Underground power lines and health

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Power lines give rise to electric and magnetic fields which fall off with distance. Burying power lines underground effectively shields the electric fields but less so the magnetic. And it is the latter that have given rise to most health concerns. Current exposure restrictions are based on limiting the electrical currents that time-varying magnetic fields induce in the human brain. Epidemiological studies have suggested that higher than normal exposure to magnetic fields could double the relative risk of contracting childhood leukaemia. However, a plausible biological mechanism has not been established. Overall, the evidence for a carcinogenic effect is still too weak to influence exposure restrictions recommended by the Health Protection Agency. These in turn follow the advice of the International Commission on Non-Ionizing Radiation Protection.

There are sometimes good aesthetic and practical reasons for replacing overhead power lines by underground ones. However, undergrounding power lines in response to health concerns would essentially be a precautionary measure.

Contents

1 Power lines

Power lines are sources of electric and magnetic fields, collectively termed electromagnetic fields. The strength of these fields determines the extent to which they interact with electric charges and currents. As the human body is a hive of electrical activity, there is scope for electric and magnetic fields of sufficient strength to have biological impacts. Safety guidelines aim to keep these to negligible levels.

We are of course exposed to natural electric and magnetic fields. The Earth's electric field is typically 120 Vm^{-1} (volts per metre). This compares with a value of 11000 Vm^{-1} directly under a 400 kV (kilovolt) overhead power line. However, buildings provide effective shields from electric fields – but not from magnetic fields.

A typical value for the Earth's natural magnetic field is 50 μT (microteslas).[1] This is comparable to the 40 μT (an average value) found directly under a 400 kV power line. A significant difference lies in the fact that magnetic fields from power lines vary cyclically – with a frequency of 50 Hz (hertz or cycles per second). Time-varying magnetic fields such as these induce electrical current in conductors like human tissues. Rather than measure the electric currents induced in the human brain, for example, it more practical to measure the external magnetic fields that give rise to these. The science of dosimetry provides the link between the two.

2 Dosimetry

2.1 Exposure guidelines

Current guidance on limiting exposure to electromagnetic fields is provided by the Health Protection Agency. These in turn are informed by "reference levels" for the average[2] external field strengths. The reference levels have been drawn up, conservatively, by the

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[1] Throughout this note, the term "magnetic field" is taken as synonymous with "magnetic flux density". The latter term is used by the International Commission on Non-Ionizing Radiation Protection.

[2] The average is actually a "root mean square" which takes into account the fact that the electric and magnetic fields vary cyclically with time.

International Commission on Non-Ionizing Radiation Protection (ICNIRP) and represent the strength of electromagnetic field that an individual may be exposed to without exceeding a more fundamental basic restriction such as induced electric currents. For example, the magnetic field reference level for the general public is 100 μT, a value in excess of that likely to be encountered near power lines. In fact, electric shavers and hair dryers can give rise to magnetic fields that are very much higher than the reference level, albeit for the relatively short periods of time when they are in use.

In 2004, a statement by the National Radiological Protection Board (now subsumed within the Health Protection Agency) explained the significance of reference levels:

> Comparison of measurements with the reference levels can be used to assess whether compliance with the basic restrictions has been achieved. If the field to which a person is exposed exceeds the relevant reference level it does not necessarily follow that the basic restriction is exceeded. It is, however, then necessary to investigate compliance with the basic restriction using more detailed methods of exposure assessment.

In 2010, ICNIRP issued revised guidelines which resulted in an increased (i.e. less conservative) reference level of 200 μT for public exposure to magnetic fields at power frequencies. This was derived from new basic restrictions based on electric fields induced in the human body rather than the associated electrical currents. The EU, including the UK, still follows the more conservative (i.e. lower) reference level from 1998. The reference levels are set to ensure that established health effects are avoided. In the case of power frequency electric and magnetic fields these relate to nervous system functions.

2.2 Legislation

EU Council Recommendation 1999/519/EC on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) embodies the guidance that is accepted by the Health Protection Agency. It follows from the ICNIRP guidelines outlined above.

There are, however, no *statutory* exposure limits in the UK. The general provisions of the *Health and Safety at Work etc. Act 1974* will apply in so far as they protect employees in the workplace. The 1974 Act also affords general protection for the public, for example in the provisions of section 3 which begins:

> It shall be the duty of every employer to conduct his undertaking in such a way as to ensure, so far as is reasonably practicable, that persons not in his employment who may be affected thereby are not thereby exposed to risks to their health or safety.

In terms of occupational exposure there is ongoing work on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) directive. This new directive amends the directive from 2004 (2004/40/EC), which has never entered into force. A delaying Directive was formally published on 19 April 2012, extending the transposition deadline to 31 October 2013. The exposure limitation system embodied in the directive as it currently stands recognises that substantially higher exposure levels are permissible in an occupational setting. Further background is available on the website of the Health and Safety Executive.

3 Cancer

Cancer is characterised by the uncontrolled proliferation of abnormal cells. The abnormalities result from some mutations in the DNA which controls the operations of individual cells. Mutations can be caused by carcinogens such as ionising radiation (e.g. Xrays) and chemicals or by hereditary or by spontaneous errors during the DNA replication which accompanies cell division. Power frequency electric and magnetic fields do not possess enough energy to damage DNA in the ways ionising radiation can.

Over twenty epidemiological studies have examined whether exposure to power frequency magnetic fields might cause cancer, particularly childhood leukaemia. Many of these studies have been of the case control type. These compare the percentage of a population of people with cancer (the cases) who have been exposed to magnetic fields above a certain level with the percentage of another population of people without cancer (the controls) who have been similarly exposed. The resulting "odds ratio" gives a measure of the relative risk of contracting cancer due to magnetic fields. When the epidemiological studies are pooled there is a suggestion that exposure to magnetic fields might double the risk of childhood leukaemia. By itself this factor of two is unpersuasive, partly because of the difficulties in choosing suitable controls to compare with the cases and the likely presence of confounding factors (such as higher road traffic density near power lines) that might not have been fully eliminated. More background to epidemiology is given in Library Research Paper 94/119, *Overhead Power Lines and Health*.

In November 2010 the journal *BMC Public Health* summarised the current consensus in the following terms:

> Since 1979, more than 20 epidemiological studies have investigated the possibility that exposure to power frequency magnetic fields may be a risk factor in the development of childhood leukaemia. A number of the studies have been pooled in four meta-analyses which point to an approximate doubling of risk at average residential levels of 0.3-0.4 microtesla (μT).

According to ICNIRP:

> A considerable number of epidemiological reports, published particularly during the 1980s and '90s, indicated that long term exposure to 50-60 Hz magnetic fields might be associated with an increased risk of childhood leukaemia. Two pooled analyses indicate that an excess risk may exist for average exposures exceeding 0.3-0.4 μT. However, a combination of selection bias, some degree of confounding and chance could possibly explain the results. In addition, no biophysical mechanism has been identified and the experimental results from the animal and cellular laboratory studies do not support the notion that exposure to 50-60 Hz magnetic fields is a cause of childhood leukaemia.
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> It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency magnetic fields is causally related with an increased risk of childhood leukaemia is too weak to form the basis for exposure guidelines.
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> [...]
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> The absence of established causality is the reason why the epidemiological results have not been addressed in the basic restrictions. ICNIRP is well aware that these epidemiological results have triggered concern within the population in many countries. It is ICNIRP's view that this concern is best addressed within the national risk management framework. Risk management in general is based on many different aspects, including social, economic, and political issues. ICNIRP in this context provides scientifically based advice only. Additional risk management advice, including considerations on precautionary measures, has been given for example by the World Health Organization and other entities.

4 Undergrounding

4.1 Planning new networks

GB energy networks including the high voltage (transmission) grid need updating. Ofgem's 2010 Project Discovery[3], which looked at security of energy supply, estimated that replacing aging infrastructure and moving towards decarbonisation might require up to £200 billion of investment by 2020 alone. More remote and renewable generation sources (e.g. onshore and offshore wind warms) as well as European interconnectors need to be linked to the grid and the energy brought to the major population centres. There is a need for investment both in the network, or grid, and in generation, to ensure energy security.

On Britain's onshore gas and electricity networks, specifically, Ofgem estimates that over £30 billion investment is needed over the next decade.[4] The proposals under its latest price controls allow for £17 billion of investment, with around a further £5 billion potentially available over the course of the new price control period (RIIO[5]), which runs to 2021.[6]

Ofgem's transmission price control proposals under its new 'RIIO' framework include 'visual amenity considerations'. Ofgem has proposed setting an 'expenditure cap' on reducing the impact of existing infrastructure in designated areas (National Parks and Areas of Outstanding Natural Beauty). It proposes to set an "initial expenditure cap" of £100m for the start of the price control. For more details please see the Ofgem proposals.[7]

The Department for Energy and Climate Change (DECC) set out planning policy for energy infrastructure during 2011, in a series of National Policy Statements for Energy.[8] The *National Policy Statement for Electricity Networks Infrastructure (EN-5)* is the most relevant to power lines. It outlines why, for instance, applying the presumption of undergrounding to particular types of designated landscape was rejected.[9] The Library Research Paper on the Growth and Infrastructure Bill[10] outlines recent and intended changes to the planning process for national infrastructure projects.

A study by Parsons Brinkerhoff published on-line by the Institute for Engineering and Technology[11] assessed the lifetime financial costs of transmission options, but did not evaluate social or environmental costs. It found that the cheapest transmission technology was overhead line, with lifetime costs of £2.2m to £4.2m per kilometre. The next cheapest is direct buried, underground cable for any given route length or circuit capacity, with lifetime costs of £10.2m to £24.1m per kilometre. This is also the least expensive underground option; underground gas insulated line is considered the most expensive, generally. However, the report cautions strongly that costs (and practicalities) will vary by project and

3 Ofgem, 3 February 2010 http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=73&refer=Markets/WhlMkts/monitoring-energy-security/Discovery

4 Ofgem 27 July 2012 *RIIO-T1: Initial Proposals for National Grid Electricity Transmission and National Grid Gas*

5 Ofgem's new outputs-led framework is called RIIO which stands for Revenue = Incentives + Innovation + Outputs. The next transmission and gas distribution price controls are due to be implemented in April 2013 under the new RIIO regime, and to last to 2021

6 Ofgem press release 16 July 2012 *Ofgem consults on £22 billion investment plans to upgrade Britain's gas and high voltage electricity networks*

7 Ofgem 27 July 2012 RIIO-T1: Initial proposals for National Grid Electricity Transmission and National Grid Gas page 16

8 DECC website *National Policy Statements for Energy Infrastructure* accessed 24 October 2012

9 DECC, July 2011

10 House of Commons Library 25 October 2012 RP12/61

11 *Electricity Transmission Costing Study* Parsons Brinkerhoff, endorsed by the IET, 31 January 2012

location so simple cost ratio comparisons are not advised between different transmission technologies.

4.2 Undergrounding power lines and health

According to National Grid, 4% of the high voltage electricity network in England and Wales is underground, mainly in urban or scenic areas. At ground level, the magnetic fields from underground cables fall off much more rapidly with distance than those from overhead power lines. However, the ground level magnetic fields can actually be higher close to the underground cable. Overall, if cost were not a factor, then undergrounding power lines would be one option for reducing magnetic field exposure in a population. This option was considered by SAGE, the Stakeholder Advisory Group on Extremely Low Frequency Electric and Magnetic Fields (EMFs). SAGE was set up in 2004 to consider possible precautionary measures in relation to EMFs. In its *First Interim Assessment* of 2007, SAGE did not recommend undergrounding of power lines as a means of reducing exposure, noting some of the cost implications:

> The costs of new underground cables can be broadly comparable to overhead lines at the lowest voltages, depending on what reinstatement of the land above is required, and are increasingly preferred, but they become progressively more and more expensive as the voltage increases. At transmission voltages, underground cables cost an average of £10M/km in the UK (compared to £0.5-1M/km for overhead lines) and they are used at present only where there is no realistic alternative. Underground cables eliminate the electric field and reduce the width over which the magnetic field is elevated

Government policy on undergrounding of power lines is contained within *National Policy Statement for Electricity Networks Infrastructure (EN-5)*, DECC, July 2011. In particular:

> Undergrounding of a line would reduce the level of EMFs experienced, but high magnetic field levels may still occur immediately above the cable. It is not the Government's policy that power lines should be undergrounded solely for the purpose of reducing exposure to EMFs. Although there may be circumstances where the costs of undergrounding are justified for a particular development, this is unlikely to be on the basis of EMF exposure alone, for which there are likely to be more cost-efficient mitigation measures.

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