HIGH-VOLTAGE LINE LOSS TESTS MADE ON THE 100-KILOVOLT 60-CYCLE 180-MILE TRANSMISSION LINE OF THE CENTRAL COLORADO POWER COMPANY

[COMMUNICATED TO HARRIS J. RYAN BY E. L. WEST AT THE
REQUEST OF THE HIGH-TENSION TRANSMISSION COMMITTEE
OF THE A.I.E.E.]

Somewhat over a year ago, Mr. West then assistant general manager and now general manager of the Central Colorado Power Co. made a careful series of high-voltage line loss, wave-distortion and charging-current tests. He gave the writer copies of the results of these tests at the time they were obtained because of the wish on the part of the latter to make a study of the fundamental principles of their highly interesting characteristics. Mr. West has consented to the publication of the data referred to above in the following charts:

The Shoshone station voltage wave form is excellent, being nearly sinusoidal.

All banks of transformers are delta-connected.

The sizes and corresponding locations of line conductors are given on their charts whence their location may be made on the profile map, Fig. 2. They are six-strand hemp-core copper conductors mounted horizontally, in line, outers 10 ft. $4\frac{1}{2}$ in. (3.15 m.) from the center.

Tower spacings average 750 ft. (228 m.). Suspension insulators disk type, four disks $10\frac{1}{4}$ in. (26 cm.) in diameter connected with solid copper links.

In a letter to the writer dated September 14, 1910, Mr. West says: "I spent a great deal of my time in the generating stations when the line was put into operation and I took the ob-

MAIN TRANSMISSION LINES OF CENTRAL COLORADO POWER CO.

Lines extend from Shoshone Power House near Glenwood Springs to Denver, 153 miles

The main transmission lines of the Boulder Project, 29 miles long, are also shown

FIG. 1

servations myself and used every means possible to secure accuracy. When the rheostat load tests were made I stationed the operators, who had previously been trained to obtain accurate observations, at the Shoshone or generating end of the line, while I conducted the test from the Boulder or load end of the line. In order to get simultaneous readings I signaled the telegraph operator at Shoshone over our telegraph line by repeating the letter R at intervals of about five seconds. The observers at Shoshone could hear the telegraph instrument so in this manner we obtained simultaneous readings at both ends of the line. In addition to this we had curve-drawing instruments for voltage and kilowatts at both ends of the line and all instruments were calibrated carefully before and after the test. After the observations were taken I compared the curve-drawing instrument charts and in this way was able to eliminate any errors of observation, so that I believe the data obtained are nearly as reliable as a test conducted in a laboratory where all instruments would be located at one point."

Again in a letter dated August 11, 1910, Mr. West writes:

"As I understand it, the specific question you would like answered is whether the difference in results shown by tests No. 7 made on July 23, and tests No. 10 made on November 14 can be explained by difference in atmospheric conditions. Both Mr. Charles S. Ruffner, our operating superintendent, and I do not think this difference is due to weather conditions, but believe that it is due to different connections of transformers to the line. You will note in test No. 7 that transformers were connected at Leadville, Dillon and Denver, and there were 30 miles (48 km.) on the end of the line from Denver to Boulder which had nothing connected to them; *i.e.*, during this test there were no transformers connected at Boulder where the line voltage was highest, whereas, during tests No. 10, transformers were connected at Denver and Boulder only, with no other intermediate connections from Denver to the generating station.

"From here on I will let Mr. Ruffner dictate:

"We believe that the differences in load shown on the same length of line may obtain under different conditions of transformer connections, being particularly affected by the location of such transformers.

"On this particular system the connection of transformers (while adding small losses in the transformers themselves) decreases the total loss, by reason of local non-uniform reduction

in voltage and modification of wave form. In the case of test No. 7 the increased losses seem to be best explained by considering that the line from Denver to Boulder was open-circuited, and that for the same voltages measured at Denver in the two cases, the corresponding voltages at the Boulder end of the line were greatly different; and that in the test No. 7, without transformers at Boulder, the potential there was so much above the

FIG. 11

critical voltage that the losses on that end of the line were very high.

"In the case of an open-circuited line on which the rise in potential is uniform throughout its length, the corona losses would, of course, not be uniform but would be several times greater at the open-circuited end. In fact, in some cases we believe that under open-circuited conditions the voltage is below the critical voltage at the power house end and is very

much above the critical voltage at the open circuited end, thereby producing the greater part of the loss at the open end of the line.

“ We believe that another factor causing the difference between tests No. 7 and No. 10 is the location at which transformers were connected, because this effect is shown by the differences between tests No. 1 and No. 4. The effect of connecting intermediate transformers is to reduce the voltage below the critical value at several intervals along the line thereby preventing the average voltage over the length of the line raising as high as it undoubtedly would in case transformers were connected at but one point.”