48-MILE TRANSMISSION LINE.

Poles charged on trolley line....		
Copper	$10,000	$11,500
Insulators, pins and cross-arms..	7,500	5,000
Erection	4,000	3,000
Incidentals	1,000	1,000
Totals	$22,500	$20,500

SUB-STATIONS ALONG THE ROAD.

Building	$2,000	$1,000
Synchronous converter	4,800	
Step-down transformers	3,200	2,000
Switchboard	2,000	1,300
Wiring	1,000	500
Incidentals	500	200
Totals	$13,500	$5,000
Four sub-stations	$54,000	$20,000

TROLLEY-LINE AND FEEDERS.

Poles, 3,500	$17,500	$17,500
Poles distributed and set	4,000	4,000
Guys and anchors	2,000	2,000
Brackets with hangers	18,000	25,000
Copper, direct current:		
Feeder, 12 mls.,500,000 cir. mils.		
Feeder, 48 mls., No. 0000.....		
Trolley, 120 mls., No. 000	95,000	
Alternating current:		
Trolley, 60 miles, No. 00		21,500
Feeder insulators	2,000	
Erection	10,000	4,000
Incidentals	7,500	4,000
Totals	$156,000	$78,000

BONDING OF RAILS.

Both rails bonded	$30,000	
One rail bonded		$15,000
Cross bonds	2,000	1,000
Totals	$32,000	$16,000

ROLLING STOCK.

Ten vestibuled passenger cars, each equipped with 4 motors, and weighing about 30 tons..	$75,000	$85,000
Two express passenger cars, equipped with 4 motors, and weighing about 35 tons......	18,000	20,500
Two freight cars, each equipped with 4 motors, and weighing about 30 tons	10,000	12,000
Snow-plough and construction car	7,000	8,500
Totals	$110,000	$126,000

RECAPITULATION.

Power House	$103,000	$106,500
Sub-station in power house	12,600	4,600
Transmission line	22,500	20,500
Sub-stations	54,000	20,000
Trolley line and feeders	156,000	78,000
Bonding	32,000	16,000
Rolling stock	110,000	126,000
Totals	$490,100	$371,600
Cost per mile, direct current system	$490,100/60=$8,168	
Cost per mile, alternating current system	371,600/60= 6,193	
Saving per mile, alternating current system..		$1,955

The decrease of alternating current cost in terms of direct current investment, 25%.

The increase of direct current cost in terms of alternating current investment, 32%.

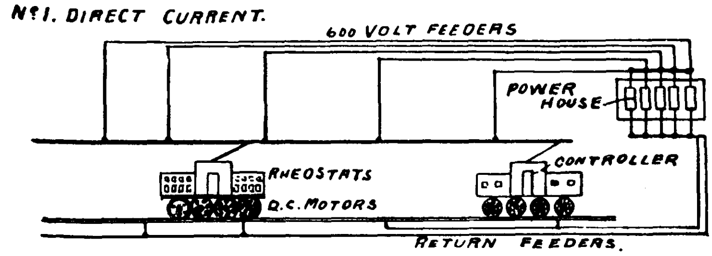
4. The Leonard system is in reality a form of foregoing system, and involves the supply of single phase current to an alternating current motor on the locomotive, motor in turn driving a direct current generator. This generator furnishes current for the operation of the car motors. By varying the voltage of d.c. generator by means of rheostat, any desired voltage may be obtained on motor supply circuit, thus allowing of the obtaining of a perfectly smooth and rapid acceleration, with minimum energy, from the supply circuit, and the starting up of a locomotive does not produce a peak in the load diagram. Such a system, while it may be feasible in the case of large locomotives, yet does not furnish a general solution of the railway problem, as the arrangement is not flexible enough. In the ideal system the same method of operation, and the same types of apparatus, should be used on the feeders or branch lines as on the main lines, if full benefit is to be obtained by electrification.

5. The polyphase system has been developed by European engineers, and a number of installations have been made in Europe. American engineers consistently refuse to adopt the polyphase induction motor for the following reasons, namely: (a) The motor is inherently a constant speed one, and therefore not adapted for traction work; at one definite speed only is the polyphase motor efficient. One expedient used to overcome this is to run motors in concatenation or tandem, which gives a second speed at one-half of normal speed. By winding motors for a different number of poles, more than the two speeds may be obtained, but this arrangement has the disadvantage of being able to use but one-half of the total motor capacity above half speed, while the greatest expenditure of energy takes place above that speed. (b) The necessity of providing for at least two overhead conductors. (c) The fact that motors must be built with small air gaps to give most efficient results.

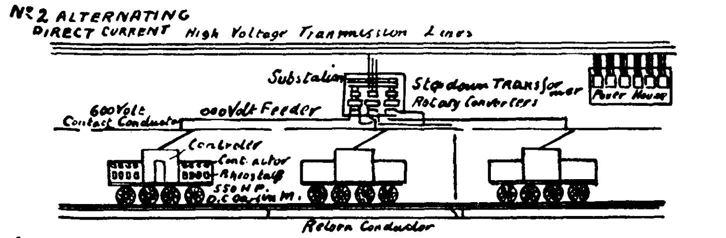
The advantages of the polyphase motor for traction purposes are as follows: In contrast to the single phase motor, the tractive effort at starting is greater. This is due to the fact that in the single phase motor the torque is not constant, but varies between a maximum and zero, with double the frequency of the line current. The mean value of the torque is only one-half of the maximum torque when slipping wheels, which means, where the tractive effort required necessitates going to the limit of adhesion between wheels and track, a single phase locomotive must have almost twice as much weight on drivers as either a d c. or three phase locomotive. This difference holds true only for motors mounted directly on car axles, and will be somewhat less if geared. The weight of a three phase motor is only about three-quarters of the d.c. motor of equal capacity, and approximately one-half that of a single phase motor, and the cost is also less. The cost of equipment is also made lower, as the transformers on the locomotive may be dispensed with, as motors of this type are now made for operation direct on voltage up to 10,000 volts. The three phase motor is probably the most robust and thoroughly mechanical piece of machinery extant, and the maintenance of same would be less than with any other system. Generally speaking, the conditions most favorable for the adoption of this system are rare, and are when the lines are long, when there are few trains with few stops, and when the lines have long and regular gradients, particularly if there is plenty of motive power and it is cheap. In the case of mountain railways, the polyphase system has a special advantage in that power may be returned to the line when running down hill, motors acting as generators and thus allowing of the electrical braking of trains.

While the wholesale retirement of the steam locomotive in favor of its electrical competitor cannot take place in the immediate future, owing to capital now invested, there are many isolated sections of steam roads in the operation of which electric traction could effect economies which would pay well for its adoption. These economies may be in the direction of a reduced fuel, labor, and maintenance account, but may be more far-reaching, and warrant changes in the present method of operating by steam. The millions of dollars contemplated for reducing grades, and double tracking certain sections of single track roads in order to increase their capacity with steam locomotives, might be spent with promise of greater return if used for installing electrical equipment.

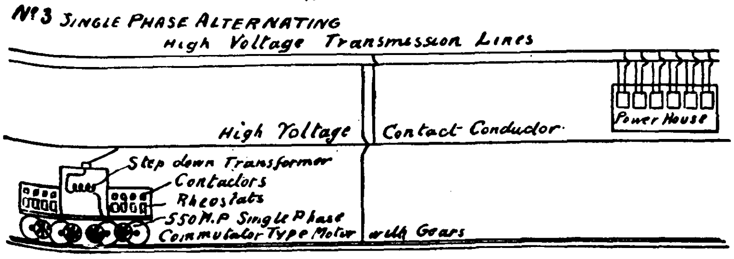
No. 1. DIRECT CURRENT.



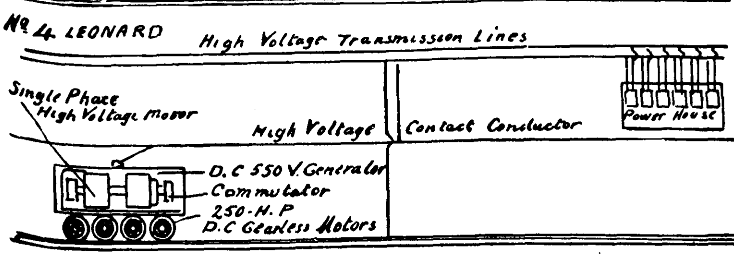
No. 2 ALTERNATING DIRECT CURRENT



No. 3 SINGLE PHASE ALTERNATING



No. 4. LEONARD



No. 5. POLYPHASE