Inaugurated in 2017, the e-government network consists of a 250 km fiber optic network. It connects approximately 560 public buildings (university hospitals, health centers, more than one-third of public high schools, universities, all Republic institutions, and all ministries) in the Togolese capital, Lomé. The e-Gov network provides the entire public administration, university centers, and public university hospitals with high-speed Internet at 100 Mbps per building. An Internet bandwidth of 2 Gbps is available to it on the international WACS band. It offers an operations center allowing data storage and management with servers capable of processing approximately 2 terabytes [47]. This network can significantly contribute to local traffic development. It would be a crucial asset in the implementation of a smart grid in Togo, allowing for the connection of all entities and services in the electrical energy sector and housing smart grid data for intelligent analysis.

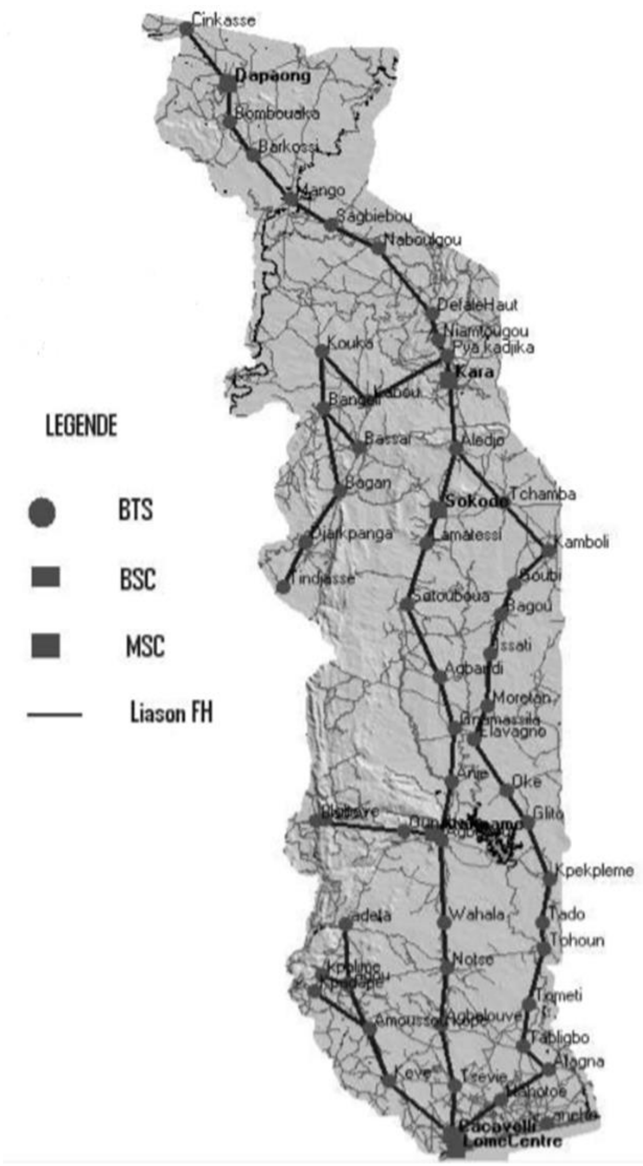

Fig. 7. Togocom network.

d) National education and research network (TogoRER): Connecting the University of Kara, the University of Lomé, and other public and private higher education institutions, the TogoRER network enables interconnected institutions to exchange information in real-time. This network, being connected to the regional WACREN network via a fiber optic link from Lomé to Accra and Lomé to Lagos, offers an opportunity to connect the Togolese grid to those of other countries in the sub-region within the framework of the WAPP project. The Togolese smart grid could, in real-time, analyze the price of electricity on the West African Power Pool (WAPP) and decide whether to sell or buy. This would help reduce the cost of electricity sales in Togo.

IV. DISCUSSION

The literature review on communication technologies for smart grids shows they often rely on existing telecommunication networks. Considering the high initial cost of smart grid implementation, exploring the use of communication networks can minimize expenses and foster cooperation between the electric grid and telecommunication operators in low-income countries. In developed countries, smart grids aim to enhance operational efficiency, integrate renewable sources, or reduce carbon footprints. However, the initial investment, technical expertise, and state decision-making remain challenges, as noted by [26], [7] and [8]. In low-income countries, the focus is on studies and concepts, with imported electric networks facing similar issues as in developed nations. Implementing a smart grid could help low-income countries manage growing demand and establish a reliable, resilient, and economically and ecologically sound electric grid. The high initial cost remains a barrier for these countries.

Analyzing Togo's energy demand reveals a growing need, for renewable energy potential in hydroelectric, solar, and wind sources. Daily consumption profiles indicate that photovoltaic systems would require batteries, increasing the smart grid's cost. Therefore, solar thermal energy could be a more cost-effective option. Telecommunication operators with nationwide coverage are crucial for smart grid implementation in Togo. Since the state is represented in both the electric grid and telecommunication networks, agreements could be facilitated in a win-win framework. The National Cybersecurity Agency (ANCy) would be vital for securing the smart grid.

The smart grid is not a one-day solution; existing issues need to be addressed first. This includes securing the transport network, making the distribution network intelligent with bidirectional management, integrating renewable sources and micro-grids, implementing monitoring systems, and integrating smart meters and customer management systems. Progressive implementation is illustrated in Fig. 8, with the conceptual smart grid architecture incorporating telecommunication networks shown in Fig. 9. Telecommunication networks will primarily be used for consumption and management, connecting smart meters to the distribution network, and allowing consumers to manage electricity costs. Electric energy distributors can manage and monitor Virtual Power Pant (VPP) formed by microgrids in real-time through these networks.

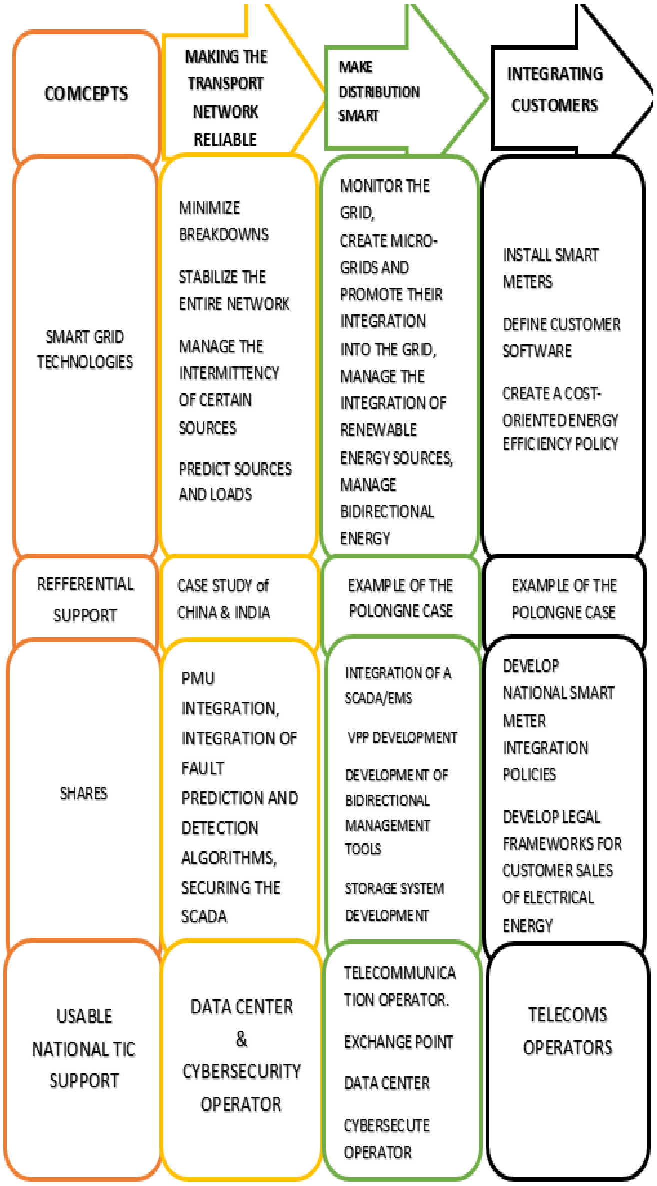

Fig. 8. Concepts for smart grid in Togo.

The government network offers an opportunity to interconnect Togo's energy sector institutions (CEB Dispatching, DGE, ARSEE, and CEET Dispatching). Micrograds and a SCADA/EMS based on the CEET power distribution network will be managed with telecom operator networks. The TogoRER network, part of WACREN, provides an opportunity to connect Togo's grid to the regional WAPP grid. The national data center will save data at each level for real-time and future use, enabling quick analysis with advanced algorithms for reliable and resilient grid management. According to Fig. 8, three priority levels are essential. First, make the power transport network reliable, second, make the distribution network smart and finally integrate the customers.

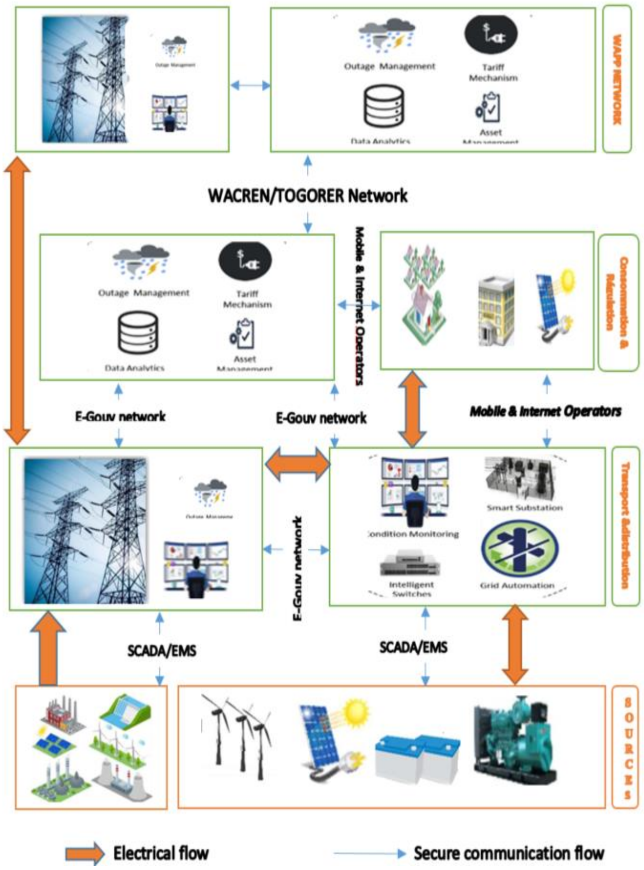

Fig. 9. Architecture of smart grid conceptual in Togo.

V. CONCLUSION

The implementation of smart grids will enable the electrical network to be reliable, resilient, economical, and ecological. This requires information and communication technologies (ICT). The implementation demands high investment costs, which marginalizes developing countries from these technologies that could boost their development. Togo, with its potential for renewable energy, struggles to implement smart grids due to high investment costs. This article has identified notable avenues for the implementation of smart grids in Togo, based on the experiences of other countries. The process of setting up tools to make the electricity transmission network reliable, the method and national policy for implementing smart meters and managing the distribution network are the notable feedback options used. Telecommunications operators' networks have been leveraged to reduce the cost of implementing smart grids. It is noteworthy that this approach can be applied in other low-income countries for effective smart grid implementation. The proposed architecture remains conceptual. So, to enable the smart grid to be implemented in Togo, an evaluation of the proposed architecture using a simulator will make it possible to assess its feasibility in low-income countries.

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