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Adoption of Smart Grid in Libya challenges and opportunities

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Abstract— **As the electricity demand is continuously increasing and aged typical national power grid operating at their critical capability and stability limits, innovative techniques for more effective electrical energy generation and management is a vital desire for the Libyan electricity sector. This implies different challenges and vital opportunities that can be utilized to propose a smarter ways to provide and manage electricity to the consumers. These novel technologies will become the mile stones of our upcoming Smart Grid. This paper reviews the key features of the Smart Grid general concept, and argues some of the leading challenges and offered prospects of applying appropriate applications of the Smart Grid in Libya.**

***Keywords*— Smart Grid, Libyan grid overview, Smart Grid challenges and opportunities for Libya.**

I. INTRODUCTION

A Smart Grid is a modernized electrical grid that uses information and communications technology to improve the efficiency, reliability, economics, and susceptibility of the production and distribution of electricity [1]. This can be achieved by adding various advanced complementary technologies to the already existing electricity power system network. Therefore, Smart Grid involve advanced metering facilities, extensive distribution automation, reliable communication systems, wide range of distributed generation and distributed storage. Special control features and intelligent highly effective management throughout the system is a mandatory requirement for this integration [2].

On the other hand, it is highly expected that this modernized intelligently integrated power grid has a considerable potential and ability to manipulate most of constraints and limitations of the existing conventional power grid systems. This additional ability may increase the system self-healing capability (that can minimize operations and maintenance expenses) and consequently, improve the overall power quality and reliability levels. Supplied voltage sags, interruptions and overloading conditions will be minimized. Moreover, the proposed digital and intelligent upgrade of the typical grid will increase the protection level against cyber-attacks, facilitates multidirectional power flow in a meshed grid. Higher electrical energy efficiency levels, equipment's duty cycles can be achieved while extra cost effective operating conditions and less carbon emissions can be accomplished [3].

However, to implement and expand this advanced set of multidisciplinary features and broad nature technology, engineers has to encounter many challenges and complications. Different methods in implementation of the SG concepts may result in various advanced grid characteristics. Meanwhile, and due to all presented discussion, governments may resist to provide the adequate support in many countries towards adopting SG promising visions, especially, in the developed countries [3].

In order to have a closer view to what engineers and research groups may come across in the area of Smart Grid technical issues, a brief comparison between the conventional power grids and the smart power grids is presented in Table 1. It is obvious that the last century great achievement of constructing and operating typical power grids has to be modified and improved. Nowadays, global major challenges (climate changes, natural disasters, economy rescissions and terrorist threats) have all focused the attention to the vital need for more secure, reliable and intelligent power grid [4].

If a Smart Grid were designed from scratch, design issues would be complicated but manageable. However, with an already existing distribution infrastructure - that was not designed with Smart Grid in mind -, the following situation may exist: first, Smart Grid is significantly different from a design point of view of that distribution systems today; second, modifying the existing system into a Smart Grid may take decades. Nevertheless, the only viable way to realize an extensive Smart Grid is to develop a vision for the ultimate design of a Smart Grid and then make short-term decisions that incrementally transform existing distribution systems into this future encouraging image. Therefore, as an initial step, a huge

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effort is needed (with strong passion) to develop an integrated vision for Smart Grid, and strong leadership is very essential to impress this vision on the people who are ultimately responsible to make it happen [2].

TABLE 1. TYPICAL POWER GRIDS & SMART GRIDS CHARACTERISTICS COMPARISON

	Typical Power Grid	Smart Power Grid
Generation	Centralized, away from load centers, limited renewables	Distributed, less size, considerable renewables
Power Flow	Radial, unidirectional	Networked, multi-directional
Main Focus	Continuity of Service	Continuity & Quality
Consumer	No contribution	Contribute to utilities with range of electricity quality and price options
Control Centers	Based on manual communications systems during faults	Computer based data collectors, processors and decision making
Sensors positions	Mainly at generation and transmission	Throughout Wide Area Monitoring (WAM)
Response to Faults	Focus on protecting assets and prevent future damage	Predicts and prevents faults
Blackouts	Cascading effect	Islanding capability
Relays	Electro-mechanical based	Digital based
Energy Storage	Very limited	Basic system driver
Manageme nt	Limited data available	Integrated data for optimizing resources
Metering	Traditional kWH meter	Smart Meters
Attacks	Exposed to natural and terrorist attacks	Robust and resistant

II. LIBYAN GRID OVERVIEW

The General Electric Company of Libya (GECOL) is totally government owned corporation and is responsible for the operation of the entire power sector in the country. All power plants in the Libyan power system network had been installed by GECOL since it was established in 1984 [5].

Libyan national electric grid has a total installed power capacity of 6,768 MW. The transmission power system of Libya consists of six geographically dispersed, sparsely interconnected island areas (West, Tripoli, Central, Benghazi, Eastern and Southern regions), which consists of substations and lines on 400KV, 220 kV, and 132 kV levels with connections to sub-transmission networks of 66 kV and distribution systems of 30 kV and 11 kV. Connections in the transmission network of Libya are realized as overhead lines (14.747 km) and cables (138 km) as shown in figure 1.[6]

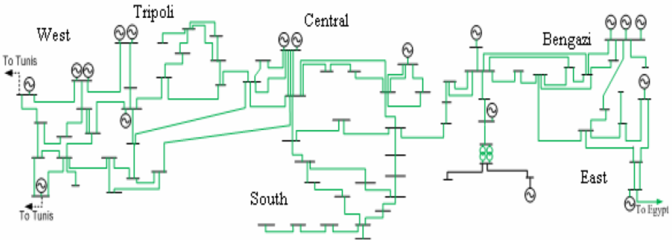

Figure 1. Libyan transmission network. [6]

Finally, the distribution networks voltage level is 30kV with a total circuit's length of 11,142km [7]. Table 2 shows the Libyan national electrical grid main characteristics, related major power and energy data as estimated in the year 2012.

TABLE 2 LIBYAN NATIONAL ELECTRICAL GRID MAIN FEATURES [7]

Year 2012 data	
Peak power demand	5,981MW
Installed power capacity	6,768 MW
Electricity generated	33,980 MWh
Consumption Per Capita	4,850KWh
30 KV transmission system length	11,142Km
66 KV transmission system length	14,311Km
220 KV transmission system length	13,706 Km
400 KV transmission system length	2,290 Km
Exchange Energy	61.020 GWh (Import) 14.419GWh (Export)

On the other hand, Figure 2 shows the electricity consumption share per sector. As can be noted from the figure, commercial and public services have the maximum share that account for 36% whilst the consumption of the residential sector and the industry are almost equal with estimated values of 24% and 22%, respectively [8].

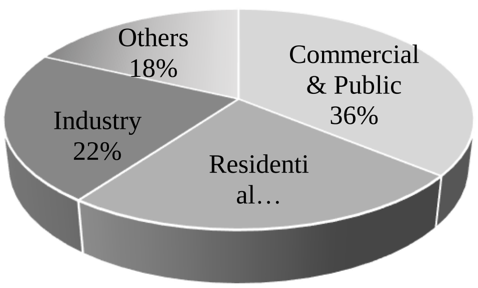

Figure 2. Electricity consumption per sector of the Libyan national grid.

Furthermore, the average daily load curve of the peak winter and summer seasons are presented. Both months of January and July related curves for the year 2014 are shown in figure 3 and figure 4, respectively. As the figure 3 reveals, an approximate 5600MW peak power is demanded at the evening time (19:00 PM) with a base load of 4000MW.

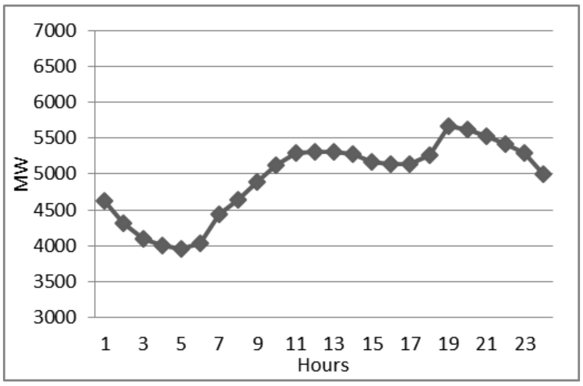

Figure 3. Average daily load curve of Jan-2014.

Similarly, figure 4 clarify that the peak winter and peak summer demanded load is almost the same amount of power. However, the summer base (minimum) load has a considerable higher value than the winter case with estimated value of 4700MW.

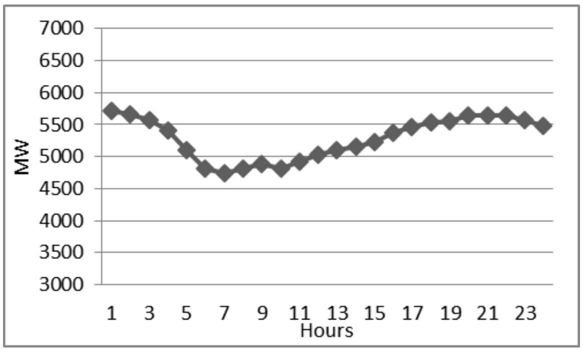

Figure 4. Average daily load curve of July 2014.

III. SMART GRID (SG)

The term grid is used for a power system that may support to the following operations: power generation, power transmission, power distribution, and power utilization control [9]. The current grid is unidirectional and does not maximize technological developments. The operation of present grid is based only on one-way communication from the utilities to the customers as shown in figure 5. The power flow is unidirectional from generation to demand.

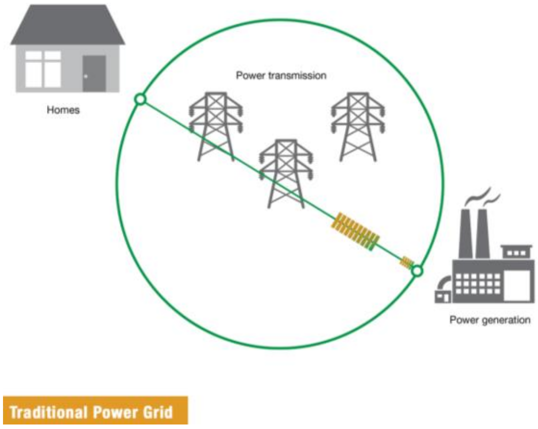

Figure 5. Traditional electrical grid. [10]

Currently there is a large gap between supply and demand powers were high transmission losses and poor use of renewable energy resources exists. This emphasis the need to move forward and adopt Smart Grid concept in order to be able to solve several related issues and provide more reliable energy to customers.

A Smart Grid, as shown in figure 6, is an electricity network that can intelligently integrate the actions of all users connected to its generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies [11, 12]. Smart Grids can help reducing transmission and distribution losses, optimize the use of existing infrastructure by helping to regulate power flows and meet peak demand, accommodate significant volumes of decentralized and renewable energy into the grid, while improving energy efficiency by managing the consumption patterns of new and existing users connected to the grid.

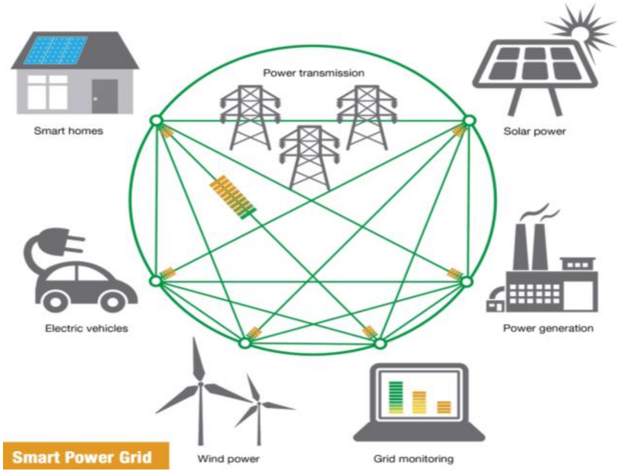

Figure 6. Integrated Smart Grid structure. [10]

A. Smart Grid benefits[9]

- Improving power reliability and quality.
- Enhancing capacity and efficiency of existing electric power networks.
- Improving resilience to disruption.

- Enabling predictive maintenance and self-healing responses to system disturbances.
- Facilitating expanded deployment and integration of renewable energy Sources.
- Accommodating distributed power sources.
- Automating maintenance and operation.
- Reducing greenhouse carbon emissions by enabling electric vehicles and new power sources.
- Reducing oil consumption by decreasing the need of inefficient generation during peak usage periods.
- Increasing opportunities to improve grid security.
- Enabling transition to plug-in electric vehicles and new energy storage options.
- Increasing consumer choices.
- Enabling new products, services, and markets.

B. Components of Smart Grid

Smart Grid implementation require the installation of numerous advanced control system technologies along with greatly enhanced communication networks, advanced metering infrastructure, sensors and phasor measurement units [13]. The National Institute of Standards and Technology (NIST) presented a conceptual model of Smart Grid system and devices. This model categorized into seven domains as shown in figure 7 and detailed in Table 3 [14, 15].

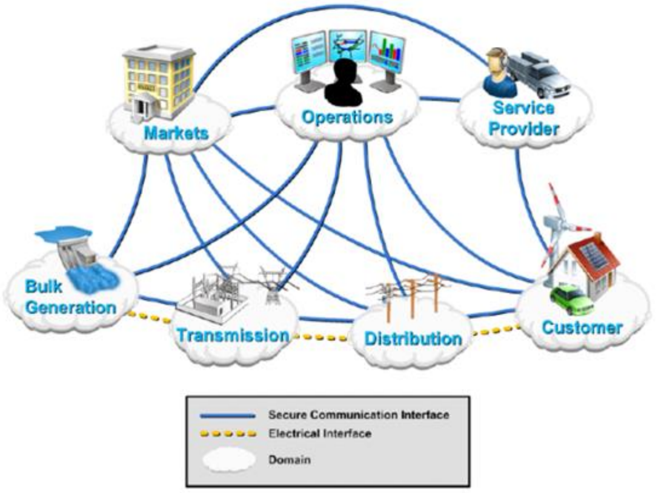

Figure 7. Domains in the Smart Grid Conceptual Model.

TABLE 3. DOMAINS IN THE SMART GRID CONCEPTUAL MODEL

Domain	Actors in the Domain
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.
Customers	The end users of electricity. May generate, store, and manage the use of energy.
Markets	The operators and participants in electricity markets
Operations	The managers of the movement of electricity
Service Providers	The organizations providing services to electrical customers and utilities

It is obvious from the briefly described major required domains of the conceptual Smart Grid model that the implementation of the associated necessary and various technologies are mandatory and vital in order to achieve its goals and objectives.

IV. SMART GRID TECHNOLOGY REQUIREMENTS:

To fulfil the various requirements of the Smart Grid, the following enabling technologies must be implemented [12]:

a) Information and communications technologies:

- Two-way communication facilities
- Open architectures for plug-and-play of home appliances, electric vehicles and micro generation.
- Necessary software and hardware to provide customers with greater information that enable them to trade in energy markets.
- Software that can guarantee adequate level of information security.

b) Sensing, measurement, control and automation technologies:

- Intelligent Electronic Devices to provide advanced protective relaying, measurements, and fault records of the system.
- Phasor Measurements Units and Wide Area Monitoring, Protection and control to ensure the security of the power system.
- Integrated sensors, measurements, and control and automation systems along with information and communication technologies to provide a rapid diagnosis and timely response to any event in the power system.
- Smart meters, communication facilities, displays and associated software to allow customers to have greater choice and control over electricity use.

c) Power electronics and energy storage:

- High Voltage DC (HVDC) transmission and back-to-back schemes and Flexible AC Transmission Systems (FACTS) to enable long distance transport and integration of renewable energy sources.
- Power electronic interfaces and supporting devices to provide efficient connection of renewable energy sources and energy storage devices.
- Series capacitors, Unified Power Flow Controllers and other FACTS devices to provide greater control over power flows in the AC grid.
- HVDC, FACTS and active filters composed with integrated communication and control to ensure greater system flexibility, reliability and power quality.
- Power electronic interfaces and integrated communication and control to support system operations.
- Energy storage for greater flexibility and reliability of the power system.

V. SMART GRID CHALLENGES AND OPPORTUNITIES FOR LIBYA

C. Challenges

There are several challenges facing the Libyan electrical grid that need to be addressed. These challenges are related to generation, transmission, distribution, and policies as well as regulations.

1) Generation challenges:

- Limited fuel supply for thermal and gas plants.
- Environmental impact due to carbon emissions.
- Political instability current situation.

- Inability to maintain the complex power plant equipment due to the current chaos and instability in the country.
- Low carbon investment plan does not exist yet.
- Lack of complementary IT technologies such as online conditional monitoring.
- Building our capacity in generation power management.
- Renewable energy integration scheme is not defined yet.
- Meeting the continuous demand increment complications.

2) Transmission:

- The transmission network in Libya covers wide extended area.
- The existing infrastructure for the transmission grid has many aging components and insufficient investments for improvements.
- The available SCADA system is not working now.
- Maintenance is a challenge nowadays due to insecurity.

3) Distribution:

- Rolling blackouts' existence due to high demand.
- Lack of real time monitoring facility of the demand.
- Limited experience with basic information and communications technology to manage the customer.
- Very little customer awareness campaigns.
- Consumer awareness, on issues like energy saving, renewable energy integration, electric vehicles, smart meters, smart buildings and appliances is at low levels.
- Cyber security and data privacy high risk.
- Theft and illegal connections of power to homes, factories and farms.
- Lack of demand side management on customer loads.
- Lack of funding and policies for Integration of Energy Sources and Distributed Generation that might incorporate more renewable and alternative energy sources in the customer's side.
- Lack of use of smart meters that increase customer awareness on his energy consumption.
- Security is the first challenges of the implementation of the Smart Grid in Libya. Installing Smart Grid in Libya require foreign companies to supply, install , and deliver onsite training in Libya and due to the current instability this will not be an easy task.
- Consumers do not pay their electricity bills.
- Lack of financial support from the government.
- Bureaucracy in the laws governing contracts with foreign companies.

4) Policies and regulations challenges

- Policies and regulations is a main challenge where we only have a one company that is responsible on generation transmission and distribution of energy. Public private partnership policies and regulations must be implemented to enable companies invest in generation, transmission, distribution, service providing, and operation of the Smart Grid.
- No incentives to encourage customers to install their own renewables in their properties and sell it to the grid.
- There is a lack policies and laws to support and encourage private investors to invest in distribution or operation of electricity.

D. Opportunities:

Even though the long list of challenges that encounter the implementation of SG to the Libyan national grid, as discussed previously, a considerable prospects also exist in the potential of SG gradual employment success. These chances and visions can be summarized in the following:

1. Due to its noticeable geographical location in the north of Africa, Libya has a daily average of the solar radiation on a horizontal plane in the coast region is 7.1 kWh/m2 per day and in the southern region it is 8.1 kWh/m2 per day. The daily average of the sun rising duration is more than 3500 hours per year [6].
2. The coastal wind speeds in Libya in three sections of the coast with different levels of annual average wind speeds in 50m above ground are from [6], which makes Libya an attractive global location for wind farms.
3. Libya has an ambitious plan aiming to increase the renewable energy share to 10% of its generated power by 2025 [16].
4. The region general plans that involve establishing a clean energy resources that can be delivered to the south of Europe (Desertic project) [17].
5. The existence of the relatively recently built and implemented national grid control centers along with other several complementary sub-centers distributed in the country. These recent centers, with better utilization and targeted improvements, can be the heart of defining a rigid plan towards fulfilling the essential up-grad effective procedures towards SG.
6. The possibility of achieving a broader local and regional interconnections will certainly help. Plans may include connecting the Middle East with the Gulf region and other African countries in the south via Sudan and Ethiopia.
7. The General Electrical Company of Libya (GECOL) has already implemented gradual plans of replacing the typical lightning lamps with energy-efficient ones both in the public sector and residential sector and has been improving successfully.
8. The GECOL implemented procedures of replacing the conventional electric water heaters with commercial thermal water heaters of the country existing mosques services.
9. The constructive trend in the industry sector of utilizing more energy effective equipment and facilities, has been progressing.
10. The recent tendency of the GECOL in assigning various regulations of controlling and monitoring industrial

consumers effect on the distribution power quality issues has to be reconsidered and refreshed.

11. The wide range usage of the digital electronic meters can be upgraded and automated to be a vital step towards smart metering.
12. The wide spread improved facilities of internet all over the country can be utilized by the GECOL in establishing more effective communication ways with their customers for various purposes of billing, knowledge transfer, awareness, and consumption self-monitoring facility,….etc.
13. The considerable existence of powerful politicians in the different parties with a strong electrical power systems backgrounds can play a crucial role in convincing the country decision makers.
14. The recent established research approach in some electrical governmental corporations (e.g. REAOL – Renewable Energy Authorities Of Libya), as well as, Libyan universities, colleges and research centers in SG can be supported, networked and accumulated towards our common goal.
15. A stronger vision is most likely clearer than ever before of the real need for an effective solutions in the electricity sector of the country that capable to meet the next generations ambitious plans and needs.

VI. CONCLUSION

In this paper, the Smart Electric Grid concept, major features and requirements have been discussed. A special focus of implementing the digital upgrading of the Libyan typical grid has been investigated. This may involve adding to the all power system existing components a smart and intelligent suitable new technology characteristics that ensure the compatibility of these apparatuses and tools, with its new role in the overall targeted Smart Grid. In the generation side, more effective efforts are needed for better utilization and integration of the renewable wind and solar rich energy sources of the country. International projects of generation and interconnection in our geographical region (e.g., European Middle East and North Africa Desertec project) is a big opportunity for Libya. Regarding the transmission network, optimal utilization of the existing lines and substations is an urgent requirement by the application of a capable management program system and automation systems.

As a matter of a great interest, enhancing the consumer's awareness using an attractive simplified materials and media is a crucial need for the distribution sector. A gradual implementation of the smart meters has to be considered. Customers should be encouraged to use smart appliances and install renewable energy systems in their homes and sell the extra energy during peak periods. Electricity misuse and exploitation has to be addressed by a rigid penalization system. The security issue of all control centers data and operations has to be improved and protected against any cyber-attacks. Therefore, new policies and regulations are needed to facilitate the investments and implementation of Smart Grid in Libya,

Finally, this presented discussion of the SG adoption in the Libyan electric national gird can be a preliminary investigation that might be utilized in further studies. This may involve suggesting a practical detailed roadmap for the Libyan authorities that assist to clarify the set of actions needed and the corresponding due dates. Political, economic and social current and near future situation has to be considered by all researches in the field to be able to build on all combined efforts.

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