Understanding the grid

Warning: This explanation is somewhat simplistice and very approximate for which I apologise, it is over 50 years since I learned all this and have forgotten too much but the internet is wonderful if you are interested.

Background

The new government has already started to implement its manifesto, in particular its policies on sustainable energy, climate change, housing and planning. These issues are supported in principle by the public as well as being rejected for reasons of aesthetics or damage to farmland, often by the same people. Delay is going to be the greatest barrier to our success in greening the grid and our electricity generation.

One major barrier is opposition to new or enlarged parts of the electricity grid. Other barriers include shortage of materials – steel, cables, switchgear and transformers and of skilled labour. Cancellation of HS2 will release both materials and skilled labour but not yet.

If we are to achieve Net Zero grid by 2030 work must ramp up. The planning process with all major obstacles removed as the Government has promised will still be measured in years.

There is genuine confusion about the best options. Two years ago, there was a campaign about the onshore sections of Offshore cables taking up too much agricultural land. Now many of the same people are arguing that the Norwich to Tilbury line should be under-grounded rather than using Pylons. To help clarify some of these issues we offer the following with apologies to those who may already know much more.

How to do it

At the beginning of the public supply of electricity there was debate as to whether it should be supplied as Alternating or Direct Current. The difference is that the actual voltage of DC is like a battery supplying a voltage fixed over time. AC provides a voltage which can be pictured as sign wave. *Sine Wave Graph - Search Images (bing.com)* ie it changes from its maximum +ve to minimum -ve. 50 times per second. The average power gives us the domestic voltage we use, in Europe 230v, +10% -6%.

We generally use AC because it is easier to increase or decrease the voltage through transformers where power loss is small. DC does have its advantages as losses are generally lower in the same size conductor.

Just to confuse matters the electricity Grids uses three phases on each circuit. It makes life easier and balances the demand. Most properties use one phase only, larger domestic and industrial premises use three phases to provide sufficient power.

There are two important formulae which helps the understanding of the main parameters of our electricity supply. They determine the voltage used and the power delivered. It is easier to understand by comparing to water; voltage (V) is the pressure and current (I) the volume. The size of the pipe is the resistance (R). A simple formula helps to understand the relationship: I=V/R.

The other formula concerns power measured in Watts (W): W= VxI. Watts are usually referred to as: kW-one thousand watts, mW one million watts, gW one thousand million watts, tW one thousand gW.. Add an h and we have the measure of power over time, the volume of water in the reservoir.

This means that for a given voltage the higher the resistance of the conductor the lower the current it carries and the lower the current the lower the power transmitted. Conversely the higher the voltage the higher the power capable of being transmitted. All conductors have a resistance to electricity and from the formulas above the higher the resistance the more power is lost, which increases in proportion to the length of the conductor.

So, there are two options increase the diameter of the conductor or increase the voltage of the system.

There are four disadvantages to increasing the diameter of the conductor. It uses more aluminium or copper (a scarce finite metal), costs more increases the number of pylons due to the extra weight of the conductors and becomes relatively less effective at conducting AC. (The AC current tends flow in the outer skin of the conductor).

Resistance of conductors decreases as the diameter increases. (see above) The higher the resistance the higher the temperature of the conductor due to power losses. In air it is relatively easy to disperse heat energy as the conductors are not insulated and open to the air.

Underground or undersea cables are larger to reduce resistance and have to be insulated but do not remove the heating effect entirely for underground, so they may have to be cooled as the electrical insulation also reduces heat losses to the ground. Generally undersea conductors do not require further cooling, but most grid lines do. This is done by placing them in concrete troughs and/or by pumping cooling liquids through the cables or packing a suitable material around the cables to disperse the heat, but each cable must be well separated from the others to avoid overheating. – normally underground cables are laid directly in ground as this gives it the greatest opportunity for dissipating heat directly, when ducted, such as crossing motorways or trainlines, often an additional material, such as bentonite is installed to help dissipate the heat. A swathe of land typically 65m wide is required with limited activity above to permit permanent access.

For the transmission of high levels of power, a very high voltage is required. This is then stepped down via local grids and final distribution, eventually to 240 volts for domestic use. Transmission in England and Wales generally is at 400kV or 275kV. Distribution is generally 132kV, 66kV, 33kV, 11kV and Low Voltage with some other voltages (such as 6.6kV) in some scenarios. In Scotland, the transmission network is 400kV, 275kV and 132kV. And the Distribution network is 33kV, 11kV and Low Voltage

Maintenance of overhead lines is generally easier and quicker than the alternatives and they are quicker and cheaper to construct with less disturbance. This will depend on the voltage of the infrastructure being installed. 33kV and below, very much the case, 132kV, constructing new Metal tower lines is not fast and often trenching is quicker.

The US uses a voltage of 110v which is marginally safer to humans but requires larger conductors and double the current which make fires more likely, particularly in switch gear. 110V is also used via portable transformers on construction sites throughout the world so it reduces the voltage to earth to 55v.

Sustainable Energy

Two major issues arise as a result of the change in the mix of energy supplies

Changes to the established technology of the grid is having to deal with a major difference in power generated by solar and wind. Most major units of sustainable energy eg from offshore, arrives at the grid as Direct Current, as you would obtain from a battery and is converted into AC at large Inverter stations at the connection to the grid.

There is no easier or cheaper way to change voltage from hundreds of thousands of volts to 240v, required in the home, than transformers which require an Alternating Current. Large amounts of electricity are transmitted by AC at very high voltages to reduce the size of the conductors, thus minimising their weight and the number of pylons. Aluminium is often the preferred material for overhead lines as it is so much lighter than copper.

Our electricity supply is maintained at or very close to 50Hertz as an Alternating Current (AC). This is the frequency of the voltage supplied. The voltage goes up and down 50 times per second, we do not notice this as devices which create heat respond slowly to electric current so can cope with this. This frequency is vital to many processes and uses to which electricity is put e.g. electric motors are often designed so the 50Hertz determines the speed of rotation and mains powered clocks are fixed to the frequency.

Until recently, most power was created through rotating generators (such as coal, gas or Nuclear Power stations which use a spinning turbine to generate power) which are very heavy providing a flywheel effect so that when demand changes the generator speed of rotation could change but relatively slowly. To change this frequency back to 50Hertz was relatively easy. A lot of effort goes into maintaining this frequency and related Power Factors.

The Power Factor is a measure of the difference between the voltage peak and the current peak. It is desired to be the same so devices are used to pull the peaks into synchronicity.

If you have been unable to travel on the A140 in August 2024, it may have been due to a very heavy load, over 356 tonnes, being delivered to a new site at Yaxley near Eye, Suffolk. A 81m long Synchronous Condenser is being installed to deal with the power factor issue, the machines inertia maintaining the efficiency of the grid for its customers.

The other issue is that much of the new energy especially wind is coming from three main areas: Scotland, Northwest, Northeast and Eastern England. The old fossil fuel stations were either close to the coalfields in the Midlands, North of England, Wales and Scotland, or around southern ports. This coincides to some degree with the new sustainable sources, but the age of the existing grid and its lack of total capacity means it has to be updated and enlarged. Demand for electricity is expected to more than double in the next two decades. Much of the demand will be in the south whereas most of the wind energy will be in the north and east, hence the need for additional North to South transmission capacity

Sustainable power and the environment

Routes for transmission cables are always controversial. Options are not always clear and the limited materials and labour presently difficult to obtain. To enable the grid to cope with net zero electricity supply and replace much of our ageing grid network and sub stations needs capacity at least doubled.

Underground and subsea cabling cost between 4 and 8 times that of overhead, to install and maintain. Under-grounding occupies up to 65m width of land with restricted subsequent usage for maintenance access, so trees and buildings are not possible. We need to build 100km of high voltage conductor **per day.** A new factory manufacturing High Voltage Direct Current insulated cables suitable for subsea and underground opens this year in the Northeast. HVDC for under-grounding, requires a large inverter station where it connects to the Grid to produce the AC current required by the grid.

Objections to construction.

The main objection to the construction of overhead super grid lines is that property prices will be reduced. A recent report published by a Scottish Energy Group on the construction of a 137 mile line following a public Inquiry, shows that **after construction,** prices are still in the same price relationship with other properties a distance away. However, one result of objections, is that from the commencement of any challenge and thus uncertainty, house prices do temporarily fall by about 10% until the line is complete when they return to where they were.

The other objection is usually that it will damage the environment. In terms of the view that may be true although a lot less than the alternatives

Your author used to frequently drive on the A1 through Nottinghamshire and South Yorkshire and was awe struck by the steam released from the many coal-fired power station cooling towers, on the route, also knowing that carbon dioxide and other pollutants were emanating from the chimneys. Coming from East Anglia, it was clear to what local people in the Midland and Northern Coalfields were subjected, in order that the rest of us could have relatively cheap and plentiful electricity. We took for granted that people living in or near the coal fields had to accept the disruption and pollution caused by coal fired power stations so that we, who lived in the South and East Anglia especially, could have our electricity. The need now is to generate more power in the south, much of it in East Anglia, without pollution, to reduce the huge scale of new transmission from North to South.

We need to fairly share that burden.

Prior to July 2024 waits of up to 3 years for a connection to the grid were being offered. Previous governmental uncertainty, planning delays and the removal/reduction of national targets have already increased the total costs of achieving Zero Carbon. We need to build this new infrastructure at record rates and affordable prices, if we are to achieve Grid Net Zero by 2035.

The lesson from all of this is that we must not let the perfect be the enemy of the good.

https://www.theguardian.com/environment/article/2024/aug/03/therell-be-no-countryside-left-opposition-to-pylons-puts-uk-carbon-targets-at-risk

Roger Spiller

20/08/24