Economic Feasibility of DC Supply for Residential DC Load System

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***Abstract*— Even though the AC system is our traditional system, there are many loads which actually run on DC at low voltage levels. If a residential load system is taken, there are a number of DC loads fed from the AC supply using a rectifier/adapter which adds extra loss and cost. In this scenario, this work explores the economic feasibility of having a direct DC supply for these loads in a residential system. Under this case, the economical voltage level that should be considered for a residential load system may play an important role. Comparing the traditional AC load system with the DC load system gives the insight of matching between these two loads. This study is helpful to determine the optimal configuration for a residential load.**

Keywords—losses, low voltage DC, conversion

I. INTRODUCTION

In the context of large increment in the power demand every year and the depletion of natural resources, energy saving plays a vital role. So the losses in the systems should also be minimized. The losses in the household appliances [1] and in the distribution system are an important issue in this scenario. All the electronic appliances such as TVs, DVDs, Personal Computers, Laptops, CFL bulbs etc. operate internally on DC. Along with that, in recent days direct DC loads are also being designed. The conversion from AC to DC involves a notable loss [2]. The electronics appliances results in losses in their standby mode also [3], where they are not performing their primary function like a device that operate on a low DC voltage with a step down transformer for .conversion. So this study shows the comparison of losses in case of 230V AC conventional supply and low voltage DC supply.

II. PROPOSED METHODOLOGY

In a typical house there are different kinds of appliances such as stove, microwave oven, dish washer etc., which are high power consumers and also electronic appliances such as TVs, DVDs, and Laptops etc., which works internally on DC voltage [4]. The number of loads is different in each house. In this study case the electronic loads, kitchen loads and the very basic appliances such as lights, fans are considered. The loads considered are air conditioner, lights, fans, refrigerator, water pump, washing machine, mixer, induction stove, oven, TV, DVD player, computer, laptop, mobile charger and router. The power rating of loads is in the range of 4W to 900W range. The on duration of appliance varies from home to home, climatic conditions and other reasons. The average on duration of loads is taken for the study purpose. The power ratings are taken according to the supply.

A. Household Appliances with 230V AC system:

TABLE I shows the load power rating, current at 230V AC, average working hours along with the cable details.

TABLE I
LOAD DATA OF A TYPICAL HOUSE

Load	*Power rating (W)*	*P.F*	*Working Hours*	*Cable length (m)*
Air Conditioner	900	0.85	5	8
LCD TV	156	0.85	5	4
Laptop (2)	50	0.9	6	2
DVD Player (2)	25	0.9	0.5	2
Cell Charger (3)	4	0.9	4	1
Washing Machine	100	0.8	0.5	6
Lights (LED) (5)	60	0.9	10	5
Fan (5)	100	0.8	2.5	2
Router	7	0.95	4	2
Freezer	200	0.8	12	4
Water Purifier	15	0.85	3	1
Computer	170	0.95	4	5
Induction Stove	2000	0.7	2	1
Oven	800	0.8	1	3
Mixer	500	0.85	0.5	4

The cable length and its area are calculated based on its current and the voltage drop. The voltage drop is very less and it can be neglected. The feeder cable losses are calculated using the formula:

$$P_{loss} = 2*I^2*R*n \quad (1)$$

where n = number of similar loads.

There are some losses in the AC to DC rectification and moreover there is a small transformer (step down magnetic) that causes no load losses though it is not performing its primary function in standby mode. If the full wave diode bridge rectifier is considered for AC to DC conversion, there will be a drop across the diode which depends on the diode forward voltage (V_f) its forward resistance and the current. In the case of 1N4007 diode, the V_f value ranges from 0.9V to 1.1V. Assuming zero switching losses, the V_f value is taken as 0.9V. Then the losses in the rectifier are

$$P_{rec\_loss} = 2*V_f*I_{rms} \quad (2)$$

In this case the losses due to feeder cable and rectification are considered. The standby losses of loads are not considered. So the value of the loss that found here is less than in actual case.

B. Household Appliances with low voltage DC system:

This proposed system of low voltage DC supply to the loads in place of conventional 230V AC eliminates the conversion loss and also the standby losses of the house loads. For this study the same system used for AC analysis is considered. The DC loads are fed by direct 48V supply whereas the existing AC loads are supplied using an inverter. All the dc-dc and dc-ac conversion losses are taken approximately in the calculation.

The analysis that has been done on the loss and cost of the system at different voltage levels of DC bus voltage. The system having the loads that work at 12, 24 and 48V are considered with respective conversions from the AC to DC and also dc-dc conversions as shown in fig.1.

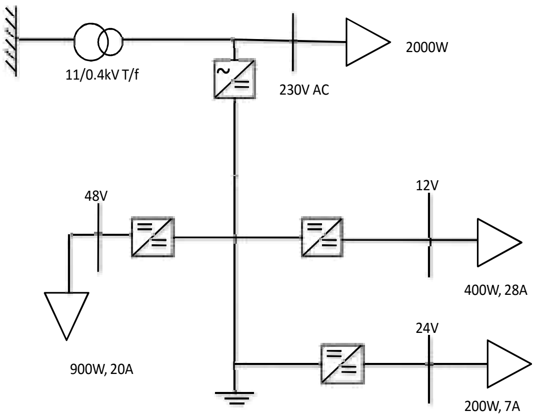

Figure.1. Layout of system

The plot of loss and cost in terms of voltage (Figure.2) in the range of 48V to 230V gives the justification for it, as the 48V is having less loss and cost as shown in fig.2.

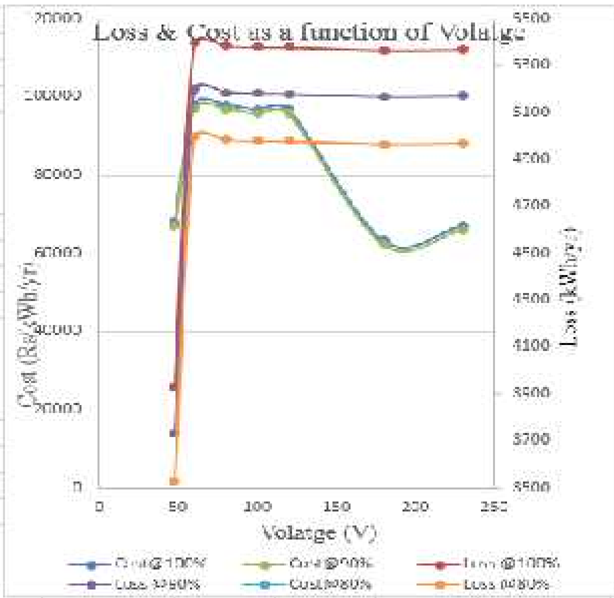

Figure.2. Loss & Cost at different voltages

This is due to the elimination of extra converter which cannot be done with other voltage levels. All these calculations are done taking the dc-dc conversion losses and switching losses with an efficiency of 95%.

After taking 48V as the reference voltage, the feeder cable losses at load end are calculated same as in case of AC system using the equation (1). The dc-dc conversion losses all the inductor loss, MOSFET conduction loss and switching losses are taken into account.

$$\text{Inductor conduction loss} = I_0^2*R_{DCL} \quad (3)$$

R_{DCL} is the inductor resistance

$$P_{loss}\,(\text{MOSFET conduction}) = I_0^2*r_{DSon} \quad (4)$$

r_{DSon} is the on state resistance of MOSFET (The ON state resistances of the two MOSFETS in the buck converter are assumed to be equal.)

$$\text{MOSFET switching loss} = V_{drop}*I_0$$

Same analysis is done by replacing the 48V DC level with 24V DC level and the losses are analyzed.

III. RESULTS

The low voltage level for DC load is considered after the analysis of loss and cost of the system shown in figure1. Using that a further analysis of losses at the residential load end has been done. The comparison of the losses at the three configurations such as 230V AC conventional system and low voltage DC supply at 48V and 24V is done and it is shown in Table. II.

TABLE II
LOSSES IN A RESIDENTIAL LOAD SYSTEM

System Type	*Cable loss (kWh/yr)*	*Conversion Loss (kWh/yr)*	*Losses at load end (kWh/yr)*
230V AC	7.85	49.36	57.87
48V DC	5.09	40.65	**42.19**
24V DC	8.21	47.49	53.61

From the comparison between the losses in both the cases, it can be seen that the 48V DC system is resulting in less losses compared to 230V AC and 24V DC. So for a residential load system, the 48V DC system can be adapted which results in less loss and the cost is almost same as AC system. This could be more advantageous if the conversion from 230V AC to 48V DC is neglected and considering the direct DC supply from the renewable sources preferably solar PV system.

IV. CONCLUSIONS

The advantages with the DC system such as, exclusion of DC to AC converter to connect solar energy, AC to DC rectification for the devices which run internally on DC which save inherent energy losses. It reduces the standby energy consumption as it doesn't need step down magnetic. This voltage is recommended as it is low level and safe. The comparison study shows that 48V level for a residential system serves better than the conventional system and it is more advantageous when the 48V DC supply is taken from a renewable source such as solar PV system.

V. REFERENCES

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