PROJECT MMIS2CG
« MOROCCO MICRO SMART CAMPUS, CITY AND GRIDS »

Final Paper title : Morocco Smart Microgrid, Case INPT

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ABSTRACT
In the Context of the adoption of the new United Nations Sustainable Development goals and the historic Paris Climate Agreement at COP21, both followed by the perspective of COP22 in Marrakech, the Kingdom of Morocco has developed a National Strategy for Sustainable Development (NSSD) and has set ambitious targets for sustainable development in general and sustainable development of energy in particular. The National Energy Strategy 2030 is set in a vision of addressing Morocco's challenging dependency on imported energy. Since 2009, Morocco has launched an ambitious solar plan part of this strategy. Till 2015, law 13-09 that regulates renewable energy sector didn't allow selling of locally produced low voltage electricity. Now it does since end of 2015 through amendments of law 58-15 opening a wide range of opportunities for smart microgrids to develop. INPT, the first ICT engineering school of Morocco drives a pilot project to equip its campus with a smart microgrid network as proof for concept.

INDEX TERMS
Smart microgrid, Renewable energy, energy access, clean energy policy, energy efficiency, energy security.

PAPER

I. Introduction

In the Context of the adoption of the new United Nations Sustainable Development goals and the historic Paris Climate Agreement at COP21, both followed by the perspective of COP22 in Marrakech, the Kingdom of Morocco has developed a National Strategy for Sustainable Development (NSSD) and has set ambitious targets for sustainable development in general and sustainable development of energy in particular. The National Energy Strategy 2030 is set in a vision of addressing Morocco's challenging dependency on imported energy. Since 2009, Morocco has launched an ambitious solar plan part of this strategy.

In fact, Morocco is dependant at 97.5% of imported energy (data 2008)[1]. Fuel and cole constitute 90% of the overall energetic mix[2]. Such situation is not sustainable considering the impact on Green house gaz emissions and economically not wise as these products benefit from 90% of compensation budget (ie. 43 Billion MADs in 2011). With an energetic invoice equivalent to 52.6% of Morocco's overall exports, it is clear that developing a local production strategy was necessary especially that Morocco predicts an increase of energy demand at 8% annually till 2030. The National strategy for energy introduces a mix of 42% up to 2020 and 52% up to 2030 of renewable energy in the energetic mix. It brings also the dimension of energy efficiency with expected savings of 12% by 2020 and 15% by 2030. Project NOOR which has as target to provide morocco with 2000 MW of solar energy and for which the first phase was recently launched remains the concrete consecration of a large vision incorporating all energy reforms in the country.

"Morocco has no other choice than reinforce its local capacity of energy production and open ways for energetic investments. It must also pursue diligently efforts aiming at making alternative and renewable energies the master key of the national energetic policy."[3]

Limiting the world-widely admitted anthropogenic warming below 2 degrees Celsius (2°C) will entail[4] a profound transformation of energy systems. Three pillars support such transformation; efficiency and conservation, decarbonization of electricity and fuels, and switching to low-carbon energy.

Energy is by far the biggest challenge to address for the world while transiting towards a low carbon economy. It is in Morocco a strategic factor of economic and social development[5]. Morocco not disposing of considerable primary energy has got a not-enough developed system of production of energy. Being on an accelerating wave of development, the country will face in the next twenty-five years the challenge of economic emergence and the need to satisfy its population well-being demand in a context of globalization and international competitiveness. Its performance will intimately depend on its energy choices. These choices are still open and possible since the country can still afford at lower cost new technology choices unlike developed nations who face the challenge of huge legacy infrastructure and slow evolutiveness.

In 2015, the world witnessed two records[6] : Global investment in renewable energy was the highest ever with some 300 Billion USD and for the first time more than half new electric capacity came from renewable sources. In paris 20 countries announced their

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[1] MoEM Ministry of Enregy & Mines, Kingdom of Morocco. "Stratégie Energétique Nationale : Horizon 2030", 2009

[2] MoE Ministry of Environment, Kingdom of Morocco. " Plan investissement vert " March, 2014

[3] His Majesty King Mohammed VI, Extract from speech on the throne celebration. July 30th, 2008

[4] SDSN and IDRRI. "Pathways to deep decarbonization", 2015

[5] HCP Haut Commissariat au Plan. " Prospective Maroc 2030_ prospective énergétique du Maroc, enjeux et défis.". Casablanca, June 9-10, 2006

[6] "Clean energy Ministerial 7 June 1-2, 2016 panel : Toward a Clean Energy Economy" https://www.youtube.com/watch?v=VkckXzxg350

intent to double research & Development budget in clean energy. In CEM7 (Clean Energy Ministerial 7 San Francisco), three initiatives were launched[7]; which shows a clear and serious sense of direction towards decarbonized energy. The three initiatives are : Procurement of electricity from renewable energy; Commercial and industrial energy efficiency and Advanced cooling technologies.

On another hand Information and Communication Technologies with regards to the unprecedented breakthroughs this industry has witnessed in terms of internet spread, social media, artificial intelligence, event-driven architecture, etc.- have the potential to profoundly support Energy Efficiency Deep Decarbonization Pathways (DDPs) through smart microgrid technology. And yet it was not considered as an option in the National energy strategy 2030.

According to the *National Institute of Science and Technology – USA*, a Smart Grid is « *a modern electrical network that allows bi-directional of energy and uses a both-way communication in addition to control mechanisms allowing numerous applications »*. And a Microgrid is « *a sub-system of the electrical network which has ability of being rapidly disconnected from the main electricity grid and functioning independently »*.

So far, the electrical distribution networks were supposed to "passively" connect charges. In order to achieve ambitious targets of energy efficiency, they need to be completely redesigned to become more intelligent[8]. By cons, electrical transport networks are already active and therefore relatively smarter than electrical distribution networks. However, they will have new challenges to balance the intermittent production and to channel energy from new remote production areas.

In the electricity sector, an economic development in the country requires in order to keep the offer/demand balance either construction of important quantities of new production capacity or at minima improvement of the existing ones.

Challenges linked to smart electrical networks are industrial, social and economic. Infrastructure equipment that composed so far the electrical netwos are adapting to incorporate this new intelligence. Smart networks are a field of innovation and major industrial applications that will require continuous cooperation between enterprises, of Information and Communication Technologies and Electrical field enterprises. The communicating character of the network should serve interactivity. It takes into account actions of all players in the ecosystem; from the producer to the consumer passing by the distributor and the suppliers of energy while insuring security, efficiency, effectiveness and flexibility of networks.

How could smart microgrid be an option for complementing the energy technology choices in Morocco? And what policy reforms adopt in that perspective?
In this paper, we propose a benchmark of policies among several countries which adopted smart microgrid technologies as a complement to their existing energy mix. The rest of the paper is organized as follows; next section discusses the main aspiration behind our INPT pilot project. Section III presents our contribution as potential solutions. In section IV we draw and finally in section V, we conclude this

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[7] "Clean energy Ministerial 7 June 1-2, 2016 announcements", accessed August 1, 2016, http://www.cleanenergyministerial.org/News/worlds-energy-and-business-leaders-announce-actions-to-accelerate-global-deployment-of-technologies-at-seventh-clean-energy-ministerial-68632

[8] "The European technology platform for the electricity networks of the future" http://www.smartgrids.eu/

paper and discuss future works.

II. Project description

In the context described above where different options for energy mix have been considered in the Kingdom of Morocco, a consortium has been created, enabling the collaboration of many research partners with the ambition of a common vision of low-carbon urban development with a comprehensive development strategy and the implementation of Smart micogrids locally (in the city of Rabat) and even nationally. This will move towards the creation of a socio-economic environment leading to creation of industry, business and social networks. This consortium is composed of partners who are AAMEN group (http://www.groupeaamen.com/), the National Institute of Posts and Telecommunications - INPT in Rabat (www.inpt.ac.ma) and the Software Development Center.

INPT is the leading public engineering school of Information and Communication Technologies in Morocco. It has got fifty years of experience in education of engineers in this field. It also holds a research lab counting more than fifty researchers, fifteen associatite researchers and internationals in addition to hundred forty research students. INPT is committed to sustainable development and aspires to pave the way and drive by example. It holds all the elements necessary by putting its research at the service of this worldwide challenge. With its educational vocation and using this proposed architecture, it also aspires to allow students to have access to a test lab of smart microgrid local deployment for ther potential own management algorithms (e.g., battery storage, production, routing of energy).

Many university campuses around the world have led similar projects like the Public University of California (UC)[9] or Illinois Institute of Technology[10]. For instance UC is the only institutional investor part of the Breakthrough Energy Coalition and made a commitment back in 2013 to become carbon neutral by 2025.

The Soft Center which is led under supervision of the National Agency of regulation of Telecommunications. Is a center of develeopment of low-cost softaware at the disposal of operations of the sectoir of Information Technology. It has got experience in producing innovative applications by mobilizing universities and engineering schools competencies in research .
AAMEN group has more than twelve years of experience in research and development in sustainable developped technologies applied in French terrirtoris in America in partnership with Eiffage Energie and also in the grand caraib (Haïti, Dominican Republic, Cuba, West Africa (in progress) in partnership with EDF Store & Forecast and EDF EN.
This international consortium : Group ANRT/INPT - Soft Centre - Groupe AAMEN will work on the project « INPT Smart Microgrid » which consists of development of an operational Smart Microgrid at the level of the school campus. The project responds in fact to and simultaneously to multiple sustainable energy challenges. Through this project, the Kingdom of Morocco will have the means to achieve its strategic objectives while solving effectively the recurring problems that occur in its grids. Therefore, we could simultaneously maximize areas of social and economic interests, based on these

[9] "Clean energy Ministerial 7 June 1-2, 2016 panel : Toward a Clean Energy Economy" https://www.youtube.com/watch?v=VkckXzxg350

[10] Mohammad Shahidehpour, "Role of Smart Microgrid in a Perfect Power System." (Paper presented at the IEEE PES General Meeting, Minneapolis, MN, July 25-29, 2010. DOI: 10.1109/PES.2010.5590068)

advances, which are a set of technological components and coupling the use of New Information Technologies with electronics power present throughout the value chain of an electrical network (Production, Transportation, and Distribution). The aim of the project is to propose a final smart microgrid local loop architecture, initially as proof of concept (POC) in INPT buildings, then on the Al-Irfane university campus in Rabat and eventually extend the architecture to the City.
Concretely, the first phase of the project focuses on the testing of the architecture on 'Administration', 'INPT PHD studies laboratory' and 'students residence' buildings in order to be able to study three different energy consumption profiles. Four consecutive steps will be considered in this deployment; Development of a data platform dedicated to energy efficiency allowing measurement and management of consumed energy by the different buildings then Dimensioning of means for local production and optimized storage of renewable energy (solar photovoltaïc panels) as per the studied profiles; Development of a controller based on a programmable automate allowing control and of converters that convert energy coming from multiple sources : main electrical grid, solar pannels, batteries, ondulors) for an optimum energy-efficient consumption, and finally Inter-liaison of the whole and functioning of the smart microgrid.

In what comes next we will detail those four phases.

Phase I consists of coupling realtime monitoring, periodic reporting and forecast of consumption. An audit of the existing installation will be operated. Current electricity invoices will be analyzed. Then smart meters will be installed in addition to network analyzers with periodic data collection in order to determine excessive consumption points. A specific data platform will be built to monitor and profile energy patterns. This audit will help prepare the dimensioning of solar energy production with storage capacities. This data platform can be connected to other databases with which it can communicate through TCP/IP protocol, WiFi, Bluetooth, Zig Bee, Radio or wire.

Phase II concerns dimensioning of the equipment. We will define capacity and size of production and storage equipment by building on charges and energetic profiles determined in Phase I. By production equipment we mean solar panels and calculation of their generators pic power. Sun radiation will be measured in kWh/m²/day. Energy will obviously be also considered for a buffer. Batteries for storage will be dimensioned through first calculating capacity of storage needed to absorb pics of traffic (example : Iftar time during Ramadan). The constraint of incremental cost of batteries as capacity grows, unlike Solar panels for which the price decreases, imposes a careful dimensioning.

Phase III is where the controler will be developped in order to control and manage converters of energy. This phase will be developed in collaboration with our partner Group AAMEN and its associates EDF Store & Forecast and EDF EN. It consists of a microgrid central controller for managemnt of produced, stored and consumed energy. In addition to the routing of energy from building to building

Phase IV is the final phase on interliaison of the whole and functioning of the smart microgrid as a local loop architecture. This is the pahese where intelligent energy managemnt algorythms will be tested

We work on the initiation of the POC before the timeframe of COP22 in Morocco in November 2016 where we would like to share our progress and concept for generalization on the city. By September 2016 we would like to present our preliminary results at the 4th ICSD in New York.

The centralized Controler is governed by algorythms of optimized management allowing decision-making on storage and redistribution of energy between buildings. In this architecture, every building is equiped with its own means of production, storage, consumption and internal control in order to be producer and consumer of energy. By the way, algorithms internally developed within this project will be adapted to the Moroccan university context (ie. Consumption peaks during special period example Ramadan, sports games periods, school vacations)

The value add of our project in terms of research and development is :

- Realtime monitoring of the smart microgrid installation ;
- Generation of alerts in case of any issue with production, storage, consumption or distribution of the Smart Microgrid ;
- Development of fusion and data aggregation algorythmes
- An applicative layer on sensors for decision making

The main objectives are :

1. Design the first green university campus in Morocco quasi-autonomous in energy and demonstrate the proof of concept in a multi-profile environment;
2. Design and implement the first smart microgrid for pedagogic and research purposes ;
3. Development of a datcenter dedicated to energy efficiency ;
4. Invent new algorythms of smart management of energy be it on routing, storage paterns, etc… ;
5. Develop collaboration partnership n terms of applied and industrial research with Group AAMEN and its partners EDF Store & Forecast, et EDF Energie (references in the domain of Smart-Grids) ;
6. Ultimately modify energy consumption behavior among students and professors not only in INPT but also by extension to the entire Al Irfane university campus

III. Potential Addition to Morocco Energy Mix

The national energy strategy brought the establishment of a number of institutions, namely MASEN (Agency for solar energy which became recently an agency for sustainable energy), ADEREE (Agency which takes care of energy efficiency), SIE (a society for investment and PPP setup) and IRESEN (Research institute) in addition to the adoption of two laws :

- Law 13-09 that allows production of green electricity by private enterprises with possibility of interconnection and integration to the main grid.
- Law 47-09 which sets modalities to insure energy efficiency in buildings, industries and transport.

When the energy sector have been anlysed during preparation of Morocco INDC[11] and National Strategy for Sustainable Development mid 2015, it was highlighted that a number of improvement points were needed. In fact Law 13-09 didn't allow to sell excess of locally produced energy from renewable sources in low voltage. It completely shut the door to decentralized microgrids proliferation. In addition the thermic regulatory framework for buildings is yet to be developed to allow the implementation of law 47-09. From a financial angle, Curent Incentives and fiscal measures are not yet sufficient to

[11] MoE Ministry of Environment, Kingdom of Morocco. "Morocco Intended Nationnaly Determined Contribution submitted to UNFCCC" June 5th , 2015

encourage the uptake of renewable energy 'filières'[12]. Also, the compensation scheme applied till last year as part of government subsidy to the advantage of fossil fuels didn't allow the renewable energy kwh to be competitive enough.

Morocco has been among the first countries in 2015 to join the FFFS (Friends of Fossil Fuel Subsidy Reform) and Finally the

The intermittence problem remains the major backdrop of adopting renewable energies
Morocco has developped since many years the PPP model in various sectors such as solid waste management, railways, ports exploitation, drinkable water distribution. In area of Energy, the most emblematic PPP project is the electrical central of Jorf Lasfar that produces 50% of local electricity consumption[13]

Let's explore the experience of smart microgrids deployments around the world. Policies that have been adopted in California state pave the way as most progressive energy policies in the world. A political coalition that explicitly include organized labor and business was formed back in 2010

A legal policy needs to show clear support to business. Where policies enable markets for distributed electricity services, they offer an opportunity to engage the private sector[14]

IV. Recommendations

Based on the analysis above, this short section wants to summarize the key recommendations to be operated in Morocco in order to prepare a favorable environment for deployment of smart micro-grids.
First of all it is good news that Law 13-09 that was regulating the entire framework of sustainable energy has been amended end of 2015 to incorporate adaptations that will allow deployment of Low voltage decentralized installations.

Finance wise, government should support private investments through a Pubil-Private-Partnership policy.

V. Perspectives

The development of smart microgrids adds value to the electrical system. They, first, optimize the use of electricity networks through accurate knowledge of the charges. Then, through the installation of sensors, they detect and easily resolve the existing breakdowns. This way, it becomes possible to improve the quality and power of the electricity distribution service.
Finally, our strategy will achieve the following objectives:

Smart Microgrids allow to systematically bring answers to multiple challenges :

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[12] MoE Ministry of Environment, Kingdom of Morocco. "Stratégie Nationale du Développement Durable". July, 2016

[13] MoE Ministry of Environment, Kingdom of Morocco. " Plan investissement vert " March, 2014

[14] Terri Walters et al "Policies To Spur Energy Access : Executive Summary" (Technical Report, National Renewable Energy Laboratory, September 2015. NREL/TP-7A40-64460)

- **Technical** : through a better optimized of energy production from renewable sources on a local scale. They can complement the official public grid by helping to maintain stability of the supply while offloadng it when it is operating standalone from the distribution network;
- **Economic** : because depending of its size and through emergence of a new aggregator role in order to adjust to the markets (spot market, adjustment market and mass market). Smart microgrids also allow to differ heavy network investments in the sense that proximity of production and consumption points allow an optimized channeling of energy without major waists ;
- **Social** : a Smart Microgrid answers to the growing demand for energy in a territory. It offers indeed a more reliable and secure network in case of natural catastrophies. The fact that it is a local project, it also allows creation of initiatives and new partnerships between local actors ;
- **Environmental** : a distributed architecture allows to better integrate renewable sources into networks and avoiding installation of big installations on fragile sites with threatened biodiversity ;

In a mid-term we would like extend this concept of smart à Madinat Al Irfane (university campus, with a population of young students and employes receptive to change). Idea would be to equip every school of higher education with its own smart microgrid , quasi-autonomous, connectable to the main grid of electricity. Smart Microgrids can also communicate among them. We believe that the opportunity of Smart Microgrids can have important advances for Morocco.

Ambition of our project is to propose a local loop architecture in a first step at the level of the three building s scope of the pilot proof of concept project. And then in a second phase at the level o all buildings of INPT. In the final architecture configuration we plan to relay the central trasnformer in a loop with all the other sites (residential, administrative, studies…) which are equipped with auto production and auto-consumption. For instance the central controler at INPT will be the space of testing for various management and prediction algorythms adapted to the moroccan context.

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