Providing mains power to masts

Connecting a mast to the mains is straightforward, but some care is needed if the mast is some distance – maybe 1000m – from the power source. First, you will be using armoured cable which, at the time of writing, can be bought for under £1 per metre. Armoured cable requires special underground junctions – be sure to use the epoxy kind – and terminals (called glands), but these are all straightforward to use. Cable should also be buried. The method and depth depends on the land and the wishes of the landowner. I have had quote of £1 per metre. for burying cable over quite rugged ground, so even when properly dug in, cable may be a cheaper alternative to solar and wind power for all but the most remote masts.

Cable weighs 300-400kg per 1000m and comes in big drums. If you have some sort of buggy like an Argocat that can reach the mast, you may be able to rig up an axle to support the drum and unroll it as you drive up the hill. Alternatively you can cut it into sections of 200-300m and have some kind of Egyptians and Israelites event when you drag it up the hillside. In fact the cable is quite slithery and dragging it over grass and heather is surprisingly easy.

[There's more to say about power consumption so the following paragraph should be expanded and go elsewhere as it applies to solar/wind powered masts as well]

Wireless equipment consumes relatively little power. For example, the manufacturers blurb on the Ubquiti Rocket[1] says 6.5W which agrees well with what I have measured (I measured the power at the mains – including the adapter – and under heavy traffic, which can increase the power draw). So a typical mast installation consisting of two long distance links and one or two wireless cards for local distribution is probably going to be around 30W (remember to add in the power required by an ethernet switch).

To keep the cost to a minimum, you will want to use the smallest diameter copper core, 1.5mm^2. The resistance of this is given as about 12 ohms per 1000m. Given that we know the power required by the equipment and the cable length we can calculate the the voltage drop on the line.[2] The following table assumes a source voltage of 230V and shows the voltage at the mast for varying cable lengths L and power consumptions W_E.

$L\backslash W_E$	20	40	60	80	100	120	140	160	180	200
200	239.6	239.2	238.8	238.4	238.0	237.6	237.2	236.8	236.3	235.9
400	239.2	238.4	237.6	236.8	235.9	235.1	234.3	233.4	232.6	231.7
600	238.8	237.6	236.3	235.1	233.8	232.6	231.3	230.0	228.7	227.3
800	238.4	236.8	235.1	233.4	231.7	230.0	228.2	226.4	224.6	222.8
1000	238.0	235.9	233.8	231.7	229.5	227.3	225.1	222.8	220.4	218.0
1200	237.6	235.1	232.6	230.0	227.3	224.6	221.8	219.0	216.0	213.0
1400	237.2	234.3	231.3	228.2	225.1	221.8	218.5	215.0	211.4	207.6
1600	236.8	233.4	230.0	226.4	222.8	219.0	215.0	210.9	206.5	202.0
1800	236.3	232.6	228.7	224.6	220.4	216.0	211.4	206.5	201.4	195.9
2000	235.9	231.7	227.3	222.8	218.0	213.0	207.6	202.0	195.9	189.3

[1] `http://www.ubnt.com/downloads/datasheets/rocketm/rm_ds_web.pdf`

[2] Let V_E = voltage across equipment, V_D = voltage drop on cable, V_S = voltage at source ($V_S = V_D + V_E$), R_C = resistance of cable, and W_E = power required by equipment. If I is the current through the cable, we have $V_E I = W_E$, $V_D/R_C = I$ so $V_E V_D = W_E R_C$ so that $V_E^2 - V_S V_E + W_E R_C = 0$. From high-school math, $V_E = 1/2(V_S \pm \sqrt{V_S^2 - 4W_E R_C})$ or $V_E = 1/2(V_S \pm \sqrt{V_S^2 - 8W_E RL})$ where L is the length of the cable and R the resistance per unit length of the conductor – remember there are two conductors!

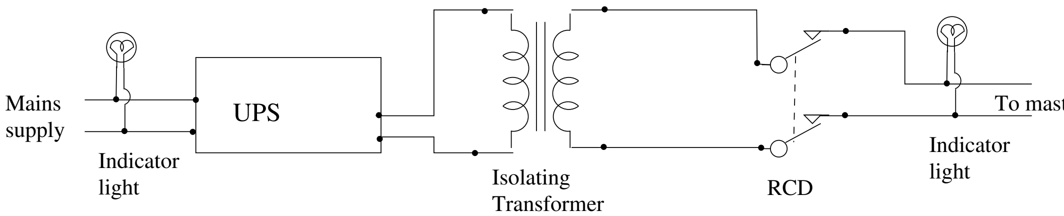

Figure 1: Wiring diagram for power supply at base

Most power adapters work over a wide range of voltages, so you can power a substantial amount of wireless kit without difficulty. But once you have mains power at a mast it is tempting to use it for other things like power tools. Be careful! It won't damage a long cable, which will just get slightly warm, but it may not be good for your tools.

Safety considerations

Once you have installed the cable, use a meter to check that there is no leakage to earth from either conductor. Also check the total resistance of the conductors (connect the two at one end and measure the resistance at the other – being sure that the whole thing is unplugged when you do this!) If you are using 1.5mm^2 cable, you should see something that is about 12Ω per kilometre. For example a 1.5km cable should give about 36Ω (remember you are measuring the sum of the resistances of the two conductors).

Whatever the rules about digging in cable, I believe that by far the best safety measure is a *residual current device* (RCD). They are standard for garden equipment and required in some countries for outdoor wiring and wiring in kitchens and bathrooms. What these gizmos do is to detect the difference in the current flowing up the cable and that flowing back. If there is a difference it is probably caused by a leak to earth caused by a cable fault or an inquisitive hiker putting his fingers in your kit. If possible get a *latching* RCD. These come back on after a power cut.

Now we have experienced problems with RCDs on long cables: they trip for no obvious reason. I suspect, though I have not done the sums, that this can be caused by spikes on the power supply. The theory is that capacitance of the cable is such that a spike *on the power supply* on one conductor will be absorbed in the cable causing a temporary difference. I need to check this with a power engineer, but we have found that adding an isolating transformer solves the problem. Try to get one that provides the power you want[3], the big ones that are designed for heavy-duty equipment outdoors waste a lot of electricity. This picture shows the wiring. The indicator light is a good idea: it provides an easy check that the power supply is working.

Backup

Rural electricity supplies are unreliable, so you may also want to put a backup power supply (UPS) at the source. About £200 buys you[4] a supply which is quoted as providing 38

[3]See, for example, `http://uk.rs-online.com/web/p/products/0504167`

[4]`http://www.apc.com/products/family/index.cfm?id=27`

Figure 2: Power supply box showing RCD (top left), isolating transformer (top right, behind cover) and UPS (bottom)

minutes at 200W. For 30W you would presumably get about about 6 times that – over 4 hours.

If you, want to provide backup that lasts for days rather than hours, you can buy a humongous UPS, but these are very expensive, and an alternative is to build one yourself with equipment designed for caravans. Caravaners have less money than IT departments, so the savings can be substantial[5].

Peter Buneman
Draft of 15 October 2011

[5]Roughly, you get a large car/truck battery. A 12V 125AH battery should last 2 days with a 30W draw, and you can connect two or more in parallel if you want a longer period. You also need an inverter and a relatively beefy charger that is designed to be used continuously. I haven't done this yet, so I don't want to give more details. Such a system would obviate the need for an isolating transformer, but it may waste electricity to have the inverter running all the time. In which case you would add a relay to switch to battery only when the mains supply fails (this is what a UPS does); and you will then need an isolating transformer.