ENERGY AUDIT METHODOLOGY IN HOSPITALS & CASE STUDY

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About Kerala State Productivity Council

- The Kerala State Productivity Council was established in 1959 as a tripartite autonomous body with representations from Govt. of Kerala, Management and trade union. KSPC is affiliated to the National Productivity Council, New Delhi and Asian Productivity Organization, Tokyo, Japan.

  Major Activities

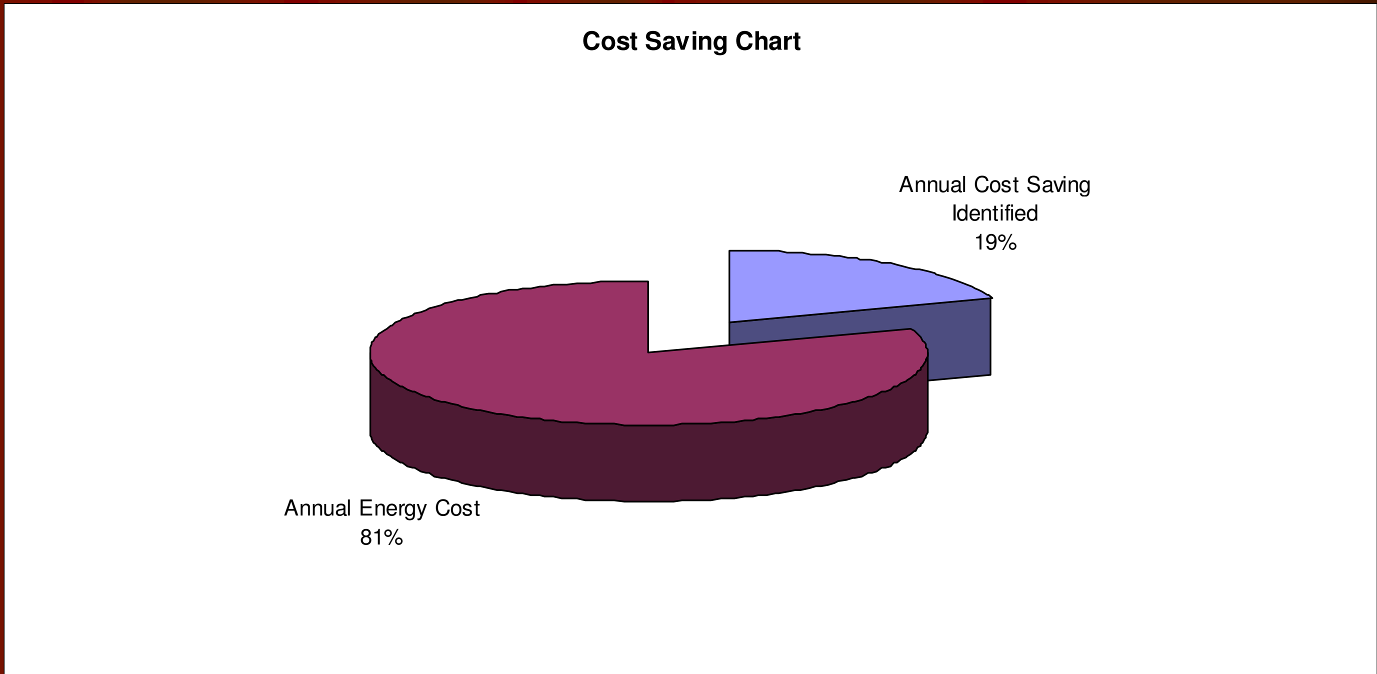
  1. Training Programmes
  2. Energy & Environment Management Services
  3. Consultancy Services like Industrial Engineering, Safety Audits, ISO Implementation, Selection Services etc..

Medical Trust Hospital (Unit-1)

Contract Demand	- 500 kVA
Average Maximum demand	- 473 kVA
Average Annual Power Consumption	- 2552.9 MWh
Average Power Cost	- Rs.4.97 /kWh

Total Cost Savings Identified

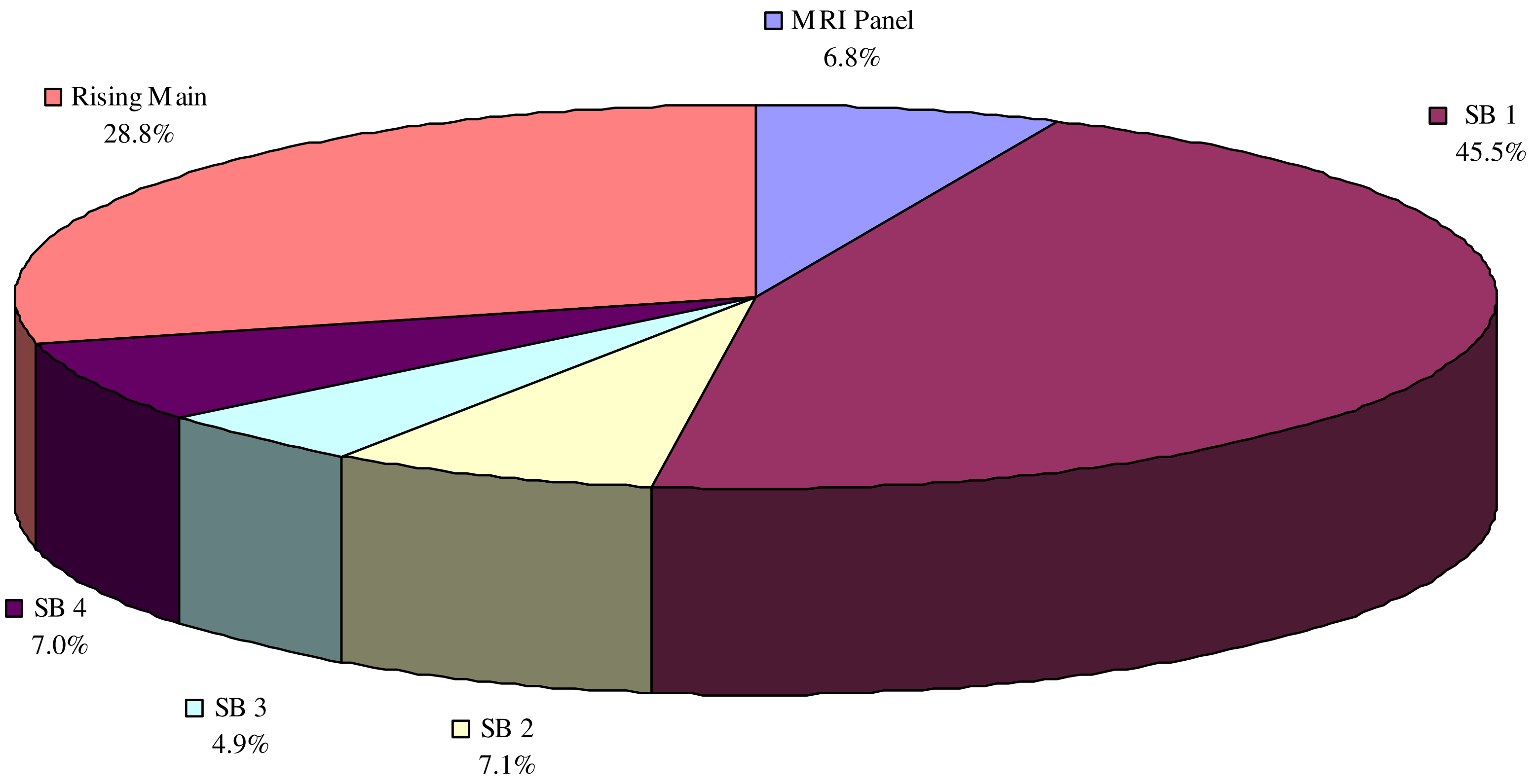
Annual Electrical Energy Cost	- 126.87 lacs
Annual Electrical Cost Saving Identified	- 24.6 lacs
Annual cost saving (%)	- 19.4



Load Distribution At the Main Panel

Panel Name	Average Load (kW)	Average Operating Hours (per day)	Energy Consumption (kWh)		
			Per Day	Per Month	%ge
MRI Panel	22.9	24.0	549	15931	6.8%
SB 1	153.6	24.0	3687	106933	45.5%
SB 2	24.0	24.0	575	16676	7.1%
SB 3	16.5	24.0	396	11491	4.9%
SB 4	23.5	24.0	565	16384	7.0%
Rising Main	97.2	24.0	2332	67637	28.8%
Total			**8105**	**235053**	**100.0%**

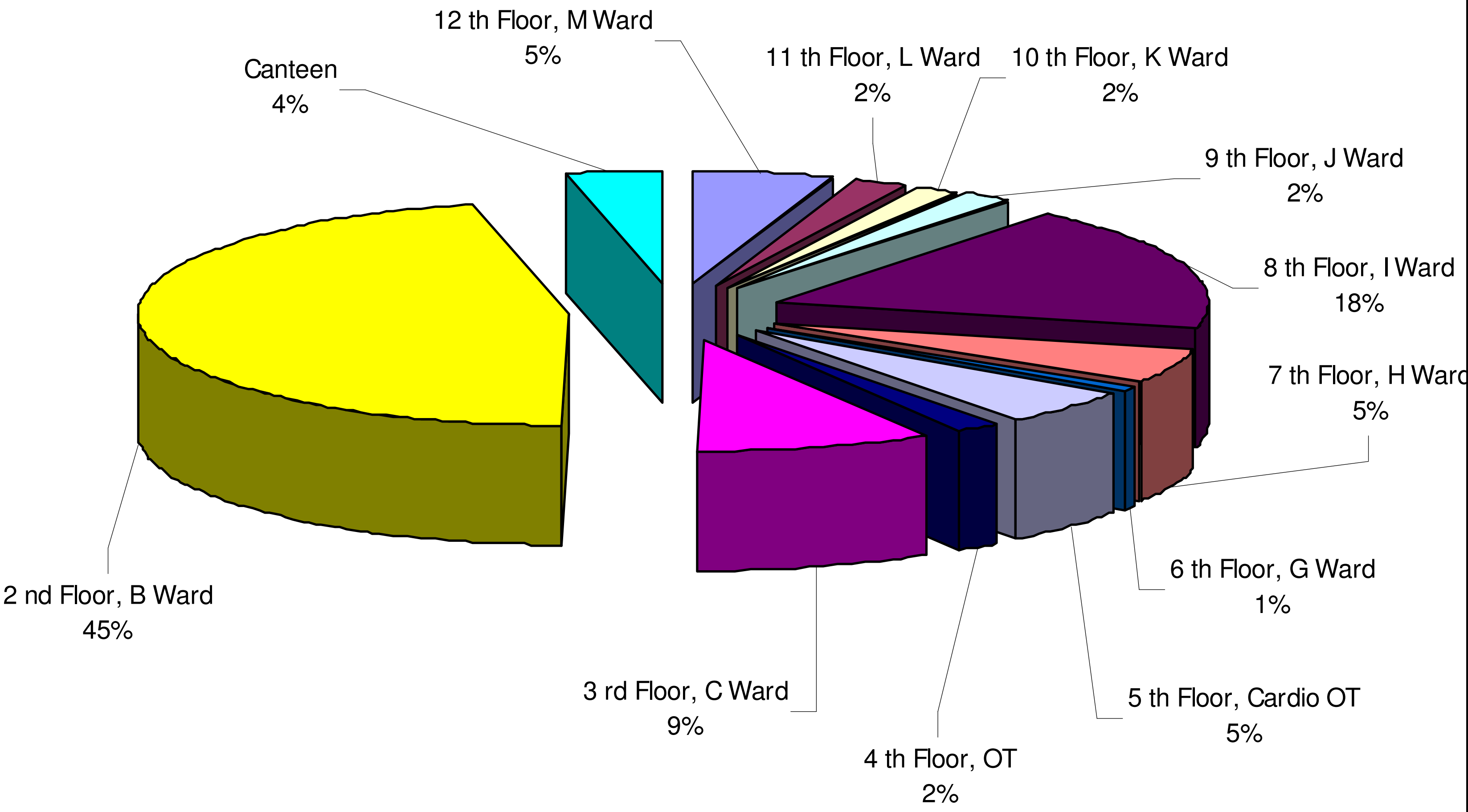
LOAD DISTRIBUTION CHART



Floor Wise Load Distribution (Main Block)

Floor	Power (kW)	Average Operating Hours.	Energy Consumption / Day	Monthly Energy Consumption (kWh)	% Energy Consumption
12 th Floor, M Ward	4.58	20.00	91.60	2748.00	5.35%
11 th Floor, L Ward	1.70	20.00	34.08	1022.40	1.99%
10 th Floor, K Ward	1.32	20.00	26.40	792.00	1.54%
9 th Floor, J Ward	1.60	20.00	32.00	960.00	1.87%
8 th Floor, I Ward	15.48	20.00	309.60	9288.00	18.09%
7 th Floor, H Ward	4.41	20.00	88.20	2646.00	5.15%
6 th Floor, G Ward	0.43	20.00	8.60	258.00	0.50%
5 th Floor, Cardio OT	4.44	20.00	88.80	2664.00	5.19%
4 th Floor, OT	1.40	20.00	28.00	840.00	1.64%
3 rd Floor, C Ward	7.71	20.00	154.20	4626.00	9.01%
2 nd Floor, B Ward	39.49	20.00	789.76	23692.80	46.15%
Canteen	3.00	20.00	60.00	1800.00	3.51%
Average/ Total	85.56	20.00	1711.24	51337.20	100.00%

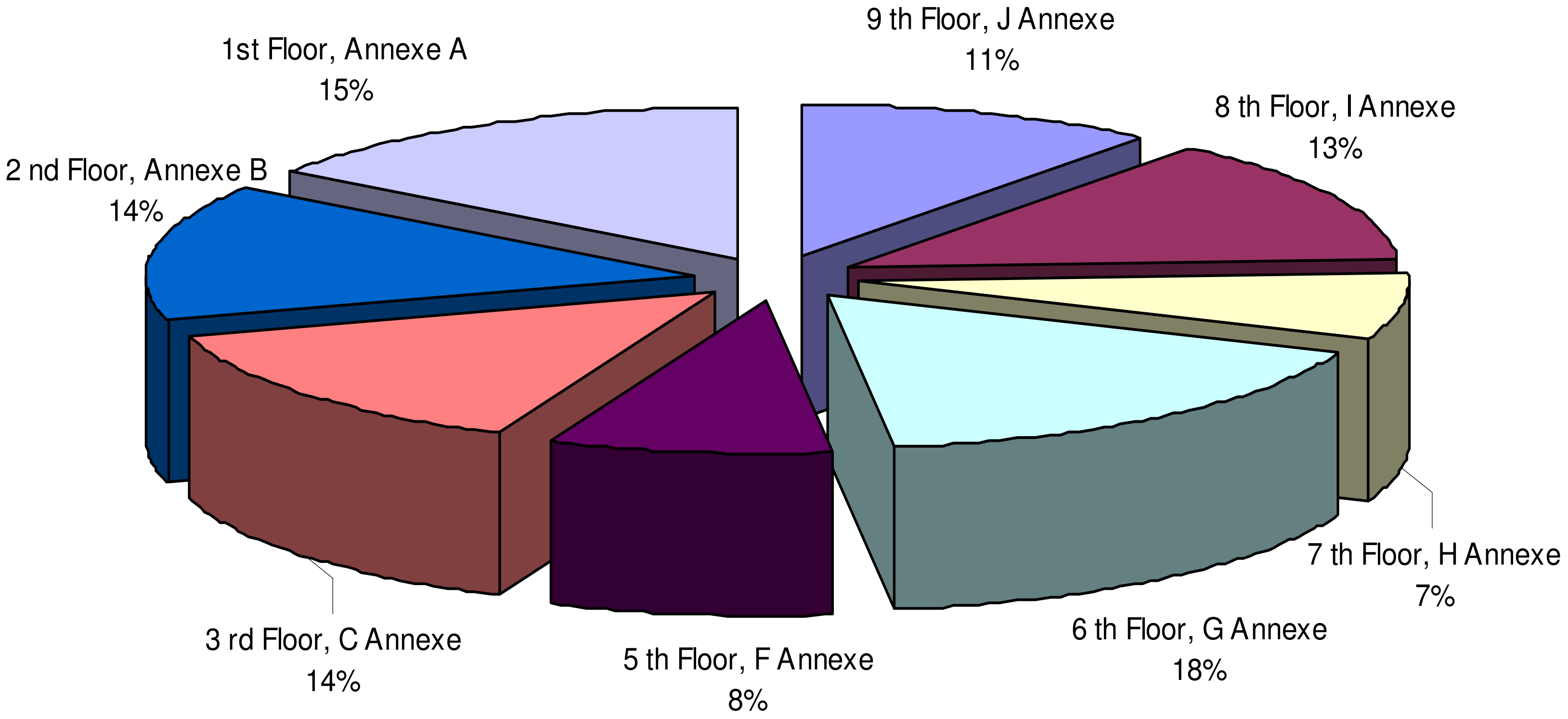
FLOOR WISE ENERGY DISTRIBUTION CHART

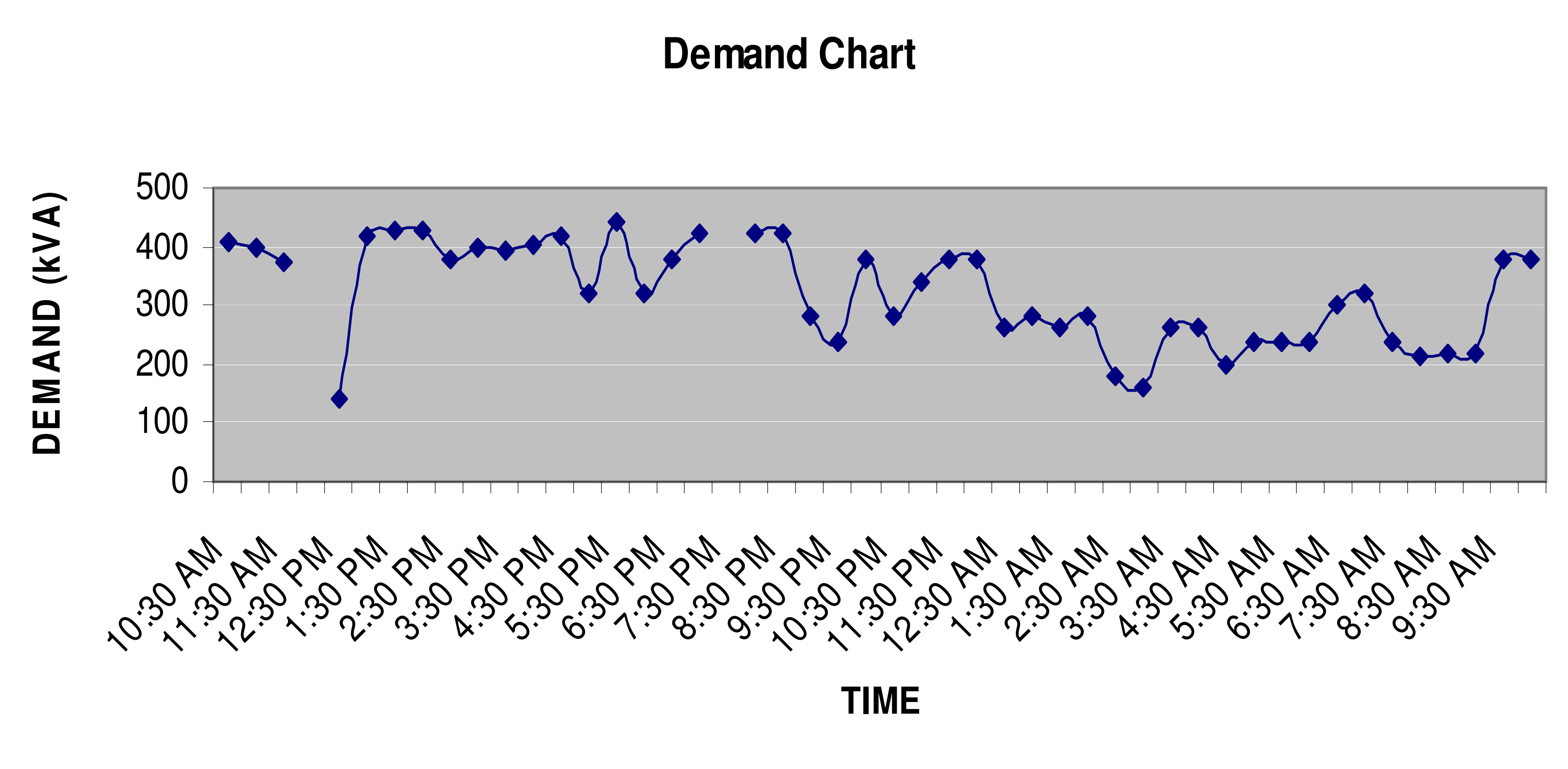


Floor Wise Load Distribution (Annexe Block)

Floor	Power (kW)	Average Operating Hours.	Energy Consumption/ Day	Monthly Energy Consumption (kWh)	% Energy Consumption
9 th Floor, J Annexe	9.71	5	48.55	1456.5	10.64%
8 th Floor, I Annexe	3.06	20	61.2	1836	13.42%
7 th Floor, H Annexe	1.60	20	32	960	7.02%
6 th Floor, G Annexe	3.88	20	77.6	2328	17.01%
5 th Floor, F Annexe	1.90	20	38	1140	8.33%
3 rd Floor, C Annexe	3.17	20	63.4	1902	13.90%
2 nd Floor, Annexe B	3.27	20	65.4	1962	14.34%
1st Floor, Annexe A	3.50	20	70	2100	15.35%
Average/ Total	**20.38**	**20**	**456.15**	**13684.5**	**100%**

FLOOR WISE ENERGY DISTRIBUTION





Demand Chart
DEMAND (kVA)
500
400
300
200
100
0
10:30 AM
11:30 AM
12:30 PM
1:30 PM
2:30 PM
3:30 PM
4:30 PM
5:30 PM
6:30 PM
7:30 PM
8:30 PM
9:30 PM
10:30 PM
11:30 PM
12:30 AM
1:30 AM
2:30 AM
3:30 AM
4:30 AM
5:30 AM
6:30 AM
7:30 AM
8:30 AM
9:30 AM
TIME

STATEMENT OF POWER COST CALCULATION

- Power cost calculation in differential pricing method applicable to Extra High Tension/ High Tension and deemed High Tension Consumers is given below:
- (Normal time set between 06.00 hrs to 18.00 hrs, peak time 18.00 hrs to 22.00 hrs and off-peak time 22.00 hrs to 06.00 hrs.)
- Billing demand will be the highest of the Recorded Maximum Demand during Normal Time, Peak Time or 75 % of the Contract Demand or 50KVA.
- 1. Demand Charge = Normal Demand Charge + Time of Use Charge - Incentive
- a) Normal Demand Charge = Billing Demand x Ruling Demand Charge/KVA
- b) Time of Use Charge = Demand during peak time in excess of 60% of the demand during normal time x Ruling Demand charge/KVA x 0.8 x 4/24.
- c) Incentive = Demand during off peak time (up to 120 % of the contract demand) in excess of 60 % of the demand during normal time x ruling Demand Charge/KVA x 0.25x8/24.
- 2. Excess Demand Charge =Excess Billing Demand x Demand Charge/KVA x 0.5 (Only if Maximum recorded Demand during normal/peak time exceeds the Contract Demand).
- 3. If the recorded Maximum Demand during the off peak time exceeds 120 % of the Contract Demand, the excess demand will be charged only at the ruling tariff.
- <u>Note: -</u>
- Para 3 above will be applicable only when the recorded maximum demand during off-peak hours exceeds billing demand.

- 4. Energy Charge = Normal Energy Charge + Time of Use Charge - Incentive.
- Normal Energy Charge=(Normal consumption + Peak consumption + off peak consumption) x ruling energy charges/unit.
- Time of Use Charge (Only if the consumption during peak period exceeds 10 % of the energy consumption during the month)=(Peak consumption - 10 % of the energy Consumption during the month) x ruling energy charge/unit x 0.80.
- Incentive (Only if the consumption during off peak period exceeds 27.5 % of energy consumption during the month)=(Off peak time consumption – 27.5 % of the total Consumption) x ruling energy charges/unit x 0.35.
- 5. Power Factor Improvement
- Incentive0.15% of energy charges for each 0.01 unit increase in power factor from 0.90 p.f
- Penalty1% energy charge for every 0.01 fall from 0.90 p.f
- 6. **Total Monthly Charges = (1) + (2) + (3) + (4) ± (5)**

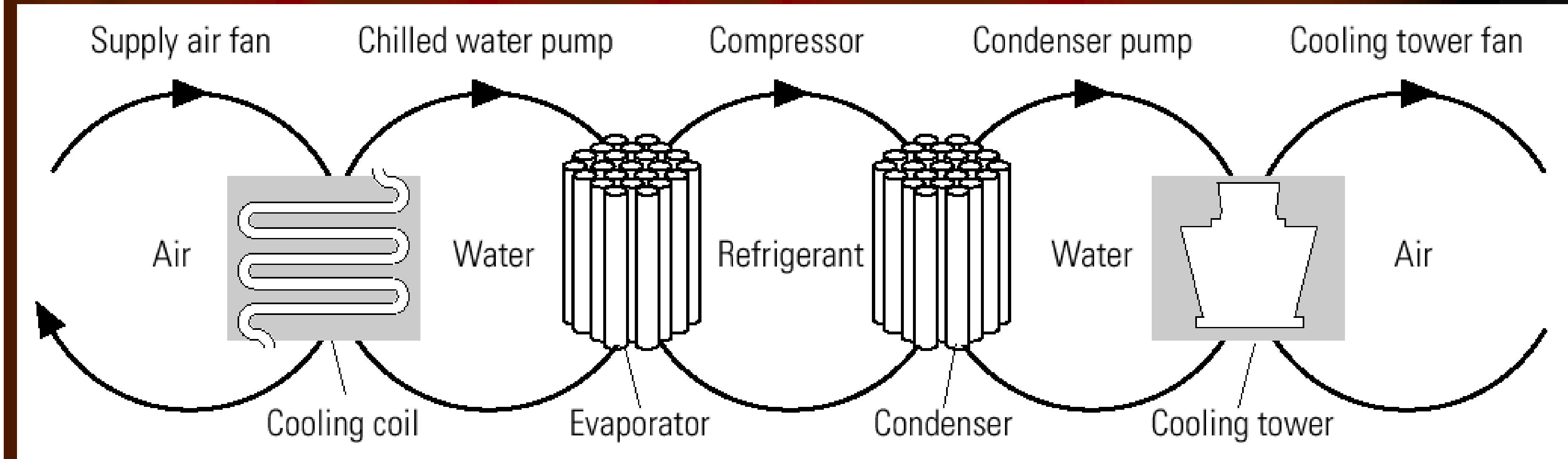
HVAC and Refrigeration System

Ton of refrigeration

The cooling effect produced is quantified as tons of refrigeration.

1 ton of refrigeration = 3024 kCal/hr heat rejected.

Conceptual view of a chilled-water air-conditioning system



Performance Assessment

The specific power consumption kW/TR is a useful indicator of the performance of refrigeration system. By messing refrigeration duty performed in TR and the Kilo Watt inputs measured, kW/TR is used as a reference energy performance indicator.

The refrigeration TR is assessed as $TR = Q \cdot C_p \cdot (T_i - T_o) / 3024$

Where TR is cooling TR duty
Q is mass flow rate of coolant in kg/hr
C_p is coolant specific heat in kCal /kg / ^{0}C
T_i is inlet. Temperature of coolant to evaporator (chiller) in ^{0}C.
T_o is outlet temperature of coolant from evaporator (chiller) in ^{0}C.

Overall energy consumption

- Compressor kW
- Chilled water pump kW
- Condenser water pump kW
- Cooling tower fan kW

Overall kW/TR = sum of all above kW/ TR

Effect of Variation in Evaporator Temperature on Compressor Power Consumption

Evaporator Temperature (^{0}C)	Refrigeration Capacity (tons)	Specific Power Consumption	Increase in kW/ton (%)
5.0	67.58	0.81	-
0.0	56.07	0.94	16.0
-5.0	45.98	1.08	33.0
-10.0	37.20	1.25	54.0
-20.0	23.12	1.67	106.0

A 1^{0}C raise in evaporator temperature can help to save almost 3 % on power consumption.

Effect of Variation in Condenser Temperature on Compressor Power Consumption

Condensing Temperature (^{0}C)	Refrigeration Capacity (tons)	Specific Power Consumption	Increase in kW/TR (%)
26.7	31.5	1.17	-
35.0	21.4	1.27	8.5
40.0	20.0	1.41	20.5

Effect of Poor Maintenance on Compressor Power Consumption

Condition	Evap. Temp (^{0}C)	Cond. Temp (^{0}C)	Refrigeration Capacity (tons)	Specific Power Consumption (kW/ton)	Increase in kW/Ton (%)
Normal	7.2	40.5	17.0	0.69	-
Dirty condenser	7.2	46.1	15.6	0.84	20.4
Dirty evaporator	1.7	40.5	13.8	0.82	18.3
Dirty condenser and evaporator	1.7	46.1	12.7	0.96	38.7

COMPRESSED AIR SYSTEM

Air Is Free !!!

Compressed Air Is Not Free !!!

Energy Efficiency practices in compressed air systems

Effect of Intake Air temperature on Power Consumption

Inlet Temperature (^{0}C)	Relative Air Delivery (%)	Power Saved (%)
10.0	102.0	+ 1.4
15.5	100.0	Nil
21.1	98.1	- 1.3
26.6	96.3	- 2.5
32.2	94.1	- 4.0
37.7	92.8	- 5.0
43.3	91.2	- 5.8

Every 4^{0}C rise in inlet air temperature results in a higher energy consumption by 1 % to achieve equivalent output. Hence, cool air intake leads to a more efficient compression.

Effect of Pressure Drop Across Air Inlet Filter on Power Consumption

Pressure Drop Across air filter (mmWC)	Increase in Power Consumption (%)
0	0
200	1.6
400	3.2
600	4.7
800	7.0

For every 25 mbar pressure lost at the inlet due to choked filters, the compressor performance is reduced by about 2 percent.

Cost of Air Leakage

Orifice Size mm	KW Wasted	* Energy Waste (Rs/Year)
0.8	0.2	8000
1.6	0.8	32000
3.1	3.0	120000
6.4	12.0	480000

* based on Rs. 5 / kWh ; 8000 operating hours; air at 7.0 bar

Power Reduction through Pressure Reduction

Pressure Reduction		Power Reduction (%)		
From (bar)	To (bar)	Single-stage Water-cooled	Two-stage Water-cooled	Two-stage Air-cooled
6.8	6.1	4	4	2.6
6.8	5.5	9	11	6.5

A reduction in the delivery pressure of a compressor would reduce the power consumption.

Energy Wastage due to Smaller Pipe Diameter

Pipe Nominal Bore (mm)	Pressure drop (bar) per 100 meters	Equivalent power losses (kW)
40	1.80	9.5
50	0.65	3.4
65	0.22	1.2
80	0.04	0.2
100	0.02	0.1

Typical acceptable pressure drop in industrial practice is 0.3 bar in mains header at the farthest point and 0.5 bar in distribution system

Steps in simple shop-floor method for leak quantification

- Shut off compressed air operated equipments (or conduct test when no equipment is using compressed air).
- Run the compressor to charge the system to set pressure of operation
- Note the sub-sequent time taken for 'on load' and 'off load' cycles of the compressors. For accuracy, take ON & OFF times for 8 – 10 cycles continuously. Then calculate total 'ON' Time (T) and Total 'OFF' time (t).
- The system leakage is calculated as
- System leakage (cmm) = $Q \times T / (T + t)$
- Q = Actual free air being supplied during trial, in cubic meters per minute
- T = Time on load in minutes
- t = Time unload in minutes

Capacity Assessment in Shop-floor

- Isolate the compressor along with its individual receiver being taken for test from main compressed air system by tightly closing the isolation valve or blanking it, thus closing the receiver outlet.
- Open water drain valve and drain out water fully and empty the receiver and the pipe line. Make sure that water trap line is tightly closed once again to start the test.
- Start the compressor and activate the stop watch.
- Note the time taken to attain the normal operational pressure P_2 (in the receiver) from initial pressure P_1.
- Calculate the capacity as per the formulae given below :

Actual Free air discharge

$$Q = \frac{P_2 - P_1}{P_0} \times \frac{V}{T} \, NM^3 / Min.$$

Where

P_2	=	Final pressure after filling (kg/cm^2 a)
P_1	=	Initial pressure (kg/cm^2a) after bleeding
P_0	=	Atmospheric Pressure (kg/cm^2 a)
V	=	Storage volume in m^3 which includes receiver, after cooler, and delivery piping
T	=	Time take to build up pressure to P_2 in minutes

LIGHTING SYSTEM

Luminous Performance Characteristics of Commonly Used Luminaries

Type of Lamp	Lum / Watt		Color Rendering Index	Typical Application	Life (Hours)
	Range	Avg.			
Incandescent	8-18	14	Excellent	Homes, restaurants, general lighting, emergency lighting	1000
Fluorescent Lamps	46-60	50	Good w.r.t. coating	Offices, shops, hospitals, homes	5000
Compact fluorescent lamps (CFL)	40-70	60	Very good	Hotels, shops, homes, offices	8000-10000
High pressure mercury (HPMV)	44-57	50	Fair	General lighting in factories, garages, car parking, flood lighting	5000
Halogen lamps	18-24	20	Excellent	Display, flood lighting, stadium exhibition grounds, construction areas	2000-4000
High pressure sodium (HPSV) SON	67-121	90	Fair	General lighting in factories, ware houses, street lighting	6000-12000
Low pressure sodium (LPSV) SOX	101-175	150	Poor	Roadways, tunnels, canals, street lighting	6000-12000

Lighting Controls

- **On/off flip switches**
- **Timer control & auto timed switch off**
- **Presence detection**
- **Luminary grouping / Group Switching**
- **Dimmers , Lighting voltage controllers**
- **Photo sensors**

Energy savings in lighting System

- Make maximum use of natural light (North roof/translucent sheets/more windows and openings)
- Switch off when not required
- Modify lighting layout to meet the need
- Select light colours for interiors
- Provide timer switches / PV controls
- Provide lighting Transformer to operate at reduced voltage
- Install energy efficient lamps, luminaries and controls
- Clean North roof glass, translucent sheet and luminaries regularly

Energy Saving in Lighting

- Separate lighting Transformer
  - To isolate from power feeder
  - To avoid voltage fluctuation problem
  - Energy saving at optimum voltage
- High frequency electronic ballast's(30khz)
  - Energy savings 30 to 35%
  - Less heat load into A/C room
- Metal halide in place of Mercury and SVL lamps
- CFT in place of incandescent lamps

MAJOR ENERGY SAVING PROPOSAL AT MEDICAL TRUST HOSPITAL (UNIT-1)

1. Power Factor Improvement

Present Situation

Present average system power factor - 0.86
Present Recorded Maximum Demand - 490 kVA
Power factor at Maximum Demand - 0.91

Recommendation

Improve average system power factor to unity
Capacitors Required - 203 kVAr
Annual Cost Saving (demand
+incentive +penalty saving) - 9.17 Lacs
Investment -3.2 Lacs
Pay Back Period - 3 months

POWER FACTOR IMPROVEMENT

The present average power factor	=	0.86		
Contract Demand	=	500	KVA	
75% of Contract Demand	=	375	KVA	
The present Recorded Maximum Demand	=	490	KVA	
Power factor at Maximum Demand	=	0.91		
Therefore the average max. load	=	490	x	0.91
	=	446	KW	
Recommended PF	=	1.00		
RMD at improved PF	=	446	/	1.00
	=	446	KVA	
Reduction in KVA	=	490	-	446
	=	**44**	**KVA**	

Annual Saving due to reduction in RMD	=	44 x 350 x 12
	=	**Rs.185,220**
Total Energy Charge	=	Rs.1,108,962
Annual Incentive due to pf improvement above 0.90	=	**Rs.199,613**
Annual Saving by improving PF from 0.86 to 0.90	=	**Rs.532,302**
Annual Saving due to pf Improvement	=	**Rs.917,135**
Additional KVAr requirement	=	KW x (Tan f1-Tan f2)
	=	446 x (0.456 - 0.000)
	=	203 KVAr

Investment Required

203 *kVAR capacitors with APFC including installation charge*	=	203 x 1200
		Rs.243,000
Simple Payback period	=	243000 / 917135 x12

2. Air Conditioning System

Present Situation

- 3x40TR chiller units are installed of which only two are operated at a time
- Chilled water temperature settings – between 5 & 6°C
- AHU's are operated continuously without any control
- Chilled water pumps are operated with full load continuously.
- Annual power consumption in air conditioning system – 6.27 lac unit

Recommendation

- provide variable frequency control to change the speed of the compressor motor according to the requirement and hence the temperature range can be increased to a higher level so that the power consumption can be reduced
- Provide VFD's for AHU's and chilled water pumps
- Annual energy saving (25%) - 1.67 lac units
- Annual cost saving - Rs. 8.28 lac
- Investment required - Rs. 5.0 lac
- Payback period - 7 months

General Energy Saving Measures in A/c System

- Comfort conditions: 25^{O}C, 55 % RH
- Minimize heat load through glass windows
  - Provide sun control film, Use double glass
- Insulate roof top in A/C Building
  - Provide under deck insulation of 50 mm, Provide lawns at roof top
- Minimize artificial lighting
  - Use natural lighting , 3.5 kW lighting consumes 1.0 TR load
- Provide controls
  - install thermostat to control peak and base load
- Air tight the building envelop
  - prevent cold air leakage, Provide door closures
- Avoid heat producing equipments inside the room
  - keep away UPS Battery , ovens, other loads

3. Compressed Air System

Present Situation

- 3x15 HP compressors are installed of which only one is operated at a time
- Pressure setting – between 6.1 & 7 kg/cm2
- Compressor is working 51% in LOAD condition & 49% in UNLOAD Condition

Recommendation

- provide variable frequency control to avoid the power loss during unload operation & also for power saving with increased pressure setting
- Annual energy saving - 10,217units
- Annual cost saving - Rs. 0.5 lac
- Investment required - Rs. 5.0 lac
- Payback period - 12 months

4. Replacing 40W fluorescent lamp fittings with conventional chokes by energy efficient T5 lamps

Present Situation

- Total fluorescent lamp fittings in the building - 709 Nos.
- Number of tubes burning 24hrs/day – 308 Nos.
- Number of tubes burning 10hrs/day - 401 nos.

Recommendation

- Total number of T5 lamps proposed - 709 Nos.
- Annual Cost Saving - 5.58 Lacs
- Investment - 2.83.08 Lacs
- Pay Back Period - 6 months

5. Replacing Incandescent Lamps with CFL's

Present Situation

- Total number of 25 W Incandescent bulbs connected - 582 Nos.
- Number of lamps burning 10 hrs/day - 250 Nos.
- Number of lamps burning 5hrs/day - 332 Nos.

Recommendation

- Total number of (11W) CFL proposed - 582 Nos.
- Annual Cost Saving - 1.02 Lacs
- Investment - 0.52 Lacs
- Pay Back Period - 6 months

6. Install Energy Saver For Yard Lighting

Present Situation

- Total light load - 50.41kW
- Present average load - 45.37 kW
- Lighting feeder voltage - 230 V

Recommendation

- Install Energy Saver (Voltage Controller)
- Proposed voltage - 210 V
- Annual Cost Saving - 1.48 Lacs
- Investment - 1.65 Lacs
- Pay Back Period - 13 months

6. DG Set performance test

Capacity of the DG set	- 500 kVA
Test duration	- 20 minutes
Units generated	- 91.17 kWh
Average load	- 273.51 kW
Diesel consumed	- 24 litres
Average pf	- 0.81
Average operating load	- 338 kVA
%ge loading	- 68 %
Specific power generation	- 3.8 units/litre