MANCHESTER 1824

The University of Manchester

Direct Current Voltage for Domestic Use

Why change the way electricity has been consumed for over 120 years from Alternating Current (AC) to Direct Current (DC)?

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Reasons for Extra-Low DC Voltage

1. Almost all household electronic goods and all rechargeable battery operated tools etc internally operate at below 24 Volts DC.
2. DC appliances don't need AC-to-DC power converters (that are used worldwide in their billions) which themselves use up energy and for many home appliances there is no need for any sophisticated DC to DC power conversion.
3. Some white goods like fridges, freezers, air-conditioning units and microwave ovens can and do operate at 24 V, the problem is that some have a very high current.
4. With the elimination of the inverter and all the external and internal AC-to-DC power converters used in the home, the total energy used by the electronic and electrical appliances should be less than their AC equivalents. Therefore the amount of PVs or the size of the renewable energy generators needed to power the house will be less smaller.
5. LED and halogen lights operate directly off DC.

Economics and socioeconomics

1. Appliances that don't need AC-to-DC power converters will be smaller, use less components and raw materials in their manufacture and have a smaller Carbon footprint
2. DC appliances are now more expensive, this is not inherent in the time it take or the amount of materials used in their manufacture, but rather in their small production runs. With economies of scale in manufacture there is no reason why a DC appliance should be more expensive than an AC appliance once mass manufacturing begins. Without the cost of the AC to DC converter a mass produced DC appliance has less component and should therefore cost less to mass produce.
3. In emerging markets there are hundreds of millions of people who are at this time not connected to an electric grid. A minimalistic DC home should give them a very large increase in their living standard quicker and cheaper than a complete centralised AC grid connection.
4. DC offers the need for smaller energy generators, which should decrease the cost and increases the proliferation of decentralised energy generation from Renewables .
5. Decentralised energy generation from Renewables in turn increases greatly energy independence for the householder and on a lesser scale for the country.
6. The more microgeneration the greater the level of energy security

Voltage drop along a conductor

The copper in a cable has a resistance which causes a voltage loss along the cable when a current flows through it. For a low voltage DC electrical mains this can be very significant. The electrical system parameters that affect the low voltage home are show in the following equations. The tabulated values for voltage drops and the current carrying capacity for cables of different gauges and equation (4) are found in the appendices to BS 7671.

The Equations

$$V_{TotDrop} = V_{tab} * I * L \qquad \text{..........(1)}$$

$$L_{Max} = \frac{V_{TotDrop}}{V_{tab} * I} \qquad \text{..........(2)}$$

$$t_{op} = t_a + \frac{I_b^2}{I_{ta}^2}(\mathrm{t_p} - \mathrm{t_{amb}})°\mathrm{C} \qquad \text{..........(3)}$$

$$C_t = \frac{230 + t_p - \left(C_a^2 * C_g^2 - \frac{I_b^2}{I_t^2}\right)(t_p - 30)}{230 + t_p} \qquad \text{..........(4)}$$

$$\mathrm{V}_{cal} = \mathrm{V}_{tab} * \mathrm{C}_t \qquad \text{..........(5)}$$

C_a	Rating factor for an ambient temperature
C_g	Group weighting factor
C_t	Correction factor (used when $I \neq I_t$)
I	The current through the cable (A)
I_b	Operating current of load and cable run (A)
I_t	Tabulated current carrying capacity of cable (A)
I_{ta}	Tabulated maximum current for cable (A)
L	The length of the cable in meters (m)
L_{Max}	The length of the cable at which a best practice value for voltage drop of 5% of system voltage occurs (m)
t_a	Actual ambient temperature (°C)
t_{amb}	Rated ambient temperature (°C)
t_{op}	Actual operating temperature for the cable (°C)
t_p	Maximum equilibrium conductor temperature (°C)
V_{cal}	Calculated voltage drop per amp per metre (mV/A/m)
V_{tab}	The tabulated voltage drop (mV/A/m)
$V_{TotDrop}$	The total voltage drop (V)

- The best way to depict a system with many floating variables is graphically
- Figure 1 shows the tradeoffs between the different system variables
- The same graph can be made for different cable gauges
- 24 and 36 volts was chosen as they are multiples of the basic 12 volts solar panel, 42 volts is a proposed voltage for the internal electric system in motor vehicles and 48 volts is the voltage used in the telecommunications industry

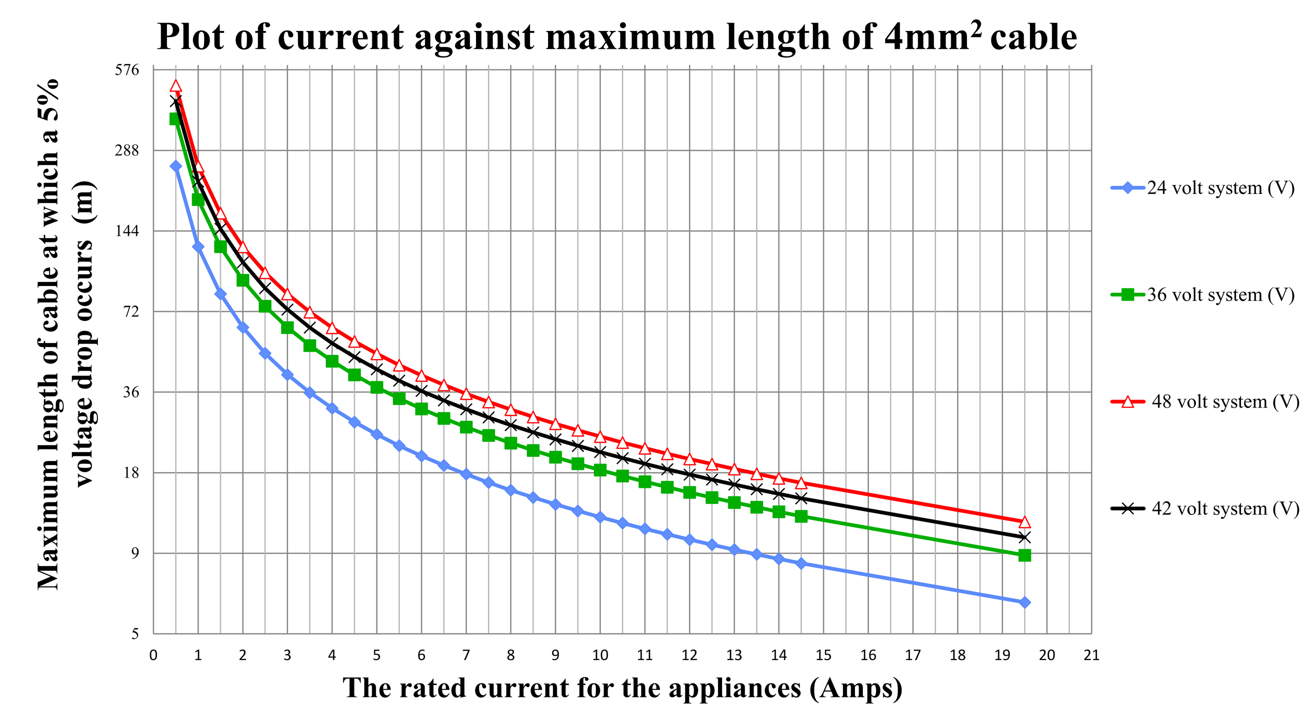

Figure1: Current against L_{Max} for a $4mm^2$ gauge cable

Designing the electrical system from the bottom up

The only comprehensive set of DC appliances available are rated 24 volts. Therefore the voltage for the example DC home, was 24 volts.

1. A list of DC appliances made for the leisure industry was chosen
2. The size and design of the physical house was set.
3. A set of appliances was apportioned to each zone in the house
4. Depending on the length of the cable a maximum current for each cable was cable was worked out
5. The size for the cables was chosen (only some shown in Figure 1)
6. The power sockets and appliances were apportioned to the cable spurs
7. Statistical data was used to work out peak power, and energy usage.
8. These are used in the design process of the energy generating system
9. In Figure 2 there are two scenarios, either the power board is the black one and the dimensions of the house are as in figure, or two power boards (red) are used which would allow for a house of twice the floor space (2 story house) or for higher power usage. The vital statistics are given in Table 1

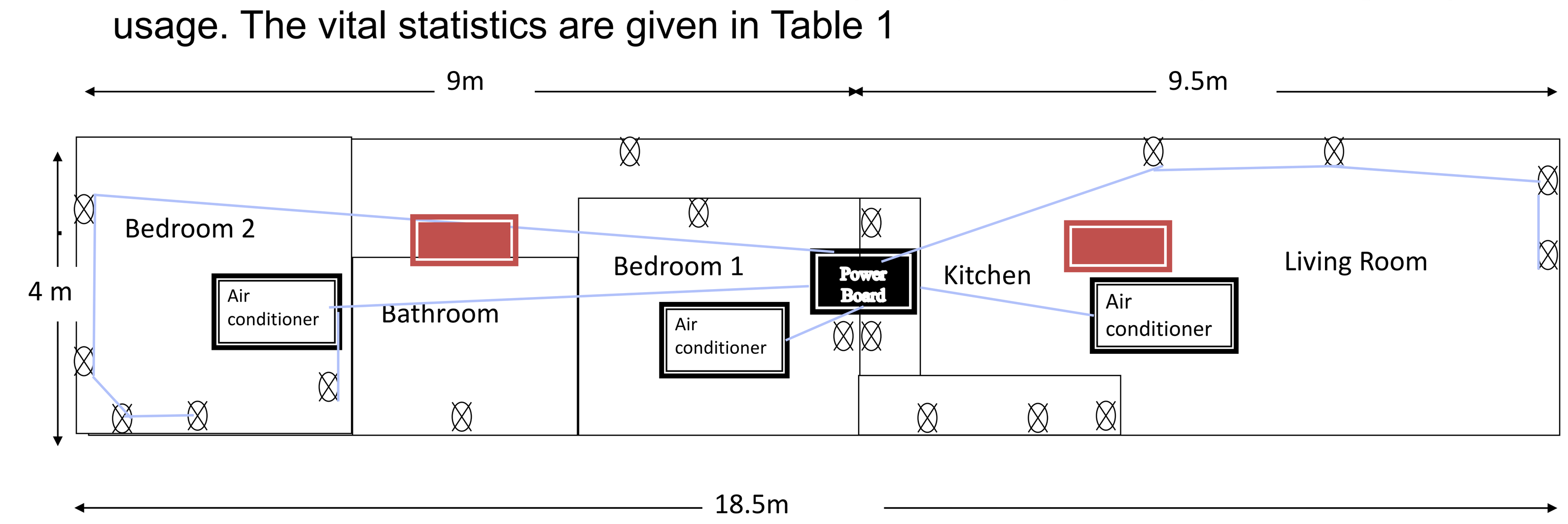

Figure 2: Layout of the DC bungalow showing some of the cable spurs

Number of cable spurs	9 of $4mm^2$ and 1 of $10mm^2$ cable
Amount of Rooms / Zones	5
Number of Power Sockets	23
Number of different DC appliances	16
Peak Load Power (W)	2960
Amount of kWh used per day	3.809
Amount of kWh used per year	1337.73

Table 1 Vital statistics of the DC home

Conclusion

1. Given the constraints, an average sized house can be practically implemented to supply extra low DC voltage using $4mm^2$ and $10mm^2$ cables.
2. The money saved by not needing an inverter, (£1,575) and from the elimination of the many AC-to-DC converters outweighs the extra cost for the electrical system and the loss of energy due to voltage loss in the cables.
3. As all the currents in a 24V system can add up especially when using three air conditioners and a 40A microwave oven, a duel 24V and 48V system is proposed.
4. Splitting the system to increase maximum length of cable (L_{Max}) will also greatly increase its capacity.
5. This house is best suited for the lifestyle of the hundreds of millions of people in the developing world who are at this time not connected to an electric grid.
6. The DC home will help towards the goals of reducing Carbon emissions, energy independence and energy security.

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