Efficient Power Transmission with Existing Grid System of Bangladesh

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Abstract—**Sustaining power quality with increasing demand is becoming a challenge to power engineers. Effective transmission and distribution of electrical power is the major concern all over the world. Existing grid system of Bangladesh utilizes about 49% of its capacity. It cannot run with its full capacity due to poor voltage regulation. IEC standard of voltage regulation is ±5% whereas power Grid Company of Bangladesh (PGCB) allows ±10% voltage regulation. It is shown that voltage regulation in some buses lower than the PGCB standard even though PGCB uses reactive power compensator to improve voltage regulation problems of the grid system. This paper demonstrates how voltage regulation improves by selecting suitable location of power compensator in the existing grid. Relation between voltage regulation and power consumption is also shown. If three power compensators relocate in the grid system, the voltage regulation increased on 32.62% of total load and no busses experiences voltage regulation lower than PGCB standard. Moreover, if the PGCB allows 464 MVAR more reactive power compensator, the voltage regulation of the power grid can achieve IEC standard (for the load connected in the year of 2012) and if PGCB redesign reactive power compensator it may reach IEC standard by 731 MVAR. The result shows in this paper is performed by ETAP software.**

Index Terms—**reactive power compensation, effective power transmission, voltage regulation, power grid of Bangladesh, PGCB, national grid**

I. Introduction

Bangladesh is presently facing shortage of power and there are always load shedding in some parts of the country. This is threatening to the agriculture, industry, commerce as well as the whole economy. Average 16 terawatts (TW) electric power is being used every moment throughout the world [1]. Generation of electricity is costly. Efficient use of electricity must be ensured. Now in Bangladesh maximum demand is about 7500 Megawatts (MW) or 7.5 Giga-watts (GW) [2] corresponding generated power is not enough to meet the present demand due to inadequate generation [2]. In the year of 1995, 2001, 2006, and 2012, installed power capacity was 2908MW, 4005MW, 5275MW, and 6693MW, respectively [3] and corresponding demand served (rated capacity) is lower than installed capacity. In Bangladesh increase of energy demand in recent years is noticeable than before shown in Fig. 1. Rising of energy demand is a tension to policy makers. To fulfill the commitment as declared in the Election Manifesto and to implement the Power Sector Master Plan 2010, Government has already been taken massive generation, transmission and distribution plan [3]. The generation target within 2016 is 13,154MW. When the present government takes charge, the power generation was 3,200 to 3,400MW against national demand of 5,200MW [3]. This government is able to add 2,944MW of power to the national grid within three years time period. According to goal of 2021, the forecasted demand would be 19,000MW and 34,000MW in 2030. To meet this demand the generation capacity should be 39,000MW in 2030.

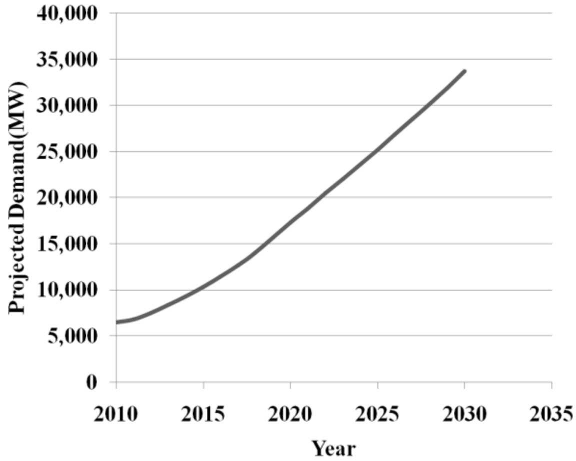

Figure 1. Forecasted energy demand of Bangladesh [2].

In recent the government has approved installation of five more coal-fired power projects by local private sector entrepreneurs having a combined capacity to generate 2,087MW of electricity. The Rampal power is a proposed 1320 megawatt coal-fired power station at Rampal upazila of Bagerhat district in Khulna. The proposed project will be the country's largest coal based power plant. Ruppur Nuclear Power Plant is a proposed 2,000 megawatt (MW) nuclear power plant of Bangladesh. It will go into operation by 2020 and will be the country's largest and first nuclear power plant. 500MW power is importing from India's grid to Bangladesh's grid. PGCB is the coordinator of the import

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process, said by the end of October-2013 around 250MW of power would be imported into Bangladesh. Another 250MW was expected to be imported from India‘s private sector by November this year [4].

The office of the Electrical Advisor and Chief Electrical Inspector (EA & CEI) emphasizes on thrift, simplicity and safety. It has been established, in order to ensure proper control of life and property in generation, transmission and distribution of electricity. The objective of Energy Monitoring Unit is to ensure efficient use of energy in industries and to induce energy conservation. Bangladesh Power Development Board (BPDB), Ashuganj Power Station Co., Ltd. (APSCL), Electricity Generation Company of Bangladesh Ltd. (EGCB), Rural Power Company Ltd. (RPCL), North West Power Generation Company Ltd. (NWPGCL), Independent Power Producers (IPPs) are work for generation. The responsibility is to operate the national power grid and to develop and expand the same with efficiency by Power Grid Company of Bangladesh (PGCB). The PGCB also handles the operation, maintenance and development of the transmission system of the country for distribution of generated electricity. The following entities are involved in power distribution: Bangladesh Power Development Board. (BPDB), Rural Electricity Board (REB), Dhaka Electric Supply Co., Ltd. (DESCO), Dhaka Power Distribution Co., Ltd. (DPDC), West Zone Power Distribution Co., Ltd. (WZPDCL), North West Zone Power Distribution Co., Ltd. (NWZPDCL), South Zone Power Distribution Company Ltd. (SZPDCL). REB is responsible for electrification in rural areas. As of today, there are 70 operating rural electricity co-operatives called Palli Bidyuit Samity (PBS), which bring service to approximately 79,00,000 connections. REB has expanded its distribution networks significantly in past years and has thus made immense contribution in increasing agricultural products and rural development as well as economic contribution. PGCB take new steps of 400kV line Meghnaghat-Aminbazar 400kV transmission line (NG1) to evacuate power from Meghaghat power station to western part of Dhaka. Bibiyana-Kaliakoir 400KV and Fenchuganj-Bibiyana 230KV transmission line (NG2) to build the power evaluation facilities for upcoming 2x450 MW at Bibiyana & to evacuate the surplus power of Sylhet area and also to supply adequate power to the northern part of Dhaka city [3].

The generated power is transmitted and distributed from generating station to consumer end through transmission and distribution line. During transmission and distribution a large amount of power is loss (15.38%) [3]. Due to the losses in lines causes the transmission efficiency lower, poor voltage regulation i.e. power quality is reduced. Reactive power compensation is one of the techniques for improving power quality. Existing grid is used 49% of its capability. Change in power grid is costly and matter of time. The capability, problems, possible solutions for optimum utilization of generated power with existing grid system is described on this paper.

Eight reactive power compensators are installed already in power grid of Bangladesh. But those are not sufficient enough. Existing grid can make more stable by relocating existing reactive power compensator. Relocating three reactive power compensators, existing grid can provide better voltage regulation across about 32.62% of total load. By placing new 464 MVAR distributed reactive power compensator existing grid can be improved to IEC standard. If we redistribute and add new reactive power compensator, minimum 731 MVAR might require to reach IEC standard voltage regulation.

In this paper Section II, III, IV described power system of Bangladesh (capability, problem). Section V described Rearrangement of Existing Grid of Bangladesh, making existing grid to IEC standard is shown in Section VI, Newly arranged reactive power compensator to make existing grid to IEC standard is shown in Section VII, results and conclusion is shown in next section. Simulation is performed by ETAP software.

II. Transmission Line in Bangladesh

The purpose of transmission line is to transfer electric energy from generating station to distribution substation. Most of the transmission lines of Bangladesh are short and medium transmission line [5]. Standard transmission voltages are established in the United States by the American National Standards Institute (ANSI) which is standardized at 69KV, 115kV, 138kV, 161KV, 230KV, 345KV, 500KV, and 765KV. Transmission voltage usually above 230KV is usually referred to as Extra High voltage. The existing transmission voltage levels in Bangladesh are 66KV, 132KV, 230KV, and 400kV (under construction) [6]. Transmission line of 132 kV is 6066.44 Circuit km and of 230kV is 2647.3 Circuit km [7]. When the length of overhead transmission line is up to about 50km and the voltage level is comparatively low (<20kV) is known as short transmission line. When the length of overhead transmission line is up to about 50-150km and the voltage level is moderately high (<20kV<100kV) is known as medium transmission line. When the length of overhead transmission line is up to more than 150km and the voltage level is high (<100kV) is known as long transmission line [8].

According to the definition in Bangladesh all of the transmission line voltage level is long transmission line category and in length is medium and long transmission line category. Existing power grid is shown below in Fig. 2.

III. Voltage Regulation

Voltage regulation is an important subject in electrical distribution engineering. It is the responsibility to keep the customer voltage within specified tolerances. The performance of a power system and quality of the service provided are not only measured in terms of frequency of interruption but in the maintenance of satisfactory voltage levels at the customers.

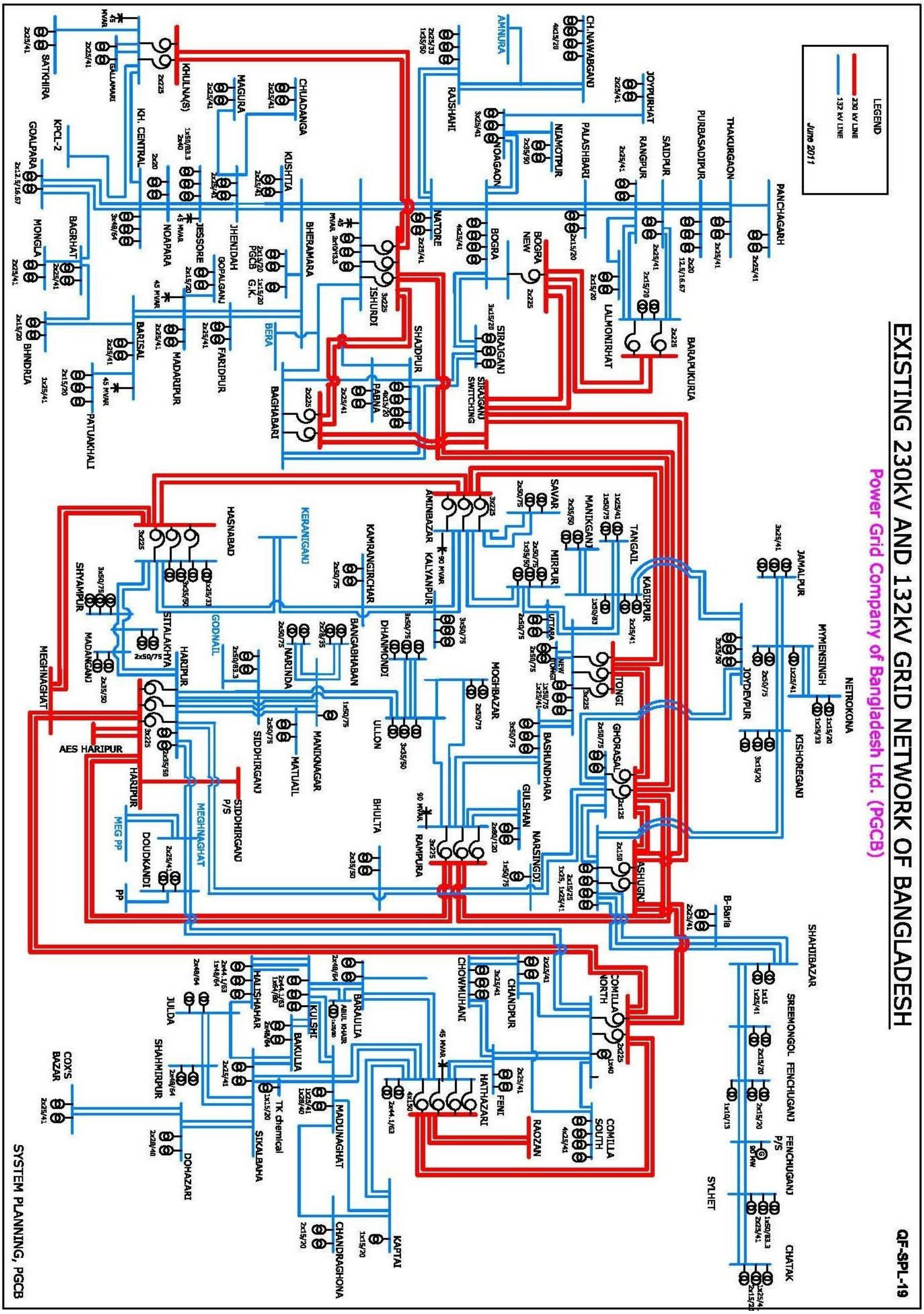

Figure 2. Power grid network of Bangladesh.

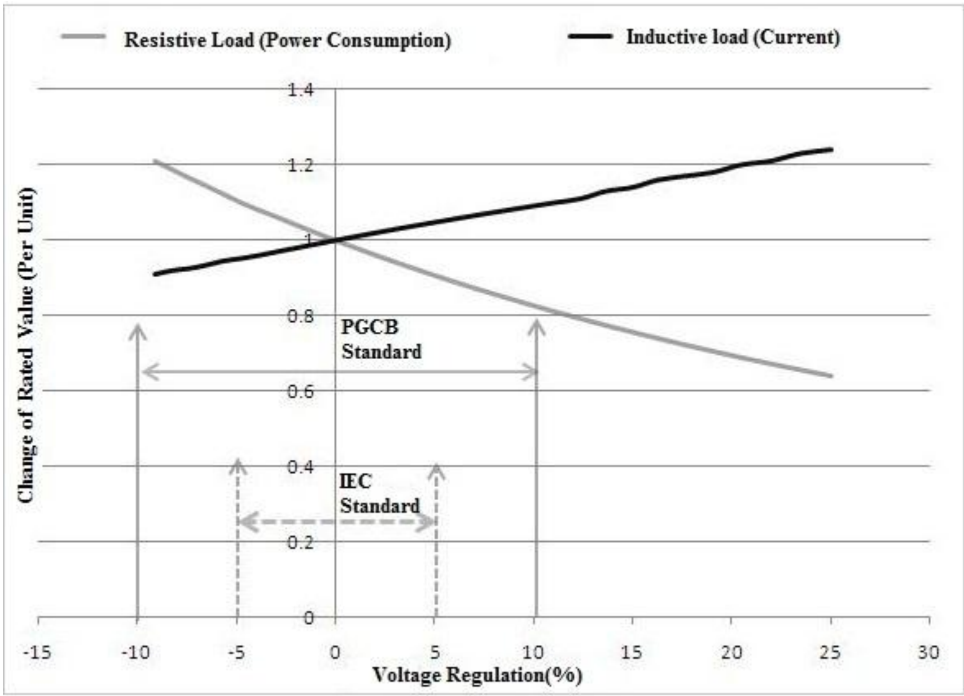

Figure 3. Behavior of resistive load and inductive load with voltage regulation.

According to Gonen [9] an over voltage can reduce lighting bulb life and reduce the life of electronic devices. On the other hand, a low voltage leads to low illumination levels, shirking of television pictures, slow heating of heating devices, motor starting problems, and overheating in induction motors. However, most equipment and appliances operate satisfactorily over some reasonable range of voltages. In resistive load power consumption become lower as shown in Fig. 3. When system voltage is less than rated voltage and higher for above the rated voltage, induction motors and synchronous motors power consumption is independent of voltage i.e. consume same power whether voltage is lower or higher than rated voltage. Over voltage can cause insulation failure of motor winding, low voltage can permanently damage the motor winding. Fig. 3 is obtained from simulation for resistive load and inductive load at different voltage from 110% to 80% of their rated voltage i.e. -9.09% to +25% of voltage regulation. IEC standard voltage regulation is ±5% and where in Bangladesh PGCB standard is ±10%. From the Fig. 3, it is clear that if generation is sufficient but due to poor voltage regulation in bus, equipment cannot run at full power rating although generating unit has capability.

A. Real Power

Real power is output power of a utility or electrical equipment i.e. heat, light, radiation, vibration, rotation etc.

B. Reactive Power

Reactive power is required to work real power effectively. Reactive power represents the energy that is first stored and then released in the magnetic field of an inductor, or electrical field in capacitor. Reactive power is used to provide the voltage levels necessary for active power to do useful work [10].

C. Limitations of Reactive Power

Although reactive power has great importance on voltage control of power system but it cannot travel far. Flowing of reactive power causes loss of real power. The capability of transmission line is limited by the current carrying capacity of the conductor. If more reactive power supplied through the transmission line it will limit the real power flow and causes more real power loss [11].

D. Transmission Efficiency

The power obtained at the receiving end of a transmission line is less than the sending end power due to losses in the line. The ratio of receiving end power to the sending end power of a transmission line is known as the transmission efficiency of the line [8], [12].

Percentage (%) efficiency

$$= \frac{Receiving\ end\ power}{Sending\ end\ power} \times 100$$

$$= \frac{V_R I_R \cos \varnothing_R}{V_S I_S \cos \varnothing_S} \times 100$$

where, $V_R, I_R, \cos\varnothing_R$ are the phase voltage, current and power factor at receiving end of transmission line respectively. $V_S, I_S, \cos\varnothing_S$ are the sending end phase voltage, current and power factor, respectively. Receiving end real power [11] is given by

$$P_R = \frac{V_S V_R}{B}\cos(\beta - \delta) - \frac{AV_R^2}{B}\cos(\beta - \alpha)$$

The receiving end reactive power is represented by

$$Q_R = \frac{V_S V_R}{B}\sin(\beta - \delta) - \frac{AV_R^2}{B}\sin(\beta - \alpha)$$

E. Short Transmission Lines [8]

A = 1, B = Z, β ≈ 90°, α ≈ 0°.

Hence, $\cos(\beta - \alpha) = 0$

$$P_R = \frac{V_S V_R}{B}\cos(\beta - \delta) - \frac{AV_R^2}{B}\cos(\beta - \alpha)$$
$$= \frac{V_S V_R}{B}\cos(\beta - \delta)$$
$$= \frac{V_S V_R}{B}\cos(90 - \delta)$$
$$= \frac{V_S V_R}{B}\sin\delta$$

For constant load V_S, δ and B are constant.

Hence,

$$P_R \propto V_R$$

Receiving end real power is proportionally related with receiving end voltage.

Receiving end reactive power [13]

$$Q_{R(max)} = \frac{V_S V_R}{B}\sin(\beta - \delta) - \frac{AV_R^2}{B}\sin(\beta - \alpha)$$

At maximum load, β = δ

$$Q_{R(max)} = -\frac{AV_R^2}{B}\sin(\beta - \alpha)$$

Hence,

$$Q_{R(max)} \propto V_R^2$$

Receiving end reactive power is square proportional of receiving voltage. Here real power and reactive power (P_R, Q_R) both are function of V_R. Similarly same result can obtain for medium and long transmission line.

IV. Power Grid System of Bangladesh

A. Capability of Existing Power Grid System

The maximum power can be transmitted or received through a line is known as power handling capability.

Power handling capability of transmission line,

$$= \sqrt{3} V_L I_L \text{ VA}$$

where, V_L, I_L are rated voltage and maximum current capacity, respectively, of conductor.

Power handling capacity depends upon some factors such as length of cable, thermal withstand capability, weather condition. One cable can transfer different power at different voltage level. In this paper total interconnected grid system capability equal to transformer MVA rating of entire grid system which is 15821MVA [7]. It is a fact that, the national grid of Bangladesh is transferred maximum of 7852MVA, which is 49% of the existing capacity of the connected equipment of the system (6675.00MW at 0.85 p.f) [2]. On the other hand, the reserve capacity of the equipments is 7968MVA, whereas 51% of the existing capacity of the grid (shown in Fig. 4).

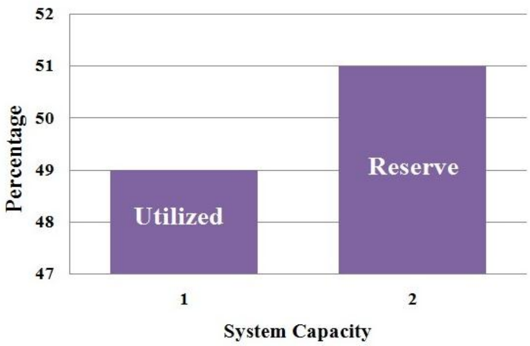

Figure 4. Equipment used in the system and reserve capacity.

B. Existing Grid System Problem

- Low power factor
- Most of the reactive power generated at power plant
- Most of the Generators are concentrated in a place.
- Existing Capacitive bank (reactive compensator) is not enough to compensate the reactive power.
- Generating stations are far from load centre. Line current is high for carrying reactive power.
- Generation of real power is reduced due to generation of excess reactive power.

From the above study it is clear that although PGCB grid has capability of handling much power but it cannot transmit power effectively.

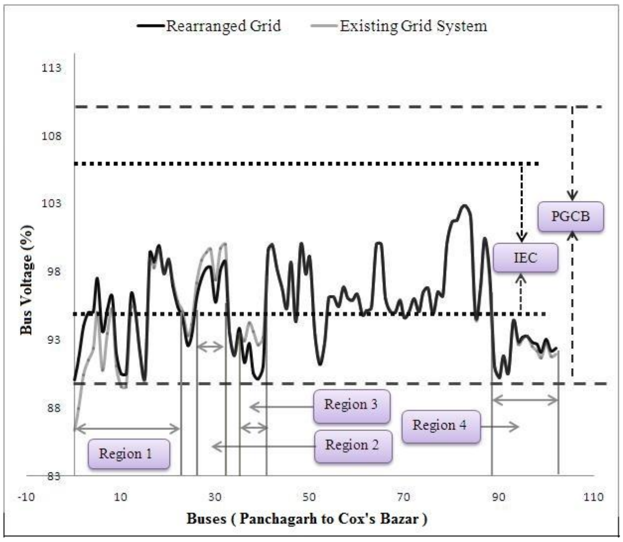

Figure 5. Comparison of modified system and existing system

V. Rearrangement of Reactive Power Compensator of Existing Grid

Eight substations contain capacitor bank in national grid of Bangladesh. Total capacity is 450 MVAR. Ishordi, Khulna South, Jessore, Barisal, Madaripur and Hathazari have single 45 MVAR capacitor bank and Aminbazar and Rampura have two 45 MVAR capacitor bank. Simulation result shows that Panchagorh, Thakurgoan, Niamotpur, Joypurhat and Cox-bazar grids' voltage level is below PGCB standard. In this paper three capacitor banks is rearranged or relocated from Khulna to Saidpur, Madaripur to Bhandaria and Hathazari to Khulsi. Performance comparison between rearranged and existing grid is shown in Fig. 5. The graph is plotted for all buses in Bangladesh.

A. Region 1

In region 1, modified system shows better performance over existing system. About 11.93 % of total load is connected in this region. In existing grid system some of the buses are below of PGCB voltage regulation standard but in modified grid system all the buses within PGCB standard limit. The voltage regulation in region 1 is better than existing system. Region 1 contains Panchaghar, Thakurgaon, Purbasadipur, Bogra, Bogra new, Saidpur, Rangpur, Barapukuria, Lalmonirhat, Natore, Palashbari, Noagoan, Niamotpur, Joypurhat, Rajshahi, Chapai Nawabgonj, Sirajgong Switching, Sirajgong, Shahjadpur grid [14].

B. Region 2

In region 2, modified system performance slightly degrades. About 4.42% of total load is connected in this region. Despite of this degradation, it has no significant effect on grid. Because in this region, the voltage regulation is within IEC standard limit as well as PGCB standard limit. All bus voltage magnitude is above 95%. Region 2 contains Noapara, Khulna South, Khulna Central, Satkhira, Gallammari and Goalpara grid.

C. Region 3

In region 3, modified system performance is degraded. About 5.55% of total is connected in this region. In existing system, all the bus voltage regulation within PGCB standard. In modified system all bus voltage regulation is also within the PGCB standard. It has slight effect on grid. Region 3 conatains Patuakhali, Barishal, Madaripur, Gopalgong, Faridpur, Baghabari, Mymensingh RPCL, Mymensingh and Bagherhat grid.

D. Region 4

In region 4, modified system performance is considerably better than the existing grid system. About 20.69% of total load is connected in this region. In this region all bus voltage is increased. Region 4 contains comilla north, Comilla south, Chandpur, Feni, Chowmohuni, Hathazari, KSRM, Baraulia, Madunaghat, Abul Khayer, Khulsi, Halishohor, Shikalbaha, Julda, Shahmirpur, Dohazari and Coxbazar grid.

E. Result

Although modified grid system have slightly less performance in region 2 and region 3, but significant effect on region 1. In modified grid system all the buses in region 1 is within the PGCB limit which was not in existing grid system. The load contribution of region 1 is more than the sum of region 2 and 3. In region 4, system is more reliable and stable. So, it is clear that the modified grid system has better performance than existing grid system.

VI. Proposal for Making Existing Grid to IEC Standard

In this paper simulation is performed for 4523MW (consider base load). Peaking power plant in Saidpur, Rangpur is in service. To improve the power grid voltage regulation into IEC standard, reactive power compensator is distributed throughout the grid. A table of distributed reactive power compensator is given below which is performed in simulation. In this paper MVAR per capacitive bank is 7MVAR and 10MVAR for switching convenient. Minimum 464MVAR is required existing grid improved to IEC standard. The grid response is shown in Fig. 6. Approximate reactive compensator required is shown in Table I.

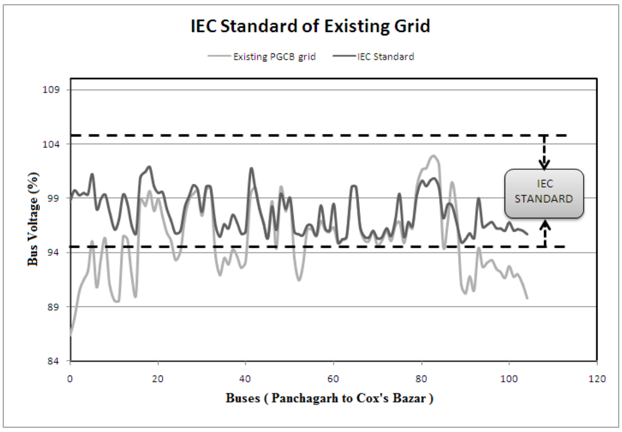

Figure 6. Comparison of IEC standard of existing grid.

TABLE I. Existing Grid to IEC Standard

Grid Name	Required MVAR	Grid Name	Required MVAR
Joypurhat	14	Niamotpur	14
Noagoan	40	Manikgong	20
Mongla	10	Joydevpur	30
Patuakhali	7	Ullon	20
Bhandaria	7	Dhanmondi	30
Kabirpur	30	Khulsi	30
Tangail	28	Halishahar	28
Bagherhat	10	Dohazari	7
Chuadanga	7	Coxbazar	14
Ch. Nawabgong	20	Comilla South	40
Rajshahi	10	Chandpur	28
Total	464 MVAR		

A. Result

Existing power grid have total 450 MVAR reactive power compensator and additional 464MVAR i.e. 914 MVAR can be made grid to IEC standard.

VII. Newly Design Reactive Compensator for Making Existing Grid to IEC Standard

In these section reactive compensators is distributed among all bus including existing reactive compensators. The grid response is shown in Fig. 7. Table shows required minimum MVAR to achieve IEC standard. Approximately minimum 731 MVAR may be required to reach IEC standard is shown in Table II.

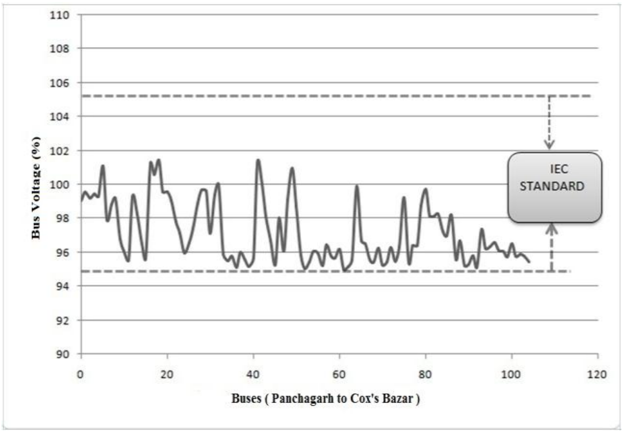

Figure 7. Newly design grid response

TABLE II. NEWLY DESIGN REACTIVE POWER COMPENSATOR

Grid Name	Required MVAR	Grid Name	Required MVAR
Noagoan	20	Manikgonj	14
Niamotpur	7	Savar	10
Natore	7	AminBazar	40
Rajshahi	14	Shampur	7
Ch. Nawabgonj	7	Dhanmondi	40
Jhinaidoh	21	Moghbazar	20
Chuadanga	7	Rampura	40
Magura	7	Comilla South	50
Jessore	20	Chandpur	28
Mongla	7	Feni	10
Bhandaria	10	Chowmohuni	10
Patuakhali	10	Hathazari	20
Barishal	28	Baraulia	10
Madaripur	30	Khulsi	50
Gopalgong	7	Halishohor	20
Faridpur	14	Julda	30
Joydevpur	21	Dohazari	7
Kabirpur	50	Coxbazar	10
Tangail	28	Manikgonj	14
Savar	10		
Total	731 MVAR		

A. Result

In new design 731 MVAR is required. It saves 183 MVAR less compared to earlier design.

VIII. CONCLUSION

Energy demand and supply is increasing, reliability and efficiency are ongoing problems. 49% of existing grid is used up to now. Reactive power compensator can improve voltage regulation problem and make system stable. Relocation of three capacitor bank can improve voltage regulation across 32.62% of total load and degrade voltage regulation across 9.97% of total load. Where 4.42% load is within the IEC standard. Placing distributed reactive power compensator (minimum 464MVAR total 914 MVAR) can improve existing grid to IEC standard. Minimum 731 MVAR is required to reach IEC standard for newly design compensation system.

Simulation results demonstrate the effectiveness of the proposed system. Proposed modification and placing proper size of reactive power compensator make system stable and can provide increasing power demand by existing power grid without compromising the power quality.

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