Smart Grids in Morocco: An Outline of the Recent Developments, Key Drivers, and Recommendations for Future Implementation

M. Laamim, A. Benazzouz, A. Rochd, A. Ghennioui, A. El Fadili, M. Benzaazoua

Abstract**—**Smart grids have recently sparked a lot of interest in the energy sector as they allow for the modernization and digitization of the existing power infrastructure. Smart grids have several advantages in terms of reducing the environmental impact of generating power from fossil fuels due to their capacity to integrate large amounts of distributed energy resources. On the other hand, smart grid technologies necessitate many field investigations and requirements. This paper focuses on the major difficulties that governments face around the world and compares them to the situation in Morocco. Also presented in this study are the current works and projects being developed to improve the penetration of smart grid technologies into the electrical system. Furthermore, the findings of this study will be useful to promote the smart grid revolution in Morocco, as well as to construct a strong foundation and develop future needs for better penetration of technologies that aid in the integration of smart grid features.

Keywords**—**Smart grids, microgrids, virtual power plants, digital twin, distributed energy resources, vehicle-to-grid, advanced metering infrastructure.

I. Introduction

POPULATION growth is increasing widely, and energy consumption is elevating as well. Thus, depending on fossil fuels for energy production to fulfill this significant demand is exceptionally environment harming. Whereas climate issues request urgent interventions, the concerned parties ought to rapidly act to help reduce the impact of traditional energy production resources.

The introduction of renewable energies is one of the promising measures to reduce the impact of energy production on the climate. The use of distributed energy resources (DERs) in energy generation can contribute to the decarbonization of the power system and to ensure a sustainable energy supply throughout the world [1]. Meanwhile, integrating DERs into the electrical power system can cause several issues regarding the power grid flexibility and stability. Consequently, the massive integration of DERs with their intermittent character ought to be managed intelligently using new information and communication technologies (ICT).

Smart grids are a significant solution for enhancing the integration of renewable energies and ensuring grid reliability and stability while managing production and demand. According to General Electric (GE), a Smart Grid is the coupling of electric utility equipment with data communications, an intelligent system that leverages real-time information, and analytics to increase reliability, renewable energy resources integration, and help managers make adequate business decisions [2]. Fig. 1 shows the concept of a smart grid.

The integration of smart grid technologies into the traditional grid entails improvements in many areas. The smart grid, for example, uses digital technologies rather than electromechanical switching systems. In addition, unlike traditional power systems, the smart grid allows for two-way power flow and employs autonomous control techniques and self-supervision rather than manual control.

Several studies have defined the smart grid, challenges, and barriers faced along with implementing its concept in the power system. Bari et al. presented an overview of the challenges in the smart grid applications and discussed smart grid features such as communications, demand response, security, and microgrids and their distributed energy integration issues [3]. Bayindir et al. did an outlined review on smart grids and its prospect in the imminent future [4]. El-hawary introduced technical, environmental, socio-economic, and other non-tangible benefits of Smart grid to society [5]. In Morocco, few studies have occurred regarding the smart grid field. Meliani et al. studied the obstacles and barriers to smart grids in Morocco [6]. Sahbani et al. developed the smart grid prospect in Morocco [7]. Rachid Habachi presented a review of the literature as well as the anticipated requirements and problems that the power grid may face in incorporating smart grid technology [52].

This paper aims to develop the previous research in Morocco and presents a study of the current situation of the Moroccan power grid and the main projects that occurred in Morocco to reinforce smart grid applications in Morocco. Also, this work elaborates the main current challenges that the Moroccan government and the electrical power system are facing and provides applications and key drivers that may interest stakeholders and the concerned parties to implement the smart grid technologies into the Moroccan electrical system.

Mohamed Laamim, Aboubakr Benazzouz, and Abdelilah Rochd are with Department of Smart Grids, Green Energy Park, Benguerir, Morocco (e-mail: laamim@greenenergypark.ma, benazzouz@greenenergypark.ma, rochd@greenenergypark.ma).
Abdellatif Ghennioui is with Department of Modeling and Simulation, Green Energy Park, Benguerir, Morocco (e-mail: ghennioui@iresen.org).
Abderrahim El Fadili is with Laboratory of Signals, Systems, and Components, University of Hassan II Mohammedia, Morocco (e-mail: abderrahim.elfadili@fstm.ac.ma).
Mostafa Benzaazoua is the Director of Green Energy Park, Benguerir, Morocco (e-mail: benzaazoua@greenenergypark.ma).

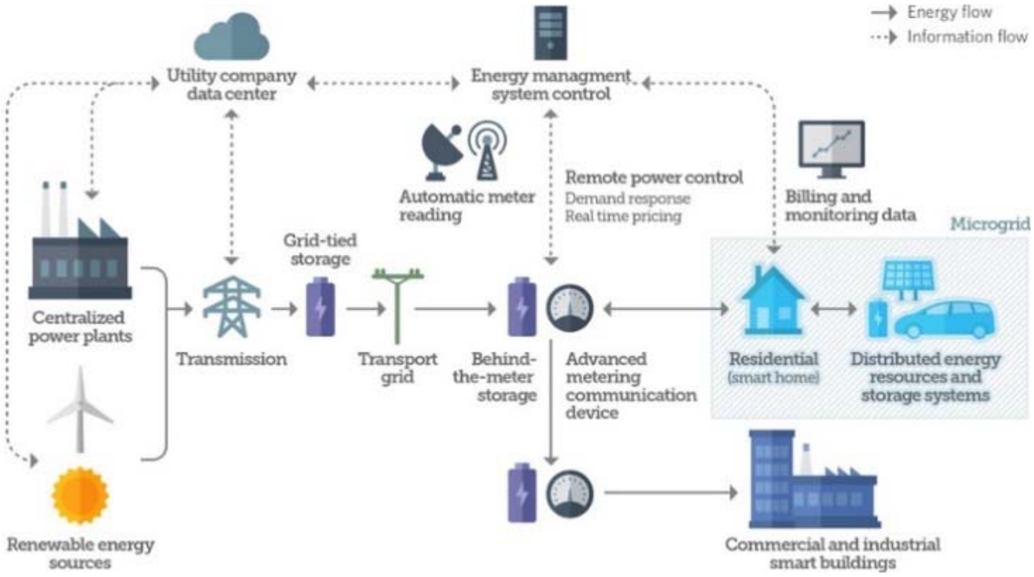

Fig. 1 Smart grid concept and architecture

The following is the outline of the paper: Section II will present a general context of the energy situation in Morocco, the electrical power system utilities, and general information about the Moroccan power grid with its generation, distribution, and transport areas. Also, this section will propose several Moroccan initiatives and projects regarding the smart grid. Lastly, a SWOT analysis will be given to encounter the smart grid situation in Morocco. Section III will propose solutions and applications destined to stakeholders to promote the Smart Grid implementation in the Moroccan power grid and finally the study will propose recommendations for this purpose.

II. Energy and Power Grid Situation in Morocco

Population growth and economic development increase the electricity demand significantly. With a current installed capacity of 10.627 GW and an energy consumption reaching 38.371 TWh (see Table I) [8], Morocco is challenged to meet growing local demand while controlling its import bills. Accordingly, the Moroccan electricity demand could rise from 38 TWh in 2020 to 80 TWh by 2050, according to historical data extrapolation. In addition, the Moroccan National Outlook predicted that demand would climb to 115 TWh by 2050 [9]. Therefore, several scenarios and solutions have been incorporated in the Moroccan Energy Strategy by the Moroccan government. As a result, the plan aimed to limit the impact of the energy sector while supporting the mobilization of energy resources, the widespread adoption of renewable energy sources in Morocco's energy mix, and the promotion of energy efficiency as a national priority [10].

TABLE I
Energy Situation in Morocco

Installed capacity in GW	10.627
The share of renewable energy sources in %	37.2
Maximum consumption peak in GW	6.44
Energy consumed in TWh	38.371
Energy produced in TWh	38.754

A. Electrical Power System Utilities

Since 1990, The National Office of Electricity and Water (ONEE) [11] has been taking the lead of the Moroccan electrical power system and the drinking water sector. Its missions encountered the electricity production, transport, distribution of electricity, purification of wastewater, liquid sanitation services, and ensuring the continuity of services of both sides. These missions were supervised and controlled by the Ministry of Energy, Mines, Water, and Environment [12] [13].

As the heart of strategic public service, ONEE plays an important role in improving the standards of living of the Moroccan citizens and the country’s economic competitiveness. Additionally, it carries out activities focused on the electricity trades: Production, Transport, and Distribution of electrical energy [14].

On other sides, the LV power distribution network in certain regions and cities is supervised by other public companies or private distributers. Morocco has currently 10 companies over its territory who are themselves ONEE's clients [15].

B. Main Power Grid

The Moroccan power generation relies on both fossil fuels and renewable resources with a share of 62.8% and 37.2% respectively. Table II details the portion of every energy source in the energy mix of Morocco [11].

The transmission network is consisting of 27583 km of transmission lines separated into different voltage levels as shown in Table III. This network is interconnected with both the Spanish and the Algerian power grid [15].

The distribution parts cover both the urban and rural areas, including 216 HV power stations, 94243 km of medium voltage network, and 244514 km of low voltage network [15].

The Moroccan policy and the actual power grid continue to grow. Therefore, several projects and improvements have occurred in 2020 to reinforce the electrical power grid. Regarding the transportation, ONEE is carrying out an investment program for the development of their infrastructures and the extension of the different level transmission lines by adding 45 km of VHV (Very High Voltage/400 kV), 87 km of 255 kV lines, and 369 km of medium voltage transmission lines [15].

TABLE II
INSTALLED CAPACITY PER ENERGY SOURCE BY 2022

Source	Installed capacity in MW
Hydraulic	1306
STEP	464
TOTAL HYDRAULIC	1770
Coal	4116
Fuel	300
Gas turbine power plant	1110
Combined cycle power plant	834
Diesel power plant	314
TOTAL THERMAL	6674
Wind power	1430
Solar power	751
TOTAL RENEWABLE ENERGY	2181
TOTAL GENERATION BY ONEE	10627

Relatively to the reinforcement of the capacity of the network, ONEE has proceeded to the commissioning of 7 sub substations and the creation of more than 1000 MV/LV stations [15].

TABLE III
DIFFERENT NETWORK INTERCONNECTIONS AND TRANSMISSION LINE DISTANCE BY 2022

Voltage level	Distance in km
400 kV	3681
225 kV	9708
150 kV	147
60 kV	12349

C. Smart Grids Initiatives and Projects in Morocco

In Morocco, the subject of smart grid is now popular. As a result, all parties involved, including the government, energy corporations, research institutions, universities, and academics, are working on pilot projects, research platforms, and large-scale initiatives where the majority of which are now operational or in the works. The subsections below describe some of Morocco's major projects and initiatives aimed at deploying smart grid technologies and reaping their benefits.

1) Microgrids Projects

Currently, Morocco is deploying several projects of microgrids that encourage the use of renewable energies and supply unelectrified regions. Among these projects:

- Green Grid: This project is jointly led by the Green Energy Park (Morocco) [16], ELEXPERT (Morocco) [17], and IDEAS TX INGENIERGENA (Spain) [18], and aims to design, deploy and demonstrate a smart microgrid within living laboratories situated in the Green & Smart Building Park platform (GSBP), with advanced control strategies and energy management services following the African context. The proposed microgrid will integrate DER, exterior lighting, energy storage technologies, and electric vehicle supply equipment (EVSE). The microgrid's services cover demand-side management, generation, and flexibility to ensure the maximization of renewable energy production.
- INPTSMG: The goal of this project is to create and implement Morocco's first green university campus. This campus will rely on renewable resources (mainly PV) as its first source of energy, and leverage IoT-based technologies developed by a team of professors, researchers, and students to develop an energy management system that can manage and control the energy inside the campus [19].
- Tahala Grid: Held by the Research Institute in Solar Energies and New Energies (IRESEN) [20], the intelligent micro-grid project (Tahala grid) aims to implement an innovative and replicable local energy architecture, optimizing the integration of decentralized production (solar photovoltaic, solar thermal), the dynamic control of loads, modeling of local production to reduce the energy costs by 70 for a community in Agadir [21].
- Id Mjahdi: This pilot project is located near Essaouira and was completed through a collaboration between various agencies including the Moroccan ministry of energy, The Moroccan Agency of Sustainable Energy (MASEN) [22], and the French business Intermarket. This project is an off-grid microgrid that supplies 20 homes with energy produced by solar panels and battery storage systems.

2) R&D, Training, and Innovation Programs for Developing Smart Grids in Morocco

Smart grids are the subject of considerable research, development, and investment throughout the world. Therefore, the government should take a position in building skills and capabilities in this area while investing in new academic programs aiming at this subject. Mohammed VI Polytechnic University with its department Green Technology Institute and in partnership with the Green Energy Park has launched in 2019 the first Moroccan Master's degree program in Morocco that encounters the smart grid field [23]. Other universities and engineering schools have started to include smart grid courses and modules into their program schedules.

Additionally, several energy institutes and companies have created living laboratories for smart grid implementation. The Smart Test Laboratory of the Green Energy Park in Benguerir is one of these laboratories equipped with power and hardware in-the-loop simulation capabilities that are committed to innovative work, capacity building, research, and development in many fields including smart buildings, energy efficiency, and smart grids. Also, Kenitra's National School of Applied Sciences (ENSA) [24], established a research laboratory co-funded by IRESEN through the Inno-PV call for proposals. This laboratory named SECRETS will enable to test key concepts and develop smart grid standards with an innovative approach. Moreover, this laboratory will study the impact of integrating DER and develop scenarios and advanced control strategies.

3) DERs Integration Projects

According to the national energy strategy that announced a 52% of the share of DER by 2030 [25], and in this context, Morocco has launched several initiatives and projects to accelerate the integration of DER into the power grid. Appropriately, the Moroccan government carried out and mobilized the necessary skills for the targeted integration of DER into the power grid. One of these projects is INTOPER [26] (Optimal integration of renewable energy resources into the Moroccan power grid), which began in 2020 and is being jointly implemented by ONEE and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) [27], under the administrative control of the Moroccan Ministry of Energy, Mines, and Environment (MEME). It addresses the following fields of action:

- Adapting instruments and processes for grid management;
- A long-term infrastructure planning toward renewable energy resources;
- Offering system services for flexibility and stability; and,
- Integrating innovative technologies.

4) Smart Metering Projects

As smart metering is considered one of the main first steps to move towards Smart grids, ONEE engaged in several projects regarding the implementation of smart meters into its electrical distribution networks. Lately, in 2021, ONEE and Atos have reached an agreement to leverage over 100,000 smart meters for customers around its territory. The goal of this project is to enable smart grid management and give data-driven services to both parties. As a result, the initiative will improve customer energy efficiency, billing techniques, and grid infrastructure management and capabilities [28]. Also, Morocco has been engaged in projects to arise smart meters rather than electromagnetic ones, the main target of these undertakings concerns VHV, HV, and MV clients while the LV side is forthcoming. Accordingly, ONEE has allotted a massive investment of 100 million MAD for this project which will help in decreasing energy losses and theft. Likewise, ONEE has reported that these smart meters will embrace a bi-hourly tax framework that will encourage utilizing power during the day rather than at night when the energy utilization is at its peak levels. Also, they will help on decreasing the high tension on the electric power system [54].

From another perspective, IRESEN, INESC-ID [29], the Moroccan Foundation for Advanced Science, Innovation and Research (MAScIR) [30], and Green & Energy Park have collaborated to work in a project called WiMeCom. This project aims to develop a hybrid wireless and wired smart metering solution. This work is a part of the InnoProject call for projects funded by IRESEN, where INESC-ID collaborated with the expertise of its Communication Networks Group on modeling and optimization of the smart metering communication protocols. INESC-ID Team provided solutions integrating Long Range Area Network (LoRaWAN) and PLC technologies in order to provide an optimal communication network for the smart metering infrastructure [31].

D. Main Challenges of the Moroccan Power Grid

The Moroccan power generation and consumption are confronting many difficulties and boundaries. Subsequently, moves should be made to work on improving the quality of the network and easily integrating smart grid aspects into the Moroccan electrical power system. A portion of those difficulties is cited in the subsections below.

1) Transport Sector

In Morocco, the transport sector is the leading energy consumption with nearly 38% of the national final energy consumption (see Fig. 2) [53]. It also contributes to more than 23% of greenhouse gas emissions. This sector depends almost exclusively on petroleum products, which are imported in their entirety and weigh heavily on our trade balance. Consequently, and following the worldwide trend to decrease the impact of the transport sector on the climate, Morocco faces a transition to e-Mobility. Thus, the electrification of the transport sector will impact the power system, especially in its generation adequacy, flexibility, and distribution grid capacity. The main challenges of this electrification of the transport sector on the energy utilities include the increase of medium voltage substations, Replacement of the head feeders and distribution transformers, and cable sections conducting to the EVSE that may still lead to voltage limits violations [32].

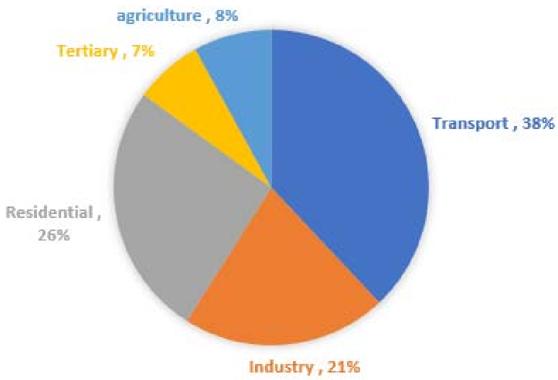

Fig. 2 Energy consumption percentage per sector in Morocco

2) Renewable Energies Integration and Grid Reinforcement

Morocco has a great potential of renewable resources, especially solar and wind power which share a capacity of 750 MW and 1430 MW, respectively [33]. Most of this capacity is integrated into the transmission line of ONEE. According to the law 13-09 and 58-15 [34], [35], electricity generated from distributed generation may only be connected to the national medium voltage, high voltage, and very high voltage grid. Therefore, one of the main concerns about integrating renewable energies into the grid is impacting the grid's flexibility and stability. However, the electricity grid to accommodate a higher percentage of renewable energies would need large quantities of conventional backup power and huge energy storage [36]. Additionally, the Moroccan grid adopts equipment dating back to the 19th century, these outage grid components may result in slowing the advancement of these projects. Therefore, reinforcing and digitalizing the aged power grid components will require massive investments.

3) Energy Theft

Energy fraud has always been a major concern for ONEE and other Moroccan energy distribution utilities. Methods for commissioning fraud include splicing the pipes to bypass the meter, tampering with the meter to stop it or to slow it down, and essentially interfacing with the appropriation network without having an agreement with the organization or a meter [37]. Accordingly, energy fraud can affect the electrical power system in a roundabout way. It can cause insignificant information among the energy utility and lead to appalling energy management. Also, in 2020, and according to Morocco's minister of energy, energy theft costs Morocco MAD 1.2 billion every year [38]. Thus, Morocco should take into thought new perspectives and advancements to stop this issue.

4) Legislative Framework

Despite the regulatory framework enacted to fulfill the energy transition in Morocco, there are still several legislations that should be applied in to accelerate the smart grid technologies implementation. Therefore, the Moroccan government should start with policies including statements of regulations for the power grid modernization. This regulation will help introduce new technologies into the power grid that support the DER integration into the electrical system. Also, Morocco has to start introducing policies for the feed-in tariffs [39], as long as these parts are designed to support the development of renewable energy resources in the electricity market. Additionally, the Moroccan government, precisely the power utilities, should take into consideration programs and frameworks to roll out smart meters instead of electromagnetic meters, especially in buildings, industries, hospitals, and other facilities that are under construction.

E. SWOT Table

TABLE IV
SWOT TABLE

Strengths	Weaknesses
• Electrification rate of 99.6% in 2019 [40]. • Solid renewable energy potential. • Solid ICT infrastructure. • Wide covering of telecommunication and internet network. • Power grid reinforcement projects.	• Unavailability of smart metering infrastructures. • Power grid components outage. • Lack of national strategy for smart grids.
Opportunities	**Threats**
• Smart grid applications. • Investment optimization.	• Growing energy demand. • Population growth. • Energy theft. • Grid quality to high penetration of EV and DER. • Intermittence of DERs.

III. Smart Grid Applications

Despite the several issues that Morocco faces, such as energy growth, grid instability due to high penetration of electric vehicles and DERs, and energy theft that causes significant losses to the power utilities, Morocco's infrastructure for integrating smart grid applications is improving. This infrastructure also comprises a strong ICT infrastructure as well as a large telecommunications and internet network coverage. These assets will aid Morocco's development in terms of incorporating smart grid features and technologies. As a result, this section will discuss some of the solutions and technologies that can assist the Moroccan government or energy utilities in improving the power grid and dealing with these difficulties.

A. Microgrids

Despite the barriers obstructing the integration of renewable energies into the low voltage distribution network, microgrids are still a valuable solution to allow the integration of DERs into the power grid. Due to their capability of working independently of the grid (also called islanding mode), microgrids present several advantages regarding the electrical power system including the ability to detect impendent disruptions in the power grid and leverage energy from more stable sources until issues in the main traditional grid have been solved.

B. Digital Twin

The increasing and sometimes, outage of the power grid makes it more complex to be understood and analyzed by the grid utilities, with a massive flood of data, digitalization is highly recommended. The digital twin (DT) is a solution developed to help utilities manage their grids while exhibiting powerful engineering that aids in the planning, operation, and maintenance of the power grid using a digitalized model of the physical world.

Fig. 3 describes how a power system DT may interact with its physical counterpart [41]. Through advanced analytics, dynamic and steady-state data management, automation, and system operators, DT is the key technology that will ensure the secure and reliable operation of the future power system. DT's main part, which is real-time simulation, is another key factor for many applications, including the acceleration of integrating distributed energy sources and the smart grid infrastructure through the high availability of models and predictions of the real physical power system. This technology will also aid in the optimization of the measuring infrastructure by allowing the grid to simulate and provide results data about other grid components without the need for a measuring interface.

C. Virtual Power Plant

Virtual Power Plant (VPP) is an energy management system tasked with aggregating the capacity of several DGs (Distributed Generation) and dispatched loads [42]. Unlike microgrids that introduce grid stability and reliability problems, VPP coordinates all the distributed sources as a single agent to integrate them into the grid without compromising the grid stability and reliability [43].

Microgrids are often considered off-grid, while VPP is integrated into the grid and uses aggregating software [44], for control and operation instead of switches (for islanding mode), EMSs (energy management systems), and hardware-based inverters. The VPP aggregation software includes a variety of energy sources and loads as shown in Fig. 4.

Several projects have been conducted worldwide in integrating VPP into power grids, FENIX project conducted in Spain introduces future scenarios including VPPs into the grid to gather the central generation, distribution, and transmission networks, and the distributed energies resources into one distributed control instead of a centralized and a passive one

[45]. VPP4ISLANDS is planning to integrate two islands as real-life cases to validate and evaluate the proposed solution. The control and optimization of different systems will be extended to consider not only electrical, but multi-energy vectors [46]. An Australian fuel cell company has sold BlueGen technologies to facilitate the integration of many VPP projects in different countries in Europe [47].

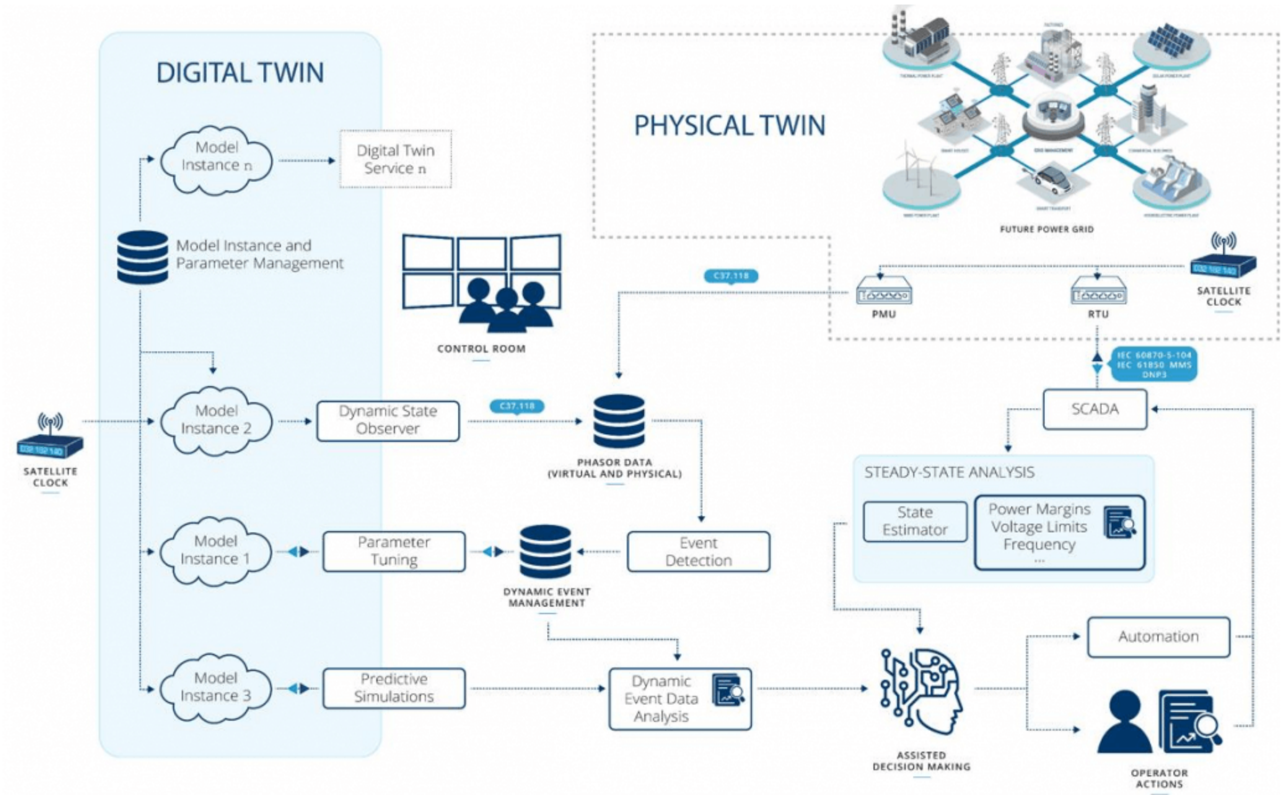

Fig. 3 DT concept and the power grid

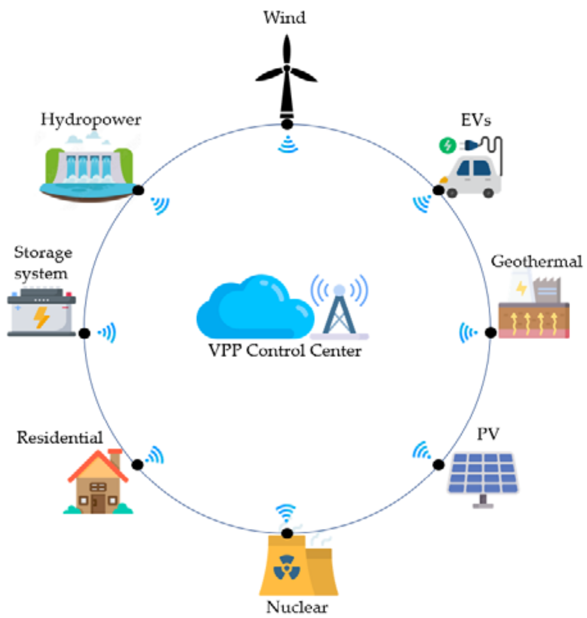

Fig. 4 VPP aggregation

D. Introducing Vehicle-to-Grid

Morocco's potential on adopting electric vehicles and e-mobility is increasing. The Moroccan government is working on the development and encouragement of the population for the electrification of the transport sector. This technology will help not only in reducing the major effect of fuel-based cars but also, it will save the power grid in many ways. Vehicle-to-grid is an efficient way to explore the energy excess of the electric vehicle in the power grid which is also known as vehicle to grid integration. This method can help on creating extra power sources when energy is needed.

E. Smart Metering Infrastructure

The deployment of smart grid technologies requires a solid database on all the loads composing the grid. One of the major components is smart meters. This component measures different energy elements (voltage, current, power, energy, cost, PF, etc.) and store them for further analysis. These data are going to be used to optimize and control energy use. Moreover, since smart grid is nothing but the modernization of the existing power grid, Advanced Metering Infrastructure (AMI) is one of the major aspects of Smart grid. It comprises of smart meters, a Data Management System (DMS), and communication networks [48]. These components will assist in overcoming many of the grid's issues, including energy theft challenges, due to their ability to detect fraud and abnormal energy consumption.

F. Discussion

Throughout the paper, we sketched out a picture of the Moroccan smart grid situation. We developed current efforts and initiatives involving the integration of smart grid into the electrical power system, which are being carried out by various energy corporations and institutes in Morocco. In the meanwhile, the Moroccan power system is facing several issues, some of which are impediments to implementing smart grid technology into the electricity framework. Furthermore, to address these challenges, we have introduced applications that may entice stakeholders and energy utilities to build new projects and goals for the transition to smart grids. Nonetheless, it is recommended that these applications are examined in detail in order to assess their maturity and efficacy in assisting with the deployment of smart grids.

Microgrid deployment necessitates not just field research, but also a solid business model with several criteria and standards. To get a favorable outcome, it is necessary to focus on microgrid technical elements such as power quality, appropriate control strategies, a strong EMS, energy optimization, stability, and protection. Moreover, the microgrid pre-deployment should acquire essential elements that every project needs to address. These elements involve consulting and planning, a solid study of the needed equipment (generation assets, electrical equipment, protections, relays, etc.), automation and control software, analytics, service and maintenance, and more importantly financing [49]. In addition, the regulatory environment for the creation and ownership of microgrids should be adjusted. As a result, the parties involved should specify the regulations and legislation that apply to each operation in the microgrid. These regulations must consider all the concerned parties including the microgrids owners, the energy utility, and the government. As a result, regulations should incorporate all legal terms of usage and duties on both sides. For example, the energy utility should be obligated to provide and improve pricing structures in order to support and stimulate the growth of microgrids. Also, on the other hand, microgrid owners are supposed to fulfill the energy utility with all the required components for better management including the installed capacity of DER, system design, location, consumption data, etc. Thus, the responsibilities of both parties should be laid out.

Regarding the smart metering infrastructures and despite their benefits, there are still several regulations and standards that must be taken into consideration to successfully roll out smart meters among customers. To ensure technical and commercial compatibility, guarantee data privacy and security, and deliver maximum benefits to consumers and the energy system, the Moroccan government and energy utilities should adopt accessible standards and the proper set of functionalities including the compliance of the different technologies and functionalities of the smart meters (communication protocols, equipment, and DMS) [50]. In parallel, the government should step up with an intelligible legislative framework to embolden the energy utilities to invest in the deployment of smart meters. In addition, DT and VPP are still new technologies. Therefore, The Moroccan current infrastructure does not allow large-scale studies or implementation of these technologies. For example, VPPs necessitate an ICT infrastructure that allows access to electricity data in the first place, and also access to the electricity market, keeping in mind the DERs aggregation. And yet, to guarantee improved analysis and future prediction for network interconnections, DTs require a stable architecture that comprises connected data environments. As a result, due to its intricate systems, integrating these technologies is costly.

Finally, the implementation of V2G is a viable strategy for improving grid capacity and meeting rising demand. However, there are several challenges to consider before implementing V2G technologies. Technically, due to the large charging and discharging cycles, V2G activities may have an impact on battery longevity, commonly known as battery degradation. Also, the regulatory side should apply new terms. Thus, separate laws must be implemented in many areas of the regulations, including bi-tax systems, standards, off-grid private EV chargers, data security, and so on.

IV. Recommendations

Through the several studies that occurred worldwide regarding the smart grid revolution and promotion, some countries have reached higher levels in integrating smart grid aspects. To lay a solid foundation for smart grid technology adoption, various actions and moves are required. As a result, Morocco should take a step ahead with the support of research and development to keep up with the progress made in the field of smart grids.

The Moroccan authorities are also asked to fulfill the legislative framework with new sections and regulations regarding the electrical power grid starting from regulations for the grid renovation that includes many aspects such as the digitalization of the electrical components and operations of the grid in order to improve their efficiency and rise their security levels. Also, the Moroccan government should imply a new smart grid strategy that includes the overall objectives of integrating smart grid aspects and their obstacles. Consequently, the government should supervise the development of this strategy through many systems reports and prospects presented by the energy utilities and distributors. Moreover, the legislative framework should adopt new regulations for data safety, data handling, and data protection. Also, it needs to define the different roles and responsibilities of the smart grid community.

Morocco could also begin this transformation by focusing on raising customer understanding of how grid digitization and technologies may help them lower their billing costs, increase their energy quality, and comfort, and reduce the impact of the physical power grid on the environment. This step is largely concerned with industries and large-scale facilities that contribute to higher energy usage. Parallel to this, the government should designate and fund smart grid penetration initiatives, such as microgrids, smart metering infrastructure, ICT infrastructure enhancements, grid rehabilitation, and large-scale digitalization. Contributing to these projects, however, will necessitate significant financial and investment resources. As a result, the government should begin prioritizing these projects by upgrading the regulatory framework, which should include all aspects of smart grid operations and prospects, as well as their effectiveness among customers.

Finally, the establishment of standards for the various levels of the smart grid, on the other hand, is one of the most important steps ahead in improving the integration of smart grid components. Many countries have created standards in response to their current power grid scenario, which encompasses not only the electrical system infrastructure but also the integration of DERs, ICT infrastructures, EMSs, home automation, and general security. To that end, Table V lists some of the standards and their roles in the smart grid that the Moroccan Institute of Normalization (IMANOR) should evaluate as part of the smart grid's future development [51].

TABLE V
OVERVIEW OF STANDARDS IN RELATION TO THE SMART GRID FIELD

Standard	Position in Smart Grid
AMI-SEC System Security Requirements	Smart metering infrastructure
IEC 60870	Communication protocol
IEC61400-25	EMS, DMS, and DER
IEC 61850	Substation automation and protection, Distributed Generation, E-mobility
IEC 61851	EV-Communication, Smart buildings, and E-mobility
IEC 61970	Energy management
IEC 62351	Information security for power system.
IEC 62443	General security.
IEEE 1547	Physical and electrical interconnection between utility and distributed generation.
IEC 62051-54/58-59	Metering standards, DMS, DER, AMI, Smart Home, E-Storage, E-Mobility.
OpenHAN	Home Area Network (HAN) device communication, measurement, and control.
ZigBee/HomePlug Smart Energy Profile	Home Area Network (HAN) communications and information Model.

V. CONCLUSION

The Moroccan government has been concentrating its efforts on growing the energy sector more recently than in previous years. Morocco's energy policy, which was unveiled in 2020, called for a huge shift to renewable energy, with a share of 52% by 2030. The electric power grid faces a significant challenge as a result of this sharing. Consequently, integrating renewable energy into the power grid necessitates a number of changes and improvements to the current electrical system. As a result, one of these changes is the transition to smart grids. The Moroccan government and energy utilities took many steps and activities in this document to improve the implementation of smart grids technologies into the electrical system. It also demonstrated some of the applications that can aid in the development of the current situation and the progression to the next steps in the development of a smarter electrical power system.

REFERENCES

[1] M. Boulakhbar *et al.*, “Towards a large-scale integration of renewable energies in Morocco,” *J. Energy Storage*, vol. 32, no. May, p. 101806, 2020, doi: 10.1016/j.est.2020.101806.
[2] W. Paper, “Defining the Smart Grid WAN.”
[3] A. Bari, J. Jiang, W. Saad, and A. Jaekel, “Challenges in the smart grid applications: An overview,” *Int. J. Distrib. Sens. Networks*, vol. 2014, 2014, doi: 10.1155/2014/974682.
[4] R. Bayindir, E. Hossain, and S. Vadi, “The path of the smart grid - The new and improved power grid,” *2016 Int. Smart Grid Work. Certif. Program, ISGWCP 2016*, no. March, 2016, doi: 10.1109/ISGWCP.2016.7548270.
[5] M. E. El-Hawary, “The smart grid - State-of-the-art and future trends,” *Electr. Power Components Syst.*, vol. 42, no. 3–4, pp. 239–250, 2014, doi: 10.1080/15325008.2013.868558.
[6] M. Meliani, A. El Barkany, I. El Abbassi, A. Moumen Darcherif, and M. Mahmoudi, “Smart grid implementation in Morocco: Case study,” *Mater. Today Proc.*, vol. 45, no. May, pp. 7675–7679, 2021, doi: 10.1016/j.matpr.2021.03.176.
[7] S. Sahbani, H. Mahmoudi, A. Hasnaoui, and M. Kchikach, “Development Prospect of Smart Grid in Morocco,” *Procedia Comput. Sci.*, vol. 83, no. Wtisg, pp. 1313–1320, 2016, doi: 10.1016/j.procs.2016.04.274.
[8] Ministery of energy transition, and sustainable development, Electicity. 2020. (Online). Available: https://www.mem.gov.ma/Pages/secteur.aspx?e=1.
[9] T. Schinko, S. Bohm, N. Komendantova, E. M. Jamea, and M. Blohm, “Morocco’s sustainable energy transition and the role of financing costs: A participatory electricity system modeling approach,” *Energy. Sustain. Soc.*, vol. 9, no. 1, pp. 1–17, 2019, doi: 10.1186/s13705-018-0186-8.
[10] K. Choukri, A. Naddami, and S. Hayani, “Renewable energy in emergent countries: lessons from energy transition in Morocco,” *Energy. Sustain. Soc.*, vol. 7, no. 1, 2017, doi: 10.1186/s13705-017-0131-2.
[11] National office of Electricity. (Online). Available: http://www.one.org.ma/FR/pages/index.asp.
[12] Ministery of Energy, Mines, Water and Environment, Department of Energy Transition. (Online). Available: https://www.mem.gov.ma
[13] (Online). Available: https://amepa.ma/?page_id=826=en
[14] (Online). Available: https://www.devex.com/organizations/national-office-of-electricity-and-drinking-water-onee-morocco-139576
[15] A. De, F. Publiques, and M. Finances, “Bilan des activites 2010,” pp. 1–13, 2010.
[16] Green Energy Park. Benguerir, Morocco. (Online). Available: https://www.greenenergypark.ma/.
[17] Elexpert, Morocco. (Online). Available: https://elexpert.ma/.
[18] ITX, Spain. (Online). Available: https://ingenieriatx.es/.
[19] National Institute of Posts and Telecommunication. (Online). Available: https://www.inpt.ac.ma/fr/projets.
[20] Research Institute in Solar Energies and New Energies. (Online). Available: https://iresen.org/.
[21] M. A. I. T. Benali and A. Outzourhit, “DLMS smart meter reading application for PV-micro-grids,” pp. 1847–1850, 1847.
[22] Moroccan Agency for Sustainable Energy. (Online). Available: https://www.masen.ma/en.
[23] Mohammed VI Polytechnic University, Green Technology Institute. (Online). Available: https://www.um6p.ma/index.php/en/master-program-electrical-engineering-renewable-energies-and-smart-grids-resma.
[24] National School of Applied Science. (Online). Available: https://ensa.uit.ac.ma/.
[25] D. E. L. E. Énergétique, “Stratégie nationale,” 2020.
[26] E. Cooperation, “INTOPER -: Optimal integration of renewable energy sources into the Moroccan power grid,” 2019.
[27] GIZ, Morocco. (Online). Available: https://www.giz.de/en/worldwide/340.html.
[28] Nicolas Nhede, Smart Energy International, ‘Morocco’s ONEE to optimise smart meter data management with Atos and Siemens’. 2021. (Online). Available: https://www.smart-energy.com/digitalisation/moroccos-onee-to-optimise-smart-meter-data-management-with-atos-and-siemens/.
[29] Available online: https://www.inesc-id.pt/.
[30] Moroccan Foundation for Advanced Science, Innovation, and Research. (Online). Available: https://www.mascir.com/en/home/.
[31] Pedro Ferreira, INESC ID, ‘Our firtst collaboration with Morocco: Research project WiMeCOM’. 2019. (Online). Available: https://www.inesc-id.pt/our-first-collaboration-with-morocco-research-project-wimecom/.
[32] “Exploring_the_impacts_of_blog.PDF.”
[33] T. Kousksou *et al.*, “Renewable energy potential and national policy directions for sustainable development in Morocco,” *Renew. Sustain. Energy Rev.*, vol. 47, pp. 46–57, 2015, doi: 10.1016/j.rser.2015.02.056.
[34] R. Maroc, “N ° 13-09 Relative Aux Énergies Renouvelables,” 2010.
[35] “La loi n ° 58-15 amendement et complétant de la loi n ° 13-09 Relative aux énergies renouvelables,” p. 2015, 2015.

[36] N. Phuangpornpitak and S. Tia, "Opportunities and challenges of integrating renewable energy in smart grid system," *Energy Procedia*, vol. 34, pp. 282–290, 2013, doi: 10.1016/j.egypro.2013.06.756.

[37] B. Coma-Puig, J. Carmona, R. Gavalda, S. Alcoverro, and V. Martin, "Fraud Detection in Energy Consumption: A Supervised Approach," in *2016 IEEE International Conference on Data Science and Advanced Analytics (DSAA)*, Oct. 2016, pp. 120–129, doi: 10.1109/DSAA.2016.19.

[38] Taha Mebtoul. 'Energy Minister: Electricity Theft Costs Morocco $131 Million Annually'. 2020. (Online). Available: https://www.moroccoworldnews.com/2020/11/326524/energy-minister-electricity-theft-costs-morocco-131-million-annually.

[39] P. Generation, W. Power, and Y. Manabe, "Feed-in Tariff Application of DERs in electricity market Power Quality Solutions for Renewable Energy Systems," 2016.

[40] Access to Electricity (% of population) in Morocco. 2019. (Online). Available: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=MA.

[41] "No Title," (Online). Available: https://www.opal-rt.com/the-digital-twin-in-hardware-in-the-loop-hil-simulation-a-conceptual-primer/.

[42] O. Palizban, K. Kauhaniemi, and J. M. Guerrero, "Microgrids in active network management - Part I: Hierarchical control, energy storage, virtual power plants, and market participation," *Renew. Sustain. Energy Rev.*, vol. 36, pp. 428–439, 2014, doi: 10.1016/j.rser.2014.01.016.

[43] L. Yavuz, A. Önen, S. M. Muyeen, and I. Kamwa, "Transformation of microgrid to virtual power plant - A comprehensive review," *IET Gener. Transm. Distrib.*, vol. 13, no. 11, pp. 2077–2087, 2019, doi: 10.1049/iet-gtd.2018.5649.

[44] O. Abrishambaf, P. Faria, J. Spínola, and Z. Vale, "An aggregation model for energy resources management and market negotiations," *Adv. Sci. Technol. Eng. Syst.*, vol. 3, no. 2, pp. 231–237, 2018, doi: 10.25046/aj030227.

[45] M. Braun, "Virtual Power Plants in Real Applications Pilot Demonstrations in Spain and England as part of the European project FENIX," *Int. ETG-Kongress*, no. August, pp. 3–8, 2009, (Online). Available: https://www.vde-verlag.de/proceedings-en/453194005.html.

[46] European Commission. (Online). Available: https://cordis.europa.eu/project/id/957852.

[47] "CFCL BlueGENs for Dutch Virtual Power Plant project, UK grid," *Fuel Cells Bull.*, vol. 2013, no. 12, p. 6, 2013, doi: 10.1016/s1464-2859(13)70408-5.

[48] R. Rashed Mohassel, A. Fung, F. Mohammadi, and K. Raahemifar, "A survey on Advanced Metering Infrastructure," *Int. J. Electr. Power Energy Syst.*, vol. 63, pp. 473–484, 2014, doi: 10.1016/j.ijepes.2014.06.025.

[49] Siemens. 'The six Elements to Successful MicrogridDeployments'. 2018. (Online). Available:https://microgridknowledge.com/elements-microgrid-deployments/.

[50] Vitiello, S, Vasiljevksa, J, Filiou, C, "Cost-benefit analyses & state of play of smart metering deployment in the EU-27," 2014.

[51] S. Rohjans *et al.*, "Survey of smart grid standardization studies and recommendations," *2010 1st IEEE Int. Conf. Smart Grid Commun. SmartGridComm 2010*, no. May 2014, pp. 583–588, 2010, doi: 10.1109/SMARTGRID.2010.5621999.

[52] R. Habachi, A. Touil, A. Charkaoui, and E. Abdelwahed, "Management and Control of Smart Grid Systems: Opportunities and Challenges in Morocco," Int. J. Math. Comput …, vol. 3, no. 2, pp. 6–14, 2017, (Online). Available: http://www.aiscience.org/journal/ijmcshttp://creativecommons.org/licenses/by/4.0/%0Ahttps://www.researchgate.net/profile/Rachid_Habachi/publication/331687706_Management_and_Control_of_Smart_Grid_Systems_Opportunities_and_Challenges_in_Morocco/links/5c8cd108.

[53] "Les Secteurs les plus énergievores" (Online). Available: https://energiewende-maroc.org/decouvrir-le-secteur-de-l-energie-au-maroc/quel-secteur-consomme-le-plus-d-energie.

[54] "No Title," (Online). Available: https://medias24.com/2021/07/05/lonee-va-installer-progressivement-des-compteurs-electriques-intelligents/.