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Smart grid application in the Iraqi power system: current and future challenges

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ABSTRACT

A smart grid could generate and distribute electricity effectively economically, securely and sustainably. It offers customers more information and choice, including the export of energy to the grid, demand-side participation and energy efficiency. However, to implement a smart grid into the Iraqi power system, various challenges should be faced, especially concerns related to understanding the contents and features of this network compared with the traditional Iraqi network. As well as the challenges and risks of implementing the smart grid itself in the modern work environment, especially with the tremendous progress in communication technologies, which has brought serious problems to the operation of the network such as cyberattacks. Also, the traditional Iraqi network suffers from various problems, including the large deficit in the generated power-to-load demand ratio, which reaches about more than a third, and the great destruction that the network has been subjected to because of the wars that the country has been exposed to during the past three decades. In this study, a clear vision was presented to researchers and engineers who are interested in applying the smart grid in Iraq on this vital topic, which will greatly help in applying this essential matter to develop the work of the Iraqi power system and improve the efficiency and services it provides.

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1. INTRODUCTION

The current electrical grid was established over 100 years ago when electricity needs were minimal [1]. Power generation was local and built around communities, with most homes having only small power requirements [2]. With a globally, annually and sharply increase in the electrical load demand, it is difficult for the traditional grid to respond to the all changing and increasing energy requirements of the 21st century where the reliability and continuously in transferring a vast amount of power energy and information through massive transmission lines is essential for any power operator control [3]. Therefore, the smart grid was introduced. Smart grid can provide a two-way dialogue where electricity and information could be exchanged between the facility and its customers, and it is an advanced network of communication control devices [4]. The automatic control and new communication technologies in smart grid work together to make the power grid more efficient, reliable, safe and environmentally friendly [5].

Different definitions of smart grid exist such as the definition of the US department of energy defines smart grids stating that they provide more reliable, secure and efficient method in terms of economy and energy for the electrical system using digital technology. Furthermore, the IEEE states that a smart grid is a revolutionary technology that entails novel communications potentials and control capabilities in addition to new sources of energy, generation models, and compatibility with different jurisdictional regulatory structures. The smart grid is a growing network of transmission lines, control devices, monitoring equipment, and other modern tools that are employed to tackle the challenges and to fulfil the high demands of the 21st century [2], [6], [7]. Clearly, there are different definitions for smart grid. Each definition chooses one aspect of smart grid's benefits and builds a definition accordingly.

The smart grid industry is an industry worth's hundreds of billions of USD dollars annually as shown in the Figure 1. Although, investment in electricity grids decreased for the third consecutive year in 2019 by dropping to 7% from the 2018 level to under 275 billion USD only as depicted in Figure 1. However, investment in the digital technologies infrastructure such as advanced of the smart metering, electric vehicle charging and utility automation represents over 15% of total smart grid expenses. Additional, electrical equipment receives the largest investment from all smart grid components around the world. As in the above, 123 billion U.S. dollars for a total of 271 billion U.S. dollars which spent on smart grids have gone to power equipment in 2019 only.

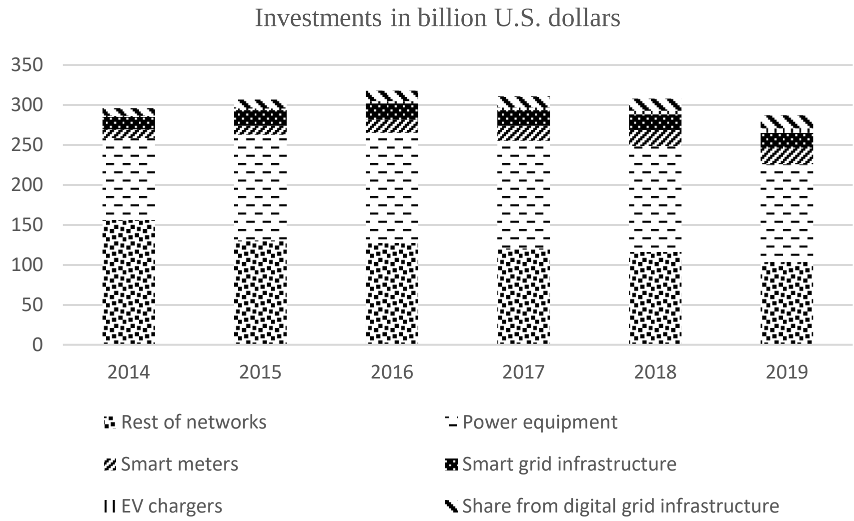

Figure 1. Global annual investments in smart grids from (2014–2019) based on the technology area [8]

For better understand the opportunities of smart grid applications in Iraq, first, it should be to know the advantages of Iraq country and its power grid where the beginning of the power grid date backs to the first quarter of the last century. Iraq, with a population of approximately 40 million people and an area of 438,317 km² which is considered one of the most important oil producers in the world. Additionally, Iraq ranked fifth globally and second in the Arab world in terms of crude oil reserves, with oil reserves amounted to 148 billion 800 thousand barrels. At the same time, the site of Iraq can be an excellent area for the application of clean energy sources such as solar energy, as Iraq has more than 3,000 hours of bright sunshine per year [9] with a daily average solar radiation up to 6.5–7 kWh/m² [10], [11]. In additional, Iraq had the first center for renewable energies research in the middle east established in 1981 [12]. With all these advantages that Iraq enjoys, but due to the conditions of war and political instability as well as great problems in planning and implementation, Iraq has witnessed great and serious problems related to this vital sector of the life of the population and the country. Where the population of this country suffers from a great shortage of electric power generation [10], [13], which has continued since 1991 until now as will shows its details in this research.

In this paper, the wide sight was presented to know the challenges that related with the implementation of a smart grid in an Iraqi electricity grid which suffers from various difficulties, as shown in this study.The rest of this paper is organized as follows, section 2 gives details the benefits of this smart grid of the Iraqi power system. The section 3 provides information of components of the smart grid itself. Section 4, demonstrated the comparison of the conventional Iraqi power system and smart grid. The smart grid security threats are discussed in section 5. The reality and the various challenges of energy sector in the Iraq grid was demonstrated in details in section 6. While section 7, gives the challenges of the application smart grid in the Iraqi power system. The future of energy in Iraq and smart grid applications illustrate in section 8. Finally, the conclusion of this paper is presented in section 9.

2. THE BENEFIT OF SMART GRID FOR IRAQI GRID

The Iraqi grid for electricity generation is considered one of the oldest networks in the region. However, according to official reports on the Iraqi Ministry of Electricity website, there is no application for smart grid in the country yet. Where, the smart grid provides many advantages to the Iraqi traditional power network, especially the availability of information about the real-time state of the electrical network, and this provides an important opportunity for the control center to be flexible in the optimal operation of the network. The main benefit for smart grid could summarize as:

- Enables the integration of modern power units technologies such as solar energy and wind energy units due to the high ability for a smart grid to control these sources that are fluctuating nature [14]–[16].
- When the outage happens, the smart grid could automatically and quickly identify problem, then restoring power delivery via the re-routing process [17], [18].
- Open up a wider range of electricity pricing options that will make the value of power pricing depends upon on the time in the day when electricity is used [19], [20]. While the current situation of the Iraqi grid is one price for all consumption times. Thus, this allows better control of the peak load of the system Thus, this will allow better control of the peak load on the system.
- Offer real-time information on the current power usage in the user's side [21], [22].
- Increase efficiencies in power delivery and enhancement reliability and quality of electrical power systems in the gird [23], [24].
- Reducing operational costs in the long time run [25], [26].
- Reduces the emission of carbon dioxide CO_2 and enhancement of the Iraqi environment by providing an opportunity to connect more renewable energy units instead of traditional electricity units that depend on fossil fuels [15], [27]. As example, the emission for CO_2 increased in Iraq by 6.28% in 2019 compared with the previous year only [28].
- Improve communication between the control center and users which will be reflected on the ability of the operator to knowledge all user requirements per day/month/year [29], [30] and that make a better planning.to meet the needs of users.

From the foregoing, the great benefit of the smart grid is evident in improving the Iraqi electrical power system work in various aspects.

3. COMPONENT OF SMART GRID

This the smart grid consists of various parts. Each part has a specific target to do, as will shows in:

- Smart meter: a piece of equipment that measures power consumption in the users. At the same time, smart meter could send this information to the control center. Thus achieve load power balance at all times to the smart grid [31], [32].
- Communication system: two-way communication channel to send/receive information or feedback between smart meter user's and control center. The media channel could be wired or wireless depending on the available facilities [30]–[33].
- Distributed generation: means a variety of technologies that produce electricity at or near the load location in which it will be used. Distributed generation could be small fossil fuels units or renewable sources units, such as solar photovoltaic panels and small wind turbines [34], [35].
- Transmission subsystem: which links all main substations and load centers in the smart grid via transmission lines, transformers and other equipment's [36]. To deliver power with reliability and efficiency. The transmission subsystem needs to design based on the current and future requirements at the same time this network needs to contain advanced technology to give real-time vision about the current state. Such as phasor measurement unit (PMU) that could can give 6-120 samples/second measurements [37].

In general, smart grid technology has two aspects, one of them is the information technology and the other is operational technology. In information technology the main target is to collect measurements data in the right and online way. However, the massive data coming from smart grids needs to advanced technologically methods for the purpose of processing and obtaining the required results within a short time frame. This challenge needs to digital transformation for the current electrical grid at the level of technique and media used to send/receive data. To make point clear, in smart grid with the advantage of the high-speed internet whether through wireless transmission technologies, satellite technologies or through an optical cable, it became possible to control center to get a clear online vision on the smart grid state. Although, the rest of the electrical grid still has difficulties in the process of obtaining data in real-time due to the poor equipment for transfer information about current state, and this will make integration process between the traditional grid and the smart grid is complex.

On the operation side, grid management is becoming increasingly complicated due to rapid increased with the installation of new numbers of renewable energy units such as of solar panels and wind turbines that coming from different geographical areas that need to be integrated into our current power grids. In general, these renewable energies tend to be always intermittent such as solar and wind energy units due to the unavailability of sunlight or wind as well as several other forms of renewable energy, that poses several operational challenges in terms of managing the entire grid. Figure 2 shows the general idea for the smart grid concept where smart grid could connect with various input power plants such as fossil fuel units or renewable energy units, then delivered power to various load units such as factories or homes and charge electric vehicles.

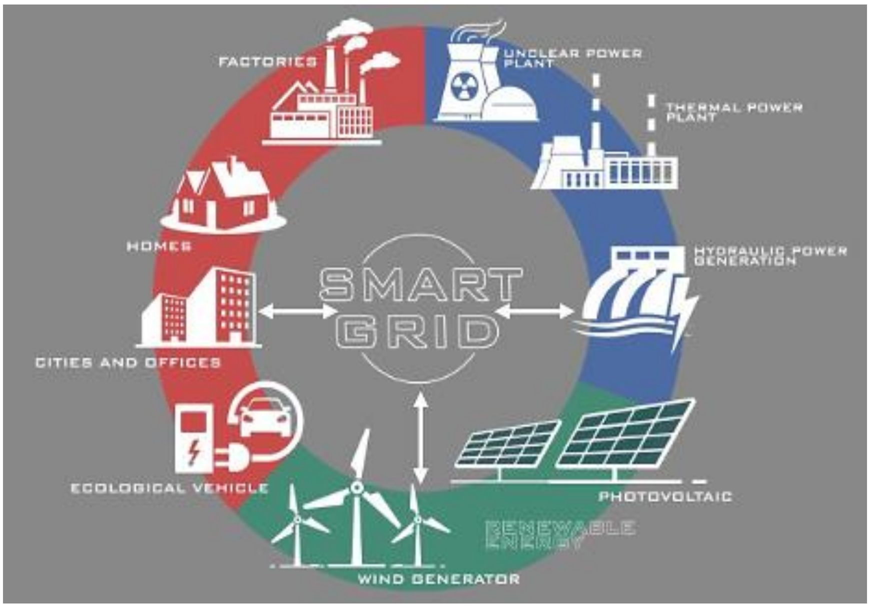

Figure 2. Smart grid concept

4. COMPARISON OF CONVENTIONAL IRAQI POWER SYSTEM AND SMART GRID

In general, conventional grid is based on supply follows demand whereas smart grid based on demand follows supply. In fact, there are many variances among the traditional electricity networks as well as the smart grid as in Table 1, the most prominent of these differences [14], [30]: Table 1 shows the superiority of the smart grid compared to the traditional grid in different types of properties. In fact, the smart grid was being designed to overcome the problems of the traditional network, however, the high amount of implementation of new telecommunication techniques makes the smart grid more effective by the threat of cyberattack. as will be explained in the next sections.

Table 1. Comparison between conventional Iraqi power system and smart grid

Characteristic	Traditional grids	Smart grid
Communication between power companies and customers	One-way	Two-way communication technology
Monitoring distribution system	Manually	Automatically
Determining fault location in distribution system.	More difficult	More easily
Restoration grid after contingency happened	Centralized control	Decentralized control
Topology of grid	Mainly radial	Network
Compatibility with new renewable energy	More difficult	More easily
Power generation concentrated	One place	Different places
Transmission lines distance	Huge	Small
Transmission lines losses	High	Low
Control the flow power	More difficult	More easily
Reduce carbon emissions	Low	High
Robust grid against sudden faults	Low	High
The customer can sell power to grid	No	Yes
Electricity prices bills	Almost fixed	More flexible in changing per one day
Maintenance cost	High	Low
Vulnerability to cyberattacks	Low	High

5. SMART GRID SECURITY THREATS

To better knowledge the threats facing the smart grid, there should be a division of them based on the nature of these threats. In this study, these threats will divide into two parts according to their technical or non-technical nature as will explain in the next sections:

5.1. Technical threats

The definition of technical threats is those threats related to the technical aspects used in smart grids. Due to smart grids heavy reliance on the modern communication technologies such as the internet network in the transmission and exchange of data, although these technologies could provide high-speed and flexibility to the smart grid data. However, this issue makes the smart grid more susceptible to cyberattacks. The consequences of cyberattacks threats have a wide range from the simple one that one related to home consumption bills to the events that causes a fall collapse of the smart grid/or whole power grid. These attacks have a variety of methods and target distributed generators, measuring devices, or exploiting the information network to reach the main control centers.

Cyberattack is defined as a doubtful intention on the part of an attacker or hacker unlawfully obtaining personal information from personal computers or computer networks that are linked to the internet. The target for the attacker is for theft or damage of the intended information. The cyberattacks have the capability of directly affecting power transmission leading to a loss in the grid and millions of dollars. Therefore, it is important to understand the various types of attacks such as false data injection, man-in-the-middle and jamming attacks.

5.2. False data injection

False data injection attacks included malevolent data injected into measuring devices. The goal of injecting fake information is according to the target area, as if it is used in the smart meter area, the goal is to reduce the value power consumption in order to reduce the bills user cost. Whereas, if the targeting was in the distributed generator area or in the transmission lines, the target is purely sabotaging. As the fake information gives a misleading picture of the current state of the system, which leads to confusion to the grid operator, and therefore he/she must take new decisions that may not be useful for the system's work or may lead to the loss of the system in the target area. This type is the most dangerous among fake data injection attacks. In the literature, there are many studies that dealt with different aspects of this attack as well as its detection mechanism as in [38]–[41].

5.3. Man-in-the-middle attacks

Man-in-the-middle attacks are some of the most common cyberattacks. As the name suggests, the bad guy inserts him/herself on a communication between two devices or more. Then, an attacker could capture data sent/received through the network via intercepts traffic without anyone noticing. This attack scenario could implement via special network programs have the ability to mislead grid devices and make them exchange information with the attacker instead of authorized devices. The danger of this attack on the smart network is that the attacker can learn all sorts of sensitive information such as passwords of devices to control them remotely control center or those assigned to users, as well as the amount of production and consumption, which in several cases considered high and critical information [42]–[44].

5.4. Jamming attack

One of the basics of any modern communication system is the ability to send and receive in real-time without any delay or data loss. In this type of attack, the data transfer in the smart grid suffers from noise signals which designed to effect on the smooth way of transferring data and prevent from reach to the final destination. This situation represents a critical situation because the smart grid depends on communication technologies to decide what is the next steps. Where, given the changing operating conditions, real-time data are crucial for deciding which of distributed generation inside the smart grid should enter or leave service, as well as what areas may have gone out of service and what is the mechanism to address the problem immediately [45], [46]. Therefore, loss or delay in the data represents a significant challenge for any system operator.

5.5. Non-technical nature

The non-technical of smart grid threats include environmental hazards such as floods, earthquake, storms, and fires. Duo to the high probability of these phenomena occurring, depending on the nature of the area on which the smart grid is built on it, this type of threat is considered to have a major impact on the functioning of the smart grid, as well as on the entire electrical grid [47]–[49]. In severe cases, this threat could make catastrophic to the transferred power. For an example, storms lead to the loss of many transmission lines, and this affects energy supplied to many regions. In fact, the best solution to this issue is to provide flexibility in backup routes to transfer capacity, especially in regions that are prone to hurricane season.

6. THE CURRENT REALITY OF IRAQ POWER SYSTEM

Until 1991, the Iraqi network was operating stably and with a sufficient reserve electric power for current and future needs. However, due to wars, as well as the state of political instability in Iraq, the national energy transmission network suffers from severe damages. In this paragraph, review for the most important aspects related to the reality of the Iraqi network, as:

- Type of fuel: according to the official reports of the Iraqi Ministry of Electricity, the power plants depend mainly on plants that run on fossil fuels, especially those that operate on gas or oil. And the other part depends on the imported energy and investment stations or hydroelectric plants built in the water dams spread over the two main rivers in Iraq, the Tigris and the Euphrates. As shown in Table 2, one of the main problems in Iraqi gas stations is their dependence mainly on imported gas, which does not guarantee its always presence for many practical reasons.
- Damage to power plants and grid: the gulf war in 1991 led to direct strikes on many power plants, which caused Iraq to lose about 75% of the energy production before the war, which was surplus to its needs. As a result of the blockade imposed on Iraq for the period 1991-2003, this led to a real energy crisis, from which Iraq is still suffering until now. Likewise, the generating stations were subjected to a second wave of destruction during the control of terrorists of (ISIS) about a third of the area of Iraq in 2014-2017, in which Iraq lost about 8 billion US dollars in the electricity sector only as a result of acts of war and sabotage according to an official report of the Iraqi ministry of planning.
- The aging of the generation stations: because of the conditions outlined in the point two, the main stations suffered from ageing, lack of maintenance, expiration of life span, low efficiency and the economic value of operating them. Even after the end of the blockade and war conditions in 2003, it was not possible to stop any of these stations, which continued to serve, given the urgent need to address the continuous deficit in the generation since 1991 until now.
- Gird maintenance and development processes: as a result of the large energy deficit (around 30%), maintenance and development operations in the network have tended to take two directions. The first is related to repairing what can be repaired from old generation stations to either increase or maintain the value of generation in them as much as possible. The second part is relying on fast-installed generation stations, such as combined cycle stations, to increase the amount of generation, as well as increase the carrying capacity of distribution transmission networks by installing new transfer stations and new transmission lines to address bottlenecks in the electrical network. However, due to the lack of security stability in Iraq, the number of towers that were subjected to sabotage from January 1 to July 10, 2021, amounted to 106 towers.
- According to a report by the Iraqi Ministry of planning, published under the name of the National Development Plan (2018-2022), the power distribution sector suffers from a 7% load growth due to unplanned bulges in housing units, as well as the bulldozing of agricultural lands and their conversion to housing, illegal encroachments on the electrical network and the lack of regular maintenance work. Additional there are losses estimated at 23-24% in distribution sector only.

Despite the large sums spent on this sector, which amounted to 80 billion of US dollars (since 2003 to middle 2021) according to official documents of the Iraqi government, however the actual power production ranges between 18 to 20 thousand megawatts, and the actual need ranges between 28 to 30 thousand megawatts. This weakness and poor planning led to the loss of great opportunities to develop this vital sector, on which many other sectors depend on it for present and future developments.

Table 2. The share of electric generating units in the Iraqi power grid in 2018 [50], [51]

Power generation plant	No of units	No of operating units	Average of production in 2018 (MW)	Percentages (%)
Gas plants	198	155	5810	42
Steam plants	31	22	3270	25
Imported energy and investment stations	24	24	3627	28
Diesel unites	322	66	376	3
Hydroelectric plants	29	23	208	2
Total	604	289	13002	100

7. SMART GRID CHALLENGES ON THE APPLICATION IN IRAQI GRID

Based on what was previously reviewed in this research, the application of smart grids in the electrical network in Iraq faces a number and various problems, and it can be summarized in the following points:

- The great shortage in the amount of capacity power generated in Iraq grid made the network operators focus their attention on providing suitable alternatives to the electric generating units, rather than on supporting the network itself in the transmission and distribution areas.

– The greatest damage to the Iraqi electrical system over decades has made it very difficult to integrate smart grid technologies into it, as the transmission and distribution network suffers from poor planning and slow implemented projects in it, which may sometimes take years to implement expansion projects as well as political instability that effect on the everything's in the network status. In addition to this, continuous overruns on the grid, which the successive electricity administration is trying to get rid of.
– Due to the large presence of fossil energy sources in the country, especially crude oil, as well as their low extraction cost and the lack of investment in the renewable sources sector, all of this affects any sustainable energy projects in this country.
– The telecommunications sector in Iraq is considered late if compared to neighboring countries, where the optical infrastructure for delivering services to subscribers is still under construction and it is hoped that will be changed in the coming years, according to the official website of the Iraqi ministry of communications. Now the Internet service is contacted by the end users mostly through Wi-Fi networks, and this matter is not without interruptions, as well as the high price of the service. All of these are obstacles to the operation of any smart grid due to its urgent need for a reliable communication infrastructure work with high speed and continuity.

8. THE FUTURE OF ENERGY IN IRAQ AND SMART GRID APPLICATIONS

In fact, the Iraqi government system depends on the central plan, therefore the Iraqi government should spend more resources and money on successful planning policies that take into consideration the experiences of developed countries as well as the successful experiences of neighbouring countries to develop the current situation for the power sector. Where the process of establishing the infrastructure of the smart grid requires spending large amounts of money to provide equipment such as smart energy meters and modern measuring equipment as well as equipment for communications. Recently, in the middle of the year 2021, the Iraqi government concluded preliminary agreements for the purpose of establishing several renewable energy plants for the purpose of adding 7,500 megawatts over the next five years to the Iraqi grid. It is true that the goal of this process is to compensate for the large deficit in energy generated, however may be an opportunity to apply smart grids in the near future.

9. CONCLUSION

This study presented the main challenges related to current and future application for smart grid Iraqi power system. Where the smart grid implementation could provide opportunities to improve the efficiency of the Iraqi power system and reduce losses in it, as well as improve the system's response to disturbances and so on. Additional, smart grid could create new investment and job opportunities for Iraqi young people, where about 38% of them are under 15 years old. Hopefully the issues highlighted in this research will be an important guide to researchers and the Iraqi engineers to the development of the local electrical grid via finding the best way to implementation of smart grids in it, especially Iraq country has suffered a lot over the last three decades from the persistent deficit in power generation and efficiency.

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