Supporting an Integrated Access to North Africa's Trade Wind Resources: The Sahara Wind Project

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Abstract : In order to address Morocco's high energy dependency from fossil fuels and a limited access to electricity a Centre in Charge of Developing Renewable Energy CDER was founded in 1983. The local water utilities and CDER installed two USAID-funded small wind turbines in 1989. Subsequently in 1994, a demonstration stand-alone 55 kW wind turbine coupled with diesels and a distribution grid was built on the trade windblown Sahara Coastline. Deterred by a lack of industrial interest Morocco's rural electrification programs (PERG) did not include wind energy. Carried-out a decade later with concessional funding, Morocco's wind energy program focused on developing large wind farms totalling 290 MW. The limited technology transfer of these projects contrasted sharply with the significant Sahara trade wind potential. Exceeding by far the country's energy needs, this wind resource could if exported, become one of the main economic drivers of the region. Within such context, developing an integrated approach to access this resource became critical. Within a bottom-up regional training and capacity building program, green campus concepts have been deployed in Morocco and Mauritania. Small wind turbines coupled to industrial Electrolysers with hydrogen storage, fuel cells, green mobility, smart grids and water pumping applications are currently training future generations of engineers. From distributed applications, to their integration within weaker grids, a variety of energy intensive applications will enable wind technologies to be effectively harnessed. Backed by Morocco's Renewable Energy Law 13-09, local industries can generate their own electricity. Excess electricity can be fed into the grid and even exported. Developing synergetic processes with large energy consuming industries such as mine processing will, in this context gradually lead to the deployment of Giga-Watt scale Wind-HVDC transmission projects. These technologies play a fundamental role in initiating the development of an integrated, competitive wind-energy driven green economy.

Keywords: HVDC, Integration, Synergies, Technology, Trade Winds

I. Introduction

Although the force of wind has historically been used for pumping water and grinding grains, the application of wind energy for electric generation was not considered until the late 1980's. In 1989 two 10kW Bergey wind turbines were installed in the rural Naima Commune to demonstrate this sustainable energy source in place of diesel engines used for water pumping. In this case, wind energy offered greater reliability than traditional village power sources, or more expensive diesel engines. Although significant investments were made into rural electrification programs (PERG), the implementation challenges relevant to this technology in remote sites combined with little commercial interest from equipment manufacturers led Morocco's authorities to base their wind energy program on larger conventional wind farms.

Built in the late 1980's the Tarifa wind farm in Spain provided a good demonstration of wind electricity generation on a larger scale. Located across the strait of Gibraltar merely 14 km north of Morocco's coastline, this wind farm provided a good example as to what could be achieved in this area. As a result, extensive wind measurements were carried out on Morocco's northernmost tip. Initiated a decade later with the unveiling of the 54 MW Koudia Wind farm near the Gibraltar strait, Morocco's wind energy program would focus essentially on developing larger wind farms. As a result in 2013, four wind farms sized 50 to 140 MW have brought Morocco's operational wind capacity to 285 MW. Influenced by the guiding rules of concessionary donor institutions which prevented local content to be effectively sought after, these projects provided a very limited impact on technological transfer and industrial job creation in the wind energy sector. As Morocco's 96% energy dependency from fossil fuels imports absorbs a significant share of its export revenues, the development of newer sustainable energy consumption schemes are critically important to the country's future.

II. Developing an inclusive approach to access wind energy technologies

In 1993, the building of a remote hybrid 55kW wind-diesel demonstration project located near the city of Dakhla, unveiled one of the world's largest wind energy potential. The trade winds blowing along the Atlantic coastline of the Sahara desert represents one of the most regular winds for electricity generation. Besides its outstanding quality, the trade winds catchment area which spread from Morocco to Senegal's coastline for over 2000 Km, makes it an exceptional resource. Within such context, the limited technology transfer in the implementation of Morocco's wind projects contrasted sharply with the wind energy potential of the Sahara trade winds. As the latter exceeds by far the region as well as the country's energy needs, an integrated approach to accessing this resource in future wind project developments becomes a vital issue. This is particularly relevant as the proximity of the Sahara coastline to larger energy markets such as Europe, could transform this region into a major wind electricity producer and net renewable energy exporter. These perspectives may help address some of Africa's pressing social and economic challenges.

Indeed, Morocco's location on the main routes of migrant populations from Sub-Saharan Africa and being itself an exporter of immigrants, together constitute a significant security threat to the region and its neighbours. The situation is fairly similar in Mauritania, whose scarce population is distributed over a vast territory in which access to potable water and electricity is difficult to grant through conventional grid infrastructures.

Under such circumstances, a bottom-up regional collaboration has been initiated since 2006 between academic institutions of Morocco and Mauritania under the scientific collaborative mechanisms of NATO. Through the 'Sahara Trade Winds to hydrogen: Applied Research for Sustainable Energy Systems' SfP-982620 Science for Peace project, smaller, more accessible wind turbines have been deployed within the region's universities. Introduced through green campus concepts, they have been coupled to various applications. As a result, Africa's first wind-hydrogen storage project has been launched at the University of Al Akhawayn. The project consists of a 30 kW Electrolyser system which stores excess wind electricity in 48 hydrogen cylinder tanks in order to feed it back with a fuel cell when wind is not available. The system is aimed at testing a variety of stationary power applications ranging from grid back-up to powering telecom infrastructures. While a similar system is being installed on the grounds of the University of Nouakchott's new campus, wind-pumping applications are also being tested on the grounds of the ENSAM School of Engineering. Within such settings, an industrial engineering program on small wind turbines and its components with in-house developed prototype designs have been being built. Small wind turbines can play an essential role for training and capacity building purposes. In total, the three partnering institution currently dispose of half a dozen 5 kW small wind turbines which have been delivered, adapted and improved as part of this project.

III. Building fully integrated functional systems

Supporting mechanisms to integrate this energy within the region's industries is of critical importance. Initially encouraged to provide employment in the relatively poor North Sea regions of Germany, the wind energy industry has emerged in the last 15 years, as a major business providing the most competitive prices of electricity even when operated under marginal European wind conditions. The trade winds that blow along the Atlantic coast from Morocco to Senegal represent one of the largest and most productive wind potentials available on earth. Because of the erratic nature of winds however, wind energy cannot be integrated locally on any significant scale unless more advanced grid technologies are considered. While the Sahara Wind project's 5 GW High Voltage Direct Current HVDC transmission line would enable significant amounts of energy to be transferred to larger regional consumption centres, its sheer size requires an effect of scale. Hence, applied research on upstream project development activities will be needed for some time. In order to support real-time integrated processes aimed at tackling energy scarcity while fostering sustainable development, a subsequent project proposal relying on the aforementioned academic network has been developed within this framework. Initiated in partnership with academia, Morocco and Mauritania's main public utilities and the local private sector, its objective is to enhance the access to potable water on a regional basis.

a. Technologies to stabilize wind-electricity and access to drinking water

The 'Production of drinking water in arid regions using renewable energies' project consists in coupling electrolyzers with wind turbine sets to generate renewable hydrogen and integrate electrolysis chlorinated by-products within Morocco's main water treatment facility (Africa's second largest). The objective of the project is to demonstrate that access to clean water technologies can enhance the uptake of intermittent sources of renewable energies such as wind power in weaker grid infrastructures found on the Sahara/Sahel region and most of the African continent. Acting as a stabilizing load in a high wind penetration system, electrolysis generated by-products such as chlorine or hypochlorite are indispensable elements in water treatment solutions for producing clean, drinking water. Chlorine and its derivatives represent the most commonly used water disinfectant product used worldwide. It represents the water utilities (our industrial partner) main commodity expense. Within this setting, several wind turbines will be fed into Morocco's power and water utility (ONEE) power distribution grid at its International Institute for Water and Sanitation (IEA). The local grid system will be stabilized by chlor-alkali electrolyzers acting as dump loads that simultaneously generate hydrogen and hypochlorite. The electrolyzer and small wind turbines (of 5 kW individual size) are designed to address environmental and energy efficiency concerns in powering the nearby main administrative headquarters of ONEE. Within this demonstration setting, hydrogen will be stored in pressurized tanks and used as a fuel for electricity generation through fuel cells in power backup (emergency power), peak power shedding and in hydrogen eco-mobility applications (fuel-cell powered vehicles). Chlorine/ hypochlorite will be used to support the sanitation needs of the main water treatment plant of ONEE. The entire system will enable its wind, electrolyzer, and hydrogen components to operate independently from each other as well, adding to the functionality and flexibility of the system. The reliability of the entire system is thereby reinforced, as a critical failure of any single component will not impact the functioning of the others.

Figure 1: Water treatment station and training center of ONEE in Rabat, Morocco

A similar system is being designed with the University of Nouakchott, in Mauritania our partnering institution for a deployment on their new campus facility. Bringing together the water utilities of Mauritania as an end-user, the system will expand the green campus system delivered under the NATO SfP-982620 project with a hypochlorite electrolysis system. The latter, co-funded by a Mauritanian institution and multilateral donors will produce hypochlorite as by-product. As a result both the public water utilities of Mauritania SNDE and the Agence pour l'Accès Universel aux Services APAUS, will be able to access wind-electrolysis technologies through demonstrators deployed at the University of Nouakchott.

b. Expanding on wind-energy related synergies

Within such framework, power and water utilities of Morocco and Mauritania will take advantage of the functionality of all individual components as for the benefits of the entire system to be compounded when operating together. These possibilities, a prerequisite in any industrial setting, will serve in the thorough analysis of the system. The systems integration will draw from the experience gained through earlier systems deployed at partnering universities. These include the ongoing industrial engineering programs on small wind turbines with integration, operation and maintenance, as well as the electrolyzer planning, configuration and site designs. As a result, project costs and technology deployment risks are reduced as improved designs and maintenance issues will benefit from experiences of previously deployed systems.

c. Smart grid technologies to support enhanced uptake of wind-electricity

In addition to the green campuses with hydrogen storage units that have been deployed in Morocco and Mauritania, Smart Grid technologies are relevant options to consider within high renewable energy penetration settings. Building on the aforementioned grid management technologies based on communicating networks, interactive loads operated by smart meters will be tested. Using the university campuses as a live test facility, the systems will capitalize on the experience of telecom operators which have agreed to provide their mast tower communication infrastructures on the Sahara trade wind coastline in both Morocco and Mauritania. As wind-hydrogen fuel-cell permanent power supply solutions are tested on-campus for our partnering telecom operators, their expertise in interactive network management is being shared as well. Consequently, several smart grid technology proposals have been submitted for funding in the latest call for projects of IRESEN, Morocco's solar and alternative technology institute. The Sahara Wind company has for that matter coordinated Morocco's first Smart Grid proposal linking several partnering academic institutions with industrial end-user. This was carried out during the first ever call for projects made available by IRESEN. As IRESEN represents an association pooling the utilities and mine processing companies together as shareholder, an emulation effect based on the approach of the Sahara Wind Project is thereby generated.

d. Deploying technologies on larger pilot projects

The utilization of wind energy and electrolysis by-products is likely to enhance the access to potable water, particularly in the Sahara desert where extended logistics and the safe transport of chlorine remains a delicate matter. The economic analysis with system performances will be thoroughly evaluated with respect to Morocco and Mauritania's hypochlorite/chlorine needs opening new integrated hydrogen applications. Configurations for system optimization and technology validations will enable the dispatching of systems within project partners in order to expand regional collaboration and support early industrial scale deployments. On the Saharan coastline, where water is extracted via energy intensive desalination processes, trade wind-powered applications using electrolysis can become even more relevant. Within such settings available on the African continent, collaborative partnerships can be extended into subsequent pilot projects. Initiated with the power and water utilities these will be gradually expanded to the energy intensive mining industries. This will open possibilities of developing integrated processes aimed at sustainably transforming the regions mineral deposits.

As the aforementioned functional demo-installations expand into collaborative pilot projects, access to wind-electricity will be enhanced. Providing storage alternatives for intermittent wind energy generation, wind-electrolysis by-products can be integrated as energy or chemical feedstock as well. The local valued-added processing and environmental performance of the region's main mining industries will be improved. Besides diversifying into new sectors such as automotive industries in the case of Morocco's Mohammadia School of Engineers (that are considering Training R&D programs on Fuel-cell powered vehicles), phosphates and iron-ore processing are interested in this applied research project as well. The Renewable Energy Law 13-09, enabling local industries to generate their own electricity while feeding excess electricity into the grid will for that matter be quite conductive. As extra capacity can even be exported to other countries, developing synergetic processes with large energy consuming industries such as mine processing could, in this context gradually lead to the deployment of the Sahara Wind Giga-Watt scale Wind-HVDC transmission project.

When focusing on a locally integrated economic development model to support a more comprehensive access to the Sahara trade winds, energy security challenges can be effectively adhered to. In the future, plans are to partner with these industries which represent the region's main electric loads to build an integrated energy system supporting the Sahara Wind High Voltage DC Transmission Project. As electricity demand grows at 8% per year in Morocco and Mauritania, and if current growth rates are maintained, the electricity consumption of the region is likely to be quadrupled within 20 years. By transferring large amounts of electricity through its High Voltage DC line, the Sahara Wind Project will enable this wind potential to be accessed by countries in the region to sustain their energy needs for economic development.

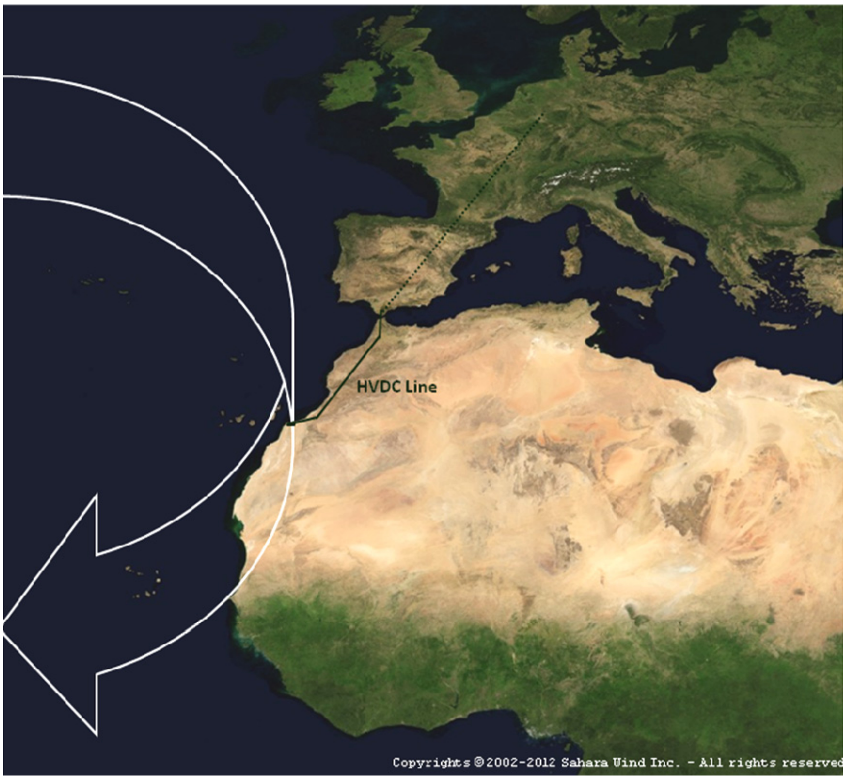

Figure 2: Atlantic trade winds blowing over the Sahara desert powering the Sahara Wind project

IV. Conclusion

Since large shares of national budgets are dedicated to the education sector in both Morocco and Mauritania, the development of sustainable energy consumption schemes is a critical issue. Political support for these perspectives is significant as these technologies can address the region's economic challenges. Fossil fuels dependencies are indeed responsible for most of the countries structural trade deficits. The appropriation of wind technologies will therefore contribute to mobilize the region's youth in the development of a more inclusive energy economy capable of addressing North Africa's current underemployment challenges. By enhancing local access to the trade winds, the project's results will contribute to support a cleaner and more efficient processing of local mining resources as well. In being economically sound, regionally integrated and gradually deployed, the Sahara Wind project might serve as a model for a broader energy transition not only within this region but also beyond.