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A Contemporary Framework of Technical Challenges in Enactment of Smart Grid

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Abstract
Smart Grid (S.G.) is emerging by way of a modern aspect of the power industry. The incorporation of various progressive technologies such as S.G. is impressive, yet it has become a significant issue of establishment within consumers regarding getting rid of the obstacles. A part of the investigation is presently going on the numerous issues and challenges on the execution and real-time operation of the different components of S.G. The paper emphasizes the sustainable renewable power generation of Bangladesh, below par (3.08%) now. The nation aims to be a mid-level developed country within a couple of years. The data or technical losses reduction, energy savings, reduced balancing cost, and the renewable generation capacity, which aims as high as 24,000 MHz in 2021 and the years, are too overwhelming. S.G.'s potential ability for the distribution and transmission of electric power to the nation is of immense importance. Finding out the technical clichés can reduce supportability issues. Thus, it can increase survivability and capability in all aspects possible by S.G. Therefore. This paper discusses significant challenges and problems for S.G. implementation and the other fulfillment identification factors. The ongoing development phases can be strategically planned to match with the constant drastic changes of high-tech equipment. Also, there can be a place for power generation companies more involved in competitions on this matter. The paper will be valuable to the analysts to find out the crucial references within the field on assessing current adjustments on the pre-planned development phases of Bangladesh with S.G.'s empowerment to lead the pathway to a more sustainable and developed nation. It can prove the importance of such examinations for the similarly developed countries for the readjustments of development phases for a more worthwhile future.

Keywords: Energy Storage, Network, Power Grid, Smart Meter, Transmission.

I. Introduction

The combination of electrical networks, communication arrange, equipment, and software to measure, observe, control, and oversee the generation, transmission, distribution, capacity, and utilization of energy is called Smart Grid (S.G.) (Shahinzadeh and Hasanalizadeh-Khoroshahi, 2014) for controlling the grid network and selecting the best method of power distribution and information. Moreover, an S.G. uses computerized technology to reduce power consumption, decrease costs, and raise transparency in the system (Lo and Ansari, 2012).

For the whole administration of electric energy, S.G. remains a selected development process that supports technology, conservation, and efficiency of power utilities. Utilizing the modern communication and data system, the S.G. enjoins an assortment of client types of equipment and assets at the side sensors to make a smart platform (Badi *et al*., 2020).

Compared to a conventional grid, an S.G. is more intelligent, penetrating, efficient, obliging, propelling, opportunistic, quality-centered, flexible, and green in its attributes as well as amplification.

In 2013, Joy *et al*. stated a disguisable definition of S.G.: Is an electrical grid an interconnected network for passing on power from the supplier to purchasers. It includes creating stations that convey electrical power, high-voltage transmission lines that cart power from a long way off sources to demand focuses, and dissemination lines that interface singular customers.

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It is a reality that electric power is one of the fundamental and most basic advancements driven by fast industrialization and globalization in the 20th century (Joy *et al*., 2013).

Following IEEE, the S.G. has come to depict a front-line electrical power framework. It is embodied by the expanded utilization of interchanges and data innovation in the age, conveyance, and electrical energy.

According to Kappagantu and Daniel (2018), a Global S.G. Federation (GSGF) report- privileges that existing power grid networks are not prepared enough to encounter the strains of 21st-century parameters viz. quality, efficiency, reliability, ecology, and economy.

Today's electrical network endures several issues, counting that it is old, inefficient, and defenseless. On the premise of the present situation and practical circumstance, the improvement plans for the S.G. in Bangladesh ought to be taken care of instantly and seriously. Smart Network's implementation in Bangladesh could be a challenging assignment with parts of the energy sector issues.

II. Literature Review

The power system is organized and interconnects the connections for the generation, transmission, and distribution of power.

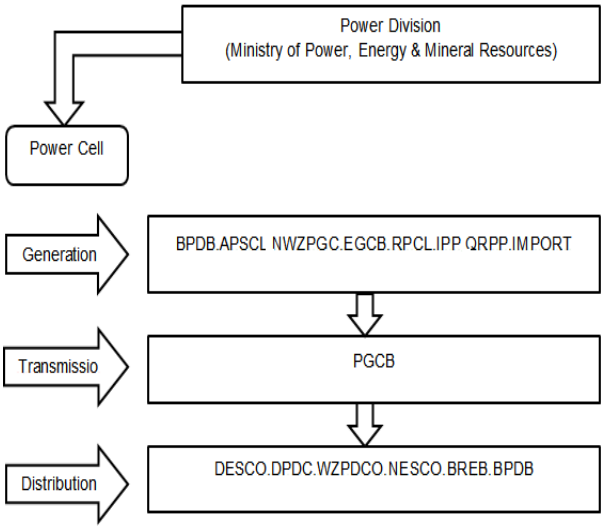

Figure 1: Structure of the power sector in Bangladesh

In Bangladesh, power is produced at 50 Hz frequency and a minimum voltage of 11 kV. Otherwise, 15 kV to be stepped up through transformers up to 132 kV in maximum (Alam and Kabir, 2017).

The power framework is coordinated and interconnects the associations for age, transmission, and distribution of power. Kappagantu and Daniel (2018) define the integrated power system as- a Power System is an incorporated network that interconnects the establishments for age, transmission, and distribution of Electricity.

A research from 2019, according to the paper of Moazzem, as of the year 2009, the Bangladesh power grid includes roughly 2314 circuit km, 230 kV lines, 5533 circuit kilometers with 132 kV lines are there. Another 167 circuit kilometer 66 kV transmission lines have already been established. The 230 kV alongside the 66 kV lines are associated with the 132 kV network through 230/132 kV and 132/66 kV tie-transport transformers individually. Eighty-five grid substations get power from high voltage transmission lines and convey it to the buyers through a considerable number of kilometers 33 kV, 11 kV, and 0.4 kV distribution lines.

In 2017, research from Alam and Kabir discussed the overall transmission of electrical power in Bangladesh. As of their research, there is 230 kV for taking care of the network, i.e., a high voltage transmission organizes that communicate the power to network substation transformers to be ventured down at 33 kV, 11 kV, and 0.4 kV conveyance to the purchasers of various classifications.

II.A Bangladesh's Power Sector: At a Glance

In Bangladesh, the state-possessed Bangladesh Power Development Board (BPDB) produces about 75% of its power (Moazzem and Ali, 2019).

The Rental Power Plants (RPPs) and the Independent Power Producers (IPPs), and practically neighborhood and global organizations joint endeavors, create the leftover 25% and offer it to BPDB through the grid. BPDB, in its turn, offers power to the distribution of substances.

According to the year 2021, as per the Power Cell of Bangladesh Power Ministry report, the grid framework is possessed and worked by a public company named Power Grid Company of Bangladesh (PGCB) Limited. The obligation of circulating Electricity the nation over is shared by different public organizations, such as REB,

BPDB, Dhaka Power Distribution Company (DPDC). Furthermore, Dhaka Electricity Supply Company (DESCO), West Zone Power Distribution Company (WZPDCO), also gets included for each having separate establishment territory (Ahsan *et al*., 2014).

As per Power Grid Company of Bangladesh Ltd., installed capacity is given beneath (Shahinzadeh and Hasanalizadeh-Khosroshahi, 2014).

Installed Generation Capacity: (approximately including Captive Power) = 22,500 MW and Captive Power: 3,500 MW (approximately) (Joy *et al*., 2013).

II.B Grid-Connected Power System

Tables 1-3 show the detailed statuses of the present National Grid-connected Power Systems in Bangladesh.

Installed Capacity: 19,195 MW (Sept, 2019)

De-rated Capacity: 18,672 MW (Sept 2019) (Shahinzadeh and Hasanalizadeh-Khosroshahi, 2014).

Highest Generation so far: 12,893 MW (29 May 2019, 2100 hrs.).

Electricity Growth: 10-13 %

Access to Electricity: 94 % (including RE).

Per Capita Electricity Generation: 477 kWh.

Table 1: Sub Station

Category	**400/ 230 kV**	**400/ 132 kV**	**230 kV**	**132/ 33 kV**	**HVDC (BtB)**
Nos.	4	1	27	129	1

Table 2: Transmission Line

Voltage Level	**132 kV**	**230 kV**	**400 kV**
Circuit (km)	7545	3406	698

Table 3: Renewable Energy Potential

Resources	**Entities Involved**	**Potential**
Cattle waste-based Biogas power plants	Public and Private sector	Enormous (Avg daily solar radiation of 4-6.5 kWh/m^2)
Biomass Gasification	Public sector / PPP	Complete Wind Mapping is required (few areas with 5-6 m/s)
Domestic Biogas System	Mainly public entities	Limited potential for micro or mini-hydro (maximum 5 MW). Est. Potential: approximately 500 MW
Hydro	Public and Private sector	8.6 Million Cubic Meter of Biogas
Wind	Mainly private sector	300 MW considering 2 kg of husk consumption of per kWh
Solar	Mainly private sector	350 MW considering 0.752 m^3 of Biogas consumption per kWh.

III. Government Vision

Electricity for every person in Bangladesh by the year 2021 is estimated (Shahinzadeh and Hasanalizadeh-Khosroshahi, 2014).

Power System Master Plan (PSMP) up to 2041 (Shahinzadeh and Hasanalizadeh-Khosroshahi, 2014).

Updates of PSMP 2006: Due to the change of planning perspective

PSMP 2010: Long term planning up to 2030

Study completion: February 2011

Updates of PSMP 2016: Vision 2041

III.A Findings

Generation capacity requirement by 2021 is 24,000 MW, by 2030, it is 40,000 MW, and by 2041, it is 60,000 MW (Joy *et al*., 2013)

Fuel Mix: Coal: 35%, NG: 35%, RC + NUKE + RE + Other: 30%.

III.B Renewable Energy Status of Bangladesh

According to Power Grid Company of Bangladesh (PGCB) Ltd., the present share of renewable energy is only 3.08% ('Renewable Energy Policy' approved in 2008) (Power Cell, 2021). The policy envisions 10% of the total generation from renewable sources by 2020.

A developing nation like, Bangladesh has plans to create power from environmentally friendly energy sources to complement commercial sources. Bangladesh includes a hot climate, and sun sparkle is accessible all year. By

utilizing sun-based sources, wind energy resources, and other renewable energy, it is possible to generate power for the nation's blocked-off zone (Plateau *et al*., 2019). These sources will offer assistance for improving the standard of living, modernization, and employment generation for the country's individuals.

Assume Bangladesh can endeavor to stay up with sustainable power advancement in different countries. Power can be conveyed from environmentally friendly power sources and spread to those reaches where the gridline augmentation is incredibly exorbitant (Gong *et al*., 2020). This methodology will stimulate the public authority's electrification program and will facilitate the current power supply lack. That is, the reason this has been given need.

IV. Numerous Characteristics of Technical Difficulties

Technical challenges for S.G.s are Issues such as communication, challenges of implementation of Smart Metering Systems, the security of cyber and communication systems, challenges of energy storage, S.G. privacy concerns, data management, and the technology of recovery control. Attributes relating to the barrier can improve the overall system. Discussions among the factors affecting the system can clarify the obstacles (Hydrocarbon Unit, 2018).

IV.A Issues of Communication

It is a more or less disoriented run of communication innovations for S.G. arrangement, but they all have their limitations. Every communication technology has some problem, such as one technology has restricted transfer speed. In contrast, the second works in a limited distance. The third has higher information loss, and the other has little success in underground establishments. For S.G., real-time information and dynamic framework administration require quick and two-way digital communication with third-party substances (Pavlovic *et al*. 2017).

S.G. utilizes a wide range of broadcast communications counting wired and wireless phones, voice and information dispatch radio, fiber optic cable, control line carrier communication, satellite, internet, and its equipment.

In S.G., Communication protocols are not well characterized. Some communication technologies are GSM, GPRS, PLCC, 3G, 4G, ZigBee, and Broadband over PLC, and so forth. These technologies have limitations, such as GSM and GPRS, have limitations in data rates. However, they have a coverage range of up to 10 km, 3G and 4G spectrums are costly (Hydrocarbon Unit, 2018).

In contrast, ZigBee has a coverage limitation range of 30-50 m only. Wired power line communication has an interference problem. Optical fiber communication is quick and secure but is exceptionally costly as well.

IV.B Problems Regarding Enactment of Smart Metering Systems

Appropriate and suitable technical knowledge is needed to maintain and operate these systems at different distribution levels (Shahinzadeh and Hasanalizadeh-Khosroshahi, 2014). There have lots of security challenges for the implementation of Smart Metering Systems. In this case, Advanced Metering Infrastructure (AMI) consists of lots of cheap measurement items; securing these items and configuring this equipment is very difficult (Uddin *et al*., 2018). For improving the ease of use, the security of the system is taken at low levels.

As a result, the attacker can quickly attack the system. The implementation of the Smart Metering systems faces five enormous challenges: first-infrastructure implementation cost, second-complexity of implementation and configuration of these systems, third-removing existing meters Rausser *et al*., 2017), and outdated information and communication sites will be one of the vast issues for electricity organizations inside the future fourth-the security hazards in Smart Metering systems (Alwisi *et al*., 2018), fifth-building robotization frameworks (Amin, 2011).

IV.C Cyber Security Integrated Communication Network

The security of cyber and communication systems is crucial to the dependable operation of the network. In 2014, Bou-Harb assumed stating 'More than 90% of successful cyber-attacks may take benefit of known vulnerabilities and misconfigured operating systems, servers, and

network devices'. Present-day power system operation depends on the complex network of sensors and computerized and manual controls tied together through a communication network. "The cybersecurity aims can be intimate into the following three categories- integrity, confidentiality, availability" as in 2016, Yao *et al*., suggests in their research paper.

Smart Networks have made many more access points and with commands radiating from interfacing in homes and businesses in Home Area Network (HAN) (Mendes *et al*., 2015). Here, attackers can easily manipulate any of these access points to enter a network and quickly gain access to control computer programs, and change load conditions to destabilize the network in unpredictable ways. Attack at any moment can affect the whole S.G. as it is mostly based on a mesh network. One crucial point of concern is that if the security mechanism is not satisfactory from a customer meter to the data collector, which can use wireless communication, this can provide an opportunity to the attacker (Alwisi *et al*., 2018).

IV.D Adoption-Oriented Impediments to Overall Energy Storage Capacity

Energy stockpiling innovation faces two critical difficulties, including specialized and monetary or financial points of view. In 2017, Pavlovic *et al*. proposed quantified that the progression of energy stockpiling innovation requires numerous breakpoints from the outset. It is the development and advancement in the limit, long-life expectancy, ease, high-security for electrochemical energy limit, and actual stockpiling innovation is required high-productivity with minimal effort that gets it. Besides, the examination ought to be fixated on energy stockpiling reproduction and activity enhancement in various applications, reinforcing energy stockpiling advancement from a hypothetical viewpoint and creating exhibition undertakings and far-reaching appraisal to advance the industrialization and commercialization of energy limit (Daki *et al*. 2017).

Besides, Daki *et al*. propose and demand to build up aggregate and careful appraisals. For instance, as the capable union, sensible grouping, straightforwardness, receptiveness, and imperativeness stockpiling norms. These elements can cement exploration and progression, age and utilization of energy stockpiling, and advance energy stockpiling innovation and related organizations. The energy stockpiling industry faces difficulties of approach uphold, high expense, hazy application esteem, an unfortunate market instrument, and different issues.

IV.E S.G. Privacy Concerns

There have many privacy concerns such as: determining particular appliances utilized, performing real-time observation, focused on domestic invasions, movement censorship, decisions and activities based upon wrong information, revealing activities when used with input from other utilities, identity theft, security suggestions of linking power network to open web, increment within the level of personal detail accessible, defend an attack.

IV.F Data Management

An S.G. is a complex electric grid that includes many devices, network systems, intelligent meters, various sensors on the network, and information data. There are fast or slow processing networks, interactive or non-interactive systems, different kinds of data, etc. Smart Networks go up against particular necessities and difficulties to oversee data joining in transmission capacity imperatives, botches, limited resources, and tall flexibility. For instance, a smart meter could send consumer energy usage every 15 min, which is stated in the literature of Ahsan et al., in the year 2014. Therefore, every million meters can generate 96 million reads per day instead of one meter reading a month in a conventional grid.

S.G. frameworks contain numerous datasets, so grid organizations face numerous troubles and difficulties overseeing information on the board. At that point, as per such removed qualities, for example, operational information, non-operational information, meter utilization information, occasion message information, metadata, specific information classes (Shawon *et al*., 2018). Considerable information advances are a decent chance for utilities to bring new techniques, assessment models, and applications and improve information the executives in Solar based enhancements to all the while total the other nano-

innovation based device improvement (Zaman *et al*., 2018).

IV.G The Technology of Recovery Control

Control advances for complicated and troublesome power failures, versatile optimization, moment decision-making technology, a strategy of self-recuperating recovery system ought to be studied by the organizers and engineers. For an appropriate crisis administration system, the emergency control and command framework should be developed (Larul, 2019). In the southern part of Bangladesh, the extreme climate is widespread. Black start technology beneath severe weather should be taken under consideration for proper coordination. For avoiding large-scale blackouts, a reserve system and mechanism at different levels is essential to set up step by step.

IV.H Interaction Mechanism of Distributed Generation with Grid

The operational characteristics of numerous distributed generations and the interaction component between the grid and different sources have to be studied. There need planning strategies for the facilitated advancement of the transmission and distribution network, enhancement of the security and reliability of the control supply, and optimization of the network resources.

IV.I S.G. Planning and Developing Strategy

Many engineers require the S.G. information because they are not yet familiar with the modern grid concept. The deficiencies in the Bangladesh control system must be pointed out after going through the different implementation of Smart Networks in several countries. With particular national conditions, the issues should be analyzed, investigated, and researched to recognize barriers to S.G. development. For planning the roadmap of Bangladesh S.G., procedures and development plans ought to be applied. The study's ultimate objective is to propose the concept and setup of the advanced control network to arrange general advancement strategies and promote the network's facilities.

V. Enhancement of the Power Grid with Advanced Technologies

It is essential to improve the grid with advanced technologies for better performance and better outcomes. The grid ought to be configured with advanced electronic gadgets such as power electronic gadgets, semiconductor gadgets, etc. It is for the sake of extending controllability, flexibility, observability, and intelligence. Power system steadiness, vitality capacity with control methods, protection framework, and progressed superconducting power equipment should be examined and connected for better performance.

V.A Checking, Simulation with Smart Decision-Making

Checking the generator and control grid status, construction and alteration of the network, course of action, and adjusting the operation ought to be secured and safe. Cleverly decision making, quick simulation ought to be examined and analyzed. The network security and defense system should be explored. Mechanisms such as that will dispatch an organized checking system with complete security and assurance work to meet the S.G.'s prerequisites.

V.B Technology Development and Delivery Risk

The assimilation of S.G. needs a wide range of hardware, computer program, and communication technologies. In numerous fields of Bangladesh, the technologies are still at an introductory stage of development. They have centered on working inside a suite of equipment and computer program arrangements.

Moreover, the policy creators, controllers, and utilities see well-established equipment suppliers for S.G. implementation (Plateau and Bhuiyan, 2017). This drift is anticipated to proceed with expanding competition from Asian producers. As a result, standards will usually form, and hardware costs will drop as economies of scale emerges and competition increases (Ali *et al*., 2018).

On the program and information administration side, the primary challenge is to overcome integrating the whole equipment system and oversee a high volume of information. With different program providers come numerous information designs and the requirement for complex information models. The proliferation of information puts stresses on information administration engineering comparable to the telecommunications industry than the utility industry. Numerous of these issues are now being

addressed in pilots, such as S.G. assignment constrain (Huebner *et al*., 2020), and, as a result, the conveyance risk will reduce as measures will be set up.

VI. Conclusions

In the power sector, the smart-grid has presented new concepts such as real-time estimating and pricing, load shedding, request administration, and integration of distributed, renewable power sources. These are based on several control systems, which the attacker can easily target. It is a significant technical challenge. S.G. systems' physical components must be secured from harm, tampering, theft, vandalism, and sabotage. In Bangladesh, as a starter, S.G. is still confronting challenges in an arrangement. These encounters are related to developing technologies, socio-economic problems, lack of policies, etc. Intelligently integrated S.G. should be configured with modern electronic devices such as power electronic devices, semiconductor devices, and so forth for increasing controllability, flexibility, and intelligence.

This paper aims to assess the comprehensive technology to discussing it from the perspective of geographically small developing nations like Bangladesh to take it to a different investigative matter for the country. However, in most of the progressed nations, utilities have made significant efficiency, unwavering quality, and proficiency by utilizing S.G. technology. Bangladesh's utilities are still lagging far behind when compared to the other nations.

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References

Ahsan, M. Q., Chowdhury, A. H., Ahmed, S. S., Bhuiyan, M. I. H., Haque, M. and Rahman, H. (2014). Smart Grid Status in Bangladesh Power System. Retrieved from *https://www.saarcenergy.org/wp-content/uploads/2019/11/Country-Presentation-Bangladesh.pdf*. Accessed on 7-Dec-20.

Alam, M. M., and Kobir, M. M. (2017). Study and Analysis of 33KV Transmission Line Loss Calculation of Pabna Pbs-2. European Journal of Engineering and Technology, 5(4).

Al-Badi, A. H., Ahshan, R., Hosseinzadeh, N., Ghorbani, R., and Hossain, E. (2020). Survey of smart grid concepts and technological demonstrations worldwide emphasizing the Oman perspective. Applied System Innovation, 3(1), 5.

Alwaisi, Zainab and O. Agyeman, Michael. (2018). On the Challenges and Opportunities of Smart Meters in Smart Homes and Smart Grids. 1-6. *10.1145/3284557.3284561*.

C. Lo and N. Ansari, "The Progressive Smart Grid System from Both Power and Communications Aspects," IEEE Communications Surveys and Tutorials, 14(3), pp. 799-821, Third Quarter 2012, *doi: 10.1109/SURV.2011.072811.00089*.

Larul, An Analysis of Opportunities and Barriers of Integrating Renewable Energy with Smart Grid Technologies in India, Available online: *https://integrationworkshops.org/2019/wp-content/uploads/sites/14/2017/09/GIZ17_163_posterpaper_I_Arul.pdf*.

E. Bou-Harb, M. Debbabi, and C. Assi, "Cyber Scanning: A Comprehensive Survey," in IEEE Communications Surveys and Tutorials, vol. 16, no. 3, pp. 1496-1519, Third Quarter 2014, doi: *10.1109/SURV.2013.102913.00020.L*.

Gong, G., Zhang, Z., Zhang, X., Mahato, N. K., Liu, L., Su, C., and Yang, H. (2020). Electric power system operation mechanism with energy routers based on the QoS index under blockchain architecture. Energies, 13(2), 418.

H. Daki, A. E. Hannani, A. Aqqal, A. Haidine, A. Dahbi, Big Data management in smart grid: concepts, requirements and implementation, Daki *et al*. J. Big Data, 2017.

H. Shahinzadeh, A. Hasanalizadeh-Khosroshahi, Implementation of Smart Metering Systems: Challenges and Solutions, Telkomnika Indonesian Journal of Electrical Engineering, 12(7), 2014.

H. U. Zaman, M. M. H. Bhuiyan, M. Ahmed, S. M. T. Aziz, "A novel design of line following robot with multifarious function ability," International Conference on Microelectronics, Computing and Communications (MicroCom), January 2016.

Huebner, N., Schween, N., Suriyah, M., Heuveline, V., and Leibfried, T. (2020). Multi-area coordination of security-constrained dynamic optimal power flow in AC-DC grids with energy storage. Advances in Energy System Optimization, 27.

Hydrocarbon Unit, (2018). Energy Scenario Bangladesh, Hydrocarbon Unit Energy and Mineral Resources Division Ministry of Power, Energy and Mineral Resources, 2020, Available online: *http://hcu.portal.gov.bd/sites/default/ files/files/hcu.portal.gov.bd/ publications*.

J. Joy, E. A. Jasmin, V. R. John, Challenges of Smart Grid, International Journal of Advanced Research in Electrical, Electronics, and Instrumentation Engineering, Vol. 2, Issue 3, 2013.

Mendes, T. D., Godina, R., Rodrigues, E. M., Matias, J. C., and Catalão, J. P. (2015). Smart home communication technologies and applications: Wireless protocol assessment for home area network resources. Energies, 8(7), 7279-7311.

M. M. Uddin, A. Faysal, M. R. Raihan, K. M. Jahangir, Present Energy Scenario, Necessity and Future Prospect of Renewable Energy in Bangladesh, American Journal of Engineering Research (AJER), e-ISSN: 2320-0847 p-ISSN: 2320-0936, Vol. 7, Issue 8, 2018.

Moazzem, K. G. (2019). The power and energy sector of Bangladesh: Challenges of moving beyond the transition stage.

Moazzem, K. G., and Ali, M. (2019). The Power and Energy Sector of Bangladesh: Challenges of Moving beyond the Transition Stage.

Pavlovic, Sasa and Daabo, Ahmed and Bellos, Evangelos and Stefanovic, Velimir and Mahmoud, Saad and AL-Dadah, Raya. (2017). Experimental and Numerical Investigation on the Optical and Thermal Performance of Solar Parabolic Dish and Corrugated Spiral Cavity Receiver. Journal of Cleaner Prod. 150. *10.1016/j.jclepro.2017.02.201*.

Power Cell, (2021). Government of Bangladesh; Ministry of Power, Energy, and Mineral Resources; Power Division; Power Cell. Bangladesh Power Sector at a Glance.

R. Kappagantu, S. A. Daniel, Challenges, Issues of smart grid implementation: A case of Indian scenario, Daraz, Amil, *et al*. "Modified PID Controller for Automatic Generation Control of Multi-Source Interconnected Power System Using Fitness Dependent Optimizer Algorithm." PLoS One, vol. 15, no. 11, Public Library of Science, Nov. 2020, p. e0242428. Previously published in the Journal of Electrical Systems and Information Technology, 2018.

Rausser, Gordon and Strielkowski, Wadim and Streimikiene, Dalia. (2017). Smart meters and household electricity consumption: A case study in Ireland. Energy and Environment, 29. *0958305X1774138. 10.1177/0958305X17741385*.

S. M. Amin, Smart Grid: Overview, Issues and Opportunities, Advances, and Challenges in Sensing, Modeling, Simulation, Optimization and Control, European Journal of Control, 2011.

S. I. Shawon, M. M. H. Bhuiyan, T. P. Plateau. An Innovative Construction of Wheelchair for Handicapped Persons. International Journal of Science and Qualitative Analysis. Vol. 4, No. 1, 2018, 13-19. doi: *10.11648/j.ijsqa.20180401.13*.

T. Ali, A. A. Mansur, Z. B. Shams, S. M. Ferdous, M. A. Hoque, An Overview of Smart Grid Technology in Bangladesh: Development and Opportunities, International Conference and Utility Exhibition on Power and Energy Systems: Issues and Prospects for Asia (ICUE), 2011.

T. P Plateau, M. T. Islam, and N. Islam (2019). Potentiostat Electro-Deposited Cuprous Oxide and Cupric Oxide Thin Films for Photovoltaic Use. International Journal of Automotive and Mechanical Engineering. Vol. 16 No. 2. *https://doi.org/10.15282/ijame.16.2.2019.11.0498*.

T. P. Plateau, M. M. H. Bhuiyan. A heuristic proposition of efficient copper-electrodeposited p-type thin film for CZTS solar cell, International Conference on Electrical, Computer, and Communication Engineering (ECCE), Feb. 2017.

Yao, B. Yang, H. Cui, J. Zhuang, J. Y.E. J. Xue, Challenges, and signs of progress of energy storage technology its application in power systems, J. Mod. Power Syst. Clean Energy, 4(4), 519-528, 2016.