International Journal of Modern Research in Engineering & Management (IJMREM)
||Volume|| 3 ||Issue|| 1 ||Pages|| 36-42 || January 2020 || ISSN: 2581-4540

Electrical Energy Audit and Management of Clean Energy Laboratory at Mehran University of Engineering and Technology, Jamshoro

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----------ABSTRACT----------

Inspecting about the energy consumption and pin pointing the means of energy loss or reducing the loss of energy is described technically as energy audit. Along with minimizing energy loss, reducing environmental effects comes under the umbrella of energy audit. In this paper electrical energy audit and management of clean energy lab of electrical engineering department of Mehran UET Jamshoro has been carried out to estimate the Energy consumed in a day, week and month. Identification of energy wastage and estimation of energy saving potential in the laboratory has been determined in the process. Environmental constraints has been addressed by replacing the conventional power supply with renewables i.e. Photovoltaic (PV) cells thus the lab consumes energy through DC source instead of AC. The objective of energy audit and management here in clean energy lab of Electrical Engineering Department of Mehran University of Engineering and Technology, Jamshoro is to achieve and maintain optimum energy procurement throughout the lab by means of minimizing energy cost /waste without affecting quality. Monthly energy consumption of the laboratory is 161 kWh and cost of electricity consumption is roughly from PKR 1400 to PKR 1500 per month as per calculations of billing formula. If changing of AC appliances into DC appliances and along with installing DC solar system is made, one has to bear the initial capital cost of up to 85000 meanwhile payback period is up to four years and nine months.

INDEX TERMS: Energy Audit, Power loss reduction, PV cell, AC & DC comparison.

Date of Submission: Date, 19. December 2019 ⟺ Date of Publication: 27. January 2020

I. INTRODUCTION

Energy is the capability to perform work and that energy transfers from one form to another while giving out the useful work. Energy is available in many tangible and intangible forms such as heat, light, mechanical, electrical, chemical, nuclear, elastic and gravitational energy. Some forms of energy are categorized as renewable energy forms while others are non-renewables are conventional energy forms. Coal and other fossil fuel that depletes when burnt out to energy are conventional forms of energy while the form of energy that is free from depletion comes under the category of renewables [1].Energy audit and management is process to evaluate the utilization and salvage of energy. It also determines how to reduce energy demand at reasonable cost efficiently [2][13]. Energy management helps producing cost efficient techniques of doing energy related jobs while not compromising over the outcomes or standards. The easiest way available in this regard is energy conservation and that one is cheapest available [3][8]. The very first step towards the evolution of low loss and energy efficient measures in any organization or industry is Energy Audit. There are simple steps to be taken in order to carry out Energy Audit that are collection of data concerned with energy consumption, real data regarding consumption of energy utility of organization which is to be compared with the energy utilization norms and standards for the development and attestation of energy savage measures [4][12]. Khan, and Ahmad (2008) studied energy scenario in Pakistan and suggested through their disaggregate analysis that electricity consumption rate is inversely proportional to living standards. They focused on increasing renewable energy resources and finding alternate energy resources to ensure development of country [5][10][11]. Thumann and Younger (2008) in their book regarding energy audit annunciated that energy audit gives step by step formulation and successive analysis regarding energy consumption in buildings and via this, it's easy to tap out the energy loss causing steps and thus making overall system energy efficient [6]. Randolph and Masters (2008) in their research regarding energy sustainability pointed out that energy audit is necessary tool which empowers consumer to have various methods of analysis to review energy utilization profile of appliances and take the necessary measures [7][9].

Bunse along with other researchers in 2011 highlighted energy efficiency and performance of industries that are backed by scientific literature. The conclusions culminated in statement that energy management is key performance in goods production and service delivery having minimum possible environmental side-effects and cost [14].

II. METHODOLOGY

The methodology in this research work embraces five steps and that steps involving laboratory visit, data collection, energy consumption recording, system source conversion from AC to DC and application of energy audit tools. Data collection has been carried out for the appliances that are in full or partial use by visiting the clean energy lab at Electrical Engineering Department. Data collection enables to estimate the peak demand of the lab and average power consumption. Furthermore, energy consumption of the lab is recorded over energy meter (AC & DC) before and after the installation of DC system.

Installed AC load: Clean energy laboratory is equipped with many appliances ranging from few watts to few kilo-watts. The load that is taken into consideration is lighting load and fans. Table 1 below shows the load installed at clean energy laboratory of Electrical Engineering department of Mehran UET Jamshoro.

Serial No.	Load Type	Rated Power	Quantity	Total Power
1	AC Bracket Fan	60 Watts	8	480 Watts
2	Fluorescent Tube Light	18 Watts	20	360 Watts
3	Energy Saver	24 Watts	8	192 Watts
			Total	1032 Watts

Table 1. Installed AC Load of Laboratory

DC Load Experimental Setup: As first and foremost principle of energy audit is replacing loss causing equipment with energy efficient ones without compromising the quality. Thus, the experimental setup is installed keeping in view that quality is never compromised. Table 2 below shows the DC load setup with components' rated power, total quantity and total power consumption.

Serial No.	Load Type	Rated Power	Quantity	Total Power
1	DC Bracket Fan	30 Watts	8	240 Watts
2	DC LED T8 Tube Light	10 Watts	32	320 Watts
3	DC Energy Saver	06 Watts	8	48 Watts
			Total	608 Watts

Table 2. DC Load Setup in Laboratory

Energy consumption per month on kWh is then collected having AC supply by applying energy meter at the distribution board of the lab. After installing the DC PV system and converting the lab from AC power supply to DC power supply same step has been repeated. Lab was left running on DC supply for one month long and data of AC and DC energy consumption is compared and the results are well described through graphs. The table setup of the DC load is shown in Fig. 1 and Fig. 2 showing the DC load and Energy meter that has been installed in laboratory.

Fig 1. DC Bracket Fans and LED T8 Lights

Fig 2. AC Bracket Fan and Energy Meter

III. RESULTS & DISCUSSIONS

Clean Energy Laboratory is taken for the energy audit and to rule out the components that are causing high losses when AC source is applied as compared to the overall DC system, lab was kept on running through DC supply from Photovoltaic cells for one month long and collecting data of energy consumption of DC and AC system, significant comparison is done on the scale of power consumption.

AC System Energy Consumption: Before installing DC system in Clean Energy Laboratory, energy meter was installed to read and note the power consumption of the components stated in table 1. The reading was taken from 13th of May 2019 to 25th of June 2019. The exact power consumption for each component was set as six hours and four hours. Table 3 shows the power consumption on each day.

Date	Time duration	Consumption kWh	Total Reading kWh
13-5-19	Six hours	6.624	6.624
14-5-19	Six hours	6.624	13.248
15-5-19	Six hours	6.624	19.872
16-5-19	Six hours	6.624	26.496
17-5-19	Four hours	4.416	30.912
20-5-19	Six hours	6.624	37.536
21-5-19	Six hours	6.624	44.16
22-5-19	Six hours	6.624	50.784
24-5-19	Four hours	4.416	55.2
27-5-19	Six hours	6.624	61.824
28-5-19	Six hours	6.624	68.488
29-5-19	Six hours	6.624	75.072
30-5-19	Six hours	6.624	81.696
31-5-19	Four hours	4.416	86.112
3-6-19	Six hours	6.624	92.736
6-6-19	Six hours	6.624	99.36
10-6-19	Six hours	6.624	105.984
13-6-19	Six hours	6.624	112.608
14-6-19	Four hours	4.416	119.232
17-6-19	Six hours	6.624	123.648
18-6-19	Six hours	6.624	130.272
19-6-19	Six hours	6.624	136.896

20-6-19	Six hours	6.624	143.52
21-6-19	Four hours	4.416	147.936
24-6-19	Six hours	6.624	154.56
25-6-19	Six hours	6.624	161.184

Table 3. Energy Consumption of AC Load

Table 3 indicates that 6.624 kWh energy is consumed for continuous six hours running of the appliances and 4.416 kWh energy is consumed for four hours. Total consumption for 26 days comes out to be 161.184 kWh.

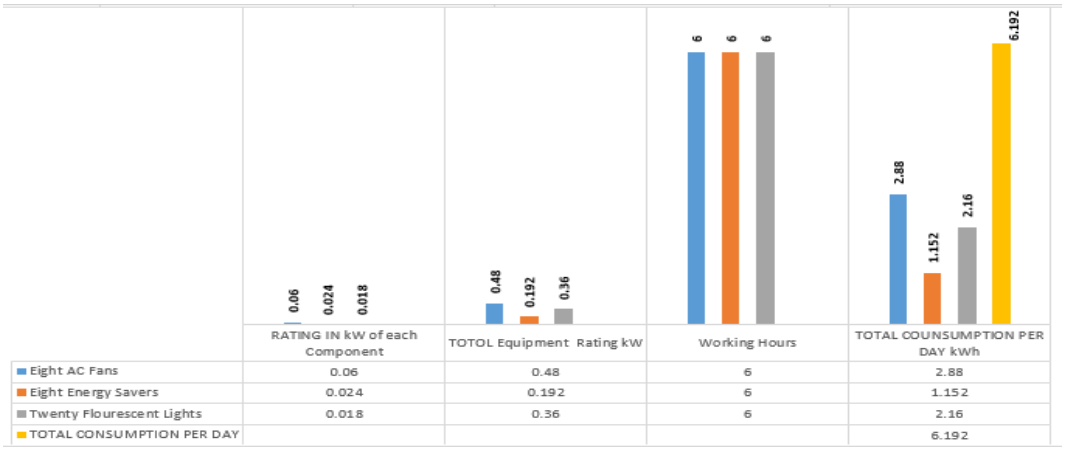
DC System Energy Consumption : After successfully noting the consumption of AC system through integrating energy meter, DC system is installed and energy consumption is recorded. The DC components has been stated in table 2.

Date	Time duration	Consumption kWh	Total Reading kWh
01-7-19	Six hours	3.64	3.64
02-7-19	Six hours	3.64	7.28
03-7-19	Six hours	3.64	10.92
04-7-19	Six hours	3.64	14.56
05-7-19	Four hours	2.43	16.99
08-7-19	Six hours	3.64	20.63
09-7-19	Six hours	3.64	24.27
10-7-19	Six hours	3.64	27.91
12-7-19	Four hours	2.43	30.34
15-7-19	Six hours	3.64	33.98
16-7-19	Six hours	3.64	37.62
17-7-19	Six hours	3.64	41.26
18-7-19	Six hours	3.64	44.9
19-7-19	Four hours	2.43	47.33
22-7-19	Six hours	3.64	50.97
23-7-19	Six hours	3.64	54.61
24-7-19	Six hours	3.64	58.25
25-7-19	Six hours	3.64	61.89
26-7-19	Four hours	2.43	64.32
29-7-19	Six hours	3.64	67.96
30-7-19	Six hours	3.64	71.6
31-7-19	Six hours	3.64	75.24
01-8-19	Six hours	3.64	78.88
02-8-19	Four hours	2.43	81.31
05-8-19	Six hours	3.64	84.95
06-8-19	Six hours	3.64	88.59

Table 4. Energy Consumption of DC Load

Energy consumption reading for DC load has been stated in table 4 above from 1st July 2019 to 06th of August 2019. Total consumption for 26 days comes out to be 88.59 kWh.

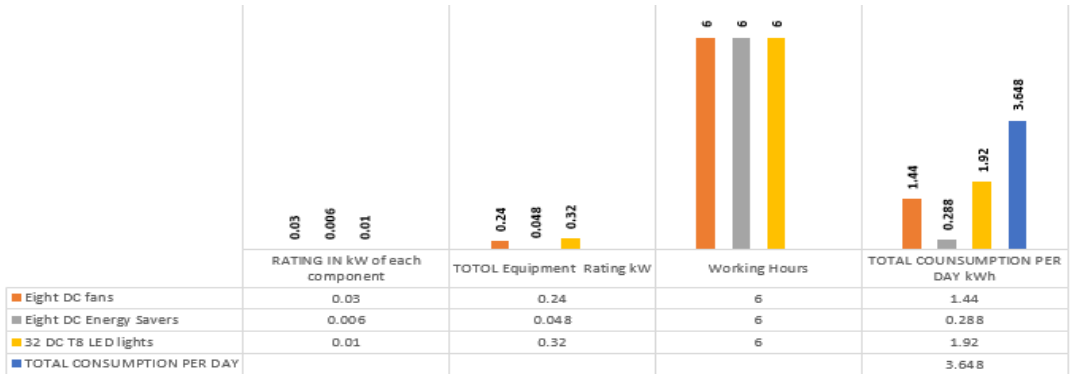
Energy Consumption Comparison : Energy consumption of AC components as stated in table 1 comes out to be 6.192 kWh per day if operated for continuous six hours as shown in Fig 3.



	RATING IN kW of each Component	TOTOL Equipment Rating kW	Working Hours	TOTAL COUNSUMPTION PER DAY kWh
Eight AC Fans	0.06	0.48	6	2.88
Eight Energy Savers	0.024	0.192	6	1.152
Twenty Flourescent Lights	0.018	0.36	6	2.16
TOTAL CONSUMPTION PER DAY				6.192

Figure 3. Energy Consumption Details of AC Components

According to the table 3, daily consumed units for six continuous hours is 6.624 kWh and for four hours 4.46 kWh. This difference is due to the energy loss in wires, distribution board indications and longtime pending maintenance of hissing sound producing chokes of fluorescent tube lights.



	RATING IN kW of each component	TOTOL Equipment Rating kW	Working Hours	TOTAL COUNSUMPTION PER DAY kWh
Eight DC fans	0.03	0.24	6	1.44
Eight DC Energy Savers	0.006	0.048	6	0.288
32 DC T8 LED lights	0.01	0.32	6	1.92
TOTAL CONSUMPTION PER DAY				3.648

Figure 4. Energy Consumption Details of DC Components

Energy consumption of DC Components as denoted in table 2 is 3.64 kWh per day if operated for six hours as cleared in Fig 4. According to table 4, energy consumption of DC components is 3.64 kWh and 2.43 kWh if operated for continuous six and four hours respectively. Figure 4 and table 4 justifies same energy consumption as on DC experimental setup because minimum length of DC wires and no distribution board indications are utilized. Thus no extra power is being tapped due to indications, lengthy wires and loss causing high voltage chokes of fluorescent tube lights.

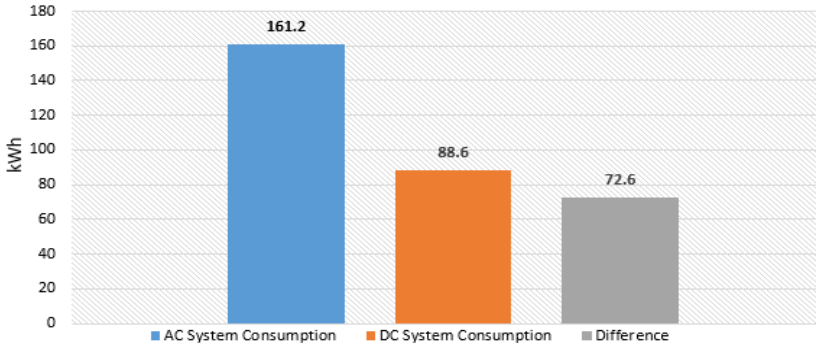


Figure 5. Difference in Energy Consumption of AC and DC System

In figure 5, it is clear that up to 45% of energy can be saved by changing the system from AC to DC, while energy

to DC system can directly be supplied through Photovoltaic (PV) system without implementing batteries in it. As the operational time of the lab is mostly on day time thus solar PV system need not to have any backup through batteries.

Capital Cost for DC System : It is pertinent to mention here that initial investment to equip clean energy with DC system requires finite amount shown in table 5 below.

Name of Appliances	**Quantity**	**Cost of each Appliance (PKR)**	**Total Cost (PKR)**
DC wall fan	8	2500	20000
T8 LED Tube / LED	32	250	8000
DC Energy Savers	8	200	1600
Solar Panel 150w	10	5000	50000
Others			5000
Total investment			84600

Table 5. Initial Capital Cost for DC System

Initial investment as shown in table 5 is round about 85 thousands, while this system is saving 45% of energy being used in one lab during the working hours. Regular electricity bill according to Hyderabad Electric Power Company Ltd. (HESCO) (including taxes and Fuel Price Adjustments FPA that vary time to time) for 161 kWh of energy is around PKR 1500 and as monthly 1500 PKR are saved thus it requires approximately fifty seven months i.e. four years and nine months to pay back complete initial cost for solar and DC appliances. Additional benefit of application of solar system is that it produces upto 1000 Watts (due to efficiency of solar PV cells) and the solar system is capable of proving power to few lights for corridor or as desired by the consumers in department of Electrical Engineering in Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan.

IV. CONCLUSION

In final conclusion, it has been cleared through above results and discussions that DC system is promising system for reducing the losses and making overall system more efficient along with utilizing one of the ample lasting renewable source of energy. The major capital cost for implementing DC system is the cost of solar photovoltaic system but the main advantage in this regard is sufficient life of PV solar panels. Payback period never exceeds five years which is very good in sense of investment versus payback period. The advantage that supersedes all this is independency from Power Supplier Company, means on DC system powered through solar system, organization can be independent of the power outages due to any faults.

Future Work: Energy audit of clean energy lab indicates that DC appliances are causing less energy loss. Same work can be extended for whole department of Electrical Engineering or up to two three nearby buildings. Research and feasibility for power sale to power companies or nearby residential is possible if installed on large scale.

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