Smart Grid Technologies in Gulf Cooperation Council Countries: Challenges and Opportunities

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Abstract- There are structural shift in electricity markets in the Gulf Cooperation Council (GCC) countries, in both supply and demand industries. Therefore, the GCC member states need to develop new models for electricity supply and demand in order to adapt to these changes. The penetration of renewable energy into existing grid networks in the GCC region, is an economical way to diversify the electricity mix in the region and create an avenue for the implementation of smart grid technologies. Solar and wind power are the most common renewable sources in the region. The smart grid technology enables multi-directional flows, control of electricity and information in a wide distributed network, hence, could be referred to as the next generation of power grids. The traditional power grids could be made smart by making them communicate, sense, control and applying intelligence. Therefore, the smart grid technologies give room for effective compatibility and optimization of variables of the power grid for optimal generation, transmission and distribution system. This paper presents some of the challenges and opportunities in the implementation of smart grid technologies in the GCC region. Some of the opportunities the smart grid would create are; need for privatization of power industries by the government of the countries in the region, encourage competitive markets instead of monopolies, diversify electricity generation from fossil fuel based system by integrating renewable energy sources in mix generation, transform regulated electricity prices to liberalized electricity prices, revenue generation, economic growth, job creation and resolving of political conflicts. However, certain challenges like regional power market, need for new legal agreements on buying and selling of electricity, monopoly in generation, and huge capital investments, are bound to occur. The opportunities of smart grid implementation in the GCC region outweigh the hurdles that could arise.

Keywords Renewable Energy, Fossil fuels, PV cells, Wind energy, Smart grid, GCC region.

1. Introduction

Lately, the Gulf Cooperation Council (GCC) Countries have realized that the over dependence on resources from oil for long term economic growth, would put the region at risk of energy insecurity in the future. Hence, the need for diversification of their economy cannot be over emphasized, in order to conserve the wealth from oil in the region. Recently, electricity generation is on the rise from renewable energy sources. There are massive investments and a set target of 2030-2040 renewable energy achievements by the GCC countries [1-3]. In the literature, it was reported that experts from Masdar Institute [4] predict that climate change would be addressed by 2050 based on renewable energy sources that would be harnessed by GCC countries. The various governments in the GCC have made renewable energy investments a priority, since about 47% of Middle East and North Africa (MENA) power generation is from the GCC region [5-7]. Based on reference [8], the solar capacity installation in the GCC region would by 2020 hit 76 GW. This shows that solar power is well suited and rapidly deployed in the region. There are six GCC countries; United Arab Emirates (UAE), Kingdom of Saudi Arabia (KSA), Qatar, Oman, Kuwait and Bahrain. A brief of the technical background of renewable energy penetration in the GCC countries are given as follows.

The first country in the gulf to pronounce 50% clean energy power strategy by the year 2050 is the UAE, hence, regarded as one of the leading countries in the world to enact and develop effective solutions for renewable energy. According to [9], the proposed solar park for Mohammed bin Rashid Al Maktoum is going to generate by 2020 about

1,000 MW and by 2030, 5,000 MW, respectively. Also, other investors like the Emirates National Oil Company (Enoc) would provide power solutions for the future considering solar energy, with a plan by 2020 to open forty eight new stations. In a recent agreement signed between Dewa and players of climate change and environment in the UAE, an environment that is sustainable with interest in good air quality, reduced carbon and dependence on pollution free energy are the goals of the vision 2021 for the UAE [10].

In the Kingdom of Saudi Arabia (KSA), the National Renewable Energy Program (NREP) operating under the National Transformation Program (NTP) that was developed, is billed to encourage energy mix by increasing the renewable energy sources with a proposed generation capacity of 3.45 GW by the year 2020 and by 2023, 9.5 GW as part of vision 2030. The key energy players in the KSA are geared towards promoting solar power in order to mitigate carbon rise in power generation [11]. Presently, not more than 1% of renewable resources are been utilized in the kingdom, however, there are plans to implement around thirty solar and wind projects over the next 10 years in order to reduce oil usage and increase power generation. One of these plans is the setting up of a solar energy initiative to sell excess solar generated power to the Saudi grid, by developing an automated city that would be powered by wind and solar clean energy sources, which will be of great benefit to the other countries located in the region.

There is a 20% solar energy generation goal in Qatar by the year 2030, according to the literature [12]. Masdar institute in 2017 had an agreement of renewable energy development and deployment in Qatar with two key players; Qatar Electricity and Water Company (QEWC) and Nebras Power (NP). This agreement would foster the growth of renewable energy in the region via the ties with a target by 2020 solar power generation of capacity 1.8 GW [13].

In Oman, there are energy mix plans to penetrate renewable energy sources especially solar and wind into the Omani national grid. Lately, Oman is making great effort in the utilization of renewable energy resources as seen in the Amal East and West projects of the Petroleum Development Company of Oman (PDO) [14, 15], where the current largest world solar farm is been built. Also, in Salalah, the ongoing wind farm project is one of the largest in the world [16], with high chances of generating employment for the citizenry of the country [17]. Studies in the literature have shown that, Oman's geographical structure, long coastline and high reach of sun radiation qualifies it to be a great example in renewable energy resources for electrical power generation [18,19]. In addition, the Oman Power and Water Procurement (OPWP) Company recently had an agreement with international consultants to build a Build-Own-Operate (BOO) solar model that would form part of the privately developed power projects in the country.

The Centro Elettrotecnico Sperimentale Italiano (CESI) went into agreement in Bahrain to develop solar power policies [20]. The synergy of the Bahrain Sustainable Energy and CESI help in the preparation of regulatory requirements pertaining to distributed renewable energy resources in the country. Policies for sustainable and efficient energy that creates awareness on the use of renewable energy sources, are some of the key areas that were addressed. A dual plan of the government of Bahrain in 2016 was to target 6% of the national electrical energy efficiency and 5% contribution from renewable energies, especially solar PV by the year 2025, with a gradual increase to 10% by the year 2035 [21].

The Ministry of Electricity and Water in Kuwait is developing renewable energy projects in partnership with private sector as part of its vision 2030 plan. The plan basically is to produce over 4.5 GW capacity which is about 15% total consumption of energy from renewable energy sources [22]. The drive came as a result of electrical load in summer amounting to 13,800 MW, from a total power generating capacity of 16,700MW for the country. Based on reference [23], another drive that could promote the use of renewable energy is the purchasing power parity rules been liberalized.

The technology of smart grid is a self-sufficient model that easily provide solutions to issues or challenges in grid networks to reduce workforce, while promoting reliable, sustainable, safe and power quality to end users. Smart grid technologies are playing a vital role today in many countries, considering various technological applications from key players in the industries, researchers and investors. However, in the GCC region, these technological applications have not been implemented. Thus, this work may constitute an initial step for the realization of the smart grid structure in the region. In the long term, the proposed smart grid network in this work would serve as a next step in achieving economic benefits for the electricity authorities in the member states and would also help in establishing regulated standards that would be compatible regarding coordinated control. The smart grid will also keep the environment free from pollution, minimize cost, effective operations, against all types of hazards and danger. This paper presents challenges and opportunities of implementing smart grid technologies in the GCC countries.

2. Electricity Consumption in the GCC Region

Due to domestic demand, there is huge expansion of the power generating capacity in the GCC region in recent times. The KSA has the largest market of about 76 GW [24, 25] of installed power capacity, with UAE and Kuwait following as shown in Figure 1. The bulk of the power generation in the region comes from fossil fuels, mainly natural gas and by products of oil [26, 27], as shown in Figure 2. Renewable energy accounts for not more than 1% of the present power generation in the region. In 2009, there was a bold step by the GCC countries to run a tie line across the region by interconnecting a small capacity of 2.4 GW for emergency power backup for countries in the region [28, 29]. Diversification of the energy mix in the region by the rapid deployment of renewable energy would lead to tremendous application of the grid, increasing the power generation capacity and creating a huge market like those in western countries.

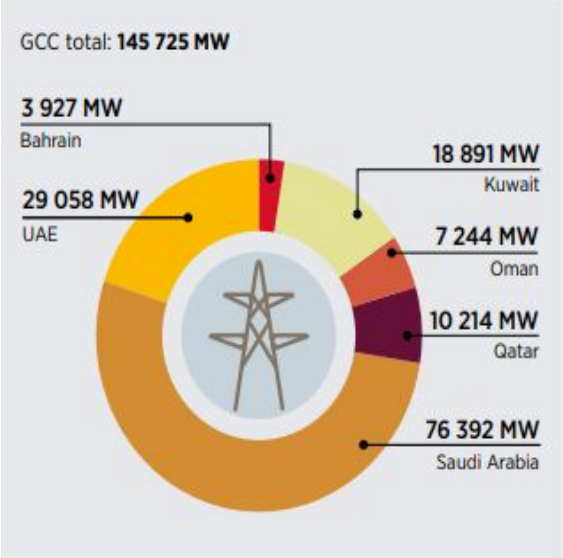

Figure 1 Installed power capacity in the region

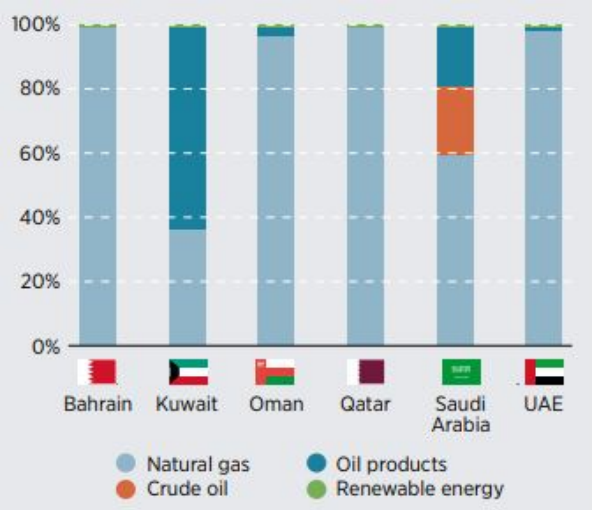

Figure 2 Power generation by fuel source in the region

3. The Interconnection Grid of the GCC Members

As stated earlier, the GCC members' national grids are interconnected for emergency and backup with a total capacity of 2.4 GW, 400 kV double-circuit, 50 Hertz (Hz) AV line in the western shore of the Gulf. The original idea of designing the grid was to promote within the GCC region, intraregional electricity trade. However, sharing spinning reserves and scheduling transfer of power during emergencies are the main goals of the network presently. It was estimated that between 2011 and 2017, the GCC members saved around 2.2 billion US Dollars, by sharing spinning reserve via electricity exchanges [29]. However, due to non-commercial trading markets, the electricity exchanged in the region has reduced considerably [25]. Thus, according to references [30, 31], the GCC Interconnection Authority (GCCIA) is urging to embark on power trading with other countries in the region like Egypt [32]. A trial of this initiative was demonstrated in 2017, with the sole aim of building a commercial platform [29]. Compared with other heavy energy consumers in the world, the GCC members have low energy consumption, giving them opportunity to export large share of hydrocarbon production from their rich oil. However, fast economic development, industrial energy based revolution, increasing populations, high revenues with improved standards of living, have all gradually changed the idea of abundance resources of hydrocarbons in the region, in order to meet the need of the citizenries. Consequently, energy policy makers in the region are under pressure and faced with issues relating to rapid energy consumption, in a bid to contain present and future exports of hydrocarbon. Therefore, a fall back on renewable energy resources to curtail some of these issues in economic growth and simultaneously maintain energy efficiency in the GCC region would be a better solution.

4. Overview of the Concepts of Traditional and Smart Grid Networks

Figures 3 and 4 show the general representation of traditional grid and the smart grid networks based on the literature.

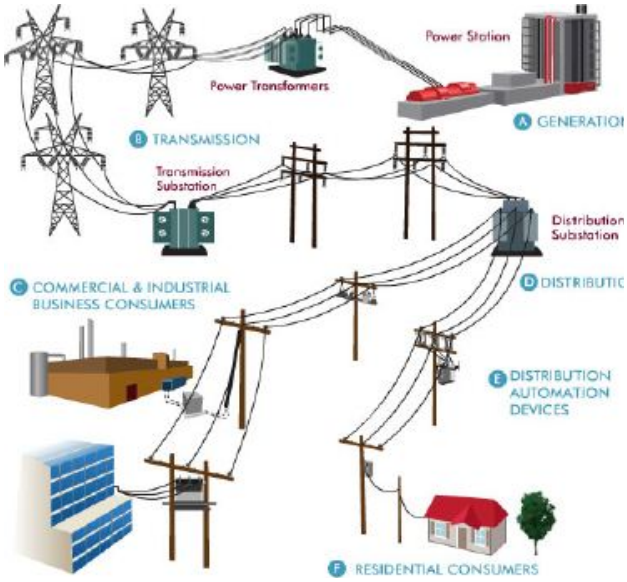

Figure 3 Traditional grid network

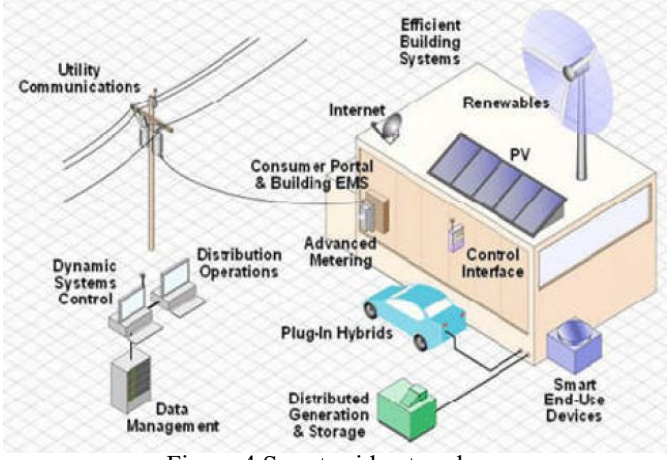

Figure 4 Smart grid network

From Fig. 3, the power system is having good communication links in order to perform effective operation, market transactions, and steady system security, enabling the smooth operation of the generating plants and the various circuits for transmission. Although, the power system shown in the figure has some automatic control measures, which may be limited to local and discrete functions, to enhance predictable behaviour by the power plants and the transmission network during events of major disturbances in the grid network. Consequently, the distribution system and feeding load sections, are quite extensive but the same time entirely passive due to minimal communication and limited controls locally. There is minimal or no interaction between the connected loads and the power system in Fig. 3. Basically, the system is performing the supply of load energy based on demand. Due to this fact, the smart grid network was developed as shown in Fig. 4 with a concise representation in Fig. 5 [33].

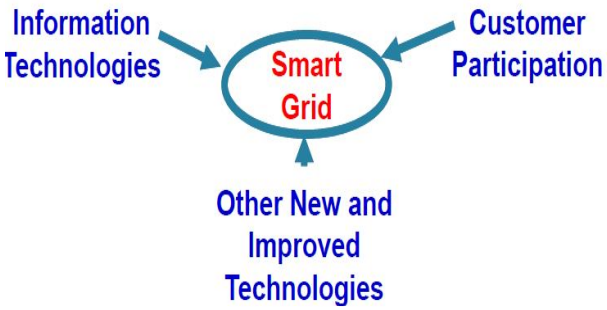

Figure 5 Initiatives of the smart grid

Motivations and challenges for Smart Grid Initiative in the GCC Region

The current communication systems revolution via the use of the internet gave the possibility of effective monitoring and control of the power system and thus, offer much flexibility with reduced operational cost of the system. The smart grid employ the usage of new information and communication technologies to change the electrical power network. However, because of the large size of the power network and much existing investment over the years in setting up the traditional grid system, proper justification for any changes to be made would require a careful thought.

Reasons why Smart Grid should be promoted in the GCC Region

The following are some of the reasons why smart grid networks should be promoted in the GCC region. First and foremost, the issue of ageing assets and lack of circuit capacity would be tackled in the region by replacing the older circuits and see the need to design new circuits to include renewable energy resources to boast power supply. In order to achieve the various power generation visions set by the member states in the region, smart grid is required, while at the same time reserve their oil rich wealth and maintain carbon footprint. Another reason may be due to thermal constraints in the traditional grid networks as a result of heat from constant currents which leads to reduction of power transfer capability. Operational constraints are also not left out and it is expected that smart grid would help maintain or keep steady the power network stability, and reduce requirement for reserve power, as presently carried out using the designed GCC interconnection grid system between the member states in the region. Again, security of power supply is very vital in modern power system, hence, modern power network requires increasingly reliable power supply as more loads are connected every now and then. Finally, national initiatives play an important role as many governments are encouraging smart grid operation as a cost effective way or avenue to modernize their existing traditional power network and the same time mitigate carbon pollution.

Simple Distribution Network with Distributed Generation for the Smart Grid Network

Figure 6 shows a simple distribution network with distributed generation that is employed in a smart grid system. There are some features of this network that makes it different from the traditional passive grid network shown in Fig.3. The differences are as follows [34]:

•The system has a non-unidirectional power flow. As shown in Fig. 6, the direction of power flows and the voltage magnitudes on the power network solely depend on the demand and the injected power generation respectively.

•There are wide range of fault currents in the distributed generators, consequently, complex and well-designed protection and coordination settings are required to protect the power system.

•The active power flows and the reactive power flows on the network are independent.

•There are many types of distributed generators that could be are interfaced via the technology of power electronics with a consequence of harmonics injection into the power network.

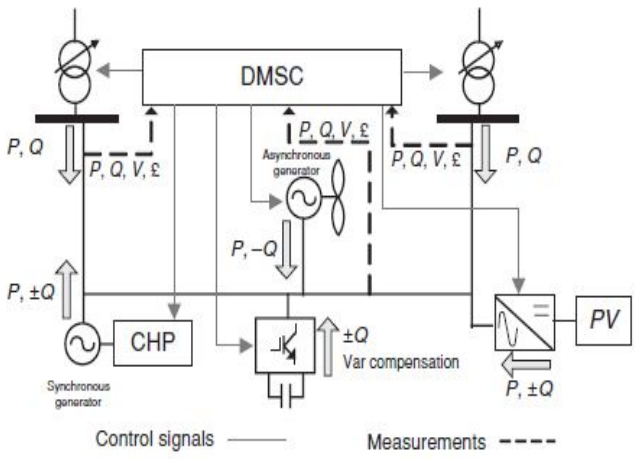

Figure 6 Distribution management system in smart grid networks

Figure 6 also shows how the function of active control is carried out with the help of the control scheme. A Distribution Management System Controller (DMSC) unit

takes action to control the system voltages and signal flows by assessing the conditions of the network. Measurements from the network are obtained by the DMSC and sends signals to the devices under its control. The necessary control actions the unit may carry out include; injection and absorption of reactive power, a tap operation of transformer, and altering the output of distributed generators.

5. Renewable Energy Penetration in the GCC Region

Recently, in the GCC region, the penetration and development plans of renewable energy have gone a long way. Although, the market size and level of development vary from country to country in the region. Figure 7 [25, 35] shows the current trend of renewable energy penetration in the GCC region. The UAE is on the lead in renewable energy integration in the region, with KSA interest in renewable energy deployment recently on the rise. There are some noteworthy projects in renewable energy in Oman, Qatar and Kuwait respectively as seen in Fig. 7.

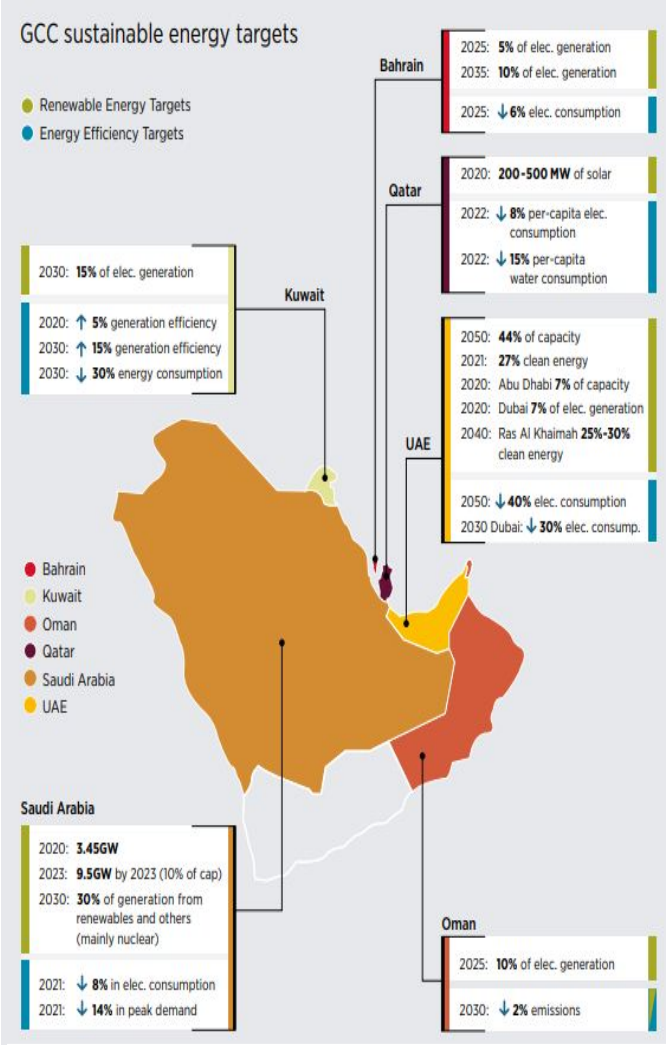

Figure 7 Renewable energy penetration in the GCC region

The United Nations Framework Convention on Climate Change (UNFCCC) [36-40], recently enjoined the GCC countries in order to achieve their goal in renewable energy deployment. The visions that were pronounced are coming into reality through the actions of the governments in the member states, especially in UAE and KSA, which are the key and largest energy players in the region. The integration of renewable energy projects in the other member countries seems slow as seen from Fig. 7. Table 1 shows the installed renewable energy capacity in the GCC region as at 2018 [25], where the major source of renewable energy is the Solar PV, with UAE taking the lead. There have been tremendous increase in the penetration of renewable energy in the GCC region from 2014 to 2018 based on Table 1.

Table 1 Renewable energy penetration in the GCC region

	2017 - 2018						2016	2015	2014
Country	PV	CSP	Wind	Biomass and waste	Total RE	Share of RE in total electricity capacity	Total RE	Total RE	Total RE
Bahrain	5	0	1	0	6	0.1%	6	6	6
Kuwait	19	50	10	0	79	0.4%	20	1	0
Oman	8	0	0	0	8	0.1%	2	2	1
Qatar	5	0	0	38	43	0.4%	43	42	42
Saudi Arabia	89	50	3	0	142	0.2%	74	74	24
United Arab Emirates	487	100	1	1	589	2.0%	144	137	137
Total	613	200	14	39	867	0.6%	289	262	210

The installed renewable energy capacity in a total power share as at 2018 and the gradual growth of renewable energy capacity from 2014 through 2018 for the members of state in the GCC region are given in Figs. 8 and 9 respectively [26, 27].

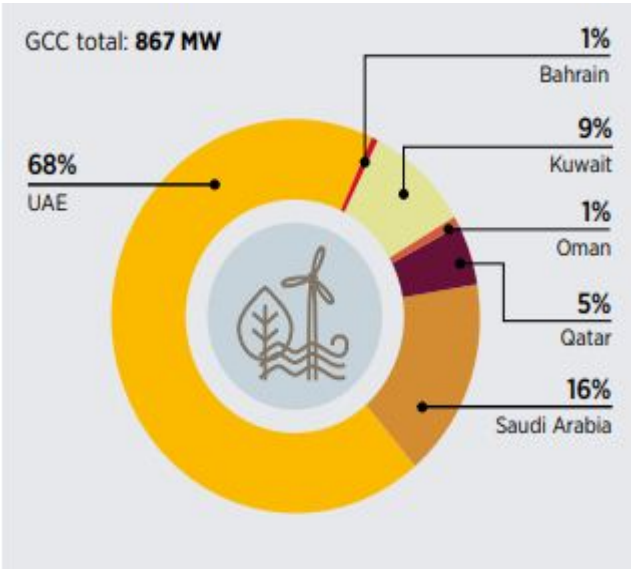

Figure 8 Share of renewable energy installation in the GCC region in 2018

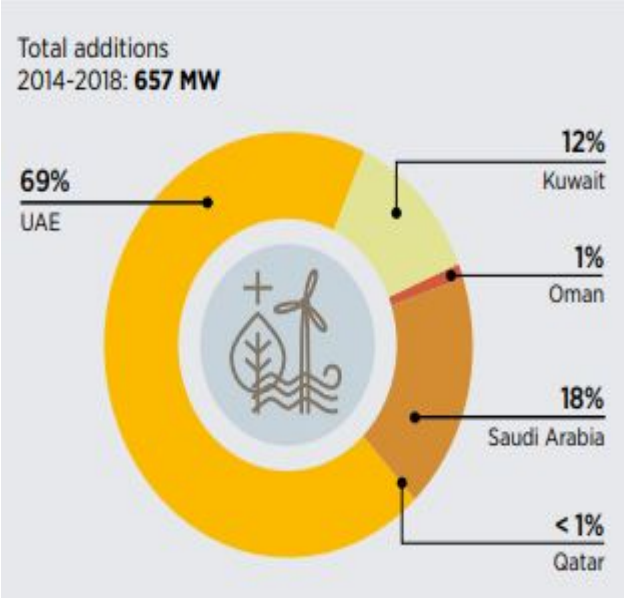

Figure 9 Renewable energy growth in the GCC region from 2014 - 2018

The Solar PV, Concentration Solar PV (CSP) and Wind energy are the three major renewable energy technologies that are employed in the GCC region presently. Figure 10 shows the planned renewable power additions in the GCC region, considering the various technologies with Solar PV dominating with 81% penetration in the region. A detail of the planned renewable energy addition based on the various countries in the region is given in Fig. 11, where UAE taking the lead with 2,727 MW compared to Bahrain having the least capacity of 105 MW.

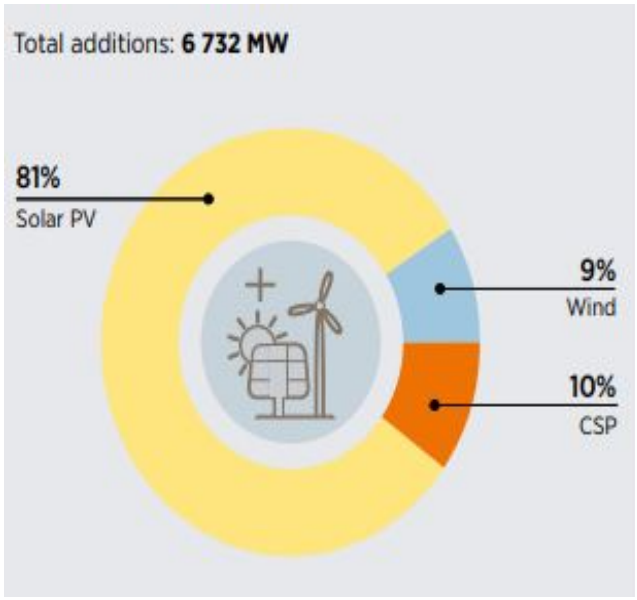

Figure 10 Planned renewable power additions

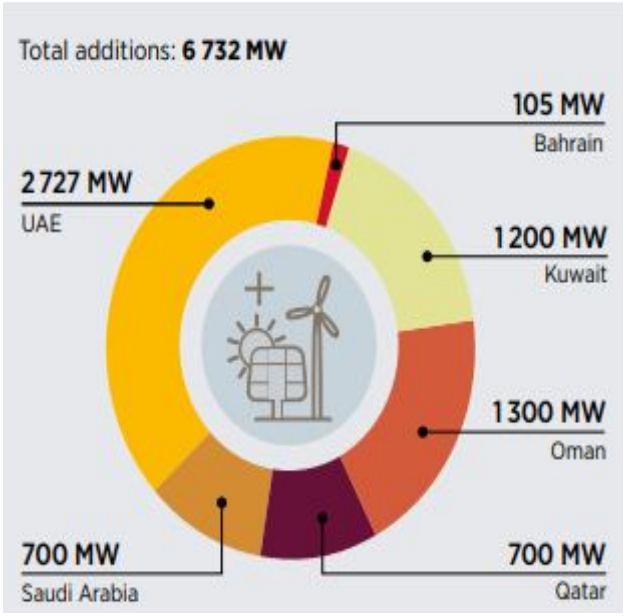

Figure 11 Planned renewable power additions by countries

6. Challenges and Opportunities of Smart Grid in the GCC Region

According to reference [29], the smart grid market network of the GCC is of high value with great prospects, based on a projected growth of up to 1.68 Billion US Dollar by the year 2026. This would be as a result of the governments of the member states rapidly deploying infrastructures for smart grid networks in the region. Figure 12 shows the smart grid market in the GCC region with the various key players and projected growth [41-43].

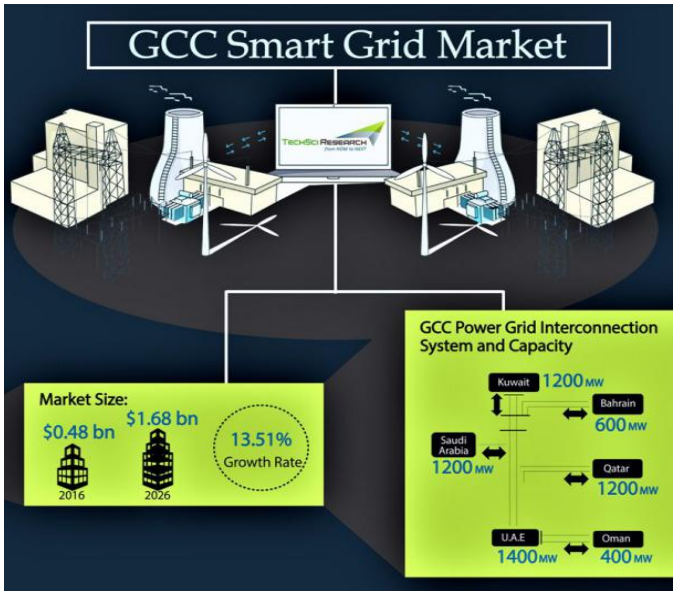

Figure 12 Smart grid market in the GCC region

Challenges of Smart Grid Deployment in the GCC Region

There are several hurdles to overcome in the implementation of smart grid operations in the GCC region. This would involve a complicated and technologically task, based on regional power market on the existing interconnection of the GCC members. First and foremost, an entire system power capacity upgrade of the member states national grid networks and the interconnection grid network, would be required, in order to contain larger volumes of traded electricity. This move is necessary so that a good investment justification for large-scale power projects like the solar power project in the KSA, the Salalah wind project in Oman and other similar projects in the region, can be made. Again, it is imperative to have new legal agreements among the GCC member states in a regional market. Consequently, this would lead to issues like intra-regional politics. Another challenge in the implementation of the smart grid network in the GCC region would be tariffing. Hurdles in national utility markets [28, 29] to enable customers buy and sell electricity from and to other member states, under a commercial mechanism have to be agreed on and dealt with properly.

Although the investment and deployment of renewable energy generation in the GCC region is expected to increase in the coming years, due to reduced cost of solar PV, advancements in power electronic technology and promotion in climate change, however, the present global low prices of crude oil, could affect renewable energy penetration. The GCC member states are under pressure recently, due to reduced budgets and financial constraints to implement most renewable energy projects and smart grid operations.

With the increased penetration of renewable energy generation, the customers in the GCC region would have to change and adjust ways of electricity usage. Consequently, new smart grid technologies that could curb and control how to use electrical utilities during peak and non-peak times is required. Distributed generation in conjunction with demand side management or integration will affect and determine the supply of electricity. Based on these facts, there is need to modify existing electricity energy market regulations to manage different market models with entirely new demand and supply, and also accommodate flexibility for integration of new technologies for smart grid operations.

It will require a heavy task to break the public monopolies of power generation that is based on fossil fuel for many years, by encouraging liberalization, private partnership, promoting various renewable energy penetrations, and adjustments of domestic electricity prices [44, 45] for the common goal of the GCC region. The GCC governments will face pressure in achieving complete liberalization, decarbonization and fossil fuel subsidies removal, at the same time maintain low electricity prices. When the power markets are made liberal, there are bounds to be challenges in renewable energy penetration since the new technologies for smart grid operations have near to zero marginal cost. The simple analogy is that with higher levels of absorption of renewable penetration in the grid network, more volatile and lower prices would be expected and more penetration of renewables would result to prices been equal zero in a liberalized market. Therefore, moving towards liberalization and encouraging involvement of private sector in power generation in the GCC region is a big hurdle because of heavy subsidies in prices. An increase price of electricity would occur in the region, if subsidies are been removed and the penetration of renewable energy technologies for smart grid operations is been increased.

Economical factor is the main driver of renewable energy and smart grid operations in the GCC region, however, a high level of transparency is required to effectively evaluate and carry out the cost analysis of the power generation using the alternative technologies. Competitive tenders for renewable energy projects in the region has led to great achievement in the promotion of renewable energy, however, this strategy may not be the best in terms of cost. Direct investment subsidies may be the best channel for the government, however, the present public financial quagmire in the GCC region makes this non-attractive.

Opportunities of Smart Grid Deployment in the GCC Region

With the presence of the GCC interconnection grid for commercial trading of electricity, huge amount of incentives could be generated for improving and expanding the tie grid network beyond the GCC region. For instance, Egypt and Saudi Arabia are in dialogue to link both national power grids in order to make use of different demand peaks between Egypt and the GCC member states, with the KSA acting as a gateway. If this dialogue comes through, an opportunity would be created to promote and generate huge incentives for other GCC members by investing massively in sustainable clean energy projects, in regions beyond the GCC. Another grid expansion option could be from Yemen with Oman acting as the gateway to the GCC interconnection grid. An interconnection of Yemen to the GCC electricity pool to provide additional stable power generation could create avenue for economic benefits and resolving of conflicts between Yemen and some of the GCC state members.

Smart grid technologies and control strategy would help in the integration of renewable energy to the grid. With the rapid rise of demand in electricity, coupled with forthcoming major world events in the GCC region, like the 2020 Dubai Expo and the 2022 FIFA World Cup in Qatar, a great avenue for smart grid opportunities in the coming years is expected. The UAE is a major key player for smart grids in the GCC region, hence, there are huge potentials for activities like automatic reading of meters and advanced metering infrastructure in the region. According to the 2050 plan for energy in the Emirates, the UAE has a vision to provide regional and global solutions for smart metering and enactment of smart grid in order to enhance renewables contributions in the region. Some of the leading players and foreign investors in the GCC smart grid market are; Siemens AG., ABB Ltd., Schneider Electric SE, General Electric Company, IBM Corporation, Oracle Corporation, Accenture PLC, DTS Solution, CISCO Systems Inc., and others [46, 47]. The presence of these companies would create employments and generate revenue for the government and people of the region. Again, due to major ongoing smart city projects in the GCC region, there are prospects for a lot of incentives and growth in smart grid market. There are

massive innovation and investments of integrating standalone solar power in various homes in the city of Dubai, a project known as Shams Dubai, by the Dubai Electricity and Water Authority [48-50]. This project has the aim of extracting 25% from solar energy in particular and by 2050, the total clean energy sources is expected to rise to 75%, thus, tagging Dubai as the least carbon footprint city in the world. As part of the UAE vision 2021, there are ongoing plans of building the largest GCC hydroelectric power station of 250 MW capacity near Al Hattawi Dam. There is currently, partnership between Emirates National Oil Company and Dubai Electricity and Water Authority to reduce carbon footprint [51].

Furthermore, the use of smart meters are been encouraged in Sharjah, one of the emirates promoting renewable energy alongside Dubai. Presently, about 20, 000 traditional analog meters are been replaced with smart meters and a target of replacing all meters by smart meters by 2020 for residential, commercial and industrial usage has been set by the Sharjah Electricity and Water Authority in UAE. This activity is in agreement with 50% contribution by the set year to implement smart grid technologies in achieving global energy efficiency. Besides, users in the GCC region would be able to effectively control supply and consumption of energy, based on new smart grid technologies that entails distributed generation and demand side integration. Renewable energy integration and battery energy storage based operating systems would go a long way to provide solutions to equilibrium services to the grid connected network. Based on references [29-31, 52], the investment from the grid interconnectivity in the GCC region for 25 years' time economic growth and accrued savings is predicted to give a revenue of about 33 billion US Dollars. In the last three years, a lumped sum of 1 Billion US Dollars was realized from the GCC interconnection system according to reference [29].

As part of its leading role in renewable energy and smart grid technologies in the region, the UAE has launched a 2050 energy plan to promote alternative energy sources, building smart cities and encourage clean energy usage, with the aim of decreasing over dependence on natural gas for power generation. This opportunity gave rise to the contract been signed by the ministry of energy with their partner Price Water House Coopers, on the economic study of the electricity sector. The Dubai Electricity and Water Authority together with the Colas Group, a French civil engineering company, are planning the installation of solar roads, to produce clean energy via solar PV cells embedded on the surface of the roads. The transportation sector in Dubai is expected to be enhanced by 2030 through this embedded solar PV smart grid network that enables the powering of autonomous vehicles that makes up 25% of transportation system in the city [53].

The Dubai Electricity and Water Authority in 2017, developed a smart grid enabled power stations, by converting all independently operating power stations. This was done by implementing an information system in all stations to jointly transmit data of the performance and development of one way data diode, in order to protect the various power stations from cyber-attacks. Thus, the smart power stations enables equipment monitoring and comparison at every station to proffer solutions to grid disturbances. Key players like Honeywell would use that opportunity to supply about 150,000 additional smart meters in addition to the already supplied 250,000 smart meters [54]. It is projected that by 2020, the electricity authority in Dubai would have millions of smart meters already installed, instead of the traditional mechanically used meters, in order to manage effectively, electricity across all buildings in the city. The installation of smart meters is expected to boost demand side management or integration, by enabling reduced water and electricity consumption by 30% by the year 2030, through public education on how to use less energy during peak times.

In the Kingdom of Saudi Arabia, there is much dependence on petroleum product, hence it is the fastest growing energy consumer in the region due to its population. However, there are plans by 2030, to limit the generation of electricity from fossil fuel to 70 % and renewables for smart grid operations and other sources to 30%. With the on-going plans by the government of the KSA to privatize electricity generation by 2020 [55], huge investment is expected to increase power efficiency and to meet expected environmental standards, by replacing older generation plants with new plants that would be easily incorporated in smart grid network. Recently, a huge sum of 1.2 Billion US Dollar was lunched on phase 1 of the Green Duba power project with generating capacity of 605 MW, that is accommodating 50MW renewable energy technologies for smart grid operations for around 600,000 buildings every year [55-57], thus, creating an opportunity for smart grid operation in the GCC, by exporting power via the Tabuk gateway to other parts of the world.

With the forthcoming FIFA World Cup 2022 event in Qatar, the country is expected to boost its power generation by 50% [55, 58]. Since most of the stadia for the world cup event would be powered by solar energy technology, there is great opportunity of integrating them for smart grid operations. The authority for Qatar Electricity and Water Company (QEWC), recently made aware of the proposed 500 to 1000 MW electricity generation from solar power project in the country in Al Kharsaah, which is expected to come on stream in 2020.

According to Oxford Business Group, private sector in Kuwait would possess a fair power generation capacity proportion within the next 10 years. The government of Kuwait has announced new Kuwait 2035 launch with 50% stake of the power and water company to be sold to the private sector. This would help create three more new power companies with main focus on renewable energy. It is expected that Kuwait would build1.2 Billion U.S Dollar, Dibdibah solar-power plant in the first quarter of 2018, which will generate 50% of the country's estimated renewable output goal, according to Shukri AbdulAziz Al-Mahrous of Kuwait National Petroleum Company [58].

In Oman, power projects privatization is of high priority because of increasing number of personal and government projects. Consequently, the demand of electricity is on the rise. The Oman Power and Water Procurement Company (OPWP) has reported that the country needs to increase its power generation capacity due to increasing demand in the near future. In light of this, a commercial scale solar power project is proposed to be tied to the Main

Interconnected System (MIS) of the Sultanate to create opportunity for smart grid operations [59]. The dual efforts by the Sultanate in the integration of renewable energy resources in the Amal East and West projects of PDO, which is currently having the largest world solar farm capacity and also the largest wind farm project in Salalah, would definitely create opportunity for smart grid operations in the GCC region [60].

Bahrain has the lowest energy capacity growth in the GCC region. As part of the renewable agenda (National Energy Efficiency Plan and the National Renewable Energy Plan), and in order to increase power generating capacity, the government of Bahrain in conjunction with private sector put up plans to build a 100 MW solar power plant that is expected to be commissioned and come on stream by early 2019. Also, there are great opportunities for smart grid operations in the country considering options for hybrid optimization of renewable energy sources [61], the technological advancements in transportation [62] and sustainable electricity developments which would adopt smart metering and smart grid network tools.

7. Cyber-security Approaches of Smart Grid Applications in GCC Countries.

Smart Grid operations rely solely on a two-way communication system for information exchange. Information must flow on real-time basis to and from the central generators, substations, customer loads and the distributed generators. Currently, communication in power system are normally limited to centrally based generation and transmission systems, and extension to high voltage distribution networks. Private communication networks are used for generation and transmission purposes. Moreover, the Supervisory Control and Data Acquisition (SCADA) and Information and Communication Technology (ICT) systems which controls the power network are not in same location, even though they are operated by the same company from business and commercial applications point of view [63]. This separation of power system communication and other control units cause limited access to important ICT facilities in the network and provides security against external threats, based on the inbuilt system.

As more members of the GCC states connect to the smart grid network, different technologies would be used by the information and communication facilities. This communication facilities are bound to be vulnerable to data theft or cyber-attacks. Therefore, it is imperative to ensure information security in the smart grid network. This would require a very complex task than the measures employed in traditional power networks, due to the fact that the systems are so large, extensive and integrated with other networks. Highly classified data would be transmitted and in order to accommodate costs control, the internet may be utilized. Information about loads of consumers in the proposed GCC smart grid may be of interest to unwanted persons, which may breach the privacy of the consumers in the network.

The breach of power system security based on fraud by operating information via the access of unwanted persons, apparently creates room for dangers in the power network. The smart grid must be reliable and safe in real time information delivery, with fast data transmission and little or no delay in information delivery, compared to traditional grids. This would require many monitoring and control strategies of information. It should be expected that during transient or unstable conditions in the grid, huge amount of messages will be sent, with patterns different from traditional grid networks.

In light of the above, necessary security measures [34] should be enacted in the GCC smart grid network to provide the following ancillary services.

- Privacy: senders and receivers of messages can only decode the message contents.
- Integrity: message at receiver end arrives in time based on the pattern it was transmitted.
- Message authentication: receiver is confident of the identity of the sender.
- Non-repudiation: receiver has proof of message from a particular sender, which the sender cannot deny.

8. Conclusion

As population, industrialization and expansion of cities increase in the GCC region, there is a growing trend for more power supply and demand with expected low electricity prices. Therefore, it is paramount to change the way electricity is been generated, supplied and used for optimal and efficient performance, by enacting smart grid technologies. The integration of renewable energy sources into the existing GCC member states national grid will not only help to boast power supply, but also promote the possibility of smart grid implementation in the region. The two most common renewable energy sources in the region are solar and wind power. Solar energy tends to be more competitive in all the GCC countries, hence there would be need to request much participation by private partners. This paper presented some challenges and opportunities of smart grid technologies in the GCC region. The effective deployment and utilization of smart grid technologies, including smart metering and other ancillary services would help to build a bright prospect for the GCC countries, with the opportunity of saving about 10 Billion US Dollars by the year 2020. Besides, a proper implementation of smart grid technologies and smart cities, would lead to sustainable supply of electricity in the region and beyond, thus, encouraging economic growth. This act may help generate revenue and same time resolve political conflicts between some countries in the GCC region and their neighbors.

Although there are certain challenges like regional power market, need for new legal agreements on buying and selling of electricity, monopoly in generation, huge capital investment and others. These hurdles could easily be overcome with time. The opportunities the smart grid technologies would present in the region, far outweigh the challenges.

Finally, the growth in the GCC power sector in the near future cannot be over emphasized, because huge amount of money is going to be invested in setting up new power production plants and smart grid technology projects. The most attractive countries for power sector and smart grid technologies implementation in the region are United Arab Emirate, Kingdom of Saudi Arabia and Kuwait respectively.

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