EFFECT OF DAYLIGHT SAVING TIME ON BANGLADESH POWER SYSTEMS

A Thesis Report (1st Semester)

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DECLARATION

I hereby declare that this thesis is based on the results found by myself. Materials of work found by other researcher are mentioned by reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

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ABSTRACT

Load Management is an usual practice to meet the increasing peak demand of electricity and is a common practice in Western countries. Implementing daylight saving Time (DST) is one option of Load Management which shifts the consumers demand from the peak period to the off-peak period.

Bangladesh has recently started the use of DST as a tool for Load Management practice. However, it has not yet been evaluated to determine how effective this practice is in our country. Does it really help use or worsen the already stretched out electric resources. The objective of the project is to evaluate the effectiveness of the DST on Bangladesh Power System.

To evaluate the effectiveness of Load Management model will be developed and the process will evaluated and data will be collected. Using these data a model will be formed along with some indices in order to quantify the effects.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

Introduction

1.1 An Overview

When Bangladesh Government implemented Daylight Saving Time (DST) mid last year, the main motive citied was that extending the hours of sunlight later into the day reduces the need for artificial lighting in the evening, and thereby decreases electricity consumption during the summer months. While the advancement of time by one hour increases electricity usage in the morning hours, this effect is outweighed by reduced consumption in the later hours of the day. In the modern electronic age of life inexpensive and uninterrupted availability of power is a necessity. With the gradual depletion of fossil fuel and the rise in fuel prices, there has been insufficient effort towards saving electricity and making the most of remaining fuel reserves.

Electricity is vital for economic development, but only about 20 percent of the population has access to it (25 percent of urban population and 10 percent of rural). Other problems in the power sector include high system losses, delays in completion of new plants, low plant efficiencies, shortage of natural gas, erratic power supply, electricity theft, blackouts, etc. These factors contribute to Bangladesh's per capita electricity consumption being among the lowest in the world at about 110 kWh per person. We require new plants and fossil fuel the country can barely afford. The availability of gas is already in decline, and has been predicted to last until about 2011.Although power generation capacities cannot be increased overnight, energy saving programs can be initiated to distribute the electricity among more people. Continuity of electricity would also save our huge investment in generators and UPS equipment. With the decline of local and global fuel reserves, actions to save energy and maximize fuel utilization are long overdue for Bangladesh. Such a program is to have a two-pronged approach. Firstly, there should be understanding and research among planners of an energy saving program. Secondly, there should be implementation of the program by policymakers, taking concrete steps, such as enacting legislation and conducting media campaigns.

Already the situation is dire. As it is not possible to make a power station in short run, DST was adopted as a load management tool aiming to shift the peak load during a day and thereby saving heaps of load shaping. Another aim was to actually use the sunlight more which would result is actual measurable save of energy. Both this maybe would not enable us to eliminate the power shortage, but would ensure less load shaping.

1.2 History of DST

Although not punctual in the modern sense, ancient civilizations adjusted daily schedules to the sun more flexibly than modern DST does, often dividing daylight into twelve equal hours regardless of day length, so that each daylight hour was longer during summer. For example, Roman water clocks had different scales for different months of the year: at Rome's latitude the third hour from sunrise, horatertia, started by modern standards at 09:02 solar time and lasted 44 minutes at the winter solstice, but at the summer solstice it started at 06:58 and lasted 75 minutes. After ancient times, equal-length civil hours eventually supplanted unequal, so civil time no longer variesby season. Unequal hours are still used in a few traditional settings, such as some Mount Athos monasteries and some Jewish ceremonies.

During his time as an American envoy to France, Benjamin Franklin, author of the proverb, "Early to bed, and early to rise, makes a man healthy, wealthy and wise", anonymously published a letter suggesting that Parisians economize on candles by rising earlier to use morning sunlight. This 1784 satire proposed taxing shutters, rationing candles, and waking the public by ringing church bells and firing cannons at sunrise. Franklin did not propose DST; like ancient Rome, 18th-century Europe did not keep precise schedules.

However, this soon changed as rail and communication networks came to require a standardization of time unknown in Franklin's day.

Modern DST was first proposed by the New Zealand entomologist George Vernon Hudson, whose shift-work job gave him leisure time to collect insects, and made him aware of the value of after-hours daylight. In 1895 he presented a paper to the Wellington Philosophical Society proposing a two-hour daylight-saving shift, and after considerable interest was expressed in Christchurch, New Zealand he followed up in an 1898 paper. Many publications incorrectly credit DST's invention to the prominent English builder and outdoorsman William Willett, who independently conceived DST in 1905 during a pre-breakfast ride, when he observed with dismay how many Londoners slept through a large part of a summer day. An avid golfer, he also disliked cutting short his round at dusk. His solution was to advance the clock during the summer months, a proposal he published two years later. Willett lobbied unsuccessfully for the proposal in the UK until his death in 1915.

Starting on 30 April 1916, Germany and its World War I allies were the first to use DST as a way to conserve coal during wartime. Britain, most of its allies, and many European neutrals soon followed suit. Russia and a few other countries waited until the next year and the United States adopted it in 1918. Since then, the world has seen many enactments, adjustments, and repeals.

1.3 Effect on Energy Use

DST's potential to save energy comes primarily from its effects on residential lighting, which consumes about 3.5% of electricity in the U.S. and Canada. Delaying the nominal time of sunset and sunrise reduces the use of artificial light in the evening and increases it in the morning. As Franklin's 1784 satire pointed out, lighting costs are reduced if the evening reduction outweighs the morning increase, as in high-latitude summer when most people wake up well after sunrise. An early goal of DST was to reduce evening usage of incandescent lighting, formerly a primary use of electricity. Although energy conservation remains an important goal, energy usage patterns have greatly changed since then, and recent research is limited and reports contradictory results. Electricity use is greatly affected by geography, climate, and economics, making it hard to generalize from single studies.

The U.S. Dept. of Transportation (DOT) concluded in 1975 that DST might reduce the country's electricity usage by 1% during March and April, but the (NBS) reviewed the DOT study in 1976 and found no significant savings.

In 2000 when parts of Australia began DST in late winter, overall electricity consumption did not decrease, but the morning peak load and prices increased.

In Western Australia during summer 2006–07, DST increased electricity consumption during hotter days and decreased it during cooler days, with consumption rising 0.6% overall.

Although a 2007 study estimated that introducing DST to Japan would reduce household lighting energy consumption, a 2007 simulation estimated that DST would increase overall energy use in Osaka residences by 0.13%, with a 0.02% decrease due to less lighting more than outweighed by a 0.15% increase due to extra cooling; neither study examined non-residential energy use. DST's effect on lighting energy use is noticeable mainly in residences.

A 2007 study found that the earlier start to DST that year had little or no effect on electricity consumption in California.

A 2007 study estimated that winter daylight saving would prevent a 2% increase in average daily electricity consumption in Great Britain. This paper was revised in October 2009.

A 2008 study examined billing data in Indiana before and after it adopted DST in 2006, and concluded that DST increased overall residential electricity consumption by 1%, due mostly to extra afternoon cooling and due also to extra morning heating; the main increases came in the fall. The overall annual cost of DST to Indiana households was estimated to be $9 million, with an additional $1.7–5.5 million for social costs due to increased pollution.

The U.S. Dept. of Energy (DOE) concluded in a 2008 report that the 2007 U.S. extension of DST saved 0.5% of electricity usage during the extended period. This report analyzed only the extension, not the full eight months of daylight saving, and did not examine the use of heating fuels.

Several studies have suggested that DST increases motor fuel consumption. The 2008 DOE report found no significant increase in motor gasoline consumption due to the 2007 U.S. extension of DST.

1.4 Background on DST in Bangladesh

To try and combat the immense deficit in the ability to meet the demand of the country, our government decided to implement Daylight Saving Time (DST).

Main aim of this shift in clock hour is to

- ensure that the peak demand of electricity does not occur in the evening, rather distribute it to other times of the day
- Reduce the energy requirement of the country, but using more sunlight and less of filament/florescent light

Daylight Saving Time (DST) was implemented on 19th June 2009at midnight and ended in 31st December 2009. Note that in USA and EU; DST starts from mid/end of March each year and ends on end of October/beginning of November. In several press releases during and after DST implementation, it is claimed that we were saving up to 200 MW a day!

But the interesting questions are still unanswered:

- Did DST actually save any energy?
- Did the in orthodox timing for implantation of DST was fruitful in any way?
- If DST did save 200MW of energy each day, why was it abound and later this year?

CHAPTER II

Project Overview

2.1 Objective

Objective of this project is to answer the questions that still remain a mystery to most of us:

- Did DST actually save any energy?
- Did the in orthodox timing for implantation of DST was fruitful in any way?
- If DST did save 200MW of energy each day, why was it abound and later this year?

What we wish to achieve is to analyze quantitatively, the effect of DST in our lives.

2.2 Limitations

Since we started our work, we found that there are several that we have to overcome and in most cases, the work around needs to be followed. Let us look at the limitations that we are able to identify:

Load shading data is never 100% accurate: Our grid is designed in such a way, that at the time of designing, load shading factors were not included. So at most times, when we do load shading, we can only guess how much load is being shaded. However, it is merely a guess and although it is said that these values can be considered as a fair guess; these are still not accurate data and may have adverse effect in our work.

It is not possible to predict a demand: we all know that human beings have the luxury of free will. As such it is near impossible to predict ones behavior.

Let's take an example. Say on 1st August, 2009, we are have DST and Person A wakes up at 6 AM (non-DST time) and turns on light, gets ready and goes to office. Normally, if DST was not implemented, he would have got off bed at 7 AM, and thereby would not need light. However, can we really say with confidence that if the later was the case, would person A really wake up at 7 AM and not 6AM?

Another reason for not being able to have accurate prediction is weather. Now weather itself is unpredictable. As such, we cannot predict its effect on load curve.

Growth in Cumulative Energy Demand: every year, we will see that demand for energy increases. Bangladesh being a developing country has a higher rate of growth than an already developed country. Identifying this embedded growth is indeed an issue, especially when considering that demand for energy is itself unpredictable

Due to so many variables, we need to find a better solution than to just process data to find a solution to our problem.

CHAPTER III

Methodology

3.1 Methodology

To overcome our limitation we have to analysis the data in every possible way so as to eliminate any error in our findings. Hence we have decided to study DST effect in several ways which are mentioned below.

3.2 Required data

To effectively understand effect of DST, we need the following data:

Load Curve for Calendar Year 2009 and Calendar2008: this we need to find out what the load was like on those days. Note that to quantify our report, we need these data on day to day basis and at half-an-hourly basis.

Load Shaping Data: to know how much energy was shaded, we need these information. This information, when added to the load curve will give the actual demand that was present on a particular day.

As already mentioned, we cannot have accurate data on load shaping due to our system limitation. So we will carry out a survey to identify user pattern. This will be discussed in later section 3.3

3.3 Analyzing data

The objective of DST is to use more day light instead of using the light produced by electricity. Therefore, the effect of DST is mainly during evening and morning hours; that is around the sunset and sunrise time. The effect is mainly on (1) energy consumption and (2) peak demand. This effect may be quantified by evaluating the degenerative energy consumption and generation capacity saving due to peak load reduction during evening and morning hours. The degenerative energy consumption may be evaluated by evaluating the difference between the energy consumed at any time after the implementation of DST and the probable energy consumption at that time if DST were not implemented. That is, the expected energy saving may be expressed as,

$$E(ES) = \int_{T_0}^{T_l} DG(t)dt \tag{1}$$

Where,

E(ES) = Expected energy saving due to the implementation of LM scheme DST.

T_O= Starting time when the effect of DST could occur

T_l = The limiting time when the effect of DST reduces to zero (negligible).

The degenerative consumption at a time, DG (t), may be expressed in terms of the difference in energy consumption as

$$DG(t) = PD(t) - AD(t) \tag{2}$$

Where,

PD(t) = the Probable demand at time t if DST were not implemented.

AD(t) = Actual Demand at time t after the implementation of DST.

Therefore, equation (1) may be written by expressing the morning and evening effects separately as,

$$E(ES) = \int_{ss}^{T_{nl}} DG(t)dt + \int_{T_{ma}}^{T_{sr}} DG(t)dt \tag{3}$$

Where,

T_{ss} = Starting time in the evening when the effect of LM shift could occur.

T_{nl} = Time at which the effect of DST reduces to zero.

T_{ma} = Time when the morning activities start before sunrise.

T_{sr}= Limiting time in the morning when the effect of DST reduces to zero during the morning hours.

3.4 Determining Probable Demand

When we started our work, our initial plan to calculate the Probable demand was via the following model:

$$PD(t) = \sum EnergyDemand^{2008} + \sum EmbededGrowth^{2008-2009} \quad (4)$$

Where,

$$EmbeddedGrowth = \sum EnergyDemand^{June-2009} + \sum EmbededGrowth^{June-2008} \quad (5)$$

Here the Embedded Growth was to be determined using the data of June 2009 and 2008. However, it soon proved to be an unwise model as we realized that the growth factor for the month of June do not apply for months from September to December where the climate has changed and so does the load pattern.

Hence we had to derive a new model which overcame this problem. In order to forecast the demand, the loads of 1998 till 2009 and the demands of 2007 and 2008 are used. The demand at any time is calculated by adding load shedding amount with the actual load supplied at the time. However, the amount of load shading was not available from 1998 till 2006, hence the loads of this period are inflated by a factor K(t), where K(t) of any time t is determined by taking the ratio between the summation of demands and the summation of loads of 2007 and 2008 at time t. A polynomial of degree 6 is used in the forecast through extrapolation.

$$\therefore PD(t) = f\{[K(L_{98}(t), L_{99}(t).....L_{06}(t)], D_{07}, D_{08}\} \quad (6)$$

Where,

L = Load ; D = Demand

$$K(t) = \frac{D_{07} + D_{08}}{L_{07} = L_{08}}$$

The forecasted results are validated through actual demands of the months of 2009 during where DST is not implemented.

Table 1 presents the forecasted and the actual demand of a few morning and evening hours of June 15th, 2009, a randomly selected date, along with the corresponding deviations. The deviation of morning hours is a bit higher than those of evening hours. The observed maximum deviation in the forecasted values is 3.4%.

TABLE I
DEVIATION OF THE FORECASTED DEMAND FROM THE ACTUAL

Time	Demand (MW)		Deviation (%)
	Forecasted	Actual	
4 AM	3376	3495	3.40 %
5 AM	3256	3169	2.75 %
6 AM	2972	3069	3.16 %
7 AM	3093	3125	1.02 %
5 PM	3532	3580	1.34 %
6 PM	3618	3580	1.06 %
7 PM	4333	4360	0.62 %
8 PM	4580	4650	1.51 %
9 PM	4553	4585	0.70 %

3.4 Capacitive Saving

The capacity saving may be evaluated by evaluating the reduction of the peak demand due to the implementation of DST scheme. That is,

$$\boldsymbol{E\ (CS)} = Min\ \{CRM_i\}; \qquad i = 1,2 \ldots N \tag{7}$$

Where,

E(CS) = Expected capacity saving due to DST.

CRMi = Expected difference during maximum generation capacity requirement for the i^{th} day.

N = Number of days in a year during which DST is implemented.

CRM_i may be expressed in terms of peak demands of ith day with and without implementing DST. That is,

$$\boldsymbol{CRM_i} = K(PPD_i - APD_i) \tag{8}$$

Where,

PPDi = Probable Peak Demand of the ith day if DST were not implemented.

APDi = Actual Peak Demand of the ith day after the implementation of DST.

K= Factor inflating peak to determine the required generation capacity

CHAPTER IV

Progress

4.1 Our Progress

So far we have collected all relevant data for our thesis work. We have collected these data from Bangladesh Power Development Board (BPDB), National Load Dispatch Center (NLDC) and Power Grid Company of Bangladesh (PGCB)

Our work has regarding initial data analysis and also determined the difference in energy consumption.

4.2 Basic Data

To evaluate the effect of DST on the energy consumption and peak load reduction of BPS, its hourly load of last 12 years are collected from the National Load Dispatch Center (NLDC). BPS is unable to meet its monotonically increasing demand and LM through load shedding scheme is its common practice. Load shedding data of all 12 years is not available, only load shedding of last 3 years, 2007 to 2009, and are collected for the study.

Before the investigation into the effect of DST, the data is analyzed. The increase in the peak load over the last 12 years is depicted in Fig. 1. The increment is expressed in percentage of the annual peak of 1998. The average increase of peak load in a year is around 210MW. The annual peak occurs usually during August to September at around 7PM. The figure shows that growth is 72% over the last 12 years.

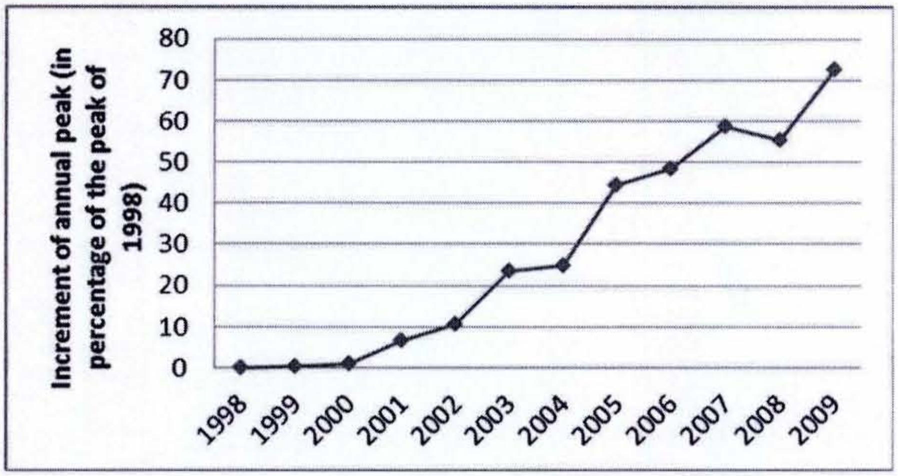

Fig.1 Growth of annual Peak

The DST scheme is implemented from June 19th to December 31st, 2009. Over this period the monthly energy sheds of last 3 years are presented in Fig. 2. The figure shows that the energy shedding is higher during June to August and starts to decrease in September. The minimum amount of energy shed is in December. The highest amount of load shed during this period is 10.8% of the supplied energy.

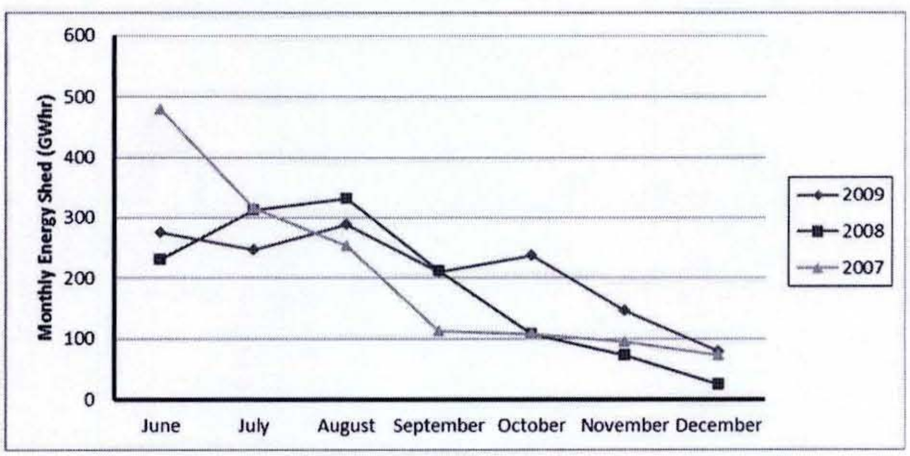

Fig. 2 Monthly Load Shaping Trend from 2007-2009

4.3 Effect of DST Scheme on Peak Load

The DST scheme implementation period of BPS is only June 19th till December 31st, 2009. The monthly average peak demands of this period of 2009 along with their occurrence time are compared in Table 1 with those of 2008. Note that the DST is not implemented in 2008. The table clearly shows that the average peak of each month of 2009 is higher than that of 2008 and the time of occurrence is shifted by an hour. That is if time shift through DST is ignored, the peak occurrence time of both the years is same. There is no significant impact due to DST, on the time of use of electricity during evening hours.

TABLE II

COMPARISON OF MONTHLY AVERAGE PEAK AFFECTED BY DST SCHEME WITH THAT OF WITHOUT DST SCHEME

	YR	June	July	Aug	Sept.	Oct.	Nov.	Dec.
Peak (MW)	2009	4489	4514	4666	4676	4734	4369	4094
	2008	4184	4285	4334	4331	4080	4059	3788
Time	2009	8PM-9PM					7PM-8PM	
	2008	7PM-8PM					6PM-7PM	

4.4 Effect of DST Scheme on Energy Consumption

The difference of the forecasted and the actual demand of different evening hours during DST implementation period is depicted in Fig. 3. The deference of morning hours is depicted in Fig. 4. The depicted values in Fig. 3 and Fig. 4 are the average values over a month. It is observed from these two figures that there is no significant demand reduction due to implementation of DST scheme except for 7PM of June to August. There is also slight demand reduction at 6PM during September to December and 6 to 8 AM of December.

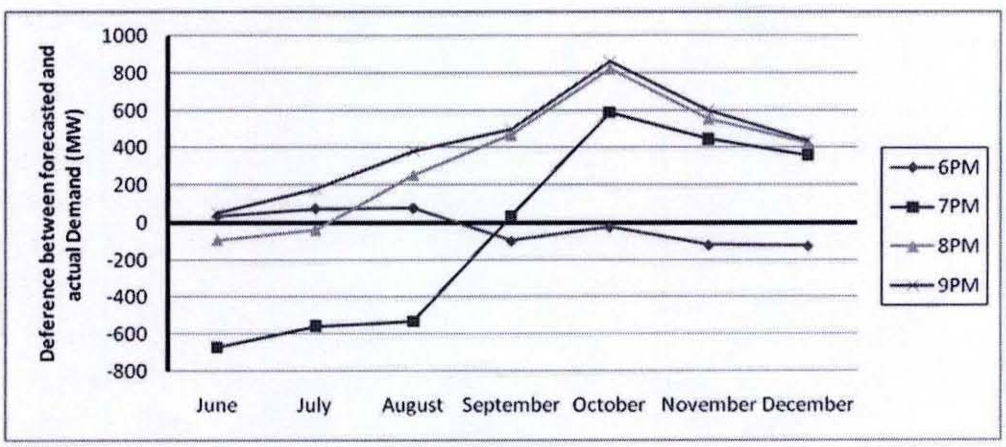

Fig. 3 Impact of DST scheme on Demand of evening hours

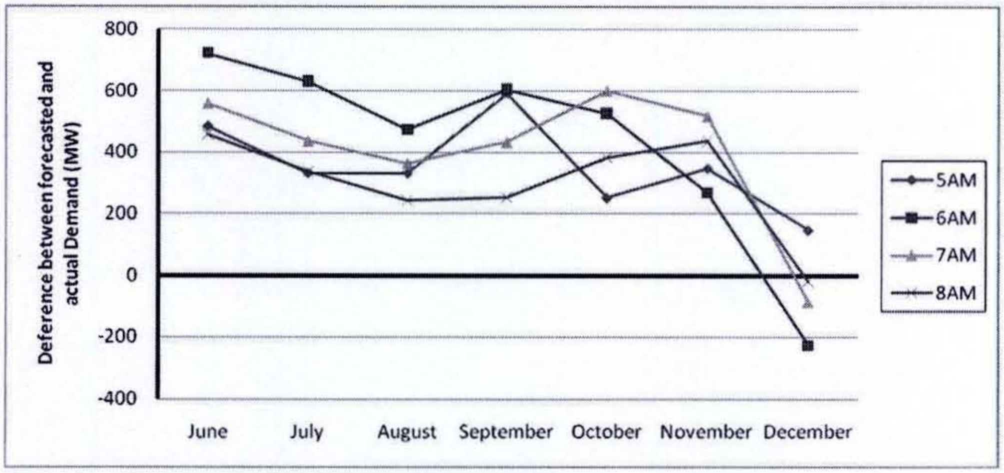

Fig. 4 Impact of DST scheme on Demand of morning hours

A more comprehensive view can be portrait by Figure 5.

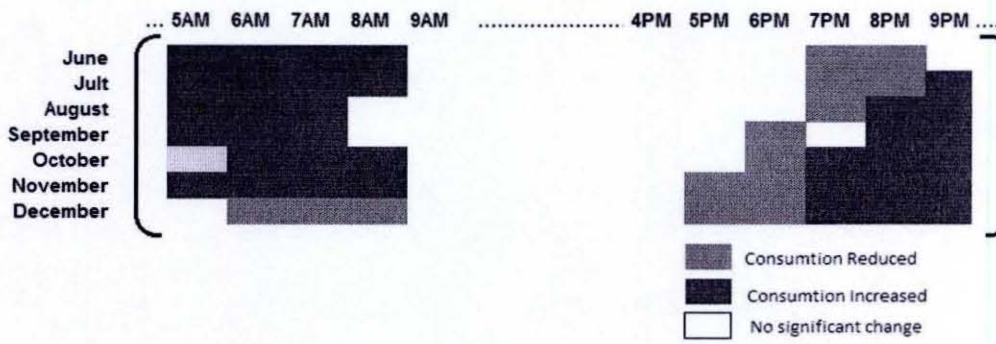

Fig. 5 Hour by hour analysis of the effect of DST

The monthly energy consumption deference between consumption with and without DST scheme implantation for morning and evening hours and also the cumulative value of morning and evening hours are represented in Table 3. The last column of this table presents the monthly energy consumption difference in percentage of the actual consumption. In this case, the evening hour is considered to span from 5PM to 11PM and the span of morning hours is considered to be from 4AM to 9AM. The table clearly shows that only during the evening period of June and July and the morning period of December there is a saving in energy consumption. However, the sum of the energy consumption during the morning and evening periods of each month shows clear increase of 576 GWhr in the energy consumption, instead of decrease. This increment is much higher than that of the percentage deviation of the forecasted demand observed in Table III.

TABLE III
ENERGY CONSUMPTION DIFFERENCE BETWEEN THE FORECASTED AND ACTUAL ONES

	Energy Consumption Difference (GWhr)			
Month	**Morning**	**Evening**	**Total**	**%**
June (11 days)	33	-6	27	5.9 %
July	72	-4	68	5.3 %
August	57	10	67	5.1 %
September	72	34	106	8.4 %
October	69	85	154	12.1 %
November	67	48	115	10.8 %
December	4	35	39	4.0 %
Total Energy Difference			**576**	**7.5 %**

4.5 Effect of DST Scheme on Capacitive Saving

To evaluate the generation capacity saving, the difference between the peak of forecasted and actual demand of each day is determined. The minimum difference in peak demand of each month is presented in Table IV. This table also presents the minimum difference of all months of the DST implementation period.

TABLE IV
CRM TREND DURING THE DST IMPLEMENTED MONTHS

Month	Peak Generation Capacity Saving (MW)	Saving over the DST period
June (11 days)	-304	
July	-377	
August	-457	
September	-592	
October	-691	
November	-574	
December	-347	-691

The table clearly shows that instead of capacity saving, there is an additional capacity requirement of 691 MW during the DST period.

CHAPTER IV

Future Work

4.1 Stability Test

So far we have collected all relevant data for our thesis work. We have collected these data from Bangladesh Power Development Board (BPDB), National Load Dispatch Center (NLDC) and Power Grid Company of Bangladesh (PGCB).Our work has regarding initial data analysis and also determined the difference in energy consumption. We will calculate using the Recursive and Segmentation methods for the evaluation of reliability index, LOLP, for a single area system are illustrated through. Since segmentation method is conceptually straight forward and computationally simple. We will be determining the production cost and LOLP for single area system.

Loss of load probability (LOLP)=probability { available capacity < load }
$$= P\{ G_A < L \}$$

Here, G_A= Availability of generation
L = Demand

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APPENENDICES

2009-2008

	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
june	1:00	2:00	3:00	4:00	2009	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
1-Jun																							
2-Jun																							
3-Jun																							
4-Jun																							
5-Jun																							
6-Jun	520	850	942	965	872	647	558	309	351	153	274	165	155	213	245	339	347	-395	-250	170	240	300	330
7-Jun	370	204	164	149	405	448	527	423	659	733	630	463	664	653	405	399	404	484	800	435	390	380	380
8-Jun	500	547	541	472	447	469	429	259	480	430	300	320	280	200	140	100	200	220	570	420	380	360	310
9-Jun	330	330	300	219	114	109	272	260	349	110	120	160	100	220	360	380	460	400	400	190	200	250	260
10-Jun	260	172	91	70	130	231	207	151	268	250	310	340	330	520	420	440	370	200	-250	320	270	280	350
11-Jun	556	494	437	445	440	455	394	280	232	326	460	320	370	399	363	389	424	-200	420	300	330	330	350
12-Jun	433	227	139	57	42	63	88	72	232	373	379	365	345	356	370	409	414	-190	-80	350	450	460	450
13-Jun	532	450	474	455	386	129	111	-43	110	245	158	130	41	142	354	351	390	238	-692	0	0	100	250
14-Jun																							
15-Jun	630	640	640	453	345	187	23	100	472	629	564	384	325	374	397	425	487	422	360	350	335	340	350
16-Jun	420	460	450	430	354	248	201	367	580	348	300	327	243	477	580	639	632	628	480	330	270	290	360
17-Jun	590	570	610	550	502	508	466	508	601	509	569	456	547	580	649	681	768	770	450	210	140	150	250
18-Jun	530	625	758	746	845	815	652	419	445	417	439	446	429	514	549	568	543	568	400	490	560	580	650
19-Jun	915							857	722	603	595	558	515	581	566	599	640	688	250	459	490	550	600
20-Jun	550	550	650	700	780	650	700	774	668	517	690	632	621	591	571	510	528	575	949	400	360	400	430
21-Jun	500	650	809	889	873	892	1127	1147	1020	919	743	639	754	799	772	409	526	632	522	580	550	540	510
22-Jun	620	930	1064	1118	1173	1202	1179	1154	999	840	724	678	650	672	684	704	767	858	736	500	550	600	655
23-Jun	750	878	821	785	713	700	669	731	757	676	524	451	462	628	657	724	736	777	610	175	260	370	450
24-Jun	700	900	934	876	842	819	794	760	821	702	613	629	549	500	513	567	612	567	518	290	180	210	310
25-Jun	670	790	770	750	740	700	680	650	528	450	480	460	400	400	520	580	600	550	400	230	180	190	210
26-Jun	690	820	810	810	770	665	521	504	441	322	244	233	212	311	393	384	356	278	217	350	120	100	140
27-Jun	550	750	670	660	550	480	293	180	210	326	229	183	370	273	263	533	502	367	158	-300	110	240	380
28-Jun	550	750	780	650	582	585	370	316	509	494	533	564	479	409	439	422	477	407	393	650	310	295	330
29-Jun	600	700	710	680	635	458	348	393	424	407	300	350	410	450	390	330	280	160	200	250	200	270	360
30-Jun	520	580	439	417	420	452	292	478	494	494	396	402	448	459	430	447	419	463	373	280	170	250	320
1-Jul	520	384	291	300	241	102	122	227	153	236	289	234	164	178	210	143	-206	-122	86	-50	80	150	100
2-Jul	93	67	3	142	64	88	225	321	141	322	225	202	140	144	222	234	221	256	245	130	290	285	310
3-Jul	450	487	350	474	418	407	389	405	352	261	152	56	161	305	133	183	133	88	12	350	150	120	100
4-Jul	300	15	-141	-149	-125	-27	15	8	-205	-274	-298	-336	-277	-238	-253	16	-13	-4	-132	-350	-150	-100	-170
5-Jul	224	97	-6	15	62	-26	153	258	283	511	368	349	235	384	567	380	405	275	292	-30	225	255	320
6-Jul	407	463	270	306	368	448	291	234	239	423	664	513	415	363	434	474	478	468	303	120	270	320	380
7-Jul	600	650	630	609	679	631	651	705	616	545	448	350	165	230	300	390	450	480	380	370	225	250	350
8-Jul	650	500	391	468	432	436	452	476	439	389	376	389	376	355	450	500	546	441	436	160	250	300	370
9-Jul	480	580	560	570	435	439	356	414	381	310	540	700	530	530	550	610	630	600	530	420	245	255	290
10-Jul	470	550	472	445	402	394	407	472	444	566	619	532	516	623	658	608	589	436	246	250	140	190	270
11-Jul	206	270	267	182	141	81	-100	-53	-173	-104	-195	-135	-35	-106	-61	153	81	17	-193	-100	0	90	200
12-Jul	518	421	304	273	194	159	184	220	212	375	365	473	498	614	812	657	695	487	424	250	250	260	310
13-Jul	550	604	545	542	508	492	520	566	547	649	561	519	414	517	492	511	474	368	338	160	350	320	315
14-Jul	590	600	600	600	590	591	510	669	523	430	560	500	470	460	540	520	530	490	370	400	200	200	270
15-Jul	500	670	734	670	692	774	745	737	637	651	523	414	495	558	635	602	675	668	580	500	230	200	200
16-Jul	580	640	570	555	618	644	819	851	713	604	480	444	440	470	460	440	430	470	490	390	300	300	300
17-Jul	430	450	511	499	564	571	655	686	650	674	413	315	314	406	442	474	485	500	398	180	300	250	270
18-Jul	600	720	650	640	625	525	341	304	125	55	144	149	161	149	266	398	476	563	357	0	100	90	210
19-Jul	730	900	930	870	864	793	565	674	743	845	614	611	763	736	715	639	654	597	529	250	300	360	440
20-Jul	550	930	950	920	900	895	679	704	750	800	630	660	730	845	750	800	670	620	500	250	350	310	330
21-Jul	730	645	610	580	670	680	664	610	623	519	550	440	250	360	380	400	430	455	-250	50	350	450	550
22-Jul	750	760	730	730	750	737	852	821	886	611	554	523	553	635	701	708	701	583	-100	130	280	400	450
23-Jul	600	740	730	700	700	721	671	660	850	698	620	500	377	470	500	500	500	450	-20	270	210	310	410
24-Jul	580	730	680	640	630	630	634	649	649	677	600	500	375	420	480	510	480	520	500	200	230	300	350
25-Jul	600	680	640	590	580	536	568	624	569	514	530	549	415	370	430	505	316	400	387	0	160	220	310
26-Jul	680	750	780	780	760	818	696	659	695	691	629	722	737	827	836	773	696	642	636	450	350	390	480
27-Jul	700	720	720	720	720	708	758	685	676	435	464	520	530	470	520	530	500	500	540	500	350	330	370
28-Jul	680	740	700	720	760	727	607	564	661	457	500	520	490	500	520	490	480	470	420	150	300	350	350
29-Jul	400	270	100	-110	-206	-258	-231	22	-92	-117	40	240	220	250	290	250	210	160	300	200	100	150	220
30-Jul	600	550	500	470	430	349	273	371	534	506	263	300	300	300	300	280	300	330	400	300	320	350	330
31-Jul	250	171	77	13	5	13	-80	46	47	89	250	355	280	350	350	360	330	330	350	320	250	240	220
1-Aug	400	330	272	252	121	204	40	-7	-136	10	141	159	208	151	70	184	258	292	125	50	50	80	150
2-Aug	400	480	283	194	86	65	29	156	259	288	476	501	352	356	424	444	448	512	449	570	390	350	350

3-Aug	510	550	590	550	530	514	442	512	541	520	617	509	443	492	410	392	416	420	441	450	350	350	350
4-Aug	610	650	620	620	450	540	658	475	303	353	320	320	370	370	400	320	380	390	390	490	360	420	450
5-Aug	660	620	600	570	580	570	626	643	396	238	280	320	350	420	420	450	410	360	350	250	300	430	450
6-Aug	520	500	450	400	370	340	437	419	352	320	266	340	370	370	360	370	380	350	-200	200	350	455	500
7-Aug	620	530	530	530	510	470	431	313	452	240	310	330	350	370	340	330	340	300	-270	100	340	400	400
8-Aug	620	657	502	398	405	318	-178	-318	-230	-32	25	47	-132	-119	143	411	277	305	94	10	120	200	300
9-Aug	470	659	464	494	493	438	341	308	331	398	350	310	340	520	430	450	530	550	470	360	350	360	370
10-Aug	550	500	480	480	550	526	557	561	672	548	314	330	340	400	430	400	350	400	340	480	330	390	430
11-Aug	600	590	570	570	530	470	524	663	603	310	310	310	340	440	400	410	470	500	440	520	250	200	230
12-Aug	730	650	660	670	680	708	865	836	720	619	441	470	460	470	510	570	570	530	-200	400	430	450	450
13-Aug	700	660	650	650	680	683	741	713	754	634	325	320	350	370	420	400	420	390	350	400	410	400	380
14-Aug	600	680	680	670	650	646	631	579	453	320	280	280	300	280	340	340	340	350	350	400	300	250	170
15-Aug	580	620	580	550	520	500	232	175	131	208	122	18	247	253	230	460	438	312	204	300	230	270	300
16-Aug	600	630	580	550	468	483	198	178	-11	-5	-13	95	30	133	266	79	-25	30	302	570	330	290	300
17-Aug	450	380	151	132	52	67	90	199	188	305	225	86	150	214	250	303	227	185	273	550	330	250	270
18-Aug	420	500	420	385	320	482	762	891	1064	956	706	687	568	568	546	676	634	627	600	780	535	390	300
19-Aug	250	300	296	358	407	482	364	508	409	582	400	320	235	260	330	410	350	380	300	380	310	300	250
20-Aug	350	280	121	64	72	81	249	327	351	488	523	480	430	420	410	410	370	420	380	560	350	310	200
21-Aug	250	170	147	189	162	180	180	342	196	225	230	150	170	190	140	100	160	100	150	250	340	300	200
22-Aug	200	230	81	23	-20	-29	100	7	-244	-268	-108	-187	-58	3	41	253	226	101	106	51	0	50	130
23-Aug	400	157	57	72	95	133	29	134	207	339	397	475	354	394	446	368	352	336	530	330	310	350	350
24-Aug	530	560	650	870	690	452	280	212	332	577	340	216	101	158	179	170	115	73	107	320	370	400	400
25-Aug	520	630	700	900	840	434	103	40	85	448	558	428	441	382	506	549	526	544	465	250	315	360	350
26-Aug	480	550	550	810	950	486	-28	35	18	211	340	385	415	465	500	540	550	450	350	100	370	450	450
27-Aug	430	520	640	770	900	398	140	62	63	294	420	500	500	470	380	480	500	510	450	600	300	250	270
28-Aug	500	480	399	608	707	42	-211	-188	-217	-12	43	111	153	170	178	174	165	147	326	250	370	370	370
29-Aug	560	502	387	535	685	61	-84	-234	-458	-401	-149	-71	-41	-24	35	460	386	314	-624	160	385	500	600
30-Aug	682	666	689	978	1084	684	527	524	502	615	575	660	719	878	894	670	730	686	557	450	500	490	420
31-Aug	700	857	1006	1149	1295	1062	996	932	823	797	579	457	394	370	338	322	291	298	332	750	500	430	400
1-Sep	640	690	700	810	880	501	424	398	285	417	462	380	380	420	500	490	430	450	400	500	425	400	400
2-Sep	800	670	730	850	920	607	387	340	262	496	628	644	723	732	692	662	600	531	522	450	490	520	480
3-Sep	600	800	780	710	500	578	651	554	585	491	460	500	590	500	560	550	540	630	480	700	380	360	350
4-Sep	570	600	680	670	600	628	356	359	412	600	510	580	540	550	580	480	500	540	450	670	390	320	300
5-Sep	720	750	780	800	500	480	339	279	72	78	160	226	158	146	55	477	470	335	100	200	230	260	330
6-Sep	730	700	670	700	400	370	411	387	283	395	306	371	417	564	639	467	559	466	303	750	475	380	320
7-Sep	580	670	509	290	230	266	440	373	313	395	372	339	317	357	432	364	508	533	798	600	425	365	340
8-Sep	500	610	630	370	370	373	283	233	363	250	320	320	370	400	410	450	520	450	770	400	390	360	370
9-Sep	420	480	520	500	500	294	323	302	166	179	111	180	163	131	74	223	109	84	410	450	130	50	90
10-Sep	250	294	242	347	76	-128	-294	-322	-208	112	473	380	330	377	373	338	393	365	470	420	280	220	220
11-Sep	430	420	371	407	85	13	-54	-29	-10	112	307	430	300	240	340	280	330	230	220	400	370	350	317
12-Sep	470	500	449	423	300	205	-86	-132	-38	154	198	76	275	223	127	318	283	408	300	300	120	110	160
13-Sep	400	580	600	480	300	350	234	428	378	327	245	421	379	370	304	376	415	499	580	580	390	350	320
14-Sep	460	480	530	450	400	639	569	508	575	505	518	486	295	288	366	380	488	458	700	630	540	490	420
15-Sep	500	530	540	550	450	500	480	441	403	335	360	400	400	380	430	430	440	440	670	500	520	520	480
16-Sep	650	570	590	580	450	457	348	230	196	349	380	380	380	380	390	410	440	440	630	630	530	1120	800
17-Sep	650	800	680	550	400	550	662	617	398	450	490	570	520	520	490	500	560	580	470	600	610	590	540
18-Sep	550	650	640	500	500	432	275	422	448	451	500	550	540	560	620	640	620	580	950	800	510	370	330
19-Sep	650	650	643	416	305	240	318	244	-14	-182	109	110	171	161	-13	442	428	425	-285	320	330	380	420
20-Sep	670	653	452	125	21	62	84	81	35	87	79	99	111	227	192	330	261	-32	100	210	405	400	320
21-Sep																							
22-Sep																							
23-Sep																							
24-Sep																							
25-Sep																							
26-Sep																							
27-Sep	180	147	60	-130	-441	-179	-223	-371	-222	-89	44	133	103	142	92	386	353	207	280	350	390	380	315
28-Sep	450	498	432	294	-154	168	404	338	208	443	300	258	191	155	153	238	287	383	130	485	600	600	550
29-Sep	461	757	834	768	551	852	1068	931	825	913	945	855	788	782	708	628	547	416	250	560	630	550	420
30-Sep	128	413	413	304	80	567	661	662	694	651	457	449	401	431	394	377	492	556	739	780	700	633	591
1-Oct	426	359	438	210	4	404	656	738	908	924	916	885	847	832	843	745	880	945	911	920	730	570	465
2-Oct	310	585	759	694	300	848	1257	1317	1427	1315	1276	1149	1099	1066	944	831	948	1010	858	940	910	760	550
3-Oct	995	488	667	753	781	797	749	881	1217	1365	1278	1253	1288	1194	1280	1408	1326	1224	706	815	889	867	845
4-Oct	837	1009	1121	977	1095	921	999	952	927	1178	1278	1236	1355	1255	1271	1326	1392	1283	588	760	842	800	782
5-Oct	840	1024	1085	998	1027	989	1035	1101	1212	1388	1299	1228	1185	1143	1142	1042	1179	1255	1194	1070	953	850	720
6-Oct	867	639	654	650	723	699	769	941	841	994	1035	934	882	831	845	955	1020	1088	987	1020	940	850	749
7-Oct	683	819	846	807	809	757	907	945	893	961	812	810	837	795	753	724	792	760	836	850	740	640	620
8-Oct	454	799	855	904	825	771	873	832	680	750	677	621	642	535	639	485	462	530	900	720	660	650	557

9-Oct	469	447	539	481	410	507	690	690	573	637	479	611	639	609	634	720	580	421	940	810	700	590	470
10-Oct	400	413	561	440	540	623	628	581	531	629	518	457	342	253	280	468	429	446	523	610	525	430	360
11-Oct	370	479	499	516	451	489	566	607	623	690	766	740	739	820	869	675	526	516	800	670	550	410	270
12-Oct	170	463	393	403	471	493	588	660	586	653	667	626	527	396	374	418	490	564	766	800	722	660	550
13-Oct	281	244	200	238	253	267	306	422	339	419	346	228	293	299	416	350	316	206	820	500	480	420	350
14-Oct	430	252	198	179	196	94	223	361	282	503	552	501	451	418	501	514	505	524	650	570	500	390	280
15-Oct	400	399	243	208	138	186	328	334	330	510	360	270	330	300	310	370	380	370	750	580	380	280	230
16-Oct	300	349	297	302	253	311	352	370	551	375	400	400	400	420	570	570	450	310	270	490	500	450	350
17-Oct	170	180	78	196	145	122	167	78	-127	-259	-186	-98	90	-105	-172	34	87	70	420	380	250	170	100
18-Oct	229	-28	-41	-74	-63	-22	52	248	249	258	518	503	537	1018	801	532	569	520	450	510	570	560	480
19-Oct	430	500	545	514	539	610	561	571	523	729	500	520	526	446	534	567	582	554	630	640	470	400	310
20-Oct	200	420	292	296	274	280	250	323	326	313	300	350	230	260	350	370	390	350	900	450	320	250	180
21-Oct	38	-14	-154	-37	-59	-38	0	79	-33	-18	280	80	170	230	260	220	220	250	450	400	400	320	200
22-Oct	-66	-175	-184	-162	-241	-217	-43	-11	-49	20	110	160	200	240	250	250	200	230	400	430	430	320	150
23-Oct	-41	-269	-330	-276	-188	-143	-47	28	46	295	450	320	340	400	430	470	380	380	400	430	430	320	170
24-Oct	-4	-266	-193	-199	-236	-191	-160	-102	-148	-114	-182	-223	-135	-189	-175	125	34	72	20	130	200	170	-29
25-Oct	408	-146	-271	-294	-312	-282	-226	7	-10	40	192	382	503	593	770	764	524	379	840	495	330	310	390
26-Oct	1177	426	439	475	493	627	751	680	563	611	701	680	786	850	1056	970	774	668	920	950	1216	1259	1343
27-Oct	1362	1012	983	960	954	998	1129	947	652	758	946	960	893	794	966	850	785	697	727	1019	1212	1442	1573
28-Oct	1004	1268	1353	1429	1673	1771	1941	1898	1884	1974	1925	1795	1623	1488	1438	1358	1179	1007	1224	1299	1130	1186	1050
29-Oct	704	966	974	937	963	797	1007	950	756	756	764	837	722	676	733	724	753	722	680	650	520	520	680
30-Oct	517	655	739	672	680	741	797	634	485	681	680	767	790	793	866	755	761	677	530	540	600	590	603
31-Oct	430	604	644	592	582	591	476	436	185	153	67	128	96	-49	22	293	238	204	220	350	350	300	233
1-Nov	281	312	339	346	371	408	496	458	448	601	732	751	736	862	820	635	689	557	650	640	470	410	395
2-Nov	310	478	401	423	440	450	503	462	370	530	655	633	607	655	710	583	601	471	800	500	460	360	325
3-Nov	272	315	362	278	355	357	421	426	261	411	442	477	465	447	485	491	554	472	600	468	460	430	365
4-Nov	343	307	236	282	337	366	494	453	372	471	502	420	423	473	543	485	531	0	510	435	480	480	430
5-Nov	542	553	597	553	550	530	616	606	410	614	524	555	583	522	564	520	625	504	420	475	500	500	521
6-Nov	507	525	547	528	543	537	523	550	405	509	521	459	541	541	587	546	556	559	580	430	430	410	410
7-Nov	517	388	455	444	454	417	411	258	114	-1	-103	-29	-71	-135	-22	73	189	-232	100	343	400	450	486
8-Nov	304	356	395	335	319	305	365	373	420	471	582	732	691	830	821	616	611	557	670	530	460	380	337
9-Nov	485	451	401	419	354	436	559	489	329	480	541	513	477	515	584	408	295	219	800	530	320	280	250
10-Nov	338	340	297	276	301	333	316	374	99	158	242	233	356	276	295	306	307	308	850	460	250	160	200
11-Nov	266	301	347	348	302	323	353	338	178	197	230	95	257	254	328	321	324	379	640	420	315	320	400
12-Nov	325	392	393	414	429	442	354	280	132	286	293	290	341	388	379	440	155	240	600	430	380	380	305
13-Nov	484	431	417	437	445	441	409	356	280	478	334	412	474	456	467	397	444	426	660	410	320	380	539
14-Nov	606	561	520	524	496	441	365	254	80	32	-39	-32	112	21	7	270	269	239	325	240	150	220	404
15-Nov	626	481	437	508	498	530	654	664	607	617	697	786	712	897	983	932	989	822	475	469	428	580	685
16-Nov	834	1076	1041	995	957	858	850	862	676	606	593	579	475	583	716	508	575	289	350	575	610	520	504
17-Nov	765	936	923	893	853	823	679	684	607	583	388	375	332	509	486	413	393	885	670	310	145	150	280
18-Nov	821	878	886	887	839	798	672	357	363	310	373	542	535	508	574	595	617	827	560	400	460	520	599
19-Nov	650	626	599	611	588	551	549	502	400	421	337	368	332	416	351	352	288	755	470	305	200	100	173
20-Nov	394	513	478	438	461	419	470	299	196	264	373	349	383	486	475	470	455	873	560	280	200	200	197
21-Nov	248	430	387	277	254	296	275	99	-31	-174	-255	-247	-164	-296	-251	-23	-13	370	300	100	120	130	142
22-Nov	86	92	77	29	70	34	102	187	182	211	309	362	345	528	469	344	359	385	530	430	300	90	69
23-Nov	35	45	-11	37	12	34	78	169	157	242	253	290	194	282	320	202	164	491	670	420	180	-50	-104
24-Nov	102	154	81	78	124	201	288	158	192	196	195	256	243	144	287	243	270	381	150	420	450	270	11
25-Nov	70	107	75	28	78	79	274	235	240	271	278	226	243	340	300	265	299	421	150	400	410	270	150
26-Nov	79	120	131	181	174	176	255	227	191	265	198	220	99	230	184	231	223	520	350	395	380	250	154
27-Nov	-39	55	14	16	54	24	-9	213	56	64	122	88	31	-263	-171	-215	-262	-133	-300	15	11	-18	-103
28-Nov																							
29-Nov																							
30-Nov																							
1-Dec																							
2-Dec																							
3-Dec																							
4-Dec																							
5-Dec																							
6-Dec																							
7-Dec																							
8-Dec																							
9-Dec	-452	-137	-98	-137	-147	-145	24	-49	29	129	64	79	28	53	138	-106	-83	293	180	280	200	50	-178
10-Dec	197	106	159	220	200	78	35	280	814	1248	1366	1437	1438	1348	1102	1060	1205	1241	779	750	530	371	264
11-Dec	230	320	312	314	295	295	381	727	929	1079	1189	1164	1086	1090	866	963	1050	1234	849	802	684	439	311
12-Dec	277	243	237	225	157	175	340	396	512	606	530	499	519	306	142	360	401	423	509	566	547	479	161
13-Dec	95	110	119	109	111	77	60	512	678	772	724	812	753	684	754	722	747	947	715	547	370	402	476
14-Dec	279	337	304	340	312	330	513	605	642	788	667	664	668	655	496	633	613	1198	589	451	423	399	594

15-Dec	205	278	329	272	264	284	392	501	571	578	532	502	509	466	383	440	526	1102	559	327	300	119	374
16-Dec	239	281	224	216	260	243	459	502	399	438	438	390	436	483	412	422	630	968	693	600	460	429	383
17-Dec	513	329	368	344	370	327	339	427	368	343	270	223	258	309	241	235	289	449	230	375	460	418	283
18-Dec	71	253	252	234	257	288	313	427	350	365	284	275	257	305	379	450	491	608	490	500	450	360	407
19-Dec	299	329	289	351	332	302	307	126	54	-34	-112	-73	-7	-130	-192	104	104	208	450	350	480	436	273
20-Dec	165	178	208	191	210	221	274	367	349	400	431	412	425	578	540	478	425	782	589	423	380	397	499
21-Dec	189	380	340	409	375	439	522	457	350	345	343	422	513	555	472	384	281	612	600	455	410	398	255
22-Dec	122	255	255	282	264	279	387	280	123	202	163	268	166	223	232	276	299	672	450	430	410	250	69
23-Dec	62	122	115	151	155	157	241	384	134	190	131	213	284	307	188	238	244	689	550	330	280	250	135
24-Dec	57	107	110	137	151	285	216	221	155	216	136	161	209	165	195	353	213	699	590	300	180	103	-26
25-Dec	-47	161	161	177	115	133	195	255	193	80	178	278	297	364	355	309	353	788	520	300	160	109	82
26-Dec	22	130	65	50	58	63	-17	-82	-101	-218	-247	-147	-126	-315	-348	-154	-136	-4	20	100	30	-6	-129
27-Dec	-162	-110	-117	-87	-64	-77	-41	64	110	120	55	197	223	409	438	350	429	889	412	250	164	82	170
28-Dec	-27	9	33	54	70	49	124	258	174	192	255	274	144	244	232	207	219	618	413	250	100	11	56
29-Dec	122	15	24	49	101	102	166	222	-45	-4	45	62	47	32	50	34	92	336	215	86	72	141	131
30-Dec	170	176	201	131	168	182	274	548	806	1176	1316	1349	1414	1336	1178	1413	1479	1578	868	747	646	561	459
31-Dec	72	224	229	232	285	290	338	422	499	538	397	459	413	293	248	260	330	630	373	289	173	192	358

Effect of Daylight Saving Time on Bangladesh Power System

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Abstract—**Load Management (LM) is an alternative to meet the increasing peak demand of electricity. The Daylight Saving Time (DST) is one of the options of LM. The implementation of DST is a common practice in many developed countries. Bangladesh Power System (BPS) has recently implemented DST to reduce its unmanageable increasing demand. However, the effectiveness of this option of LM has not yet been evaluated. This paper develops a technique to quantify the effect of DST on a power system. The paper also presents the application of the technique in BPS.**

Keywords— **Load management, day light saving time, forecasted demand, load shedding and generation capacity saving**

I. INTRODUCTION

When Bangladesh Government implemented DST on June 19, 2009, the main motive citied was that extending the hours of sunlight later into the day reduces the need for artificial lighting in the evening, and thereby decreases electricity consumption during the summer months [1]. While the advancement of time by one hour increases electricity usage in the morning hours, this effect should be outweighed by reduced consumption in the later hours of the day.

The potential of DST to save energy comes primarily from its effects on residential lighting. Delaying the nominal time of sunset and sunrise, reduces the use of artificial light in the evening and increases it in the morning. Although energy conservation remains an important goal, energy usage patterns have greatly changed since then, and recent research is limited and reports contradictory results. Electricity use is greatly affected by geography, climate, and economics, making it hard to generalize ([2]-[10]).

This paper develops a technique to quantify the effects of DST on a power system in terms of energy saving and additional generation capacity requirement. The technique identifies the time zones of the day during which the impacts of DST are significant. It compares the electricity use and generation capacity requirement with and without DST implemented system. The technique utilizes the simple load forecasting method. The proposed technique is applied to BPS to evaluate the effectiveness of DST option of LM for BPS.

II. METHODOLOGY

The objective of DST is to use more day light instead of using the light produced by electricity. Therefore, the effect of DST is mainly during evening and morning hours; that is around the sunset and sunrise time. The effect is mainly on (1) energy consumption and (2) peak demand. This effect may be quantified by evaluating the degenerative energy consumption and generation capacity saving due to peak load reduction during evening and morning hours. The degenerative energy consumption may be evaluated by evaluating the difference implementation of DST and the probable energy consumption at that time if DST were not implemented. That is, the expected energy saving may be expressed as,

$$E(ES) = \int_{T_o}^{T_l} DG(t)dt \qquad (1)$$

Where,
$E(ES)$ = Expected energy saving due to the implementation of LM scheme DST.
T_o = Starting time when the effect of DST could occur
T_l = The limiting time when the effect of DST reduces to zero (negligible).

The degenerative consumption at a time, DG (t), may be expressed in terms of the difference in energy consumption as,

$$DG(t) = PD(t) - AD(t) \qquad (2)$$

Where,
$PD(t)$ = The probable demand at time t if DST were not implemented.
$AD(t)$ = Actual demand at time t after the implementation of DST.

Equation (1) may be written by expressing the morning and evening effects separately as,

$$E(ES) = \int_{T_{ss}}^{T_{nl}} DG(t)dt + \int_{T_{ma}}^{T_{sr}} DG(t)dt \qquad (3)$$

Where,
T_{ss} = Starting time in the evening when the effect of LM shift could occur.
T_{nl} = Time at which the effect of DST reduces to zero.
T_{ma}= Time when the morning activities start before sunrise.
T_{sr} = Limiting time in the morning when the effect of DST reduces to zero during the morning hours.

The capacity saving may be evaluated by evaluating the reduction of the peak demand due to the implementation of DST scheme. That is,

$$E(CS) = Min\{CRM_i\} \quad i = 1, 2 \ldots n \qquad (4)$$

Where,
$E(CS)$ = Expected capacity saving due to DST.
CRM_i = Expected difference during maximum generation capacity requirement for the i^{th} day.
n= Number of days in a year during which DST is implemented.

CRM_i may be expressed in terms of peak demands of i^{th} day with and without implementing DST. That is,

$$CRM_i = K(PPD_i - APD_i) \qquad (5)$$

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Where,

PPD_i = Probable Peak Demand of the i^{th} day if DST were not implemented.

APD_i = Actual Peak Demand of the i^{th} day after the implementation of DST.

K= Factor inflating peak to determine the required generation capacity

III. Basic Data

To evaluate the effect of DST on the energy consumption and peak load reduction of BPS, its hourly load of last 12 years are collected from the National Load Dispatch Center (NLDC). BPS is unable to meet its monotonically increasing demand and LM through load shedding scheme is its common practice. Load shedding data of all 12 years is not available, only load shedding of last 3 years, 2007 to 2009, and are collected for the study.

A. Data Analysis

Before the investigation into the effect of DST, the data is analyzed. The increase in the peak load over the last 12 years is depicted in Fig. 1. The increment is expressed in percentage of the annual peak of 1998. The average increase of peak load in a year is around 260MW. The annual peak occurs usually during August to September at around 7PM. The figure shows that growth is 72% over the last 12 years.

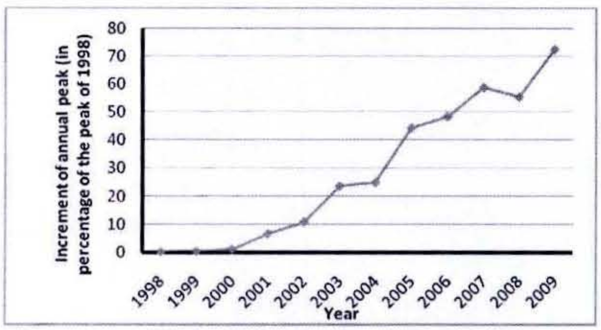

Fig.1 Growth of annual Peak

The DST scheme is implemented from June 19th to December 31st, 2009. Over this period the monthly energy sheds of last 3 years are presented in Fig. 2. The figure shows that the energy shedding is higher during June to August and starts to decrease in September. The minimum amount of energy shed is in December. The highest amount of load shed during this period is 10.8% of the supplied energy.

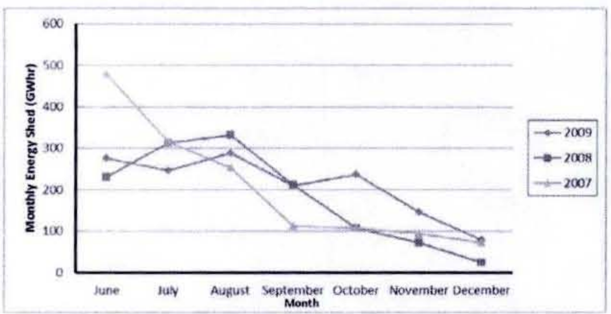

Fig. 2 Monthly Load Shedding of the last 3 years

IV. Effect of DST Scheme

The DST scheme implementation period of BPS is only June 19th till December 31st, 2009. The monthly average peak demands of this period of 2009 along with their occurrence time are compared in Table I with those of 2008. Note that the DST is not implemented in 2008. The table clearly shows that the average peak of each month of 2009 is higher than that of 2008 and the time of occurrence is shifted by an hour. That is if time shift through DST is ignored, the peak occurrence time of both the years is same. That is, there is no significant impact due to DST, on the time of use of electricity during evening hours.

TABLE I
COMPARISON OF MONTHLY AVERAGE PEAK AFFECTED BY DST SCHEME WITH THAT OF WITHOUT DST SCHEME

Month	Peak (MW)		Time of Occurrence	
	2008	2009	2008	2009
June	4184	4489	8-9PM	7-8PM
July	4285	4514		
August	4334	4666		
September	4331	4676		
October	4080	4734		
November	4059	4369	7-8PM	6-7PM
December	3788	4094		

A. Energy Saving

To evaluate the amount of energy saving due to DST scheme, the probable hourly demand of June to December of 2009 during which DST is implemented, is forecasted first.

In order to forecast the demand, the loads of 1998 till 2009 and the demands of 2007 and 2008 are used. The demand at any time is calculated by adding load shedding amount with the actual load supplied at the time. However, the amount of load shading was not available from 1998 till 2006, hence the loads of this period are inflated by a factor $K(t)$, where $K(t)$ of any time t is determined by taking the ratio between the summation of demands and the summation of loads of 2007 and 2008 at time t. A polynomial of degree 6 is used in the forecast. The forecasted results are validated through actual demands of the months of 2009 during where DST is not implemented.

Table II presents the forecasted and the actual demand of a few morning and evening hours of June 15th, 2009, a randomly selected date, along with the corresponding deviations. The deviation of morning hours is a bit higher than those of evening hours. The observed maximum deviation in the forecasted values is 3.4%.

TABLE II
DEVIATION OF THE FORECASTED DEMAND FROM THE ACTUAL

Time	Demand (MW)		Deviation (%)
	Forecasted	Actual	
4AM	3376	3495	3.40 %
5AM	3256	3169	2.75 %
6AM	2972	3069	3.16 %
7AM	3093	3125	1.02 %
5PM	3532	3580	1.34 %
6PM	3618	3580	1.06 %
7PM	4333	4360	0.62 %
8PM	4580	4650	1.51 %
9PM	4553	4585	0.70 %

The difference of the forecasted and the actual demand of different evening hours during DST implementation period are depicted in Fig. 3. The deference of morning hours is depicted in Fig. 4. The depicted values in Fig. 3 and Fig. 4 are the average values over a month. It is observed from these two figures that there is no significant demand reduction due to implementation of DST scheme except for 7PM of June to August. There is also slight demand reduction at 6PM during September to December and 6 to 8 AM of December.

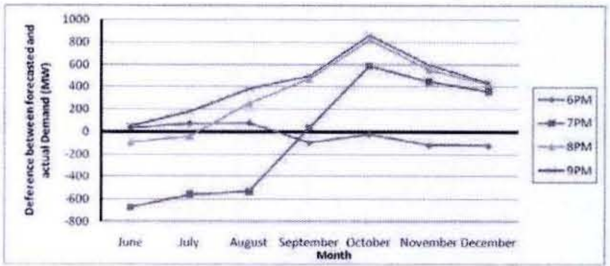

Fig. 3 Impact of DST scheme on Demand of evening hours

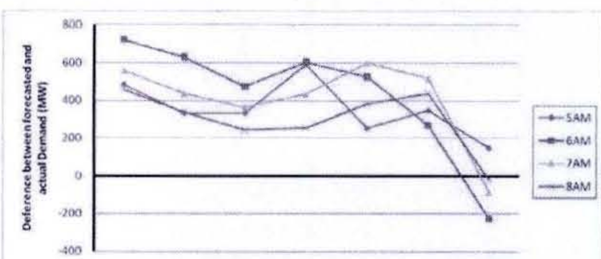

Fig. 4 Impact of DST scheme on Demand of morning hours

The monthly energy consumption deference between consumption with and without DST scheme implantation for morning and evening hours and also the cumulative value of morning and evening hours are represented in Table III. The last column of this table presents the monthly energy consumption difference in percentage of the actual consumption. In this case, the evening hour is considered to span from 5PM to 11PM and the span of morning hours is considered to be from 4AM to 9AM. The table clearly shows that only during the evening period of June and July and the morning period of December there is a saving in energy consumption. However, the sum of the energy consumption during the morning and evening periods of each month shows clear increase of 576 GWhr in the energy consumption, instead of decrease.

TABLE III
ENERGY CONSUMPTION DIFFERENCE BETWEEN THE FORECASTED AND ACTUAL ONES

	Energy Consumption Difference (GWhr)			
Month	**Morning**	**Evening**	**Total**	**%**
June (11 days)	33	-6	27	5.9 %
July	72	-4	68	5.3 %
August	57	10	67	5.1 %
September	72	34	106	8.4 %
October	69	85	154	12.1 %
November	67	48	115	10.8 %
December	4	35	39	4.0 %
Total Energy Difference			**576**	**7.5 %**

This increment is much higher than that of the percentage deviation of the forecasted demand observed in Table II.

B. Capacitive Saving

To evaluate the generation capacity saving, the difference between the peak of forecasted and actual demand of each day is determined. The minimum difference in peak demand of each month is presented in Table IV. This table also presents the minimum difference of all months of the DST implementation period.

TABLE IV
CRM TREND DURING THE DST IMPLEMENTED MONTHS

Month	Peak Generation Capacity Saving (MW)	
June (11 days)	-304	
July	-377	
August	-457	**Saving over the DST period**
September	-592	
October	-691	
November	-574	
December	-347	-691

The table clearly shows that instead of capacity saving, there is an additional capacity requirement of 691 MW during the DST period.

V. CONCLUSIONS

The implementation of DST option of LM derives benefit in terms of energy consumption and capacity savings through wider use of sunlight instead of artificial light produced by electricity. The implementation of DST in BPS fails to achieve its objective. Study shows a decrease in energy consumption during the evening hours for a few months. However, the total energy consumption over the entire DST implementation period is increased. Similar is the case for the generation capacity requirement.

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