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APPENDIX 5B

EMF and Powerline Concepts

EMF CHARACTERISTICS

The power system frequency in the United States is 60 cycles per second or 60 hertz (Hz). At 60 Hz the electromagnetic field is calculated as two separate fields: an electric field and a magnetic field. These fields are a naturally occurring phenomenon associated with electricity. The electric and magnetic fields have the same frequency as the electricity that creates them. Thus, the fields that are the subject of this report are 60 Hz fields. Electric field concepts are presented below, followed by a discussion of magnetic fields.

Electric Fields

The quantity of electricity is defined in terms of electric charge. "Electric charge, like mass, length, and time, is accepted as a fundamentally assumed concept, required by the existence of forces measurable experimentally: other definitions of electromagnetic quantities are developed on the bases of these four concepts."[1]

The potential energy stored in an electric charge is measured in volts. Voltage on a wire is often described as analogous to water pressure in a pipe.

An electric field exists wherever there is an electric charge. The electric field is an invisible force that exists in space between positive and negative electric charges. An electric field has a direction associated with it, from positive charge to negative charge. It is measured in units of kilovolts per meter (kV/m). An electric field is present wherever there is electrical energy, including home wiring, appliances, and power lines. Electric fields have the following characteristics:

1 The strength of the electric field is proportional to the voltage of the electric system causing it. Thus, a high-voltage power line would have a higher electric field than low-voltage house wiring.

2. The strength of the electric field decreases as the distance from the source increases. Thus, moving farther from a power line will reduce the field.

3. An electric field is stopped by ground and can be shielded by enclosing it within a grounded metallic object. Trees, bushes, houses, etc., will also significantly attenuate electric fields.

4. Two electric fields may tend to add together or cancel each other depending upon whether they are in the same or opposite directions.

5. Electric fields will induce a charge on ungrounded metallic objects within the field. Thus, electric utilities take precautions to ground fences and metal buildings that are very close to transmission lines.

IEEE Standard Dictionary of Electrical and Electronics Terms

6. People are able to detect the presence of some electric fields by sensation of small body hairs. This detection depends upon the strength of the field and the sensitivity of the person.

Magnetic Fields

A magnetic field is produced whenever electric current flows. Current is the movement of electric charges and is measured in amperes (also called amps). The magnetic field is an invisible force that exists in space around the current source. The unit used to measure magnetic field is milliGauss (mG).

The characteristics of magnetic fields are listed below. In many ways, magnetic fields differ from electric fields described above.

1 The strength of a magnetic field is proportional to current. The relevance of this will be discussed in more detail in the section on power lines.

2. The strength of a magnetic field decreases as the distance from the source increases. Thus, moving farther from a power line will reduce the magnetic field, similar to the electric field.

3 A magnetic field is not stopped by ground and is not significantly attenuated by buildings, trees, etc. It is attenuated only if the current source is enclosed by a magnetic material.

4. Two magnetic fields may tend to add together or cancel each other depending upon whether they are in the same or opposite direction.

5 A magnetic field will induce current in a conducting metallic loop. This is a concern to electric utilities where pipelines or railroads are close to and parallel to power lines. Precautions are taken to prevent the induced currents from causing interference to the corrosion protection system on pipelines or to communication systems on railroads.

6. People are not able to sense the presence of a magnetic field.

A magnetic field will be found near household appliances and home wiring, as well as power lines.

To review the terminology, voltage is a measure of the potential energy of the electrical charge, analogous to the potential energy of water pressure inside a pipe. An electric field is associated with voltage. Current is the movement of electrical charge in a wire, analogous to the flow of water in a pipe. A lamp plugged into the household wall outlet will have voltage to the switch, but current will flow only when the switch is turned on. A magnetic field is associated with current.

Measurement and Calculation of EMF

The measurement of the strength of electric and magnetic fields is made with readily available meters. A different meter is needed to measure each. The Institute of Electrical and Electronic Engineers (IEEE) develops and publishes guidelines and standards for instrumentation and measurement procedures. Near power lines, the standards state that the fields are to be measured at 1 meter (3.28 feet) above ground. The field strengths given in this report are calculated at 1 meter above ground.

The electric and magnetic fields associated with a power line have a special orientation with regard to the power line. The electric field (near the power line) at 1 meter above ground is essentially vertical along the route of the power line. Magnetic fields, on the other hand, may have vertical and horizontal components. It is important, especially when making measurements, that orientation of the field be taken into consideration.

In this report, calculation of magnetic field strengths refers to the maximum field rather than a horizontal or vertical component.

POWER TRANSMISSION CONCEPTS

Power Line Voltages and Currents

The electric and magnetic fields are calculated for typical transmission line configurations. Transmission lines are almost always three-phase (three conductors servicing a particular load or customer). For the calculations in this report we have assumed the three phases to be balanced in voltage and current.

Electric utilities operate power lines at nearly constant voltage; normal operation is typically within 5 percent of the nominal voltage. Similarly, the voltage maintained within a house is nearly constant at 120 volts. The current over a power line, however, will vary considerably as power requirements change. This same situation occurs within a house. The electrical outlets in the home will all supply power at nearly 120 volts, but if no appliance is turned on, then no current flows. However, as refrigerators, lamps, and various appliances are turned on, more and more current flows to provide power. Thus, the current varies considerably depending upon the amount of power being used.

The electric field, which is proportional to voltage, will be nearly constant under a transmission line since the line is held at nearly constant voltage. On the other hand, the magnetic field, which is proportional to current, will vary greatly during the day as the power requirements on the transmission line vary. In discussing the magnetic field near a transmission line it is, therefore, important to distinguish the current that was used to determine the magnetic field level. In this report, discussion of magnetic fields will include reference to the associated current level.