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A Topological Survey of Energy Base Line Methodologies and Measurement Verification Approach for Data Centre Environment

Ramesh. Gamasu
Department of Electrical & Electronics Engineering, St.Ann's College of Eng& Technology, Cherala (A.P), India
Email: ramesh.gamasu@gmail.com

***Abstract*— India is an utmost developing country. In that energy is prototype key parameter in lacking one. India is also an energy based scenario followed place in Asian region. Energy places a prominent role in the development of nation's progress. In this article, we describe and conduct a survey on topological aspect of energy base line measurements and methodologies. We follows a different metering and sensor based devices with particular procedure initiates methodology and measurements named as a "base line". This paper was able to explain the key energy consumption impact parameters for data center and establishment of base line methodologies for facility too. To establish the model for base line energy consumption, the facility should accommodate load consuming element changes. As the data is not much available, these will be doing after installation of meters and sensors. The proposed article will be for energy consumption base line and energy cost base line of entire facility. The entire topological survey was conducted and extracted data from real time data acidulation energy based center.**

***Index Terms*—energy base line methodologies, data acidulation energy center, cost and economic base line, energy consumption base line**

Abbreviations

PUE- Power Usage Effectiveness
MSC- Mobile Switching Centre
DC – Data Centre
YTD- Yearly till Date
KPI- Key Performance Indicators
DCIE- Data Centers Infrastructure Efficiency
PDU- Power Delivered Usage
SLD- Single Line Diagram
HVAC- Heating Ventilation Air Conditioning
BLM-Base Line Methodologies

I. Introduction

This article provides details of energy baseline, measurement and verification methodologies, and energy conservation measures of Data Centers Facility in Particular proposed area. This document covers complete data collection during our baseline visit to the facility, analysis, calculations, assumptions etc Baseline month, baseline energy, baseline KPI all are captured and embedded in this document for ready reference. To develop a cost effective metering plan to capture energy consumption profile on ongoing basis to track baseline movement and deviation from baseline.

The use of energy in buildings accounts for a large share of the total end use of energy. In sectors such as residential and the commercial sector the major part of the energy consumption takes place buildings. This includes energy used for controlling the climate in buildings and for the buildings themselves, but also energy used for appliances, lighting and other installed equipment. In other sectors a small part of the energy consumption is similar used for similar purposes in relation to the buildings. This is for instance the case for some buildings in the industry used for administration or some buildings agriculture or forestry. The energy efficiency of new buildings determines the building sector's energy consumption for far longer than other end-use sectors components determine their sector's efficiency. Buildings will typically be constructed to be used for many decades and, in some cases, for more than a hundred years.

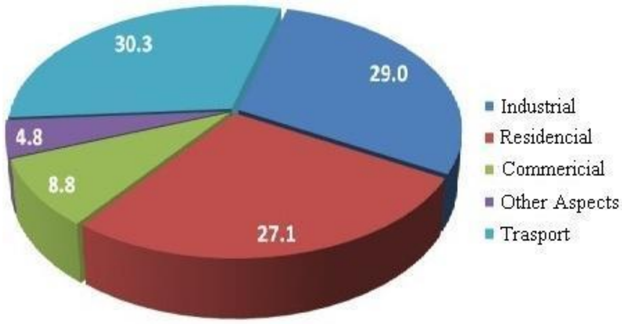

Figure. 1. Share of energy consumptions in different sectors

In other energy end uses, the capital lifetime for efficiency improvement will be, at most, a few decades. Improvement of buildings' efficiency at planning stage is relatively simple while improvements after their initial construction are much more difficult: decisions made during a building's project phase will hence determine

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consumption over much, if not all, of a building's lifetime. Some measures to improve efficiency are possible only during construction or by major refurbishment, likely to happen only after several decades. Other improvements will be very cost effective or maybe even free or at negative costs when implemented at project stage, but can be expensive at a later stage

Energy efficiency requirements in building codes or energy standards for new buildings are therefore among of the most important single measures for buildings' energy efficiency. This is in particular the case in times of high construction activity or in fast developing countries. The importance of energy efficiency requirements in building codes or standards extends beyond their role in new buildings. Building codes and efficiency standards often serve as the efficiency target for refurbishment or other improvements of existing buildings. Buyers and renters of buildings or units will often compare new and existing buildings.

II. Energy Efficient Buildings Benefits Society

Energy consumption in buildings is a large share of the world's total end use of energy. In member states of the OECD, residential and commercial buildings require approximately 35 % of the end use of energy in addition to this energy is used for buildings also in the industry. Globally, buildings account for close to 40% of total end use of energy. Given the many possibilities to substantially reduce buildings' energy requirements, the potential savings of energy efficiency in the building sector would greatly contribute to a society- wide reduction of energy consumption. The implications of such potential reduction should not be underestimated, as the scale of energy efficiency in buildings is large enough to Influence security policy, climate preservation and public health on a national and global scale.

TABLE I. PRIMARY ENERGY CONTRIBUTORS FOR MSC ENERGY CONSUMPTION

MOBILE SWITCHING CENTRE (MSC)	
Primary energy contributors	Type of Loads
UPS and Power Plant Load	Telecom equipments load (Active Load)
Precision Air conditioning	Cooling for telecom equipments
Low side AC	For Passive element cooling like battery, UPS, PP losses
Lighting Load	For illumination of MSC
Shell load of MSC	Heat ingression due to weather changes

Moderation of energy-end use in buildings will also reduce greenhouse gas emissions and pollution produced by the combustion of fossil fuels. This environmental benefit appears on two scales, local and global. Because much of buildings' demand for energy requires local energy combustion in individual heating systems or district heating, reduced energy demand improves air quality at the local level. In particular in developing countries a reduced demand for energy requires fewer power plants, thereby delaying or obviating the construction of new generation and grid capacity and enabling communities to devote public funds elsewhere.

III. Topological Survey of Data Centers Environment

A. Type of Service Areas

This facility comprises of MSC, Data Centre and Facility of Data centers business units. Followings are the details of service area which covers in this baseline document.

TABLEII. PRIMARY ENERGY CONSUMING ELEMENTS OF DC

DATA CENTERS(DC) ENVIRONMENT	
Primary energy consumers	Type of Loads
UPS Load	Active Load
Precision Air conditioning	Cooling for active equipments
Low side AC	For Passive element cooling like battery, UPS losses
Lighting load	For illumination of Data Centre
Shell load of Data Centre	Heat ingression due to weather changes

TABLE III. PRIMARY ENERGY CONSUMING ELEMENTS OF OFFICE AREA

OFFICE AREA	
Primary energy contributors	Type of Loads
UPS load	Computer, Laptops etc
Low side AC	For Passive element cooling like battery, UPS losses
Raw Power	Fax, Photocopier, Water cooler, Tea Point etc
High Side AC	For People Area Cooling
Shell Load of office area	Heat ingression due to weather changes
Lighting load	For illumination of office area

IV. Baseline Methodology

Methodology for working out the Baseline of the whole facility would comprise of the following steps

A. Pre -Study of Site Infrastructure

In the month of July & August 2010, our baseline audit team visited Data centres facility for detail study of the kind of operations like DC, MSC, and office areas handled in the facility and also the infrastructure available for supporting the same. The detail profile of energy demand, design and measured data of all Equipments in DC, MSC and Facility areas are studied. We reviewed the present site energy tariff structure provided by Electricity Company.

B. Historic Data Collection

EB Energy consumption data/bills of the site are collected for last 12 months from June 2009 to June 2010. The D.G units generated / diesel consumption are also available from June 2009 to June 2010. These data's are taken from the log book maintained at facility. The details of data collected on electricity, DG units and Diesel consumptions are shown below figure. The Complete survey of existing metering was done and the same are notified in the below metering Single line diagram.

Actual record of load changes over a period of time was not available. The Operating conditions of equipments, present loading on different equipments are captured during our visit and the details are shown from Following Tabular forms. This also covers the complete asset of the DC, MSC and Facility area which is under scope of our boundary.

TABLE. IV. TOTAL CONSUMPTION OF WHOLE FACILITY

Month	Total Consumption of whole building				Billed kVA	Contract kVA of Data Center with Builder	kVA billed for Data center by Facility
	H.T meter Reading		Difference	M.F - 1500			
	Final	Initial					
Jun-09	3859.52	3525.48	334.04	501060	1200	980	744
Jul-09	4175.41	3859.52	315.89	473835	1200	980	744
Aug-09	4502.58	4175.41	327.17	490755	1200	980	744
Sep-09	4818.7	4502.58	316.12	474180	1200	980	744
Oct-09	5139.22	4818.7	320.52	480780	1200	980	744
Nov-09	5457.82	5139.22	318.6	477900	1200	980	744
Dec-09	5769.1	5457.82	311.28	466920	1200	980	744
Jan-10	6071.46	5769.1	302.36	453540	1200	980	744
Feb-10	6348.82	6071.46	277.36	416040	1200	980	744
Mar-10	6705.13	6348.82	356.31	534465	1214	980	753
Apr-10	7027.18	6705.13	322.05	483075	1272	980	789
May-10	7363.96	7027.18	336.78	505170	1238	980	768
Jun-10	7704.6	7363.96	340.64	510960	1283		

TABLE. V. DATA CENTRE AND OTHER ENERGY CONSUMPTIONS

Month	Data Center Energy Consumption				Others Energy Consumption			
	Meter Reading		Difference	M.F - 1000	Meter Reading		Difference	M.F - 1000
	Final	Initial			Final	Initial		
Jun-09				385110	314.04	210.31	103.73	103730
Jul-09	299	0	299	362654	413	314	99	99440
Aug-09	675.46	299.17	376.29	376290	515.98	413.48	102.5	102500
Sep-09	1040.69	675.46	365.23	365230				97170
Oct-09	1411.26	1040.69	370.57	370570	193.88	95.94	97.94	97940
Nov-09	1781.26	1411.26	370	370000	288.43	193.88	94.55	94550
Dec-09				369110	374.59	288.43	86.16	86160
Jan-10	707.11	343.95	363.16	363160	453.6	374.59	79.01	79010
Feb-10	1036.38	707.11	329.27	329270				76990
Mar-10	1455.56	1036.38	419.18	419180	177.36	74.94	102.42	102420
Apr-10	1833.52	1455.56	377.96	377960	270.59	177.36	93.23	93230
May-10				397330	366.29	270.59	95.7	95700
Jun-10	708.8	312.43	396.37	396370	468.94	366.29	102.65	102650

TABLE. VI. TOTAL BILLING OF DATA CENTRE AND FACILITATION

Month	Total Losses (H.T -(Data Center + Others)	DC Share in Losses in %	Actual loss in kWh	DC Total kWh (Consumption + Losses)	Unit Cost Rs (As billed)	Total Electricity bill
Jun-09	12220	62	7576	392686	4.85	2248185
Jul-09	11741	62	7279	369933	4.85	2125160
Aug-09	11965	62	7418	383708	4.85	2199653
Sep-09	11780	62	7304	372534	4.85	2139218
Oct-09	12270	62	7607	378177	4.85	2171665
Nov-09	13350	62	8277	378277	4.85	2170273
Dec-09	11650	62	7223	376333	5.6	2470631
Jan-10	11370	62	7049	370209	5.6	2432377
Feb-10	9780	62	6064	335334	5.6	2214489
Mar-10	12865	62	7976	427156	5.6	2790037
Apr-10	11885	62	7369	385329	5.6	2536283
May-10	12140	62	7527	404857	5.6	2653874
Jun-10	11940	79.43	9484	405854	6.64	2694870

TABLE. VII. TOTAL BILLING FOR DATA CENTRE ACCREDITED BY BEE

Month	Slab - 1 consumption	Slab - 1 actual rate	Slab - 2 consumption	Slab 2 Actual rate	kVA rate	Total Rs (kVA + Slab1 + Slab2)	Tax @ 5%	Total bill
Jun-09	100000	485000	292686	1507335	148800	2141135	107057	2248192
Jul-09	100000	485000	269933	1390157	148800	2023957	101198	2125155
Aug-09	100000	485000	283708	1461098	148800	2094898	104745	2199643
Sep-09	100000	485000	272534	1403548	148800	2037348	101867	2139215
Oct-09	100000	485000	278178	1432617	148800	2066417	103321	2169738
Nov-09	100000	485000	278277	1433127	148800	2066927	103346	2170273
Dec-09	100000	560000	276333	1644181	148800	2352981	117649	2470630
Jan-10	100000	560000	270209	1607746	148800	2316546	115827	2432373
Feb-10	100000	560000	235334	1400235	148800	2109035	105452	2214487
Mar-10	100000	560000	327156	1946580	150600	2657180	132859	2790039
Apr-10	100000	560000	285329	1697706	157800	2415506	120775	2536281
May-10	100000	560000	304857	1813898	153600	2527498	126375	2653873
Jun-10	-	-	-	-	-	-	-	2694870

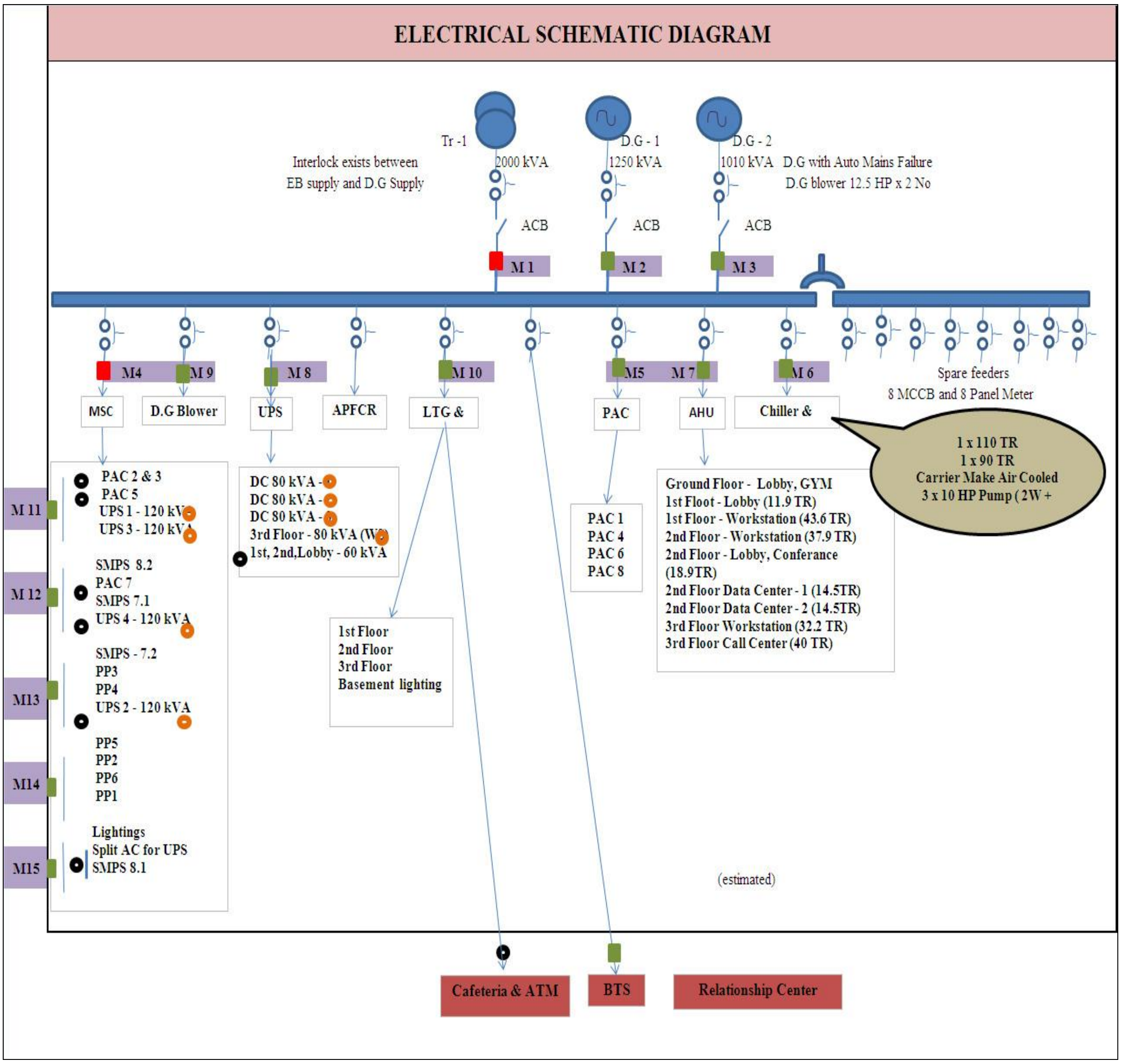

Figure. 2. Exisisting metering single line diagram

The Design Details of connected load, covering parameters like rated power, voltage, amperage, etc are also captured separately for MSC, Data Centre and Facility in the below tabular forms.

V. Site Measurements and Building Code Prior to Base Lining

Energy log is generated from the facility log data at main income level and also in Main MSC income for 24 hrs to understand the load profile of the complete facility and MSC. Site observations are Type of controls, occupancy patterns, equipment loading patterns, operating practices (like timing of switching on/off of people area AHUs), type of metering, connectivity status of meters are studied and populated in excel sheet named Asset & Measurement and Instantaneous energy measurements have done and scope for continuous monitoring have identified and can be found in Metering SLD.

A. *Creation of Energy Consumption Model*

The basic objective of base lining is to develop a model to accurately capture the energy consumption in as is scenario (BAU scenario) and as well analyse for energy and cost savings Energy consumption modelling shall be developed to validate the monthly energy consumption on as run basis, which is to be Estimated the composition of site energy load by various service areas like DC, MSC, and Facilities during our site visit. This is basically collection of daily log data of July 2010 at equipment end. This data is represented in the following pie-chart and the table and Establish breakup of monthly energy consumption for HVAC load, for cooling load, segregated energy consumption for cooling load due to shell load and other heat load for relevant conditioned areas.

- The Factored the impact of key variables on the energy consumption of relevant loads and Factored the loading percentage and operating conditions of equipments for working out monthly energy consumption.

- Establish energy consumption of different service areas/ sections. The areas shall be segregated into MSC, Data centres, office areas.
- Segregate energy consumption of areas lying outside scope of baseline

Finally, create the relationships between the key variables and energy consumption. One month after commissioning of the meters and sensors, the above parameters (Mentioned in 2.5 a to f) shall be observed in addition to observing the past consumption. Apart from this, internationally proven references were also considered to build the relationships. After installation of Please note that some of these relationships (like shell load Vs weather) can only be established over longer period of time

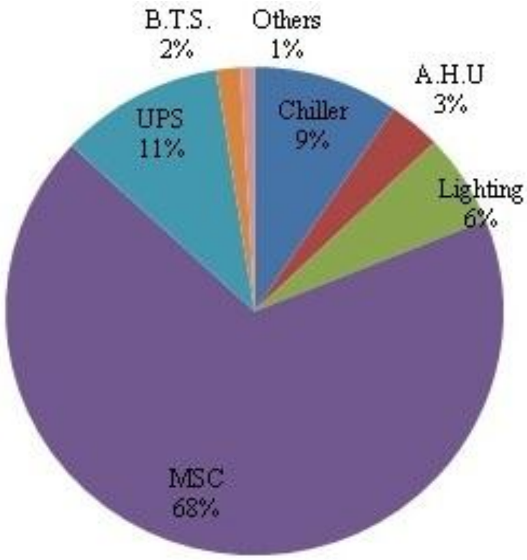

Figure. 3. Energy breakup for per day consumption

The model for monthly energy consumption represents the month during which measurements were taken at definite intervals there after model is to be validated.

B. Validation of Energy Consumption Model

Monthly energy consumption for previous months is estimated based on energy model after factoring in seasonal variations and addition in installed load in various sections from historical data. Seasonal variations in cooling load are estimated based on cooling degree days at the location of facility. The cooling consumption during past 12 months are not available, this is arrived at after 12months of data collection. Shell load of work areas is worked out based on difference between total energy consumption and other measured load energy consumption. Energy consumption of areas lying outside the boundary scope is metered and recorded month over month, as the load is significant. For previous months data the same is subtracted from total energy. Metered data, if available for outside scope areas, would be considered for calculation. The model developed (mentioned in Section 2.5) shall be validated with the actual consumption (month over month). The difference should be less than +/- 2 % (Example: if the model simulates that the consumption is 100 units for the month of April, the actual consumption shall be with the range of +/- 2 %. If the correlation coefficient between modelled energy data and historical data is high (with variation of +/- 2 %)for all months through the year, then the model is considered valid for future months as well. In case, the correlation is weak for some months, relevant adjustments are made to the model.

C. Model for Adjustments- Routine and Non-routine Adjustments

For routine adjustments, with respect to weather and operation shifts/operating hours, which are generally seasonal or cyclical, energy measurement is carried out on all load centres / sections along with operating conditions which shall show variation. The measurements may be carried out on continuous basis (by recording at a certain interval or totalising / integrating the consumption) depending on operational profile of load, to establish baseline energy consumption of identified loads. For analysis purpose, weather data from a credible source would be given priority. In case of non-availability of such data, alternate data source could be considered in agreement with client. For non-routine adjustments, which generally address influence of static variables like change in air conditioned space area, illumination intensity level, temperature set points and occupancy, on energy consumption of service area/facility, appropriate sub-model/ relationship is incorporated in the model. The Following points are additionally considered:

- Conditions in base-year are documented with respect to each service area and load centre.
- Methodology of tracking of conditions on on-going basis is established, clearly earmarking responsibility of monitoring, frequency of monitoring and mode of reporting.
- Non-routine adjustments are made in advance for such change in conditions which can be anticipated based on capacity addition plans of facility.

At the end of every quarter the model is validated for addition or removal adjustment factors if any to incorporate the changes.

VI. Key Performance Indicators

A. Overall Facility

Energy Cost/ kWh – This KPI indicates the average energy cost per unit consumption. This is impacted by the following factors

- Availability of Grid Power
- Energy Tariff
- Amount of energy generated by local sources
- Landed cost of alternate sources like diesel or gas
- Energy Cost per kWh has following sub-components
- Grid Electricity Cost / kWh
- Electricity generation cost / kWh

All these KPIs are monitored on Monthly and Yearly till Date (YTD) basis

B. Office Areas

KWh/sft – this KPI provides energy intensity of the people area. This KPI helps in relative benchmarking for similar type of sites under similar weather conditions. Sites with highest energy intensity are addressed at priority for improving energy efficiency. The most energy efficient sites are targeted for learning the best practices.

This KPI is monitored on monthly and yearly till Date basis

Energy Performance Index (EPI) – As per the Bureau of Energy Efficiency (BEE), EPI reports energy intensity in kWh/ Sq. m/ year. EPI benchmarking has been done by BEE for buildings classified as

- Buildings with > 50% conditioned area
- Buildings with < 50% conditioned area

The methodology of working EPI shall be based on the terms and conditions stipulated by BEE which are given below

C. Main Switching Centre/DC Area

The main switching Centre varieties with Power Usage Effectiveness, as defined by LBNL, PUE is the ratio of the total data centre energy use to total IT energy use. The total data centre energy use is the sum of the electrical energy for the servers, HVAC system, power distribution and lighting.

We are considering only electrical energy for reporting the above KPI.

Powr Usage Effectiveness

$$= \frac{Total\ MSC / DC\ Energy\ Consumption\,(kWh)}{Total\ IT / Telecome\ Equipment\ Energy\ Consumption} \quad (1)$$

This KPI is reported on monthly and YTD basis. Converse of PUE is DCIE. For DC, MSC and MSU, DCIE (Data centre infrastructure efficiency) can be used.

DCIE=IT equipment energy consumption in kWh measured at PDU level / Total facility energy consumption in kWh (at facility incomer side)

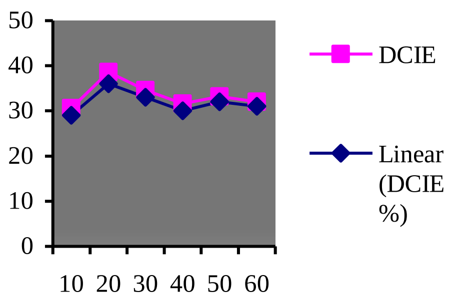

Figure. 4. Data centre infrastructure efficiency with respect to IT load

The DCIE is a key parameter in data center initiates increasing and decreasing changes in the facility. Meanwhile for the consideration of individual load parameters, data center will have a less efficiency. We execute the metering and sensor based base line methodologies for knowing consumption of energy and economic aspects of building. Effectively, before execution the building dissipates more heat and having less efficiency. Fig. 4. shows the variation between DCIE and total facility load. Fig. 4. inititaes the 4-5% energy of data center was due to infrastructure of total facility building.

Apart from that, the 4-5% of energy loss is occurring is due to Building code and infra facilitation. This can be avoiding by using HVAC Equipments in the premises of data centre. The whole data centre and facility was inspected with Sensor based equipments and investigated with indicated instruments. Finally, concluded that by implementing and following a different building codes and base line methodologies leads to an energy saving and conservation in facilitation. Fig. 4. Indicates dissipation of Heat and ambient temperature of HVAC Equipments in data centre premises.

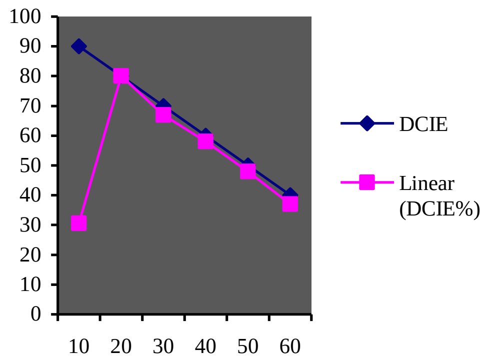

Figure. 5. Data centre infrastructure efficiency with respect to ambient temperature

VII. Future Scope

The proposed base line methodologies are implemented in data centre premises are helpful for knowing about

- Cost effective metering plan to capture energy consumption
- Preparing the economic metering facility
- Establish the model for energy consumptions
- Study in depth about Building code of data centre at different levels
- For reducing the energy consumption equipments

VIII. Conclusion

This article facilitates the base line methodologies and topological survey of data centre. The proposed base line methodologies initiates saving and conservation of key performance indicators from initial stage itself. Before implementing the BLM the data centre and facilitation having an energy consumption loss is 4-5%. After implementing the BLM i.e HVAC Equipments, there is possible energy conservation and saving is 2-3%.Hence BLM is important parameter in the view of data centre and finally by implementing different BLM and topological survey initiates present and past energy consumptions. Adequately, the total data centre facility and facilitation was investigated and extracted the real time past and present energy consumptions and economic parameters.

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Mr. Ramesh. G received B.Tech in Electrical Engineering from JNT University, Kakinada. He worked as Assistant Professor of Electrical Engineering Departments at Centurion University of Technology & Management, Perelakemundhi (Odisha), India; and RISE Prakasam Group of Institutions, Ongole (A.P). Now, he is M.Tech Scholar in Power Systems from St.Ann's College of Engineering & Technology, Cherala (A.P); He published more than six number of research articles in highly indexing patent journals. He is Member in Various Technical and Engineering Societies like American Society of Engineering Education (ASEE), Engineering & Technology Publications (ETP), International Association of Engineers (IAEng), and IAENG Society member of Artificial Intelligence and Electrical Engineering, International Association of Computer Science and Information Technology (IACSIT), and Member in Universal Association of Computer and Electronic Engineers (UACEE), International Association of Engineers and Scientists (IAES), SERC,WASE and SCIEI etc. His areas of Interests include Role of Optimizing Techniques for Identification of Power Quality Problems, Power Systems Deregulation and Dynamics, Modeling and Simulations of Electro Mechanical Models& Systems etc.

