nates the magnetic field, and they depend primarily on the frequency of the change in velocity or direction and on the intensity of the current itself. They are also affected

Table I.—Resistance of Hard Drawn Copper and Aluminum Stranded Conductors. Conductivity: Copper, 97.3 per cent.; Aluminum 61 per cent. Temperature, 20 Deg. Centigrade or 68 Deg. Fahrenheit.

Gauge B. & S.	Copper D-C.	Copper 25-Cycle	Copper 60-Cycle	Aluminum D-C.	Aluminum 25-Cycle	Aluminum 60-Cycle
	EFFECTIVE RESISTANCE IN OHM PER MILE OF WIRE					
0000	0.2704	0.2706	0.2715	0.4330	0.4332	0.4337
000	0.3418	0.3420	0.3427	0.5438	0.5439	0.5444
00	0.4309	0.4310	0.4316	0.6893	0.6895	0.6898
0	0.5434	0.5435	0.5441	0.8670	0.8671	0.8674
1	0.6851	0.6852	0.6856	1.0932	1.0932	1.0935
2	0.8655	0.8656	0.8658	1.3786	1.3786	1.3788

by the spacing of the conductors (mutual inductance), and by their size, shape and permeability.

Like the ohmic resistance loss, the inductive reactance loss can be written as I^2Ri, where $Ri = 2\pi fL$, f being the frequency of the current and L the coefficient of mutual self induction of the conductor.

The resultant of the ohmic resistance and the inductive reactance represents the equivalent resistance or impedance of the circuit, and can be written:—

$$Z = \sqrt{Ro^2 + Ri^2} = \text{impedance.}$$

The effect of capacity reactance in a transmission line is to compensate for the lagging current produced by the inductive reactance, not only that of the line but also that of the load connected thereto, to the extent that the leading wattless component of the current charges the condenser represented by the line.

The capacity, and hence the charging current, of a line increases with its cross-section, and as the separation between the conductors decreases. It is of special importance in insulated cable installations and its effect on the regulation and losses should be taken into consideration in such cases, as well as when treating long transmission lines of high voltage carrying a relatively small current with respect to the power transmitted.

Thus in an alternating current circuit the ohmic resistance loss is substituted by an impedance loss, in phase with the current, which is the resultant of the ohmic resistance, hysteresis, and eddy current losses of the circuit, and denoted by Ro; and of an inductive reactance (Ri) having a negative sign, or of a condensive reactance (Rc) having a positive sign, both being at 90 deg. to the ohmic resistance Ro.

The impedance can then be expressed as follows:

$Z = Ro - jRi$, for an inductive reactance,

and $Z = Ro + jRc$ for condensive reactance

Inasmuch as the vectorial sum of these two quantities is in either case the hypotenuse of a right-angled triangle, they can be more conveniently written thus:

$$Z = \sqrt{Ro^2 + Ri^2} \text{ and } Z = \sqrt{Ro^2 + Rc^2}$$

The impedance of a conductor carrying alternating current can, in most short lines, be treated as the ohmic resistance of direct current circuits for the determination of losses and voltage regulation.

When a current I is not in phase with the voltage, but is either lagging or leading, it consists of a power component Io, and of a wattless component Ix, at right angles to Io, and such a condition can be expressed by

$$I = \sqrt{Io^2 \pm x^2}$$

The line drop then becomes by Ohm's law:

$$e = \sqrt{(IoRo + IxRi)^2 + (IxRo - IoRi)^2}$$

for a lagging current and inductive reactance,

$$\sqrt{(IoRo - IxRi)^2 + (IxRo + IoRi)^2}$$

for a lagging current and condensive reactance

$$\sqrt{(IoRo + IxRi)^2 + (IxRo - IoRi)^2}$$

for a leading current and inductive reactance

$$\sqrt{(IoRo - IxRi)^2 + (IxRo + IoRi)^2}$$

for a leading current and condensive reactance where

$e = IZ$

Along with the line constants must be considered the character of the load, as the complete circuit consists of the line with the load at the receiver's end in series with each section. The treatment of such problems requires the analysis of each section separately.

Knowing the resistance, inductive reactance and condensive reactance of a conductor per unit of length, the impedance can be calculated and then the losses and line regulation can be determined for any line voltage, load and power-factor.

The constants of a transmission line carrying alternating current can be determined from Table IA.

To apply these formulæ to a practical case, we will assume, for instance, a three-phase, three-wire overhead transmission line 10 miles long, to transmit 1,000 kw. at 60 cycle, 13,200 volts, at an average power-factor of customer's load 0.8, and with the necessary step-up and step-down transformers and substation equipment. The average annual load-factor is assumed to be 20 per cent., the revenue per kilowatt hour averaging 1.25 cents, and the ratio operating expenses to revenue 60 per cent.

Find: The permissible investment; the gauge of the conductors; the regulation of the line; the transmission losses.

Table IA.

		Single-phase	Two-phase	Three-phase
True power	W	$EI\cos.\phi$	$2EI\cos.\phi$	$EI\sqrt{3}\cos.\phi$
True power losses	w	$eI\cos.\phi$	$2eI\cos.\phi$	$eI\sqrt{3}\cos.\phi$
or	w	$I^2Z\cos.\phi$	$2I^2Z\cos.\phi$	$I^2Z\sqrt{3}\cos.\phi$
The current per wire	I	W/E	$W/2E$	$W/E\sqrt{3}$
The true current per wire	Io	$I\cos.\phi$	$I\cos.\phi$	$I\cos.\phi$
The wattless current per wire	Ix	$I\sin.\phi$	$I\sin.\phi$	$I\sin.\phi$
The potential drop per circuit	e	IZ	IZ	IZ
The impedance per circuit	Z	e/I	e/I	e/I
The impedance per wire	Z^1	$e/2I$	$e/2I$	$e/I\sqrt{3}$
The per cent. potential drop	P	$100e/E$	$100e/E$	$100e/E$
The per cent. efficiency	F	$\frac{100W}{W-w}$	$\frac{100W}{W-w}$	$\frac{100W}{W-w}$