An approach to demand side load curtailment for the future intelligent and smart power grid of Bangladesh

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An Approach to Demand Side Load Curtailment for the Future Intelligent and Smart Power Grid of Bangladesh

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Abstract—**Smart Grid, the future of the present electric grid has become one of the burning issues in energy and power industries and research. Being a developing country, Bangladesh has not yet taken any remarkable initiative regarding smart grid. Whereas, there is a strong possibility that a careful adaption of modern electric grid could significantly improve the present dissatisfaction among the consumers due to interrupted supply of electricity. Load shedding is the traditional approach of balancing supply and demand through scheduled power cut off. But in Bangladesh, customizing the load shedding through smart power grid, user satisfaction could be greatly improved. In this paper, an approach to smart grid and demand side load curtailment (DSLC) is proposed to reduce peak load for customizing load shedding and thus optimizing consumer satisfaction. Here, demand side load curtailment will be a key component of future smart grid that can help reduce peak load, reshape the load profile and adapt the increasing demand to generated power with the massive deployment of smart meters. DSLC empowers the load curtailment rather than full cutting off the power line. The proposed technique categorizes the consumers into three categories namely High, medium and low consumption users based on their consumption history and load profile. Moreover, the home appliances of the consumers of different categories also divided into three more categories namely high load, medium load and low load. Smart meter that every consumer owns is responsible for communicating with the different appliances connected and clustering them into appropriate category based on prior load threshold information provided. This paper describes a way to reduce the pick load selecting the victim consumer list and curtailing load in real time environment providing the consumer a minimum support rather than complete power cut off and thus optimizing the user satisfaction. To observe the various aspects of the model an experiment has been demonstrated in the paper.**

Keywords— Smart Grid in Bangladesh, Intelligent Load Management, Demand Response, Demand Side Load Management, Victim Consumer List, Load Shedding in Bangladesh.

I. INTRODUCTION

Bangladesh is a power starved nation and there is a considerable gap between demand and supply that is persistent for years after years and anticipated to continue for the next half of a century. Electricity demand is increasing every year surpassing generation capacity and distribution capabilities. Building new power station is not so easy in the current situation of Bangladesh. Moreover, there is lack of fuel energy in Bangladesh and power stations need wide amount of fuel every hour. This insufficiency of fuel will continue unless the nuclear power station becomes operational. But Nuclear power station incurs several threat to the safety of human and environment. For the lacking of power generation against the demand, [1] the severity of load-shedding is increasing day by day in Bangladesh. At the time of load-shedding the total power supply of a certain area is switched off. As there is no electricity supply at that time, the entire area goes into dark.

Our present electric network is the century old one way network and incurs many system losses. The world is waiting for a break to this century old energy network. For a sustainable intelligent ICT enabled two way and more interactive power network, the future of our electric transmission and distribution system, is undoubtedly walking towards a new paradigm called “Smart Grid” that ensures greater well-being for both utilities and consumers.

Smart Grid [2] represents a vision of the future power systems integrating advanced sensing technologies, control methodologies and communication technologies at transmission and distribution levels in order to supply electricity in a smart and user friendly way. Enabling informed participation by customers, accommodating all generation and storage options, optimizing asset utilization and operating efficiently, addressing disturbances through automated prevention, containment, and restoration and operating resiliently against all hazards are some of the objectives of the smart grid [3]. Smart Grid is relatively a new concept in Bangladesh [4].

Smart Metering System, an integrated part of smart grid, has some outstanding features such as control of energy usage, saving of electricity bill, control of load usage, continuous monitoring of the total system, self-healing capability, smart display system, use of modern devices, reliable communication between generating unit and consumer end etc [2]. Many developed nations like Australia, USA, China,

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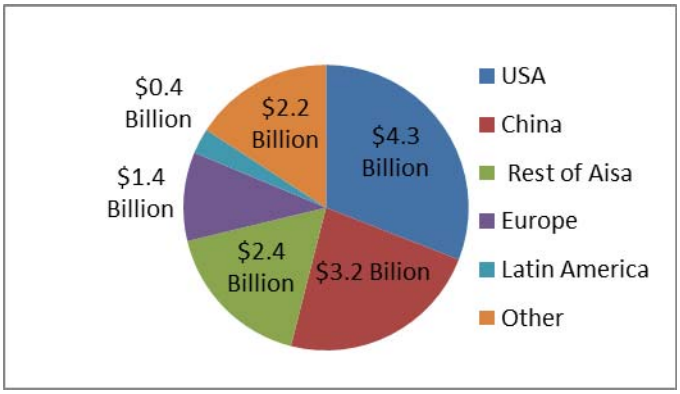

Fig 1: Investment on Smart Grid by region, 2012 [5]

Japan, Sweden etc. have started using Smart Metering System in order to achieve energy efficiency of the whole power system. The AMI (Advanced Metering Infrastructure), Automated Meter Reading (AMR) and Automated Meter Management (AMM) are solving electricity related problems around the world being the integrated part of smart grid. The chart in Figure 1 depicts the investment on smart grid for the year 2012 across the world [5].

With the feature of its control of the load usage, Smart Metering System is capable of minimizing the power crisis of Bangladesh. If selective load cut off is made possible instead of total load cut off at the time of peak demand or shortage supply, is it possible to avoid total black-out [1]. Therefore, consumers can be serviced with low loads like fan, light etc. during the scarce situation and thus improving consumer experience and satisfaction. There is research problem of selecting the Victim consumer [1] list for selective load cut off when deploying intelligent load management. This paper demonstrates an approach for selecting victim consumer list for demand side load curtailment to reduce the demand and supply gap.

In the next section of the paper discusses up-to-date research on the field. In section 3, customization of load-shedding using demand side load curtailment is elaborated. Section 4 describes the experimental setup and analysis. Finally a conclusion is drawn at the end section.

II. RELATED WORKS

Smart energy management is a burning topic in the field of power and energy research. Lots of research works have been carried so far. Demand side management (DSM) [3], is a most popular technique for energy management of the future smart grid. DSM supports smart grid functionalities in various areas such as electricity market control and management, infrastructure construction, and management of decentralized energy resources and electric vehicles. Controlling and influencing energy demand can reduce the overall peak load demand, reshape the demand profile, and increase the grid sustainability by reducing the overall cost and carbon emission levels. Efficient demand side management can potentially avoid the construction of an under-utilized electrical infrastructure in terms of generation capacity, transmission lines and distribution networks.

A heuristically defined demand side management strategy has been proposed based on load shifting technique for demand side management of future smart grids [3]. In [6] authors have focused in novel stochastic framework leveraging distributed storage using energy routing algorithm. Here focus on maximize the use of existing power-line resources. Someone want to generate new power without installing the new generation sources and use this efficiently using different programs [7]. [8] Studies the user preferred loads at different time and use a real time pricing algorithm to optimize energy consumption levels. [9] Uses an approach of demand response using the distributed algorithm and optimally schedule the power consumption of the household appliances to create the dynamic pricing system on a demand response. There are many things related with smart grid. [10] Discusses the internet concepts for smarten the grid. [11] focuses on the smart grid technique and it considers some key terms that are advanced metering infrastructure(AMI), meter data management, geographical information system(GIS), Enterprise Asset management, distribution automation, customer relationship management(CRM), automated call center, utility portals, demand response, renewable energy. [12] Considers a system which helps the consumer to control and optimize the energy consumption level by improving the way of using energy and available resource. [2] Describes about the problems of power distribution and the perspective of smart grid and its use in Bangladesh. [4] Studies the use of sensors, communications, computational ability and control with the smart grid for solving the major problem of electricity and overloading of system components, poor planning of Distribution network, power theft, corruption etc. Most of the works focuses over the power and energy consumption scenario of the developed countries. A very few works mainly literature survey have been done considering the power networks of Bangladesh. An intelligent load management technique has been proposed in [1]. This paper extends the works in [1] designing a demand side load curtailment technique that finds the victim consumer list based on the real time load management.

III. SMART GRID LOAD CURTAILMENT

With the growing population of Bangladesh, the demand for electricity is ever increasing. It is not possible to combat this huge demand only through establishing new power plants due to the fact that power plants require a large initial investment and a continuous maintenance for its sustainable. Moreover, power plants are a potential source of carbon emission which is a threat for our environment. So demand side selective load curtailment is feasible way to reduce the gap between demands and supply that is currently being achieved through the means of load shedding. But the problem with load Shedding is that it makes part of a network to go completely dark. Whereas it is possible to provide a sufficient amount of lighting and fan though the careful design of demand side load curtailment strategy based on smart power grid and smart metering infrastructure. In this paper, a system model is described along with some algorithms that are integrated to achieve the demand side load curtailment and customization of load shedding. The proposed technique is based on some assumptions that there is a strong secure communication network present to connect the metering facilities from consumer end to the distribution end. That means the grid operator has a direct control over the consumer meters to direct the meter behave accordingly. The smart meter at the consumer end has the direct control over the home appliances using Home Area Network (HAN). That means the smart meter could control the appliances to operate in various mode and speed and also could shut them down when necessary to curtail the total consumption. Smart meters are capable of clustering the appliances into predefined categories and have responsibility to provide real time consumption and price information when requested from distribution end.

IV. PROPOSED DEMAND SIDE LOAD CURTAILMENT

Demand Side Load Curtailment (DSLC) is a technique which is the key component of the whole system considered to be the alternatives for Load shedding. It helps to reduce peak loads and control the demands against the present supply. When Current demand (Dc) if greater than current supply (Sc) i.e. $D_C > S_C$, it is necessary to shed some loads to attain the stability of the power system. Traditional Load Shedding does this by cutting off the entire supply to some scheduled areas. Whereas, DSLC performs the task by selective cut off that means cutting off the heavy consumption load interacting with consumer meters directly.

Fig. 2(a) depicts the trends of demand and supply at different times of the day in Bangladesh. It clearly shows the gap between demand and supply. Figure 2(b) entails the demand and supply curve for peak hours. In Bangladesh peak hours are normally considered from 5 pm to 11 pm [13].

Consider a smart power distribution system which consists of power substations, thousands of consumers, and smart meters. Substations can control the loads through the smart meter using the bi-directional communication. Each smart meter at the consumer side is connected with the smart grid. The smart

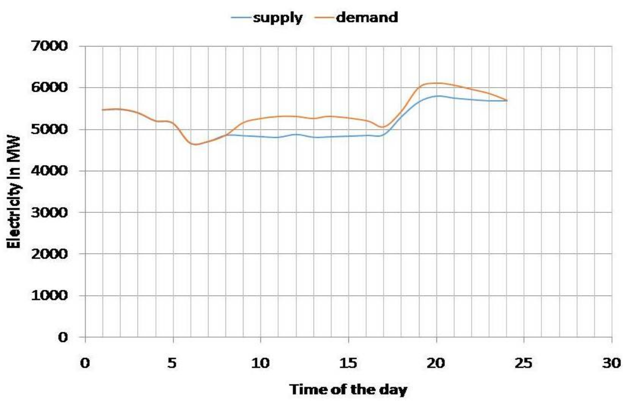

Fig 2(a): Trends of demand and supply at different times of the day for 4th September, 2013

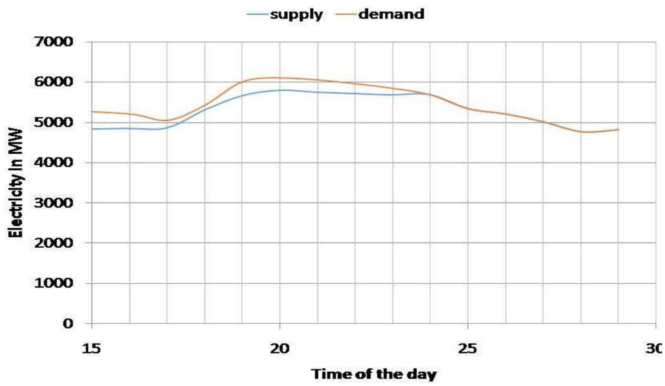

Fig 2(b): Trends of demand and supply for the pick hour (1700-2300) at 4th September, 2013.

meter is operating on two mode i.e. normal mode and the power saving mode. In Normal Mode, the consumer is provided with full supply of electricity [1]. The operational flow diagram is depicted in Fig. 3. But in Power Saving Mode the smart meter selects the load types which will be getting supply at that time of power saving mode.

DSLC's main objective is to bring the demand curve below or equal to supply curve. For doing this, demand side management system will control the loads through the smart meter and will cut the loads at the time of power Scarcity. The Strategy proposed in this paper will select the victim consumer and their loads on the basis of some real time consumption information and consumption history. The proposed technique categorizes the consumers into three categories namely High, medium and low consumption users based on their consumption history and load profile. Moreover, the home appliances of the consumers of different categories also divided into three more categories namely high load, medium load and low load. Fig. 4 shows the categorization for the proposed approach.

For notifying the decision of smart meter about load cut off to the smart appliances, the smart meters generates control signals and sends to the each type of loads.

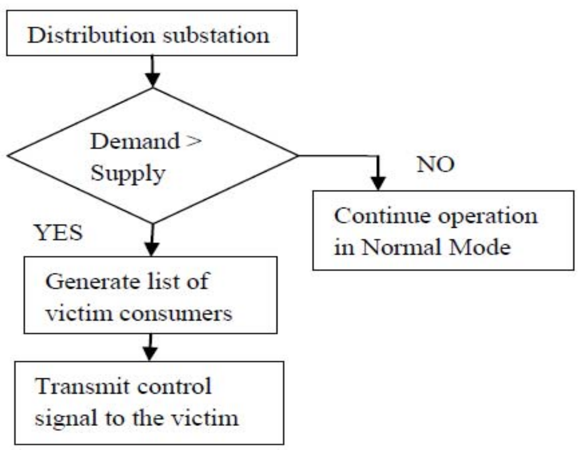

Fig 3: Flow Diagram for the Load Curtailment [1]

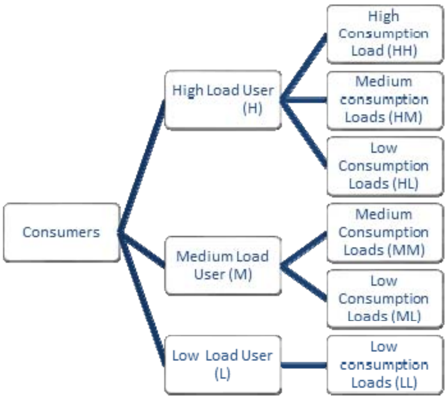

Fig 4: Load and Consumption based categorization of Consumers and appliances

There have been many different constraints that have to be satisfied when generating a list of victim consumers. There might be situation that demands continuous power supply provided special request and permission. This entire criterion have to be considered and ensured that the all the consumers must have at least lighting and fan at a minimum extent at the time power scarcity.

Similar works have been done considering the situation in developed countries. But in Bangladesh, this situation is even worse and need a continuous treatment as there is always a shortage of supply. Therefore selecting consumer list ensuring no consumers starve for a long time is challenging.

Fig. 5(a) shows the stack of loads at different times of the day while there is sufficient power supply to meet the demand. Here, Temporary Connection Load (TCL) is unscheduled load and Requested Uninterruptable Load (RUL) are also unscheduled load that cannot be interrupted for a specific duration. Other notations are mentioned in the Fig. 4.

Fig. 5(b) represent the current situation when demand surpasses the supply and needs to shed some loads. In this figure, at time duration from t2 to t3, we see a load shedding indicated with orange color. Similar cases happened at the time duration t4 to t5, tn+1 to tn+2 and so on. The problem with this approach is that at the time of load shedding all the loads at a particular region is cut off and the whole area goes under dark.

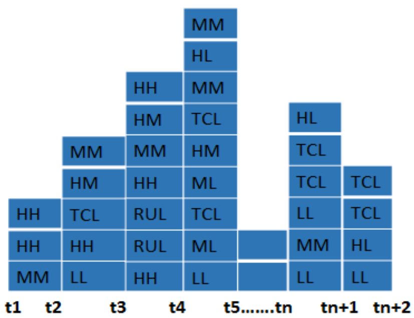

Fig 5(a): General situation of loads when no need load-shedding.

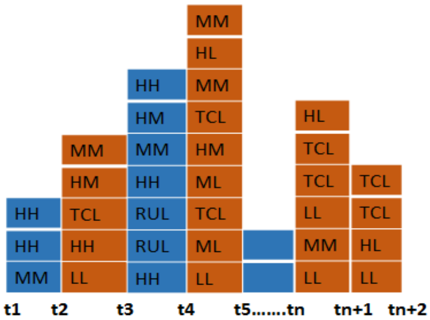

Fig 5(b): Present situation of load at the load-shedding

In Fig. 5(c), it is shown that though at the time duration t2 to t3 demand surpasses supply, it is feasible to cut off the high loads rather than total black out, yet balancing the demand and supply ratio. Only the loads that have been shaded with orange color are cut off. For cutting off the loads, a predefined sequence is maintained shown as below:

HH -> HM -> MM

This sequence means that high consumption loads(HH) of high load users(H) is considered first then eventually high consumption loads(HM) of high load users(H) and finally medium consumption loads(MM) of Medium load users(m) are considered. This sequence is maintained so that every consumer is at least served with their low consumption loads. This is also ensured that no consumer is starved for power forever.

The following steps depict the whole process of demand side Load curtailment for the Fig 5(c):

Case 1: At time t2 to t3, HH loads are cut off at first and then HM considered. If it is seen that the demand and supply gap is diminished there is no need to cut off other loads.

Case 2: At time t_3 to t_4, there are some Requested Uninterruptible Loads (RUL). In this case, to remove the demand-supply gap rest of the loads are encounter similar to case 1 and make a balanced situation.

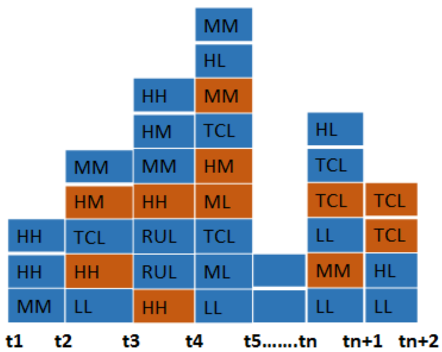

Fig 5(c): Situation of loads when using our proposed algorithm

Case 3: At time t_4 to t_5, to balance the demand-supply gap at first HM loads are cut off and then cut off the low priority load BM.

Case 4: At time t_n to t_{n+1} at first, cut off the MM. It might be case (worse) that the supply and demand cannot be balanced and also there is no such high or medium load which loads can be cut off, then TCLs are cut off on the basis of their request and consumer priority.

Case 5: At time t_{n+1} to t_{n+2}, it is not possible to balance supply and demand without total load shedding. All the RULs are cut off first, then HLs, MLs, LLs are cut off to get system stable.

The proposed DSLC algorithm is for selecting the victim consumer who will get power cut at the load-shedding time. There is bi-directional communication system between the substation distribution side and consumer side as shown in Fig. 6.

Distribution center requests smart meters to send the current load profile of the consumers. Smart meter send the requested information containing consumer Identification number, amount of loads consuming for each categories of loads i.e. high load, medium load and low loads etc.

To reduce the execution overhead the whole process is divided into two parts. One is offline and another is real time.

A. *Offline part*

The flow diagram at Fig. 7 depicts the offline parts. This flow chart (Fig. 7) shows the technique that verifies different criterion and selects and sorts the consumers who are to be candidate for next round. The candidate consumers are indicated with status=1 and other consumers who have are not selected to be candidate are set with status=0.

B. *Real Time part*

The real time part of the process is shown in Fig. 8. This portion of the algorithm mainly works based on the real time consumption information received from smart meter upon request and use DSLC strategy to select the victim user list and thus perform selective load curtailment.

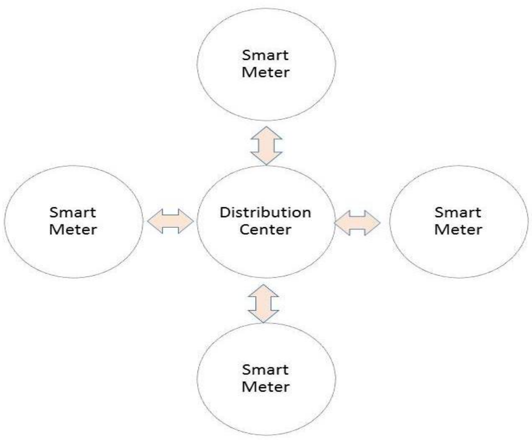

Fig 6: Bi Directional Communication between Distribution Center and Smart Meters.

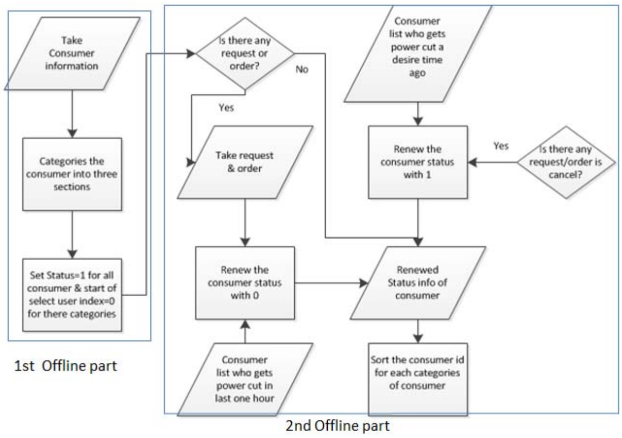

Fig 7: Working Flow Chart of the Proposed Demand Side Load Curtailment

V. EXPERIMENTAL RESULT ANALYSIS

To investigate the feasibility of the model, a simulation based experiment has been conducted. The demonstration has been written in C++ and using the existing the functionalities a number of consumers have been generated randomly with a random load profile. This experiment demonstrates when integrated with smart grid, how there will be the selection of victim consumer list to achieve the demand side load curtailment. For this experiment, it is considered that the consumers are belongs to a single substation.

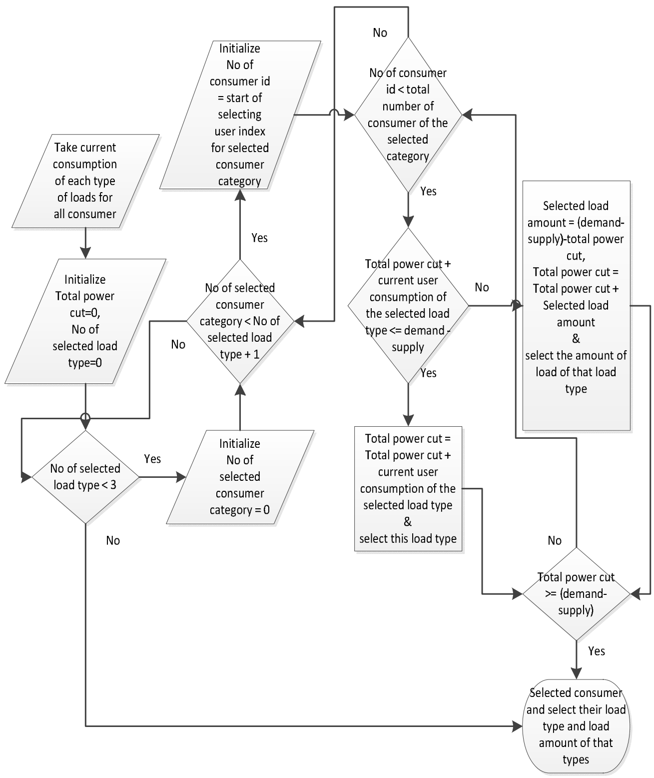

Figure 8: Real time portion of the process to select the victim consumer list.

The number of consumers, categories of consumers and their load profile that have been considered for the experiment are listed below.

The experiment has been conducted over different set of consumers generated randomly and results are averaged to get a glimpse of the system model and its effectiveness. The nature of the data is shown in table 1. The data depicts the different categories of consumers along with different types of loads for each consumer. The table also listed the percentage of consumer who are currently using which types of loads. For example 26.24% of high load users are consuming loads that are consuming 1500-2000W.

The technique has been applied to the generated data set along with a varying demand and supply. The output is analyzed to see if the technique successfully finds the victim consumer list to curtail the loads for balancing the demand and supply.

TABLE I: Consumer Categorization and Load Profile

User Category	Load category	Wattage usage	Percentage of consumer falls in each category
High Consumption Users (H)	High Load(HH)	1500-2000	26.24
		2001-2500	25.02
		2501-3000	23.89
		3001-3500	23.78
		3501-4000	1.06
	Medium Load(MM)	400-600	31.23
		601-800	30.79
		801-1000	30.39
		1001-1200	7.58
		1201-1500	0
	Low Load(HL)	0-100	21.87
		101-200	43.14
		201-300	34.99
		301-400	0
Medium Consumption Users(M)	Medium Load(MM)	400-600	19.90
		601-800	19.27
		801-1000	19.63
		1001-1200	19.39
		1201-1500	21.81
	Low Load(ML)	0-100	17.38
		101-200	34.27
		201-300	34.09
		301-400	14.06
Low Consumption Users(L)	Low Load(LL)	0-100	14.78
		101-200	28.67
		201-300	28.37
		301-400	28.16

Following table shows the outcome of the proposed approach for 6 consecutive curtailments.

TABLE II: NO OF VICTIM CONSUMER SELECTED AT DIFFERENT TIMES

SL	Total consumer	Total Demand (MW)	Total supply (MW)	Deficit (MW)	No of victim consumer			No of user repeated
					H	M	L	
01	49810	14	1	13	6052	0	0	0
02	49810	14	6	8	3728	0	0	0
03	49810	14	8	6	525	4990	0	0
04	49810	14	7	7	0	7702	0	0
05	49810	14	9.5	4.5	0	4918	0	0
06	49810	14	3.55	10.45	1397	8294	0	1397

The demand and supply are chosen to reflect the general and worst case scenarios. From the table 2, it is seen that for a deficit of 13 MW, 6052 high load users are cut off from their high loads like and all the consumer are provided with medium and low loads operating.

VI. CONCLUSION

Smart Grid is definitely revolutionizing the 21st century's power grid integrating the information and communication technologies with electric network. It would greatly help the nation to build most powerful and intelligent modern power grid. Though the authority is concerned about the advancement there is not yet any remarkable initiative to embrace the blessings of smart grid in Bangladesh. Demand side load curtailment is technique that works in smart grid environment and achieves balance between demand and supply through selective load cut off rather than complete load shedding that eventually reduce the dissatisfaction presents energy sector of Bangladesh. This paper demonstrates the feasibility of employing DSLC to improve the current load management.

REFERENCES

[1] Monalisa C. Urmi and Bishnu Sarker, "Optimizing User Satisfaction With The Blessings Of Intelligent Load Management And Smart Metering Through Customization Of Load-Shedding In Bangladesh", In Proc. of International Conference on Engineering, Research. Innovation and Education (ICERIE), CD-ROM, Sylhet, Bangladesh, 2013

[2] Jamal T. and Ongsakul, W., "Smart Grid in Bangladesh power distribution system: Progress & prospects," Students Conference on Engineering and Systems (SCES), pp. 16-18, March 2012.

[3] *U.S. Energy Infrastructure Investment: Large scale Integrated Smart Grid Solutions with High Penetration of Renewable Resource, Dispersed Generation, and Customer Participation',* White Paper, U.S department of Energy, *March 2009*.

[4] Ali, T., Al Mansur, A., Bin Shams, Z., Ferdous, S.M., and Hoque, M.A., "An overview of smart grid technology in Bangladesh: Development and opportunities," International Conference and Utility Exhibition on Power and Energy Systems: Issues & Prospects for Asia (ICUE), pp. 28-30 Sept. 2011.

[5] Smart Grid Technologies Continue To Spread (Smart Grid And Energy Storage Installations Rising), Available At: Http://Vitalsigns.Worldwatch.Org/Vs-Trend/Smart-Grid-And-Energy-Storage-Installations-Rising **, February 27, 2013**

[6] Baghaie, M., Moeller, S., and Krishnamachari, B., "Energy routing on the future grid: A stochastic network optimization approach," International Conference on Power System Technology (POWERCON), 2010.

[7] Pedrasa, M.A.A., Spooner, T.D., and MacGill, I.F., "Scheduling of Demand Side Resources Using Binary Particle Swarm Optimization," IEEE Transactions on Power Systems, vol.24, no.3, pp.1173-1181, Aug. 2009.

[8] Samadi, P., Mohsenian-Rad, A.-H., Schober, R., Wong, V.W.S., and Jatskevich, J., "Optimal Real-Time Pricing Algorithm Based on Utility Maximization for Smart Grid," Smart Grid Communications (SmartGridComm): First IEEE International Conference on , vol., no., pp.415,420, Oct. 2010 .

[9] Na Li; Lijun Chen, and Low, S.H., "Optimal demand response based on utility maximization in power networks," IEEE Power and Energy Society General Meeting, vol. 1, no. 8, pp. 24-29, July 2011.

[10] Srinivasan Keshav and Catherine Rosenberg, 'How Internet Concepts & Technologies Can Help Green And Smarten The Electric Grid,*' ACM SIGCOMM Computer Communication Review 41.1 (2011): pp.109-114*.

[11] Sinha, A., Neogi, S., Lahiri, R. N., Chowdhury, S.,Chowdhury, S. P. and Chakraborty, N., "Smart grid initiative for power distribution utility in India," *Power and Energy Society General Meeting, IEEE* , vol. 1, no. 8, pp.24-29 July 2011.

[12] Aman, S., Simmhan, Y., and Prasanna, V.K., "Energy management systems: state of the art and emerging trends," Communications Magazine, IEEE , vol.51, no.1, pp.114,119, January 2013.

[13] Power grid Bangladesh Company Limited ,"Hourly Generation and Load Shed" available at; http://www.pgcb.org.bd/index.php?option=com_wrapper&view=wrapper&Itemid=282 , September, 2013.