1. INTRODUCTION

THE PROJECT

The project is to undertake Energy Audit of Raj Bhawan Complex, Guwahati, Assam.

The basic objective of the Energy Audit was to study the operations/performance of both Electrical and Thermal energy intensive equipments/ systems for identification of potential areas wherein energy savings are practically feasible.

BUILDING PROFILE

The building complex consists of two parts, Governors Residence and Lachit Wing. Lachit Wing is four storied and consists of VVIP guest house, Darbar hall and Secretariat for Governor. The maintenance activities are being looked after by **Sri K. Das, Asst. Exe. Engineer** and **Sri B. Saikia Asst. Engineer** of PWD, Guwahati and assisted by other professional/ technical staff.

The main sources of Energy being used are Electrical Power purchased from M/s. ASEB Limited and HSD for DG set.

PREVAILING RATES OF VARIOUS ENERGY SOURCES

- Purchased Power = Rs 5.46/ unit (2008 avg.)
- HSD = Rs.33.0/ Litre

TARIFF STRUCTURE

Charges on Billing Demand	@ Rs 145/- per KVA
Energy Charges	@ Rs 4.10/- per unit

Contract Demand	216.47 KVA
Penalty on P.F. (below 0.85)	@ Consumed unit X (0.85 – P.F.)
Billing Demand	216.47 KVA

SCOPE OF WORK

The study was aimed at identifying the potential for reduction of energy consumption in the following areas:

❖ **Electrical Distribution System**: Study and analysis of contract demand, power factor, performance of transformers, and suggestions to improve performance.

❖ **Illumination System**: Study of the lighting systems and measures for improvements wherever feasible.

❖ **Air Conditioning Systems**: Study and analysis of TR requirement, opportunity to reduce loss and need of air conditioning.

❖ **Motive Load**: The operations of Electric Motors/Pumps were studied to assess the Loading Pattern, Power Factor and other operational parameters.

❖ **DG set**: In addition to above, the study also covered the performance of DG set, to suggest measures for Energy Efficiency Improvements.

METHODOLOGY

The Methodology adopted for achieving the desired objectives viz: Assessment of the Current operational status and Energy savings included the following:

☞ Discussions at site with the concerned officials for **identification of major areas of focus** and other related systems;

☞ A team of engineers visited the institute and had discussions with the concerned officials/supervisors to collect data/ information on the operations and Load Distribution. The data was analyzed to arrive at a **base line** energy consumption pattern.

- **Measurements and monitoring** with the help of appropriate instruments including continuous and/ or time-lapse recording, as appropriate and visual observations were made to identify the energy usage pattern and losses in the system.
- Computation and **in-depth analysis** of the collected data, including utilization of computerized analysis and other techniques as appropriate to draw inferences and to **evolve suitable energy conservation plans** for improvements/ reduction in specific energy consumption.

PARTICIPATION

Head and all other the working group members of Raj Bhawan co-ordinated and helped the Energy Audit Team during the site visits, these include amongst others the following:

- Sri K. Das, Asst. Exe. Engineer
- Sri B. Saikia Asst. Engineer, PWD, Guwahati

A team of PCRA engineers comprising of the following officials were involved in conducting the study.

- Sh. K.L. Bhutia, Deputy Director & SRO Guwahati
- Sh. A. Chakroborti, Jt. Director
- Sh. Rabindranath Mandal, Jt. Director

SUMMARY OF ENERGY CONSERVATION OPPORTUNITIES

Electrical Savings						
Recommendations	**Energy Savings**				**Estd. Investment**	**Simple Payback period**
	KWh	**Lac K.Cal**	**KL of oil equivalent**	**Rs Lacs**	**Rs Lacs**	**Yrs.**
Installation of Automatic P.F. Controller				0.94	0.27	0.3
Installation of 100 KVA transformer during normal operation	7663			0.4	1.0	2.4
Replacement of conventional tube lights (40w TFL) with energy efficient tube lights (28w T5)	2966			0.154	0.193	1.25
Replacement of 133 nos conventional bulbs (60/40w GSL) with CFL lamps (11w)	2350			0.122	0.045	0.37
Replacement of 9 numbers 1.5 TR air conditioners	13297			0.726	1.8	2.5
Replacement of Electric Geyser with solar water heater	4320			0.236	1.0	4.2
Total – (A)	**30596**			**2.578**	**4.3**	

2. STUDY OF ELECTRICAL DISTRIBUTION SYSTEM

Governor's House, Assam is importing power from Assam State Electricity Board through an 11.0 KV supply. The contract demand of the institute is 216.47 KVA. Two 250 KVA DG set meets the emergency power demand during outage of M/s. ASEB.

ANALYSIS OF DEMAND

Monthly electricity bill

Month & Year	KWH (Consumed)	Avg. PF	KWH (PF Penalty)	KWH (Charged)	KW (Billed Demand)	Energy Charge (Rs.)	Demand Charge (Rs.)	Total Charge (Rs.)
July,03	17037	0.8	851.85	17337	184	4.1	145	97761.7
June,03	14933	0.73	1791.96	14933	184	4.1	145	87905.3
sept,03	23917	0.81	956.68	13935	184	4.1	145	83813.5
dec,04	18417	0.64	3867.57	18417	184	4.1	145	102189.7
Jan,04	18822	0.65	3764.4	18822	184	4.1	145	103850.2
march,04	17952	0.64	3769.92	17952	184	4.1	145	100283.2
Oct,07	28639			28639	184	4.1	145	144099.9
Oct,07	28639			28639	184	4.1	145	144099.9
April,08	23912	0.78	1673.84	25586	216.47	4.1	145	131582.6
July,08	27187	0.86	-271.87	26915	216.47	4.1	145	137031.5
Nov,08	20837	0.71	2917.18	23754	216.47	4.1	145	124071.4
Monthly Avg 08	23978.67	0.78	1439.72	25418.33				130895.2
Avg. unit cost, Rs.								5.46

Observations

1) An average of 1440 KWH of electricity has been charged monthly in excess of consumed units for maintaining P. F. below 0.85. This can be avoided through installation of **Automatic Power Factor Controller (APFC)**. Resultant savings can be calculated as below:

PF Penalty and Savings:	
Average unit as penalty, KWH	1440
Monthly avg. penalty, Rs	7848.00
Annual penalty, Rs.	94176
Average Demand, KVA	90
Existing average P. F.	0.78
Improved P. F.	0.99
Required KVAr	46.26
Cost of 50 KVAr APFC, Rs.	27500
Pay back, Yr.	0.3

TRANSFORMER OPERATIONS

There are two numbers of transformers are installed and operated for the institute. One 250 KVA transformer giving supply to governors residence and another 250 KVA transformer is supplying power to Lachit Wing.

Transformers are extremely efficient devices; however, since the entire power consumption of the building complex is through the transformers, some loss does take place. These losses are difficult to measure under site conditions as its magnitude in relation to the actual power consumption of the complex is very small.

Site testing of transformers is not possible without isolation of the transformers.

$$Transformer\ efficiency = \frac{kW}{kW + No\ load\ Losses + (\%loading)^2 \times Load\ losses}$$

Observations & Comments

Distribution transformers generally have full load efficiency around 98.5%. At lower loading levels, the efficiency increases, peaks at a value around 99.1% to 99.5% at about 50% kVA loading and then falls to around 98% to 98.5% at lower loading levels. If the transformer loading is very low i.e. below 10%, the efficiency deteriorates as then the fixed iron losses become the predominant loss.

Higher power factor at the load end helps reduce the current and the resistive losses in electrical distribution and generators.

Power reading Lachit Wing Transformer down stream:

	Vr (Volt)	Vt (Volt)	Ir (Amp)	It (Amp)	f (Hz)	P.F.	P (KW)
Feeder 1	417	420	5.5	8.3	49.7	0.68	3.2
Feeder 2	420	421	5.4	12.9	49.7	0.88	5.9
Average / Total						0.78	9.1
Transformer Loading %							4.67%

Power reading Governors Residence Transformer down stream:

	Vr (Volt)	Vt (Volt)	Ir (Amp)	It (Amp)	f (Hz)	P.F.	P (KW)
Feeder 1	410	414	4.85	5.9	49.4	0.46	1.76
Feeder 2	410	413	4.85	10.83	49.4	1	5.6
Average / Total						0.73	7.36
Transformer Loading %							4.03%

TECHNIQUES FOR IMPROVING EFFICIENCY OF EXISTING TRANSFORMERS

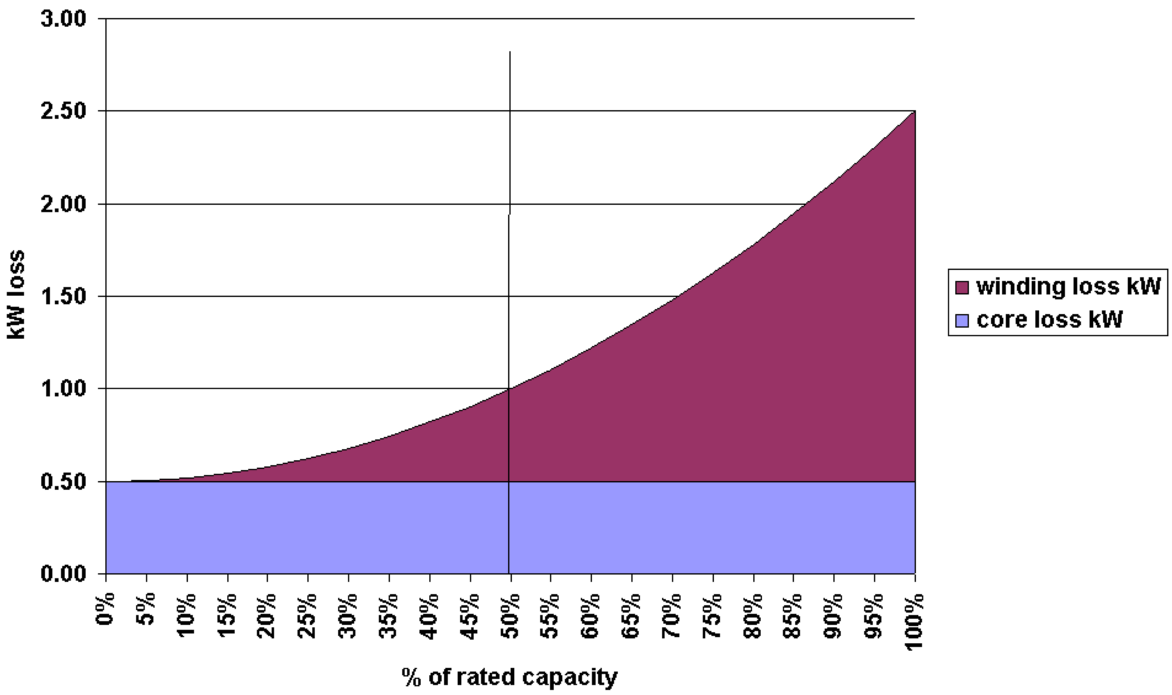
Reduction of Transformer Losses by Power Factor Improvement

Transformer load losses vary as square of the current. If the power factor is poor, for the same kW load, the current is higher leading to higher losses in transformers and cables; the transformers also reach their limits for kVA loading with smaller kW loads when the power factor is poor. If the power factor is maintained at unity the saving in load losses =

(Per unit loading as per kW)^2 x Load losses at full load x [(1/PF)^2 – 1]

At Governors House, there is scope for improvement of power factor as the power factor of the feeder is in the range of 0.46 to 1.0. If the transformers are operated at unity power factor by **installation of capacitor bank (APFC)**, the total transformer losses can be reduced minimum. Capacitors can help in reducing kVA loading on transformers operating close to their rated load.

Operation of Transformer close to 50% loading



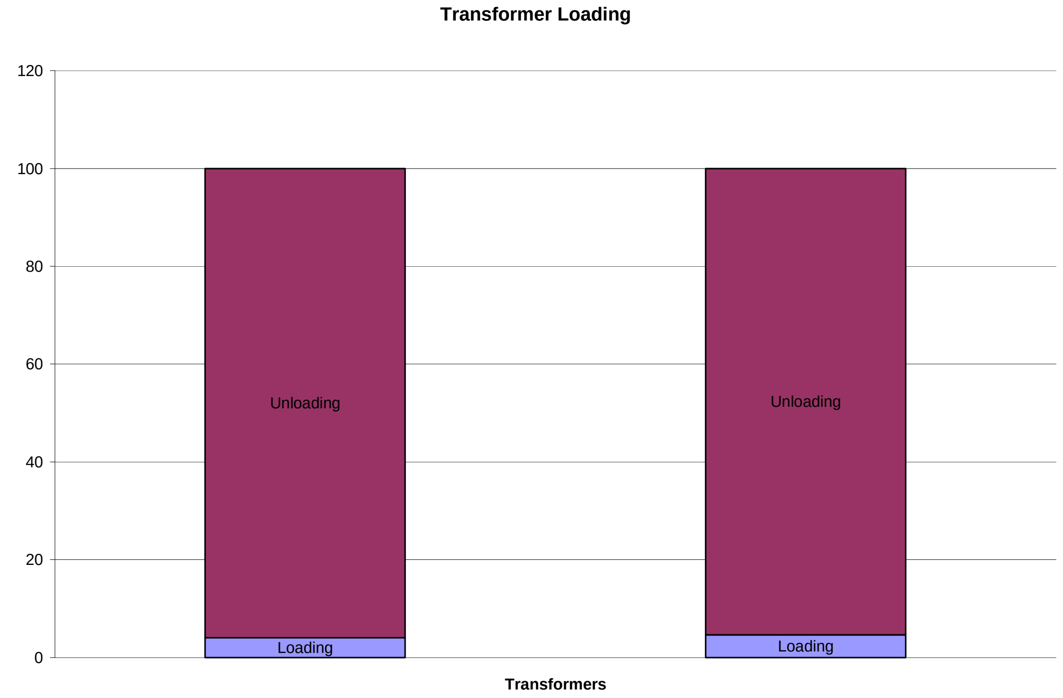
The peak efficiency of distribution transformers generally occurs near 50% to 60% loading when the fixed losses (iron losses) are equal to the variable (copper losses). Academically speaking, efficiency can be improved by loading some of the transformers to about 50% level, wherever the electrical distribution system permits the same. However, since the electrical distribution of the institute is built on the concept of reliability and zero forced downtime, it is not advisable to attempt any such relocation of loads for the achieving the relatively minor energy savings.

Lachit Wing Transformer loading:

	Vr (Volt)	Vt (Volt)	Ir (Amp)	It (Amp)	f (Hz)	P.F.	P (KW)
Feeder 1	417	420	5.5	8.3	49.7	0.68	3.2
Feeder 2	420	421	5.4	12.9	49.7	0.88	5.9
Average / Total						0.78	9.1
Transformer Loading %							4.67%

Governors Residence Transformer Loading:

	Vr (Volt)	Vt (Volt)	Ir (Amp)	It (Amp)	f (Hz)	P.F.	P (KW)
Feeder 1	410	414	4.85	5.9	49.4	0.46	1.76
Feeder 2	410	413	4.85	10.83	49.4	1	5.6
Average / Total						0.73	7.36
Transformer Loading %							4.03%



It can be observed from above that both transformers are loaded very poorly. Therefore, it is recommended **to install and operate one 100 KVA transformer** during normal operation and existing two numbers transformers will be de-energized. The savings due to this can be estimated as below:

Description	**Details**
No load loss of a 250kVa Transformer, KW	0.57
No load loss 2 nos Transformer, KW	1.14
Load loss of Lachit Wing transformer, KW	0.01
Load loss of Governor Residence transformer, KW	0.01
Total loss, KW	1.16
After Switching 100 KVA transformer	
No load loss 100 KVA Transformer, KW	0.26
Load loss 100 KVA Transformer, KW	0.02

Total loss, KW	0.28
Savings, KW	0.87
Annual Savings, KWH	**7663.42**
Annual Savings, Rs. (@5.46/- per KWH)	**41842.29**
Investment for 100 KVA transformer, Rs	100000.00
Simple Pay Back, Yr.	2.39

Stopping Idle Operation of Transformers

Another important issue is that transformers, even when not loaded, will consume power i.e. no load losses (also called iron losses). To avoid the same, idle transformers will have to be switched off. Switching off transformers for prolonged periods, especially during periods of high humidity, can lead to deterioration of transformer oil, makes it difficult to energize the transformer at short notice. Keeping in view the very high reliability requirements, we do not recommend any switching off of transformers in case of process plants, since the energy savings are relatively minor.

Amorphous Core Transformers

Amorphous core transformers, in comparison to the laminated core transformers, have lower iron losses, and can save energy (refer table below). The thickness of amorphous steel foils is about 0.03 mm compared to 0.18 to 0.23 mm for CRGO laminations, this reduces iron losses by about by about 75% (comparisons are given at a magnetic flux density of 1.5 Tesla). However, since magnetic flux densities in amorphous core transformers are likely to be lower, the volume of the core may be larger, leading to longer winding length and higher copper losses. Hence, at the time of transformer selection, comparison of total losses is preferred at the most probable loading level.

Evolution of Transformer Core Material with Reference to Core Losses

Year (Approx.)	Core Material	Thickness (Mm)	Loss (W/Kg At 50hz)
1910	Warm rolled FeSi	0.35	2 (1.5T)
1950	Cold rolled CRGO	0.35	1 (1.5T)
1960	Cold rolled CRGO	0.3	0.9 (1.5T)
1965	Cold rolled CRGO	0.27	0.84 (1.5T)
1975	Amorphous metal	0.03	0.2 (1.3T)
1980	Cold rolled CRGO	0.23	0.75 (1.5T)
1985	Cold rolled CRGO	0.18	0.67 (1.5T)

These transformers are available up to 2000 kVA rating in India. Considering energy savings and investments (about 40% higher than conventional transformers with laminations), it is not economically viable to replace existing transformers. However, these transformers can be considered for expansion. We suggest that these transformers can be installed for non-critical applications initially till sufficient confidence is gained by the electrical department in the new technology.

3. STUDY OF LIGHTING SYSTEMS

INSTALLED FITTINGS LUMINOUS EFFICACY AND LIFE

S. No.	Light Sources	Lamp Wattage (Watts)	Lumens	Efficiency (Lumens/ watt)	Choke Rating (watt)	Avg Service life (hrs)	Colour Rend. index
1	Incandescent lamps (GLS)	100	1360	14		1,000	100
2	Fluorescent tubes	40	2400	60	15	5,000	70
	Fluorescent tubes (super)	36	3250	90	2	14,000	70
3	T5 Fluorescent lamps	28	2700	96	2	18,000	70
4	Compact Fluorescent lamp	15	810	56		8,000	85
5	High pressure Mercury Vapor lamp	80	3400	43	9	5,000	45
		125	6300	50	12	5,000	45
		250	13000	52	16	5,000	45
		400	22000	55	25	5,000	45
6	Metal Halide	70	4200	84	26	10,000	70
		150	10500	70	20	10,000	70
		250	19000	76	25	10,000	70
		400	31000	76	60	10,000	70
7	Halogen	500	20000	22		2,000	100
8	High pressure Sodium Vapor lamp:	70	5600	80	13	15,000	25
		150	14000	93	20	15,000	25
		250	25000	100	20	15,000	25
		400	47000	118	40	15,000	25

Good lighting design is the key to minimize energy costs for lighting. Approximately 20% - 30% of the total energy cost in a building accounts from lighting. Besides incorporating efficient technology, effective lighting design should address users' priority for visual performance, comfort and ambience, incorporate natural lighting and provide the occupants flexibility in controlling light levels.

The Lachit House building has 50 Nos. of Fluorescent tube lights (FTL) which are the conventional 40 W FTLs. There are also 133 Nos. of GLS lamps (40 watts each) and 183 Nos. of Compact Fluorescent Lamps.

The Governor's Residence Building has 57 Nos. of FTLs, 52 Nos. of GLS lamps (40 watts each) and 213 Nos. of Compact Fluorescent Lamps. All the FTLs are installed with electronic ballast which is more energy efficient.

The outside ground is illuminated through 98 Nos. of CFLs, 17 Nos. of Mercury Vapor lamps (70 Watts each) and 9 Nos. of Metal halide lamps (150 watts each).

Illumination study was carried by measuring the LUX level of the entire Building and was compared with standard level. The lux level measured at different locations is tabulated below. There are different types of light fittings in the building and a detailed inventory of the lights with type, area, wattage, measurement of LUX (Lumen/M^2) is shown in the table below.

All the switching arrangement is individual switching. The overall illumination in some of the Halls were found low but based on its use as bedroom / lobby it has been designed for low level of illumination. The Durbar Hall is used for Govt. Official functions mostly during the day. The general house-keeping of the light fixtures and luminaries is good. It should be noted that dirty fixtures, broken or aged diffusers, old lamps in dilapidated condition reduces efficiency of lighting by about 40%.

ILLUMINATION DETAILS FOR GOVERNOR'S RESIDENCE

Sl. No.	Location	Fittings NOS	Fittings Type	Fittings Watts	Total Watts	Lux Level Measurement	Avg Lux	Target Lux	Remarks
1	**ADC's Office**	**12**	**CFL**	**13**	**156**	98,131,109,115,132,141	121	300 - 750	
2	**Governer's Office**	**19**	**CFL**	**18**	**342**	267,331,286,271,213,176, 209,233,294,300, 245	257	300 - 750	
3	**PS to Governer**	**12**	**CFL**	**13**	**408**	260,274, 268,277,402, 423, 425, 452	348	300 - 750	
		6	**FTL**	**42**					
4	**Governer's 1st Drawing Room**	**19**	**CFL**	**11**	**209**	46, 38, 52, 66,130,122, 45, 70	72	300 - 750	
5	**Governer's Formal Drawing Room**	**16**	**CFL**	**11**	**656**	159,152,154,158,153,164, 158,174,165,178	162	300 - 750	
		12	**GLS**	**40**					
6	**Governer's Bed Room**	**5**	**CFL**	**11**	**177**	64, 84, 72,137,96,85,110, 96, 93	93	300 - 750	
		2	**FTL**	**42**					
		1	**FTL**	**38**					
7	**Main Dining Hall (Ground Floor)**	**8**	**FTL**	**42**	**1296**	118, 108, 119, 120, 113, 89, 98, 74	105	300 - 750	
		24	**GLS**	**40**					
8	**Guest Room Manas**	**3**	**FTL**	**42**	**366**	58, 78, 55, 77, 68, 89, 90, 133, 155, 382, 283, 119	133	300 - 750	
		6	**GLS**	**40**					
9	**Guest Room Kaziranga**	**3**	**FTL**	**42**	**366**	60, 56, 76, 45, 76, 90, 132, 67, 88, 157, 381, 120, 282	126	300 - 750	
		6	**GLS**	**40**					
10	**Guest Room Orang**	**1**	**FTL**	**42**	**162**	76, 144, 86, 84, 90, 88	95	300 - 750	
		3	**GLS**	**40**					
11	**Guest Room Pabitra**	**2**	**FTL**	**42**	**124**	23, 44, 34, 75, 65, 52	49	300 - 750	
		1	**GLS**	**40**					
12	**Guest Room Rupahi**	**6**	**CFL**	**13**	**78**	74, 80, 24, 102, 35, 95, 86	71	300 - 750	
13	**Guest Room Subanshiri**	**4**	**CFL**	**13**	**107**	154, 164, 74, 118, 122, 120, 135, 128, 148	130	300 - 750	
		5	**CFL**	**11**					
14	**Luhit Sitting Room**	**4**	**CFL**	**13**	**404**	331, 318, 325, 324, 354, 248, 310, 264	310	300 - 750	
		2	**CFL**	**8**					
		8	**FTL**	**42**					

15	**Luhit Bed Room**	**4**	**CFL**	**13**	**401**	219, 249, 247, 252, 224, 207, 240, 188, 192, 203, 192	220	300 - 750	
		5	**CFL**	**11**					
		7	**FTL**	**42**					
16	**Guest Room Tipkai**	**7**	**CFL**	**13**	**336**			300 - 750	
		7	**CFL**	**11**					
		4	**FTL**	**42**					
17	**Guest Room Kapili**	**4**	**CFL**	**13**	**401**	239, 227, 222, 253, 207, 247, 241, 194, 205, 190, 187	220	300 - 750	
		5	**CFL**	**11**					
		7	**FTL**	**42**					
18	**Conference Room**	**8**	**CFL**	**36**	**579**	286, 240, 156, 214, 167, 199, 436, 152, 173, 136, 175, 239	215	300 - 750	
		8	**CFL**	**13**					
		17	**CFL**	**11**					
19	**Kitchen (Gr. Floor)**	**5**	**FTL**	**42**	**210**				
20	**Dining Hall (1st Flr)**	**4**	**CFL**	**13**	**52**				
21	**Parking Area**	**40**	**CFL**	**11**	**440**				
22	**Outside Area / Perimeter Lighting**	**17**	**MVL**	**70**	**3339**				
		9	**MH**	**150**					
		95	**CFL**	**8**					
		3	**CFL**	**13**					
23	**Total Wattage (Watts)**				**10609**				

THE INSTALLED LOAD EFFICACY RATIO (ILER)

Lightning detail for Lachit Bhavan

Sl. No.	Location	Fittings NOS	Type	Watts	Total Watts	Lux Measurements	EAV Avg.	Lux/W/ M2	Target Lux/W /M2	ILER	Remarks
1	**VVIP Floor Passage**	10	CFL	13	130	54, 48, 45, 51,96,71,76,101	68	11.07	46.00	0.24	
2	**VVIP Lobby**	10	CFL	13	174	96,135,124,154,174,130,1	135	25.23	40.00	0.63	

		4	CFL	11		24,174,121,117					
3	**Dikhow Suite**	22	CFL	13	686	144, 180,168,110,108,138 ,169, 196,214, 141,129, 110,214	155	8.73	40.00	0.22	
		10	GLS	40							
4	**Dikhow Lobby**	22	CFL	13	286	165,171, 150,173,196, 233,240, 235, 220	198	9.00	40.00	0.23	
5	**VVIP Waiting hall**	12	CFL	13	156	219,236,241,264,256,234, 278,281	251	34.53	43.00	0.80	
6	**Bramhaputra Suite**	4	CFL	13		91, 89, 110, 106, 89, 110,126, 130, 113, 101, 84					
	Drawing hall	10	CFL	8	612		105	5.56	43.00	0.13	
		12	GLS	40							
7	**Bramhaputra Suite**	16	CFL	13		113, 130,138,163,187,208, 201,214					
	Bedroom	12	CFL	11	900		170	8.35	43.00	0.19	
		14	GLS	40							
8	**Dhansiri Suite**	10	CFL	13		115, 106, 198, 217, 157, 178, 198, 221, 124					
		3	CFL	11	523		169	7.14	36.00	0.20	
		9	GLS	40							
9	**Durbar Hall**	48	CFL	13	4144	94, 92, 86, 101, 96, 105, 97, 102, 110, 95, 89	97	4.44	43.00	0.10	
		88	GLS	40							
10	**Secretariat Lobby**	4	FTL	42	168	365,230,298,192,180,238, 122	233	46.88	40.00	1.17	
11	**Corridor**	1	FTL	42	42	56,109,128,153,68	103	34.22	36.00	0.95	
12	**Secretariat Hall**	11	FTL	42	462	211,207,147,153,155,174, 192,136,238,239,192,281, 299,280	208	28.85	43.00	0.67	
13	**Principal Secretary's Office**	6	FTL	42	252	438, 494, 320, 780, 497, 531, 567, 542	522	59.25	40.00	1.48	
14	**Jt. Secy's Office**	4	FTL	42	168	498,747,722,765,720,825	713	82.05	36.00	2.28	
15	**Under Secy's Office**	4	FTL	42	168	650,437,524,395,559,518	514	36.95	36.00	1.03	
16	**Dy. Secy's Office**	2	FTL	42	84	346,448,480,406,271,435, 413,269	384	66.21	36.00	1.84	
17	**Garage Space**	18	FTL	42	756						
18	**Total Wattage (Watts)**				9711						

RECOMMENDATIONS

The Installed Load Efficacy Ratio (ILER) indicates how efficiently the installed luminaries are functioning. A low figure indicates that a review and action is required for improving. The improvement can be done through:

(i) By replacing the existing lamps by energy efficient luminaries- like replacing the conventional tube lights (slim 36 Watt & 40 Watt T/L) by T-5 tube lights, which consume only 28 watts. This can be done phase wise on failure replacement basis.

(ii) The color & reflectivity of wall and ceiling is to be bright to reduce the lighting requirement. For example, the cupboards and wooden paneling in some rooms are dark brown in color thereby reducing the overall illumination.

(iii) Effective use of daylight wherever possible should be made.

OTHER MEASURES TO REDUCE LIGHTING LOAD ARE:

- Installing zone switching.
- Luminaries to be cleaned regularly to increase illumination. Normally 10-20 % light output reduces over a period of six months if not cleaned.
- Whenever replacing a burnt out lamp we should replace it with a more efficient lamp and replace the ordinary choke of T/L fitting with an electronic ballast fitting. This result in power savings as the electronic ballast consume only 2 to 6 Watts compared to the electromagnetic ballast, which consumes around 15 Watts of electrical energy.
- Use of time clocks or photocell control for outdoor lighting.
- During breaks the lights of the specific workplace should be switched OFF, for which individual switches at the worktable is helpful.
- Where it is possible the entire lighting load can be supplied through voltage stabilizer (AVR). On maintaining 190 V single-phase voltage tremendous scope of savings exists.

POTENTIAL SAVINGS IDENTIFIED

A) Replacement of 107 nos. 40 Watt Tube lights with 28-watt electronic ballasts tube lights (T5):

Advantage: Lamp efficacy (in lumen/watt) of T5 is much higher than T8 and life of T5 is almost 3.5 times of T8.

Savings calculation for Replacement of 40 watt TFL with 28 watt T5:

Total No. of 40 watt TFLs in the area= 107

Power consumed by each TFL with electronic ballast = 42 watt

Power consumed by each EE Tube with electronic ballast = 30 watt

Present cost of each existing tube =Rs. 100/-

Rated life in burning hours of new Energy efficient tubes are at least three times more compared to present conventional TFL.

Avg. Lighting time/day =10 hours.

Since 65 Nos. of FTLs are in office space, it operates for around 22 days every month round the year. The balance FTLs are located in Guest rooms which are operated only when there are guests occupying hence assumed operating for 6 months in a year.

Cost of three 40w tube =40x3= Rs. 120/-

Total power consumed by existing TFLs Per Annum in office space

=(65 x 42 x10 x 22 x 12) /1000= 7,207 Units

Total power consumed by existing TFLs Per Annum in Guest rooms

=(42 x 42 x10 x 30 x 6) /1000= 3,175 Units

Total power consumed by present TFLs = 7207 + 3175 = 10,382 Units

If all TFLs are replaced with T5 Tubes, Total power consumed

= ((65 x 30 x 10 x 22 x12)+(42 x 30 x 10 x 30 x6))/1000 = 7,416 Units

Annual savings in energy = **2,966 Units**

Annual savings @Rs 5.2/-per Unit = **Rs.15,423/**-

Investment:

Approximate Price of each Energy efficient tube set = Rs.400 /-.

Salvaged value of existing TFL Set = Rs. 100/-

Total investment for replacement of all TFLs

=107x (400-(100+120)) = **Rs. 19,260/-**

Payback period

Investment /Annual savings =19260/15423 = **1.25Years**

B) Replacement of 133 nos. GLS lamps with 11-watt CFLs:

Replace all 40 watt GLS with 11 watt CFLs). Advantage: Power consumption is lower and life is much higher.

Savings calculation for Replacement of 40 watt GLS with 11 watt CFL:

Total No. of 40 watt GLS in the area= 133

Lamps installed in Guest rooms assumed to operate 10 hours for 6 months (assuming guest rooms are partially occupied in a year) = 45 Nos.

Durbar Hall has 88 Nos. of GLS lamps but they are operated only on official functions so not considered for replacement.

Present cost of each existing lamps =Rs. 12/-

Rated life of CFLs are is eight times more than present GLS lamps.

Avg. Lighting time/day =10 hours.

Total power consumed by existing GLSs per Annum in Guest rooms

=(45 x 40 x10 x 30 x 6) /1000= 3,240 Units

If the GLSs are replaced with 11 watt CFLs, total power consumed

= (45 x 11 x 10 x 30 x 6)/1000 = 890 Units

Annual savings in energy = **2350 Units**

Annual savings @Rs 5.2/-per Unit = **Rs.12220/-**

Investment:

Approximate Price of each CFL lamp = Rs.100/-.

Total investment =45 x 100 = **Rs. 4500/-**

Payback period

Investment /Annual savings =4500/12220 = **0.37 Years**

4. STUDY OF AIR CONDITIONERS

INSTALLED AIR CONDITIONERS

Sl. No	Description of Room	Window/ Split	Make	Loca tion	Year of Instln.	Rated TR	I (Amp)	Volts	KW	PF
1	VIP Gust room	Split	Blue Star	LHS		1.5	9.9	239	1.96	0.77
2	VIP GR	split	Blue Star	RHS		1.5	17.4	234	3.71	0.91
3	Entrance VIP GR	split	Blue Star	RHS		1.5	10.76	208	2.085	0.93
4	VIP Gust room	split	Blue Star	RHS	2001	1.5	10.54	200	2.07	0.98
5	VIP Gust room	split	Blue Star	LHS		1.5	10.5	240	2.26	0.88
6	Sitting room	Split	Blue Star	RHS		1.5	10.7	209	2.16	0.97
7	Attendant room	Split	Blue Star	RHS		1	7.5	210	1.53	0.966
8	Office Secy room	Split	Blue Star			1.5	7.5	231	1.65	0.93
9	A C room	Split	Blue Star			1.5	8.15	231	1.75	0.93
10	Secy room	Split	Blue Star	LHS		1.5	8.3	233	1.77	0.93
11	Secy room	Split	Blue Star			1.5	7.4	204	1.46	0.97
12	Governors Res. Office	Split	Blue Star		2006	1.5	10.2	235	2.1	0.89
13	PRO Office	Split	Blue Star			1.5	7.61	197	1.55	0.95
14	Governors Res Drawing Room	Split	Jajodia			1.5		200		
15	Gov's Bed room	Split	Jajodia			1.5	8.37	242	1.96	0.97
16	Gust room	Split	Blue Star			1.5	5.73	213	1.2	0.97

CRITERIA

For Star Rating Analysis

Star Rating	EER (Wc / Wp)	
	Min	Max
1 Star *	2.30	2.49
2 Star **	2.60	2.69
3 Star ***	2.70	2.89
4 Star ****	2.90	3.09
5 Star *****	3.10	

Measurements Made and Analysis

Sl. No	Description of Room	Window/ Split	Location	Rated TR	I (Amp)	Volts	KW	PF	EER Wc/Wp	Operating Star level
1	VIP Gust room	Split	LHS	1.5	9.9	239	1.96	0.77	2.69	**
2	VIP GR	split	RHS	1.5	17.4	234	3.71	0.91	1.42	Below *
3	Entrance VIP GR	split	RHS	1.5	10.76	208	2.085	0.93	2.53	**
4	VIP Gust room	split	RHS	1.5	10.54	200	2.07	0.98	2.55	**
5	VIP Gust room	split	LHS	1.5	10.5	240	2.26	0.88	2.33	*
6	Sitting room	Split	RHS	1.5	10.7	209	2.16	0.97	2.44	*
7	Attendant room	Split	RHS	1	7.5	210	1.53	0.966	2.30	*
8	Office Secy room	Split		1.5	7.5	231	1.65	0.93	3.20	*****
9	A C room	Split		1.5	8.15	231	1.75	0.93	3.01	****
10	Secy room	Split	LHS	1.5	8.3	233	1.77	0.93	2.98	****
11	Secy room	Split		1.5	7.4	204	1.46	0.97	3.61	Less Refrigerant
12	Gov's Res. Office	Split		1.5	10.2	235	2.1	0.89	2.51	**
13	PRO Office	Split		1.5	7.61	197	1.55	0.95	3.40	Less Refrigerant
14	Gov's Drawg. Room	Split		1.5		200				
15	Gov's Bed room	Split		1.5	8.37	242	1.96	0.97	2.69	**
16	Gust room	Split		1.5	5.73	213	1.2	0.97	4.40	Less Refrigerant

The analysis has been carried out assuming:

1) Air conditioners are delivering their rated TR of cooling
2) Field electrical measurement

As the measurements have been taken in winter season it can be safely assumed that the performance of the machines will not be improved in summer, however, the same can deteriorate further.

Therefore, **the machines with star rating of two and below can be replaced with new five star rated machines**. New air conditioners with deviated performance (marked as less refrigerant) can be given for immediate maintenance.

Savings due to replacement of under performing air conditioners:

Nos. of 1.5 TR machines	9
Avg. power consumption (existing), KW	2.29
Avg. power consumption (new), KW	1.72
Avg. Savings, KW	0.57
Savings per day(@12 Hrs/day), KWH	123.12
Annual savings (9 months), KWH	**13296.96**

Annual savings, Rs. @Rs.5.46/KWH	72601.40
Approximate Investment, Rs.	180000.00
Simple Pay Back, Yr.	2.5

PERFORMANCE TEST

The following A/c's were checked for performance, the result is indicated below.

Performance of a split a/cs at Raj Bhavan:

Description	VVIP GR RHS	Ent. VIP GR RHS	VVIP GR B'putra RHS	VVIP GR B'putra LHS	B'putra Sitting Room RHS	Dhansiri
Average Air velocity, m/s	4.18	3.14	3.19	3.77	3.26	4.16
Cross scetion, Sq. cm	656	810	810	810	810	656
Average Air flow, Cu.m/s	0.25	0.23	0.23	0.27	0.24	0.25
Average Air flow, Kg/Hr	1022.51	947.10	963.04	1137.16	983.38	1016.40
Hot air I/L temperature, deg c	21	18	18	17	19	20
Cold air O/L temperature, deg c	11	9	11	10	11	11
Hot air I/L relative humidity, %	101	75	82	77	89	93
Cold air O/L relative humidity, %	88	89	83	86	92	92
Power drawn, KW	3.7	2.085	2.07	2.26	2.16	1.53
Hot air enthalpy, KJ/ Kg of Dry Air	61	43	44.5	40.5	50.5	54.2
Cold air enthalpy, KJ/ Kg of Dry Air	28.8	24.6	28	26	30	29.5
Ton of cooling	2.59	1.37	1.25	1.30	1.59	1.98
EER, (Wc/Wp)	2.46	2.31	2.13	2.02	2.58	4.54
EER, (12 / KW/Ton)	1.25	4.19	4.63	4.09	3.50	3.97
Operating Star level	*****	*****	**Below ***	**Below ***	**Below ***	********

It is clear from above that most of the old AC's are underperforming. It is recommended to replace them.

As indicated in the table for installed air conditioners there are many instances of excess height of the ceiling, windows without sun filming, gaps in windows and ventilation windows etc. All of them are contributing to loss of cold i.e. TR generated by the air conditioners. The loss was not estimated owing to their low running hours.

The approximate thumb rule is that for every 1^{o}C higher temperature in the evaporator, the specific power consumption will decrease by about 2 to 3%. So, **maintain air conditioned room temperature at 25^{o}C instead of 22^{o}C.**

In air conditioned spaces, use of circulation fans can provide *apparent comfort* and help raise the room temperature settings about 26^{o}C instead of 24^{o}C.

Room Air Conditioners

Air Conditioner is an appliance for controlling, especially lowering, the temperature and humidity of an enclosed space. It is designed to extract heat from an area via a refrigeration cycle. Its purpose is to provide comfort during either hot or cold weather. Air conditioner, once considered a luxury is now becoming a necessity. Air- Conditioning manufacturers have made them more affordable along with increasing their efficiency and improving components and technology. Air conditioning systems vary considerably in size and derive their energy from many different sources. Popularity of room air conditioners have increased dramatically with the advent of central air, a strategy that utilizes the ducting in a home for both heating and cooling.

The Efficiency of room air conditioners is rated only by EER (Energy Efficiency Ratio), which is cooling output divided by power consumption. The higher is the EER, the more efficient the air conditioner.

Tips for Saving Energy

- We can reduce air-conditioning energy use by as much as 40 percent by shading our home's windows and walls. Plant trees and shrubs to keep the day's hottest sun off your house.
- One will use 3 to 5 percent less energy for each degree air conditioner is set above 22^{0}c (71.5^{0}F), so set the thermostat of room air conditioner on 25^{0}C (77^{0}F) to provide the most comfort at the least cost.
- Using ceiling or room fans allows you to set the thermostat higher because the air movement will cool the room.
- A good air conditioner will cool and dehumidify a room in about 30 minutes, so use a time and leave the unit off for some time.
- Keep doors to air- conditioned rooms closed as often as possible.

- Clean the air- conditioner filter regularly.

MAINTENANCE TIPS FOR SPLIT / WINDOW AC

- Make sure your AC doesn't get overloaded; check the fuse or circuit breaker if it doesn't operate.
- Remember to replace or clean the filter and have your mechanic clean the evaporator and condenser coils regularly, for the air conditioner to cool your home efficiently.
- Install a programmable thermostat, it will lead to 10-15% energy saving.
- Set your thermostat as high as possible comfortable.
- Set the fan speed on high except on very humid days, when humidity is high set the fan speed on low for more comfort.
- Install units in shade, it will lead to 10% saving in energy consumption.
- Use sun films on windows. That will cut heat entry by 70% of the building.
- If the AC makes noise it needs to be checked by the mechanic.
- Giving your air conditioning system a good electrostatic air filter is the best thing you can do for your air conditioner. A good air filter will extend the life of your air conditioner because the important parts, like the cooling coil, and other inner parts will stay cleaner, operate more efficiently and last longer.
- Avoid frequent opening of doors/windows. A door kept open can result in doubling the power consumption of your AC.
- Ensure direct sunlight (and heat) do not enter the air-conditioned space, particularly in the afternoons.

- Most people believe that a thermostat set to a lower temperature than desired, will force your air-conditioner to cool faster, not really, all it does, is make your air-conditioner operate for longer. Moreover, you will have an unnecessarily chilly room and wasted power. Every degree lower on the temperature setting results in an extra 3-4% of power consumed. Hence, once you've found yourself a comfortable temperature and set the thermostat at that level, avoid touching the thermostat thereafter.

- Once an air-conditioning system has been designed and installed avoid any major change in the heat-load on the AC. This will add to wasted power.

- Always ensure that whenever you install new unit, make sure its EER (12/(kW/TR)) should be between 9.5 to10.5.

- No gap should be left during installing units for cool air escape.

GEYSERS IN GUEST ROOMS / KITCHENS

The geysers in guest rooms and kitchens can be replaced with solar water heater and a savings can be achieved as estimated below.

Savings due to replacement of Geyser amps with Solar water heater:

Nos. of geysers	10
Power consumption, Watt	2000
Running hours	1
Expected Power consumption with solar heater, Watt	0
Average nos. of day per year	270
Annual savings (80% geyser on), KWH	4320
Annual savings, Rs.	23587.2
Investment (@ Rs.10000/- per geyser), Rs.	100000
Payback Period, Yr.	4.24

5. STUDY OF DG SET

INSTALLED DG SET

There are two DG sets catering the power requirement during grid failure.

DG Set details		
Catering to	Lachit Wing	Governors Res.
Make, Engine	Cummins	Cummins
Make, Generator	Stamford	Kirloskar Electric Co.
KVA	250	160
Voltage	415	415
Amp	348	222
Frequency, Hz	50	50
Phase	3	3
Power Factor	0.8	0.8
Year of Manufacture	1991	1991
Insulation Class	H	H

Observations

- Trail run for 10 minutes is made daily to check their readiness and noted in the log book.
- Time of running is noted whenever DG sets are run.
- HSD consumption is not being recorded.
- There is no energy (kWh) meter so generated power can not be recorded
- Both the DG sets were provided with silencers in a later period.
- Both of them are fitted with turbo chargers.
- DG room was found airy and well ventilated.
- DG trial could not be taken for non availability of energy meter.
- Monthly HSD consumption in DG sets is as below.

Month	160 KVA		250 KVA	
	Running Hrs.	HSD Consumption (Litre)	Running Hrs.	HSD Consumption (Litre)
Aug-08	46	960	24.36	1000
Sep-08	41	600	25	1200
Oct-08	22.4	640	61.5	920
Nov-08	27.55	240	11	420
Dec-08	27	700	6.4	Nil
Jan-09	NA	440	NA	480

Energy conservation in DG set

Generating efficiency of a DG set is measured by the nos. of units generated per litre of fuel consumed. As a rule, lower speed engines are more fuel efficient in larger sizes and less efficient in smaller sizes. While the engine speed is maintained constant within certain limits by means of governor of the engine, the load on the engine can vary from zero to full rated power and to a further 10% overload on the rated hp. The brake horse specific fuel consumption of an engine is characteristic of function of the bhp or load at any synchronous speed. It is seen that BSFC is at the minimum at approximately rated power increasing slightly at 10% overload and substantially at all lower loads. This situation arises due to the fact that the internal frictional horse power of the engine remains almost constant due to constant speed while the useful brake horse power taken from the engines decreases resulting in reduced mechanical efficiency of the engine and BSFC. It is recommended to load the sets at least 70% of the rated load, at all times. Action taken is to be based on the loading pattern. It may also be mentioned here that BSFC of air-cooled engines are lower than that of water-cooled engines, especially those water-cooled engines in which fans are driven by electric motors and not by the engine. In engine driven fan and water pump, there is a loss of 7 to 10% of engine bhp. Water-cooled engines having separate and independent cooling system that is cooling tower attached with fountain and heat exchangers have lower fuel consumption.

The way the unit was maintaining the logbook was quite adequate. It is very much essential for any unit to maintain proper logbook wherein all the data related to engine operation and performance should be recorded. The recorded data should also reflect the performance of various components like heat exchanger, etc. As discussed above, consumption will keep on varying with the change in load on the engine. It is therefore very important to take half-hourly or hourly reading of fuel consumption and energy produced, together which will give **specific fuel consumption (SFC)** in **KWH per Litre of fuel** consumed and a very good idea as to how to load the DG set judiciously and what is the load at a certain point of time. It is therefore recommended to maintain the SFCs. This will also indicate when the engine or its components need maintenance. This will help in scheduling the preventive maintenance of the DG set and thus reduce the down time and loss of production. The SFC will be reduced with the decrease in load and malfunction of any vital component of the engine. Although SFC varies with load, it is of utmost importance to conduct trial on all the sets to determine the actual SFC of each set. This will help in finding out the set or sets with low SFC. They have to be attended to immediately.

The following is the format recommended for any DG set logging:-

Date - Starting & Closing Time - kWh meter reading - AC Voltage - AC Amp - DC Voltage - DC Amp - Rpm - Frequency - kW - HSD Consumption in Litre (Physical measurement from the service tank and not by running hours) - SFC (KWH/Litre of HSD) - Lube Oil Pressure - Lube Oil Outlet Temperature - Total Running Hours - Total Lube Oil Consumption.

Engine room heats up during the DG set operation due to heat radiation from the hot exhaust pipes and due to the hot air from the radiator fan or from the exit of the air-cooled engines circulating inside the room. When the ambient temperature in the engine room goes up, fuel consumption increases due to decrease in the air fuel ratio due to lower density of available air. As the mixture becomes richer there is a decrease in the fuel efficiency. It has been seen that with the increase in the air intake temperature from 25^oC to 42^oC the air fuel ratio decreases by about 5% and this will result in higher BSFC in the range of 0.5 to 2% depending upon the engine design i.e. naturally aspirated or supercharged or inter-cooled. In other words, the engine output varies with the change in the intake temperature. It has been seen that for a rise of every 3^oC in intake temperature beyond 32^oC the engine output drops by about 1.2%. It is therefore essential to make arrangements for proper ventilation so that hot air is continuously removed by circulation of cool air. Using insulation lagging can reduce heat radiation from the exhaust pipe and manifold. The table given below gives the loss of heat from lagged and un-lagged pipes of different diameters at exhaust temperature of around 400^oC and ambient temperature of around 30^oC.

a) Diameter of exhaust pipe (mm)	150	200	300	400
b) Heat radiation in Kcal /hr. per meter of pipe length				
i) Base pipe	5800	7800	11600	15600
ii) Pipe with 50 mm thick lagging	235	350	520	630
iii) Pipe with 100 mm thick lagging	145	215	300	370

This will help to select the insulation thickness to reduce radiation heat. It is observed that all the exhaust pipes are un-insulated in the room, as a result when the DG sets are running the room temperature goes up.

Exhaust temperature of a DG set is an indication of the engine health and hence the fuel consumption. If the exhaust temperature is more than the recommended, the power generation is not proper and engine needs immediate attention before the situation worsens. Provision of measuring the cylinder temperature is very useful in identifying the damaged cylinder. So, it is recommended to incorporate the cylinder head temperature in the logbook to monitor the health of the DG set. Exhaust gas temperature should never be allowed to go beyond 450^{o}C. Overloading and air starvation are the major reasons for increased exhaust gas temperature, poor efficiency of heat exchanger also has a bearing.

While designing the engine room, factors like ambient temperature, relative humidity, whether the batteries are positioned inside the DG set room or not and whether the engine is air-cooled or water-cooled, whether the engine is naturally aspirated or supercharged should be taken into account.

Exhaust system should be properly designed for proper fuel and engine efficiency so that the exhaust backpressure is within the permissible limits. If the exhaust backpressure higher than the permitted value the scavenging of the engine will be adversely affected and there will be less oxygen in the cylinder during the subsequent compression stroke. The mechanical efficiency will reduce due to higher exhaust pumping losses. This will increase fuel consumption. The following steps are to be taken to maintain the exhaust backpressure within permissible limits: -

i) Small diameter pipes and large number of bends increase the backpressure.

ii) Pipe diameter should be such that exhaust backpressure is about 30 to 40 mm Hg for uncharged engines and about 20 to 30 mm Hg for turbocharged engines.

iii) Gas velocity should be below 33 m /sec for optimum exhaust backpressure.

iv) Number of bends should be minimum, and they should be smooth, not sharp. Radius of the bends should be at least 4 times the pipe diameter.

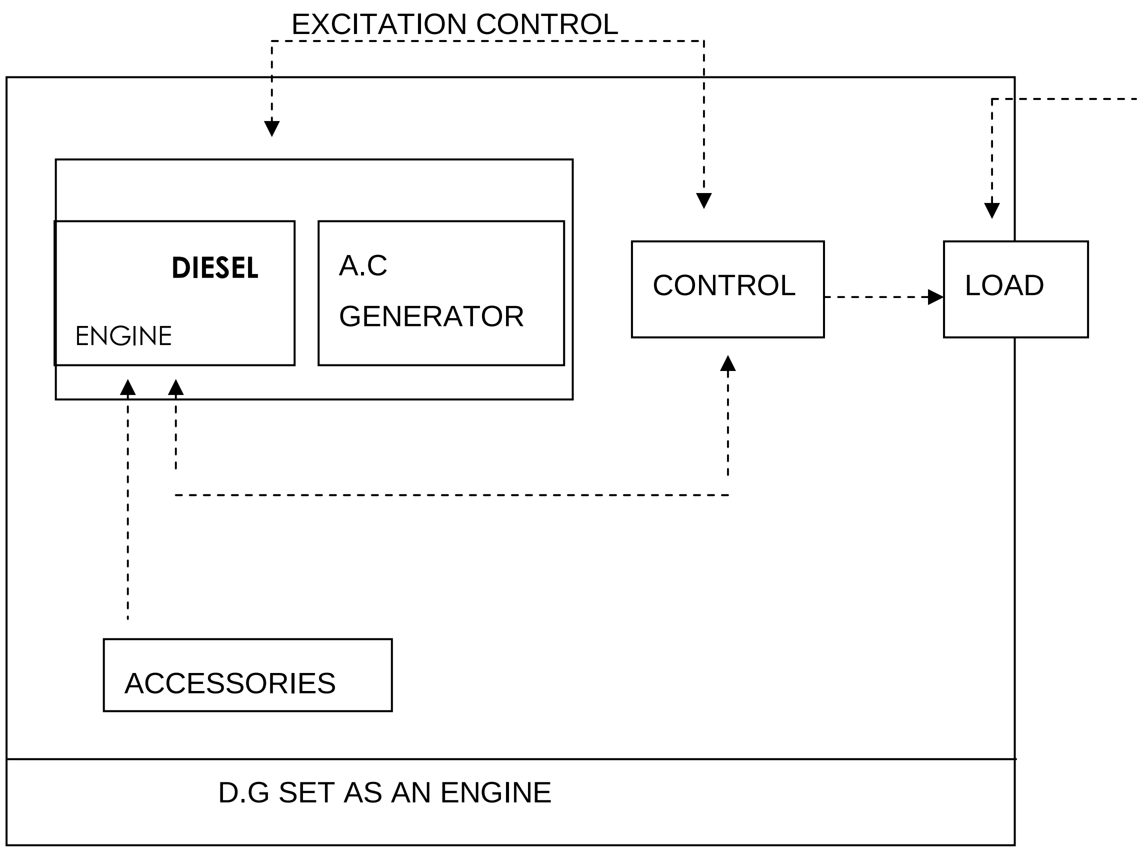
v) In case multiengine sets are connected to a single exhaust manifold the mean gas velocity should not exceed 15 m/sec.

Leakage even though they are of minor nature, should be avoided scrupulously as they are largely the major factor for higher fuel and lube consumption.

Monitor lubricant condition through regular sampling. Maintain proper cooling. Change oil on condition basis and not only on the rule of thumb as recommended by the Oil companies or engine manufacturers. In most of the cases it is found that the engine oil is discarded much before their life is over. This means wastage of oil and money. The parameters of oil change are sometimes ad hoc, bearing no relations to the actual state of oil in use. Many a time the extent of deterioration could be excessive resulting in damage to the equipment. Again, at times the deterioration may be mild and the oil may be in good condition and suitable for further use. Hence the condition-monitoring program is necessary.

3.12 Load Management:

A diesel generating set should be considered as a system since its successful functioning depends on the well-matched performance of its components namely:



1. The diesel engine and its accessories
2. The A.C. generators
3. The control system and switch
4. The foundation and power house civil works
5. The connected load with its own components like heating, motor drives lighting etc.

It is necessary to select the components with highest efficiency and operate them at their optimum efficiency levels to conserve energy in this system.

Energy conservation depends more on the management of the load connected to the D.G set than the performance of the D.G. set itself. Some of the aspects to be looked into are:

a) Load Balancing

There are a number of single-phase loads in the plant, which is fed through three-phase supply system. If the loads are not balanced the supply voltage will be heavily unbalanced though the D.G set can take up some degree of unbalanced loads. Such unbalanced supply for motors and other three phase loads will result in additional losses in the equipment and hence will make the system less efficient**. It may be noted that at no point of time the difference between maximum and minimum current in the R, Y and B phase should be more than 10%. It is necessary to distribute the loads judiciously or avoid single-phase loads in a three-phase system.**

b) Non-linear/ Fluctuating loads

Certain load causes serious output voltage variation and due to that the function of other voltage sensitive loads can be affected. For example, a thyrister converter driver or motor may malfunction if a flywheel rolling mill drive or a **compressor** is switched on. Hence it is necessary to provide a separate supply system for **such non-linear loads or at least isolate them through simple harmonic filters and transformers.**

c) Optimum loading

The efficiency curve of D.G set is almost flat above 60% load whereas below that load the fuel consumption increases drastically (Though the DG Set supplier mentions that at 25% load the

6. CONCLUSIONS

ENERGY CONSUMPTION

Energy consumption present / expected is computed as:

PARAMETERS (As provided by the Installation)	
Annual Electricity Consumption (monthly average ’08, kWh)	287744
Annual Electricity Consumption (kWh) **Expected**	257148

SUMMARY OF ENERGY CONSERVATION OPPORTUNITIES

Electrical Savings						
Recommendations	**Energy Savings**				**Estd. Investment**	**Simple Payback period**
	KWh	**Lac K.Cal**	**KL of oil equivalent**	**Rs Lacs**	**Rs Lacs**	**Yrs.**
Installation of Automatic P.F. Controller				0.94	0.27	0.3
Installation of 100 KVA transformer during normal operation	7663			0.4	1.0	2.4
Replacement of conventional tube lights (40w TFL) with energy efficient tube lights (28w T5)	2966			0.154	0.193	1.25
Replacement of 133 nos conventional bulbs (60/40w GSL) with CFL lamps (11w)	2350			0.122	0.045	0.37

Electrical Savings						
Recommendations	**Energy Savings**				**Estd. Investment**	**Simple Payback period**
	KWh	**Lac K.Cal**	**KL of oil equivalent**	**Rs Lacs**	**Rs Lacs**	**Yrs.**
Replacement of 9 numbers 1.5 TR air conditioners	13297			0.726	1.8	2.5
Replacement of Electric Geyser with solar water heater	4320			0.236	1.0	4.2
Total – (A)	**30596**			**2.578**	**4.3**	