Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 151 (2019) 909–915

Procedia Computer Science

www.elsevier.com/locate/procedia

The 9th International Symposium on Frontiers in Ambient and Mobile Systems (FAMS 2019)
April 29 - May 2, 2019, Leuven, Belgium

Energy 4.0: Towards IoT Applications in Kazakhstan

Botazhan Satuyeva[a], Chingis Sauranbayev[a], Ikechi A. Ukaegbu[a*], HSVS Kumar Nunna[a]

[a]*Electrical and Computer Engineering Department, Nazarbayev University, 53 Kabanbay Batry Avenue, 010000 Astana, Kazakhstan*

Abstract

The IoT is emerging as one of the most novel regulated approaches towards the future smart and green energy system. The Internet of Things combined with the energy management can make an efficient future with reduced costs and improved performance. IoT technologies are used in power grids to improve the performance of traditional power grids and increase their flexibility and reliability. The combination of IoT and power grid is known as a smart grid. The main concept behind smart grid is the distributed generation. Contrary to the conventional grids, distributed generation introduces small and decentralized power plants allocated near or at the end-user location. This paper discusses the existing applications of IoT technology in power industry and analyzes their possible implementations in Kazakhstan. Considering low urbanization level and low population density of KZ, the potential of IoT implementation in energy sector of country is promising. In the paper we are presenting the possible applications of the IoT in the energy sector of Kazakhstan: its future potential, benefits and the challenges and problems that are related with the adoption of Energy 4.0. A novel regulated MAS approach for the energy market as well as online power lines monitoring is presented.

Keywords: Energy 4.0, IOT, RES, demand-side management, load forecasting

1. Introduction

IoT is the connection of everyday objects in the physical world to the Internet. IoT imparts intelligence to the current devices and equipment using sensors and software that are networked together through the Internet. Providing access to clean and affordable energy has become a global priority and countries around the world are working towards achieving this goal. IOT in the energy can revolutionize the current power and energy systems to meet the global energy demands. Smart energy concept means smart grid automation, smart metering, micro grid, renewable energy sources (RES) and distributed energy resources (DER) integration to the grid, energy sharing/trading by developing IoT-based smart energy platform technology.

The next step is reinvention of the ways that energy and utilities companies do business, engage their customers and interact with them. And let us not forget about Energy 4.0 is a digital revolution in the energy sector.

*Corresponding author. Tel.: +7(7172)708960
E-mail address: ikechi.ukaegbu@nu.edu.kz

1877-0509
10.1016/j.procs.2019.04.126

By deploying IoT technologies, smart cities intended to increase quality of life while lowering energy consumption. Advances in IoT can reduce energy usage, diminish losses when transmitting and distributing electrical energy, providing more reliable energy delivery, and improving our standard of living with new applications.

Energy 4.0 presents opportunities to companies to establish new business models and sustainable strategies of producing and delivering energy. The worldwide electrical energy demand continues to grow and is expected to increase by more than two-thirds by the year of 2035. Therefore, the existing power infrastructure will experience a considerable increase in burden. The conventional power grids still lack decent monitoring techniques. Additionally, the integration of distributed energy resources in already existing power systems is a challenging task, thus slowing down the implementation of renewable energy sources [1].

1.1. Reliability

The conventional power grids suffer from faults and require assistance from the maintenance crew. Smart grids allows self-healing of electrical networks, thus making power grid more resilient and self-sufficient.

1.2. Flexibility

Traditional power grids were designed to handle one-way flow. The flexibility of the smart grids allows for distributed generation and maintaining bidirectional energy flows. Distributed generation concept is highly connected to renewable energy: solar, wind, etc. This is due to regular power plants distributing electrical power over long distances. On contrary, distributed energy systems are allocated closer to their loads.

2. IoT applications in Energy Sector

IoT is a network of devices that can connect, interact,exchange data which each other. Connection between devices establishes through the internet.

2.1. Online power lines monitoring

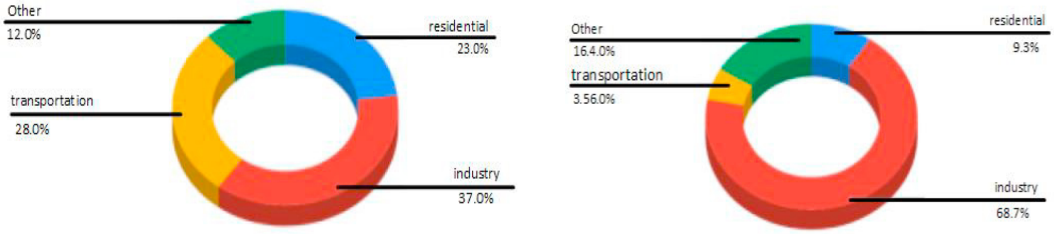
With the increasing number of structures in the system, the impact and number of power outages increases as well. Implementation of IoT in power systems is aimed to solve the reliability issue. Grid control units monitor the system and use the data to deal with faults.

2.2. Smart meter

Smart meter is an electricity meter that digitally sends meter readings to energy supplier. Smart meters also have monitors which enable you users to better understand your energy usage. Smart Grids can digitally detect and take required action in case of local changes in uses. Smart meters, unlike conventional ones, will determine the indicators of energy consumption in more detail. Smart meter data is available in electronic form, and all readings can be taken remotely using a special data collection device, which, in turn, sends the collected readings to a service company via the Internet [2]. The main part of the power lines monitoring is smart meters. Smart meters are devices which record power flow data and transfer it to the provider company. The regular data mostly contain values of voltage, phase angle and frequency. For instance, using consumption values from the grid, smart meters may bill customers based on their consumption from the main grid or distributed generation sources. A smart meter is an advanced meter which has both analog and digital components and which is installed to constantly record the usage of electric power by the consumer [3]. The consumer can avoid estimated monthly electric bills, whilst the supplier can monitor the power consumption in real-time using the smart meter. The real-time monitoring of power consumption was established owing to wireless technologies such as Zigbee, GSM, Wi-SUN, as well as wired power line communication (PLC) [4]. However, the cost of these technologies is considerable and the security of the transmitted data is not guaranteed. An error-prone real-time monitoring of electrical energy consumption is a challenge that should be properly addressed by the energy providing organizations. The delay and latency can occur when the huge amount of data from the smart meter are secured using encryption algorithm. Hence, the prime purpose of this project was to design a smart meter that records energy consumption and saves the data over IoT Cloud Platform [5]. Fig. 1 shows IoT application in the energy sector, including power consumtion in Kazakhstan and worldwide. IoT Cloud Platform proposes a low cost for data transmission and ensures optimal security without impacting network performance.

Utilities	**Consumers**
• Load control • Enhancement of grid resilience and operation • Load forecasting	• High-usage alerts • Time-based pricing • Accurate monthly bills
Government	**Environment**
• Green agenda • International commitment • Avoidance of energy shortages	• Control of carbon emission • Managing energy resources

(a)



(b) (c)

Fig. 1 (a) IoT applications in energy sector (b) Energy consumption worldwide (c) Energy consumption in Kazakhstan

2.3. Demand-side energy management

Demand-Side Energy Management (DSM) is the management of energy resources depending on the consumers demand. This method is used to adjust peak load demand, reduce operation and electricity cost, energy loss and greenhouse gas emissions [6]. IoT components collect data about energy demand and transfer it to the smart meters. The control unit modifies energy distribution schedule according to the users preferences [7].

2.4. Integration of distributed energy sources

IoT with wireless sensors collects information to predict the energy availability in the future. Generation of RES and DERs is unpredictable [8]. IoT with sensors collects information and predicts the fluctuations in power.

2.5. Integration of electric vehicles

IOT helps to develop scheduling methods for charging and discharging of electric vehicles [9]. Sensors collects information about electric vehicles type, battery state, configuration, etc. This leads to the reduced greenhouse gas emissions[10].

3. Perspectives of Kazakhstan towards Renewable energy sources

3.1. Hydro power

In the table I, the information about hydro power projects in Kazakhstan is presented. Annual production for each region is given in GWh. It is seen that the hydro power is popular energy source in Kazakhstan.

3.2. Wind energy

Kazakhstans steppe geography facilitates installment of wind energy applications. Kazakhstans territory has average wind speeds suitable for energy generation (46 m/s) [11]. In the table the data regarding possible regions for installment of wind energy applications is presented and their possible annual production data is given.

Table 1. Hydro power projects in Kazakhstan based on region.

Regions(*t*)	Annual production (GWh) (*t*)
East Kazakhstan	1700
Almaty preovinc	8700
Southern Kazakhstan	1800
Zhambyl province	700
Total	12900

Table 2. Possible Regions for Wind Power installments in Kazakhstan

Location of potential wind farms(*t*)	Annual production [billion kWh] (*t*)
Mangystau mountains	0.4
Peak Karatau	0.23
Chu-Ili mountains	0.27
Mount Ulutau	0.13
Yerementau mountains	0.01
Mugojary mountains	0.01
Djungar gates	0.66
Total	1.71

3.3. Solar energy

Kazakhstan has areas with high insulation [12] that can be used for solar power. South region of country receives 2200 and 3000 hours of sunlight per year. Even, in southern regions sunlight reaches a 3000 hours per year resulting in energy potential of 2.5 billion kilowatts a year [2]. Construction of solar-power-generating complex was announced in Kyzylorda that will be capable of generating 65 megawatt hours of electricity a year. In Astana Solar LLP photovoltaic solar panel production plant works that provides country's demand for solar panels.

3.4. Renewable energy auctions

On May 23, Kazakhstan launched the auction system for for the selection of projects in the field of renewable energy sources [13]. The first auction was held in Astana. At the auction, projects were chosen for the northern zone of the republic. Projects of wind power stations with a total capacity of 20 MW were selected. The auction organizers received nine applications from Kazakhstan's companies wishing to implement projects with a capacity of 2 to 7 MW. The total capacity of the proposed power plants covered by the applications amounted to 40.7 MW.
Bidding began with a starting rate of 22.67 tenge. During the three-hour session, the minimum proposed tariff of 18 tenge was reached. Following the results of electronic trading, the following participants were determined as winners:

Table 3. Possible Regions for Wind Power installments in Kazakhstan

Company(*t*)	Energy(MW) (*t*) price(tenge) (*t*)	
KT ”Zenchenko and K”	2	18
Vichy LLP	7	18.01
Ventum Energy	4.95	18.99
EastWindEnergy LLP	4.95	19.99
LLP Ivan Zenchenko	2	22.53

Auction, is one of the stages of the planned development of renewable energy sources, is aimed at selecting the most efficient projects. In addition, they are aimed at creating market competitive prices for electricity generated by renewable energy sources [14]. The Ministry of Energy has formed a special schedule for 2018 to hold auction bidding in the amount of 1,000 MW of installed capacity, broken down by types of power plants:

Table 4. Possible Regions for Wind Power installments in Kazakhstan

Company(*t*)	Energy(MW) (*t*) price(tenge) (*t*)
Solar power plants	290
Hydroelectric power stations	75
Bio electric power plants	15
Wind power	620

3.5. IoT

In Kazakhstan, you can deploy a network to which up to 100 million different devices can be connected, transmitting a huge amount of information needed for making quick decisions and for data analytic. Potential market for IoT in Kazakhstan is presented in Fig. 2.

Total Population: 18 Million	Facilities
5.2 million households	75 million sensors
4 million automobiles	4 million eCall terminals
80 thousand buses	200 thousand cameras and 200 pay terminals
100 thousand km highways	100 thousand cameras, detectors and sensors
26 thousand manufacturing facilities	More than 400 thousand industrial sensors, cameras and counters
220 million ha of farmlands	More than 1 million soil sensors
7.5 thousand schools	1.5 million children
900 medical facilities	10 million wearables
87 cities	More than 1 million park sensors, GPS trackers, cameras, etc.

Fig. 2. Potential Market for IoT

Kazakhtelecom company launched the project to install about 50 thousand surveillance cameras in 24 thousand entrances [15]. Among the projects of the telecommunications operator, not only video surveillance in entrances, but also in houses, as well as projects for monitoring the transport, organizing online collections of electricity meters and other utilities, and also large projects of the so-called ”Smart City”. The IoT World Summit Eurasia was held on June 14-15, 2018 in Astana. Representatives from 15 countries of the world talked about their practice of using and using IOT technologies. More than 35 innovative projects and 175 smart solutions were presented in 8 key streams. 75 reputable speakers during the two days of the summit shared their experience in the field of IOT.

3.6. Challenges

While the government is adopting new legal frameworks to encourage the transition towards renewable energy sources there are still significant barriers to address including a lack of awareness of the opportunities associated with renewable energy, a lack of technical expertise and capacity, insufficient governmental support to overcome high initial financial and capital requirements and investment disincentives due to subsidies of other energy sources (primarily fossil fuels). The financial barriers including the low price of electricity in the country, uncertainties with the long term power purchasing tariffs, difficulties in attracting foreign investment and a lack of access to credit for both consumers and investors are currently acting against rapid adoption. Institutional barriers include the absence of a clear national program for renewable energy development, a lack of specific action plans and instruments, a lack of concrete competitive legislation and regulation relating to the newly developed energy market, given the increasing success of the oil and gas sector.

3.7. *Governmental efforts*

The EBRD is a leading international financial institution in renewable energy and energy efficiency. The bank remains the largest and in some cases the only source of financing for renewable energy projects. In 2017, EBRD devoted 40 percent of its investments to projects promoting green economy [16]. Subsidies for renewable sources is a efficient strategy for the adoption of the RESs. Thanks to these subsidies, renewable energy sources (RES) have become increasingly popular. The national program "Kazakhstans Vision 2050" is aiming to bring the share of renewable energy in electricity generation to 30 % by 2030 and 50 % by 2050. ASTANA The Eurasian Bank for Reconstruction and Development (EBRD) plans to invest approximately $ 244.2 million in Kazakhstan RES attracting private and international financial investment. Currently in Kazakhstan there are 55 operating RES with a total capacity of 336 megawatts.

4. Case study

By demand side management the cost of generation of energy can be reduced greatly. Moreover this move can help to reduce the pollution rate of the world and save the resources. Fig. 3 shows the 24-hour load profile for Kazakhstan for one working day. Power supply demand in Kazakhstan is increasing greatly over the past years. As the result, more power plants need to be built to balance a demand [17]. Time of use prices for Kazakhstan's residential consumers need to be identified so that they are willing to shift their demands in peak hours.

Table 5. Electricity prices for peak, off-peak, half-peak periods

off-peak	Half-peak	Peak
9,59 tenge/kwH	15,32 tenge/kwH19,15 tenge/kwH	

Table 6. Electricity prices for different consumers

Consumer type	Price
Residential	16,01 tenge/kwH
Commercial	12,77 tenge/kwH

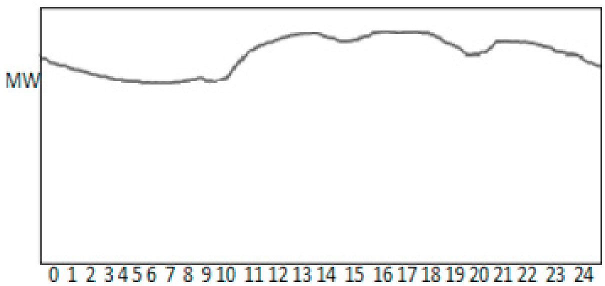


Fig. 3. 24-hour load profile for Kazakhstan for one working day

5. Significance of Energy 4.0: iot applications for Kazakhstan

The reasons for the smart grid establishment in Kazakhstan include: Aging infrastructure; Need for energy resource conservation; Plants are old; Transformers are old; Approximately 10 of electricity output is lost during transmission of electricity; Electric power consumption in Kazakhstan is 5600 kWh per ca pita; and Investment and governmental support is going to increase by year 2030 and 2050. The condition of the existing power infrastructure in Kazakhstan is quite poor. The implementation of the power monitoring system should assist in maintaining and securing power structures. The reasons for the smart meter establishment in Kazakhstan include: Save energy; Encourage offpeak energy use; Provide information on most used appliances and offer energy saving tips; Link up household appliances;

Help people dynamically monitor energy consumption and cut energy bills; displays showing on demand electricity consumption; Managing peak loads; Load forecasting; and Improve billing accuracy.

6. Conclusion

The increasing rate of population and economics around the world is leading to a huge demand for electrical energy and energy resources. Because of the limited resources of fossil fuels, the electrical energy demand issue is becoming more serious problem. It is predicted that by 2025 Energy demand will rise by 54 %. Electricity demand will grow by huge amount not only for KZ, but in all over the world. Also, there is an aging grid infrastructure and because of it electricity is lost during generation and transmission. So, time to make changes has arrived. Renewable energy sources, green and smart energy can be solution to all these challenges. Particularly, IOT can be really effective one. IOT applications in energy sector: smart meter and smart grids can revolutionize whole energy sector. Smart grids delivers electricity to consumers by using IT in distribution network. Smart meters collects and manages data relating to energy consumption. Advanced Metering Infrastructure (AMI) is beneficial for effective energy management and changing customer behaviors. These IOT applications help customers to monitor usage of energy and participate in demand response, help to lower energy consumption, reduce bills. These applications are now widely used in some foreign countries. In this paper it has been proven that Kazakhstan has a great potential to adopt these IOT applications. In the case study, (TOU) time of use price for Kazakhstan was calculated by which Kazakhstan's residential consumers will want to shift their load demands in during peak periods. The potential of Energy 4.0 in Kazakhstan was discussed by observing the existing power plants. To conclude, the potential for IoT implementation in Kazakhstan's power sector is promising due to the rise of the RES and power infrastructure, governmental efforts and price incetivized consumers.The condition of the existing power infrastructure in Kazakhstan is quite poor. The implementation of the power monitoring system should assist in maintaining and securing power structures.

References

[1] C. Dahl and K. Kuralbayeva, "Energy and the environment in kazakhstan," *Energy Policy*, vol. 29, no. 6, pp. 429–440, 2001.

[2] M. Karatayev, S. Hall, Y. Kalyuzhnova, and M. L. Clarke, "Renewable energy technology uptake in kazakhstan: Policy drivers and barriers in a transitional economy," *Renewable and Sustainable Energy Reviews*, vol. 66, pp. 120–136, 2016.

[3] R. J. Sexton, N. B. Johnson, and A. Konakayama, "Consumer response to continuous-display electricity-use monitors in a time-of-use pricing experiment," *Journal of Consumer Research*, vol. 14, no. 1, pp. 55–62, 1987.

[4] S.-W. Luan, J.-H. Teng, S.-Y. Chan, and L.-C. Hwang, "Development of a smart power meter for ami based on zigbee communication," in *Power Electronics and Drive Systems, 2009. PEDS 2009. International Conference on*. IEEE, 2009, pp. 661–665.

[5] P. Palensky and D. Dietrich, "Demand side management: Demand response, intelligent energy systems, and smart loads," *IEEE transactions on industrial informatics*, vol. 7, no. 3, pp. 381–388, 2011.

[6] M. Amin, "Smart grid," *Public Utilities Fortnightly*, 2015.

[7] A.-H. Mohsenian-Rad, V. W. Wong, J. Jatskevich, R. Schober, and A. Leon-Garcia, "Autonomous demand-side management based on game-theoretic energy consumption scheduling for the future smart grid," *IEEE transactions on Smart Grid*, vol. 1, no. 3, pp. 320–331, 2010.

[8] T. Aboumahboub, K. Schaber, P. Tzscheutschler, and T. Hamacher, "Optimization of the utilization of renewable energy sources in the elec- tricity sector," *renewable energy resources*, vol. 11, no. 12, pp. 13–14, 2010.

[9] A. Koshim, M. Karatayev, M. L. Clarke, and W. Nock, "Spatial assessment of the distribution and potential of bioenergy resources in kaza-khstan," *Advances in Geosciences*, vol. 45, pp. 217–225, 2018.

[10] N. Apergis and J. E. Payne, "Renewable energy consumption and growth in eurasia," *Energy Economics*, vol. 32, no. 6, pp. 1392–1397, 2010.

[11] E. Sortomme, M. M. Hindi, S. J. MacPherson, and S. Venkata, "Coordinated charging of plug-in hybrid electric vehicles to minimize distribu- tion system losses," *IEEE transactions on smart grid*, vol. 2, no. 1, pp. 198–205, 2011.

[12] K. Clement-Nyns, E. Haesen, and J. Driesen, "The impact of charging plug-in hybrid electric vehicles on a residential distribution grid," *IEEE Transactions on power systems*, vol. 25, no. 1, pp. 371–380, 2010.

[13] Y. Glemarec, W. Rickerson, and O. Waissbein, "Transforming on-grid renewable energy markets. a review of undp-gef support for feed-in tariffs and related price and market-access instruments," United Nations Development Programme (UNDP), New York, NY (United States), Tech. Rep., 2012.

[14] S. H. Lee and M. ho Lee, "A study on the development of egg information system using iot based connected system," , pp. 241–243, 2017.

[15] N. Saparkhojayev, A. Mukasheva, and P. Saparkhojayev, "The concept of monetization of iot-based project: case of medical system in kaza-khstan," *Information Technologies, Management and Society*, 2017.

[16] I. Overland, H. Kjærnet, and A. Kendall-Taylor, *Caspian Energy Politics: Azerbaijan, Kazakhstan and Turkmenistan*. Routledge, 2010.

[17] M. D. Yasyn, "Factors and conditions influencing investment tariffs of power companies," *Buletin of the Turan University*, vol. 3, no. 67, pp. 205–210, 2015.