

Chicago, Milwaukee & St. Paul Railway Company

Instructions for Substation Operation

Rocky Mountain, Missoula, and Coast Divisions

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PART I

INSTRUCTIONS FOR THE OPERATION OF SUBSTATIONS EQUIPPED WITH GENERAL ELECTRIC APPARATUS

The main body of these instructions applies to all substations on the Rocky Mountain, Missoula and Coast Divisions, except those equipped with Westinghouse apparatus, which are Taunton, Doris, and Kittitas, and for which instructions are given in a separate section of this book. Where the method of operation varies on different divisions, this is noted in the text.

The following instructions cover the fundamental operations only. They are supplemented by additional or special instructions issued either as additions to this book or in the form of bulletins mailed to each substation and there placed on file.

The operator before applying these instructions should thoroly familiarize himself with all of the apparatus both by study of the descriptive matter and diagrams which follow these instructions and by study in the station of the apparatus and the actual circuits. He should know how to operate the switches, know from the position of the handles of otherwise whether switches are open or closed, and understand the operation of the rheostats and the methods of using the meters.

The Main Purposes of the Substations are three in number. First, transforming the 100,000 volts alternating current to 3000 volts direct current, and the distribution of the latter for the propulsion of trains. Second, maintaining the high tension service. Third, supplying 4400 volts A. C. power for signals.

Preparation for Operation. See if power is on the incoming high tension lines. This will be evidenced by the sound of the voltage detectors. Observe the high tension switches to determine if power connections are made from the incoming lines to the high tension bus. If the bus is not energized, proceed as directed below under "Operation of High Tension Switches."

Note the oil level in the power transformers which are to be used. The oil should show plainly in the gauge glasses. If it does not show, the transformer must not be used without special authorization.

Energizing Main Transformers. See that the transformer oil switch (2) and motor switches (3 and 4) on corresponding motor panels, and the selector switch (20 or 21) are open. Close the three blades of the disconnecting switches (1) in the transformer leads in the high tension room. You should get an arc as each switch is closed. See that each blade is properly latched. Close the transformer oil switch (2) on the proper transformer panel. The transformer is now energized and will give out a pronounced hum. On the Coast Division the voltage may be checked by putting potential plug in its receptacle (RE-1) and reading

the voltmeter (V-1). The voltage should be approximately 2300.

Energizing Selector Bus. See that the selector disconnecting switches (22 or 23) in the high tension room are closed on the transformer in use. (These disconnecting switches do not obtain on the Rocky Mountain and Missoula Divisions). Close selector oil switch (20 or 21) corresponding to the transformer which is to be connected to the bus. This energizes the signal and lighting transformers if the switches 25 and 32 (Plate X and XII) are closed. It also energizes thru current and potential transformers various relays and interlocks. It can be determined whether or not the selector bus is energized by noting if the coil on the emergency lighting switch (13) on the battery panel is energized. See that this switch is thrown to the down position and properly latched. The connections are now such that one M. G. set can be operated and A. C. auxiliary power is available by proper switching as desired. This can be considered the normal condition of the station power supply circuits with no sets running.

Starting Motor-Generator Set, Rocky Mt. and Missoula Divs. Go over the set carefully and see that the oil is showing in the various oil gages and remove any tools or material lying on the machine. See that any dust or dirt that has collected on the commutators is cleaned off.

See that the motor field switch (5) is in the out position. Throw in the starting switch (3), making sure that the latch on the handle catches. If it does not, hold the switch closed until the set comes up to speed, then let the switch out and throw it in again, with enough force to latch it.

While the motor is coming up to speed, examine the oil rings of each bearing to see if they are turning. If any of the rings are not carrying up oil, use a wire or stick to start them.

When the motor has come up to speed, close the field switch (5). When the field current (AM-2) becomes steady, open starting switch and immediately throw in running switch (4). Do no attempt to close the running switch until the starting switch is open, otherwise the interlock will prevent the running switch being closed. It is desirable to use both hands in closing the running switch. The motor current (AM-1) should decrease until the meter pointer is close to the zero mark.

If the rheostat handles are in normal operating position, no field adjustments will be necessary. However, this should be checked and corrections, if required, made as follows:

On the 2000 KW set with the machine cold the reactance meter (RVA) should read about 200 k.v.a. to the right and the motor field current (AM-2) about 120 amps. If the readings are not approximately these amounts, adjust the motor field rheostats as follows: Turn the motor field rheostat (RH-1) to the left to its

stop and then back $\frac{1}{4}$ th of a revolution. Turn the 125 volt shunt field rheostat (RH-3) to the left to its stop and then $\frac{1}{2}$ revolution back. With no load on the machine, the field ammeter (AM-2) should now be made to read 120 amps. by further adjustment of RH-1.

On the 1500 K. W. set the reactance meter (RVA) should read about 200 k. v. a. to the right and the motor field current (AM-2) about 100 amps. If not approximately these amounts adjust as follows: Turn the motor field rheostat (RH-1) to the left to its stop and then back $\frac{1}{2}$ of a revolution. Turn the 120 volt shunt field rheostat (RH-3) to the left to its stop and then $\frac{1}{2}$ revolution back. With no load on the machine, the field ammeter (AM-2) should now be made to read 100 amps. by further adjustment of RH-1.

Starting Motor-Generator Set, Coast Division. Go over the set carefully and see that the oil is showing in the various oil gages and remove any tools or material lying on the machine. See that any dust or dirt that has collected on the commutators is cleaned off.

See that the motor field switch (5) is in the out position. Throw in the starting switch (3), making sure that the latch in the handle catches. If it does not, hold the switch closed until ammeter (AM-1) drops below 600 amps., then let out switch and throw it in again with enough force to latch it.

While the motor is coming up to speed, examine the bearing oil rings to see if they are turning. If any of the rings are not carrying up oil, use a wire or stick to start them.

When the motor has come up to speed and the motor ammeter (AM-1) is reading below 600 amps., close the field switch (5). When the motor current has settled back near zero, open starting switch and immediately throw in the running switch (4). Be careful not to start to close the running switch until the starting switch is open; otherwise the interlock will prevent the running switch being closed. For this reason it is desirable to use both hands in closing the running switch. The motor current should decrease until the meter pointer is close to the zero mark.

If the rheostat handles are in normal operating position, no field adjustment will be necessary. Check the generator exciter voltage by placing voltmeter plug in RE-2. The voltmeter (V-2) should read approximately 120 volts. If it does not, adjust to this value by means of rheostat (RH-5) on generator panel. The reactance meter (RVA) should read 1000 k. v. a. or less to the left and the motor field current (AM-2) about 100 to 120 amps. If the readings are not approximately as above, adjust the rheostat as follows: Turn motor field rheostat (RH-1) to the left to its stop and then back $\frac{1}{4}$ th of a revolution. Turn exciter shunt field rheostat (RH-2) to the left to its stop and 125 volt motor field rheostat (RH-3) to the left to its stop and then $\frac{1}{2}$ revolution back. With no load on the machine, the field am-

meter (AM-2) should now be made to read 100 to 120 amps. by further adjustment of RH-1.

Putting Generator in Service, Rocky Mt. and Missoula Divs. Throw the three pole switches No. 16 and No. 17 to connect the battery to the set to be run, as follows:

No. 1 set: No. 16 up No. 17 down

No. 2 set: No. 16 down No. 17 down

No. 3 set: No. 17 up.

Close battery switch (15). This will supply battery or exciter current to certain contactors and relays and will connect up the battery ready for charging. (See instructions on battery charging).

Close the contactor knife switch (12) at top of equalizer panel. Close the high speed breaker by closing single pole knife switch (6) on the high speed breaker panel. As soon as the closing motor starts, open this knife switch as the motor is stopped automatically when the breaker is closed. If the switch were left in, the motor would run indefinitely. In case the motor closing apparatus is not working, the breaker may be closed by hand, using the long wooden handle. Insert it in the socket in the ratchet mechanism and turn the ratchet wheel until the breaker is set and the cam rigging drops to the lowest point on the cam. Do not turn the ratchet wheel beyond this point. Set the high speed breaker for the number of sets in service, allowing 1200 amps. per machine for 1500 KW sets and 1500 amps. per machine for the 2000 K. W. sets.

See that the generator disconnecting switch (8) is open.

Close the generator circuit breaker by its operating handle (7). Watch the operations of the breaker to see that it latches. If the breaker does not stay in, inspect (after making sure that field switches 9 and 10 are open) the low voltage release on the breaker, the speed limit device on the end of the motor-generator set, the overload relay on the equalizer panel, and the auxiliary contacts on the high speed circuit breaker.

Close the generator field switches (9 and 10). Place the voltmeter plug in the upper set of holes (RE-4) of the voltmeter receptacle so that the voltage of the set can be read on the meter (V-3) at the extreme end of the switchboard. Adjust the field rheostats by their operating hand wheels (RH-4) to get 3000 volts, turning both hand wheels simultaneously. Transfer the potential plug to the lower set of holes (RE-5) to determine the voltage on the low generator. This voltage should be one-half the voltage of the set. If not that amount, loosen the lock nut between the rheostat handles and adjust the rheostats to divide the voltage equally; then tighten the lock nut again.

Putting Generator in Service, Coast Division. Throw the three pole switch (16) on the battery panel, up if starting No. 1 set, and down if starting No. 2 set. See that switch No. 17 on house service panel is thrown up.

Close battery switch (15). This will supply battery or exciter current to certain contactors and relays and will connect up the battery ready for charging. (See instructions on battery charging.)

Close the contactor knife switch (12) at top of equalizer panel. Close the high speed breaker by pulling its control switch (6). The red light (L-4) lighting will indicate that closing has taken place. (If the high speed breaker does not stay in, inspect the speed limiting device on the end of the motor-generator set and the overload relay on the equalizer panel.) See that the generator disconnecting switch (8) is open. Close the generator circuit breaker by its operating handle (7). Watch the operation of the breaker to see that it latches. If it does not, inspect, after making sure that field switches 9 and 10 are open, the low voltage release on the breaker and the auxiliary contacts on the high speed circuit breaker.

Close the generator field switches (9 and 10). Place the voltmeter plug in the upper set of holes (RE-4) of the voltage receptacle so that the voltage of the set can be read on the meter (V-3) at the extreme end of the switchboard. Adjust the rheostats by their operating hand wheels (RH-4) to get 3000 volts, turning both hand wheels simultaneously. Transfer the potential plug to the lower set of holes (RE-5) to determine the voltage on the low generator. This voltage should be one-half the voltage of the set. If not that amount, loosen the lock nut between the rheostat handles and adjust the rheostats to divide the voltage equally; then tighten the lock nut again.

Connecting Generator to Bus. Usually the 3000 volt station bus will be energized by the east or west feeder or both, in which case it will be necessary to adjust the voltage of the generator to that of the bus before closing the disconnecting switch. Under such conditions, transfer the potential plug to the receptacle (RE-6) on any feeder panels which is connected to the station bus and observe the line voltage. Adjust the machine voltage to equal the line voltage and check twice before connecting the machine to the bus. The bus voltage should be read last, as this may vary while reading the machine voltage. When the machine voltage is properly adjusted, close the disconnecting switch (8) on the generator panel. This connects the generators to the main 3000 volt station bus and to whatever feeders are connected by their circuit breakers and disconnecting switches to this bus. Adjust the voltage of the machine and feeders to 3000 volts, provided the load current is not 50% over the normal capacity of the generators. If the switches on both feeder panels are open, the generator set can be connected to the bus without adjusting the voltage.

Operation of Blowers. The blowers are equipped with thermostatic control, which starts them when the temperature of the windings of the generators rises to

a certain value. The blower should start after the set has carried full load for about 40 minutes or double load for 10 minutes. If the thermostatic control is not in service or if in doubt whether it is working properly, the blower should be started by closing knife switch (48) at the side of the equalizer. Separate blowers are not used on the Rocky Mountain Division.

Charging Storage Battery. Normally the storage battery should be charged at the rate of seven amperes for five or six hours each day. This is accomplished by closing knife switch (14) during the operation of the motor generator set and adjusting the current by means of rheostats (RH-6). During the rest of the period of operation, keep knife switch 14 open. At any time that the battery voltage as indicated by the voltmeter (V-4) drops below 30 volts, the battery should be charged regardless of previous charges.

Placing Second Set in Service. When load conditions demand the service of both sets, proceed as follows, assuming that one set is in service:

Energize as described above the main transformer corresponding to the set to be started. No changes in the selector switches are necessary. Start the set in the usual manner.

Close the equalizing switch (11) on both sets. Close the contactor switch on equalizer panel, the high speed breaker, circuit breaker, and field switches as explained above. Bring the second set up to voltage, adjusting it to the voltage of the station bus. Then close the disconnecting switch (8). Read the ammeter (AM-3) on each generator panel and adjust the rheostats (RH-4) to balance the current equally on both machines. This should be kept balanced by occasional adjustment of the field rheostats.

Connecting Feeder to Station Bus. In case a feeder breaker is open and it is necessary to connect the feeder to the station bus, the bus voltage must be adjusted in a similar manner to that used in connecting a generator to the bus. See that the disconnecting switch (19) is open. Close the feeder breaker (18). Regulate the station voltage to equal that of the feeder to be connected and check twice as previously described. When the voltages are equal, throw in the feeder disconnecting switch (19).

In case a circuit breaker opens on a heavily loaded feeder and the other feeder is slightly loaded, it may not be possible to lower the voltage of the station bus to the voltage of the loaded feeder on account of the voltage of the next substation. In such a case, disconnect from the feeder having the higher voltage. Lower the generator voltage to that of the loaded feeder, and connect to this feeder. Raise the voltage to that of the second feeder. Then connect to the second feeder.

Note. Before doing any switching involving the feeders, the operator must be sure that the lines are

clear, i. e., that no one is working on the lines and that neither line is grounded. Except when a breaker has automatically opened a short time previously, a dead feeder should not be energized without consulting the dispatcher. Lines on which men are working should be marked with a danger tag provided for that purpose.

Note. The line sides of the feeder breakers are connected to a system of disconnecting switches (51 to 55) (located inside the substations on the Rocky Mountain and Missoula Divisions and out doors on the Coast Division) for the purpose of securing various feeder connections which may be desirable under different operating conditions. These switches, when located inside the building, must never be opened under load. They should not be closed under load unless it is necessary to do so. Load from the operator's own station can be removed by opening the feeder breakers, but when the feeders are tied together, clearance must be obtained from the substations on either side of the operator's substation before opening the tie switch. The above holds good for substations on the Coast Division where the feeders are of the horn gap type and are located out of doors, except that in case of emergency, the horn gap switches may be opened under load.

To Shut Down Motor-Generator Set. Adjust the generator field rheostats (RH-4) until the ammeter (AM-3) reads approximately zero. Operate pull button (7-T) which opens the generator circuit breaker. Open generator disconnecting switch (8). If more than one set is running, open the equalizer switch on the set being shut down. Open the contactor switch (12) on the equalizer panel. Open field switches (9 and 10). If more than one set is running and but one set is to be shut down, see that the battery is connected by switches 16 and 17 to the exciter left running. In the case of shutting down a set with none other running, the battery switch (15) must be opened.

Shut down the synchronous motor by operating pull switch (4-T) on the motor generator panel or by pressing button on the end of running switch handle (4). When pull switch is used, the alarm horn will blow until the running switch (4) on the motor panel is unlatched by operator. Open the motor field switch (5), but do not change the rheostats.

Note—Synchronous Motor out of Step. Due to a drop in voltage on the supply lines, the improper operation of the reverse current relay, or other reasons, the synchronous motor may sometimes drop out of step. When this happens, the set will make a peculiar dropping noise and the pointer on the motor ammeter (AM-1) will be at the right side of the scale. Remove the load on the set by operating pull button (7-T), which will open the generator circuit breakers; then open the generator disconnecting switch (8). The motor will now come into step, as evidenced by normal motor

ammeter reading. The generator can then be put back on the bus in the regular manner.

Note—In case A. C. Power goes off with a machine running, trip the generator breaker and the motor switch, open disconnecting switch (8) on generator panel and switch 16 on battery panel. After power has been re-established on the station high tension bus and the voltage becomes steady, start up the set in the usual manner.

Note—In Case Motor Running Switch Opens due to overload or other reasons, trip generator circuit breaker (7) and generator disconnecting switch (8). Open motor field switch (5). Unlatch the motor running switch handle (4). Start up the set again in the usual manner without waiting for the set to come to rest.

HIGH TENSION SWITCHING

Operation of High Tension Switches, Rocky Mt. and Missoula Divs. Disconnecting switches must never be closed or opened unless the corresponding oil switches are open. All operation of the high tension switches (except the transformer switches) must be done only on orders by the dispatcher.

If an high tension oil switch trips out, unlatch the operating handle to stop the alarm and notify the dispatcher. Proceed according to his directions.

Operation of High Tension Switches, Coast Division. Disconnecting switches must never be closed or opened unless the corresponding oil switches are open.

Before closing high tension line switches, get orders from the dispatcher, except where an oil switch opens automatically as indicated by light (L-10) and horn signal, in which case,—if there is no voltage on the line affected, as indicated by the voltage detectors,—the switch may be reclosed immediately. Should the switch immediately trip out again, try closing the second time. If it still fails to stay in, notify the dispatcher and await his instructions. If unable to reach the dispatcher due to trouble on dispatcher's wire, follow instructions headed "High Line Switching Instructions" on file in substation office. If there is voltage on the incoming line and the high tension bus as well is energized (as indicated by the voltage detectors and by transformers humming), it will be necessary to synchronize before closing the oil switch.

Synchronizing High Tension Lines. If there is voltage on both sides of an oil switch, it is necessary for the lines to be in phase, i. e., synchronized, before the switch is closed. With switch pole, close switches 45, 46, and 47 to connect the synchronism indicator to the station bus and to the line to be switched. The glow lights on the static indicator will now light up alternately, in one direction or the other. When this rotation of lights is slow enough so that the top light is dark for a sufficient period of time to allow closing the switch, close the oil switch. The wiring of this

apparatus is so arranged that when the top light is dark the voltages of the two systems are the same and the lines in phase and can therefore be thrown together without causing any line disturbance. When synchronization has been affected, open switches 45, 46, and 47. If it is impractical to synchronize at a certain station, the dispatcher will arrange the switching so that the synchronizing can be done at a Power Company's station.

Grounding Switch, Coast Division Only. In case it is necessary for line crews to work on the high tension transmission line, operators at stations controlling the section of line to be worked on will be called to **Give Clearance** to dispatcher and foreman in charge of the men doing the work. Giving clearance on the line implies that the line is safe to work on. For instance, if it is desired to work on the high tension line between Cedar Falls and Hyak substations, the operator at Cedar Falls will open up the Railway East oil switch and the disconnecting switch between this oil switch and the station bus. Having assured himself that these switches are open, he will call Hyak substation and be assured by the operator that the Railway West oil switches at that station are open. He shall then advise dispatcher that the line is dead and that he is closing grounding switch and proceed to do so. Tags of two types are provided, one indicating that men are working on the line and the other that the line is grounded. After the line is open and grounded, the operator should fill out a clearance tag and attach it with a grounding tag to the handle of the oil switch; or at stations where air break switches are installed in place of oil switches, on air break switch handle. As long as the tags are on the switch handle, the switch must not be closed. These tags are not to be removed until the man who originally asked for clearance advises that the men are off the line and that the switches may be closed and then only by order from the dispatcher. Be sure to open the grounding switch before the oil switch is closed.

Charging High Tension Lighting Arresters. In order to keep the electrolytic resistance in the proper condition, it is necessary periodically to pass current thru the arresters by short circuiting the horn gaps. This operation is performed every 24 hours, and is carried out as follows: See that the contact arms are resting on their contacts. Charging handle (CH) is pushed to its stop and is held there for approximately 5 seconds, and then brought back to the former position, or further if necessary, to break the arc. This operation is repeated three times, and then the transfer handle (TH) is turned so that the contact arms are swung to the opposite contacts and the charging operation is repeated. Be sure that the charging handle is left in the correct position, that is, with the horns of the gap in line.

SIGNAL CIRCUITS

Operation of Signal Circuits. All switching operations in the signal circuit must be done in accordance with direct orders from the dispatcher. The signal primary circuits between substations are normally fed from one station only. This is in order to avoid transferring power between two substations thru the signal circuits and transformers.

To Take Power off the Signal Feeder, open the oil switch (26 or 27) and both blades of the disconnecting switch (28 or 29). Open the disconnecting switch by means of the 4 ft. wooden operating stick. Never open disconnecting switch unless the oil switch is open.

To Put Power on the Signal Feeder, first make sure that the line has not been grounded at the arresters. Then close both blades of the disconnecting switch (28 or 29), and then oil switch (26 or 27).

In Case the Signal Oil Switch Trips Out, the alarm will sound and pilot light will burn. Stop the alarm by pulling the oil switch handle. Re-close the oil switch, and if it trips again, try the second time. If it then fails to remain closed, notify the dispatcher.

Grounding the Signal Circuit. On the Coast Division the signal primary circuit must be grounded at the substation when men are working on that circuit. Open the oil switch (26 or 27), the disconnecting switch (28 or 29), and the two-blade switch (30 or 31) to the lightning arrester. Make sure, by communicating with the dispatcher or the operator of the adjoining substation, that the line is not energized. Connect the three top terminals of the arrester by wire of at least No. 6 B. & S. gauge. This will short the two sides of the circuit and connect them to the station ground. Close the lightning arrester switches 30 and 31 only, thus grounding the line. Tag the oil switch handles with properly filled out clearance and grounding tags as explained under high tension switching. Then advise the dispatcher that the line is dead and grounded and can be worked upon.

In Renewing Signal Fuses, make sure that the oil and disconnecting switches are both open and make certain from the dispatcher or the operator of the adjacent substation that there is no power on the signal line. Then remove fuses, taking hold of the fuse only with fuse tongs. Put in the new fuse, and after getting instructions from the dispatcher, close disconnecting switch and oil switch.

To Connect the Two Signal Feeders Thru without taking power from the substation selector bus, open the oil switches (26 and 27) on both signal feeders. Then open disconnecting switch (25) over the signal transformer (T-2); then close oil switches (26 and 27). With such connection, there is voltage on the transformer and on the disconnecting switch (25), and due precaution should be observed.

TELEPHONE EQUIPMENT

Each substation is equipped with telephone apparatus for communication with the dispatcher and with other substations. Two lines enter the substations, i. e., the dispatcher's line and the so-called block line for use to adjacent railway stations. Switches and jacks are labelled and a card giving the rings for stations on the block line is posted on the ringer box. The equipment consists of the following:

- Desk telephone set mounted over desk;
- Ringer set for signaling stations on block lines, mounted on desk;
- Push button switch for cutting in talking set, mounted on ringer set;
- Jacks or throw-over switch for connecting telephone to either dispatcher's line or block line, mounted to right side of ringer set;
- Box containing selector apparatus, mounted on wall;
- Loud ringing bell in dispatcher's line, mounted on office wall in motor-generator room;
- A separate push switch is installed beside the ringer set in some stations for stopping the dispatcher's line from ringing. In the other stations the button for the talking set stops the bell.

Power Company telephone connections are installed in all Power Company tap stations. Stand on the insulated stool when using these Power Company phones.

To telephone to dispatcher, connect phone to dispatcher's line and listen in. If line is not busy, press push button switch to cut in talking set. Speak to dispatcher.

Use dispatcher's line for company business only; and only in case of great emergency should you interrupt the dispatcher giving train orders or station operators repeating orders back.

In case dispatcher's line is out of order and it is important that you communicate with him or another station, ring nearest telegraph station on block line and possibly operator there can wire your message.

When loud ringing bell rings, close button switch to right of ringing set. This opens circuit of holding relay in bell circuit and stops bell ringing. Then see that phone set is connected to dispatcher's line and answer phone by giving name and substation.

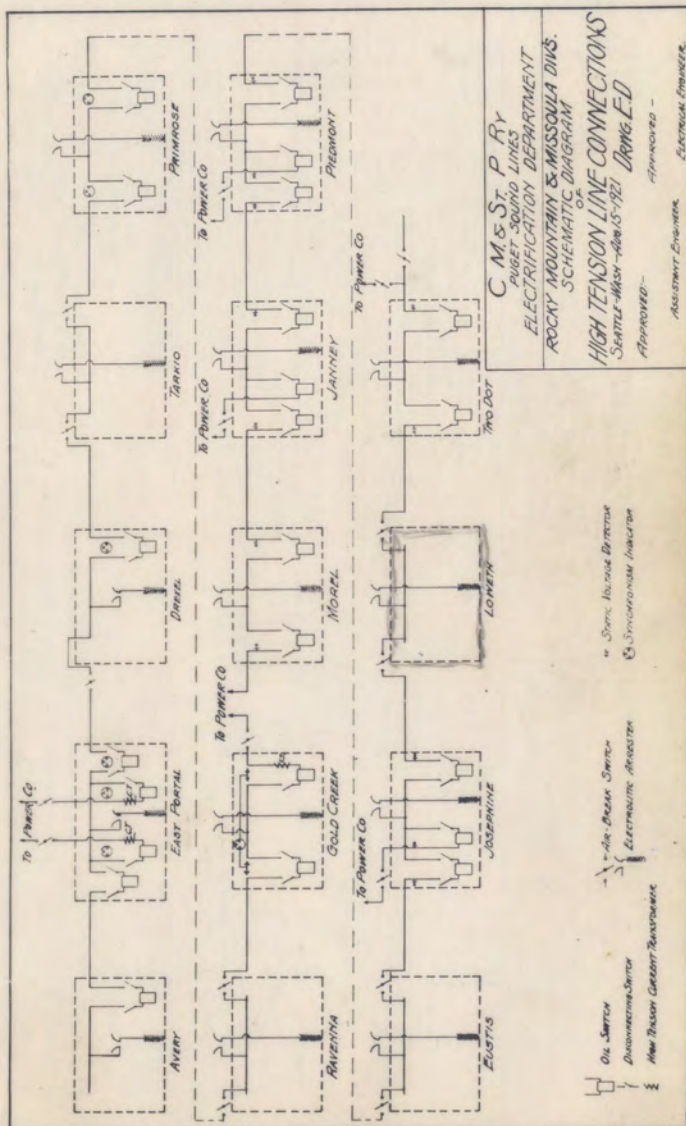
Learn your ring on the block line.

Report to dispatcher when any part of telephone apparatus is out of order.

Be brief when using dispatcher's line.

SPECIAL PRECAUTIONS

- 1 Do not touch or operate any switches except with the handles, operating handles, or operating sticks, furnished for that particular switch. Learn the location of the switch sticks and keep them in that location when not operating a switch.
- 2 Do not open or close a disconnecting switch in an A.C. circuit unless the corresponding oil switch is open.
- 3 Do not open a disconnecting switch in a generator or feeder circuit (direct current) unless the corresponding circuit breaker is open. Always close the disconnecting switch **after** the breaker is closed.
- 4 Do not open motor field until running switch is first opened.
- 5 Never open the generator field switch until the generator circuit breaker and disconnecting switch are open.
- 6 In case the motor starting switch should not happen to latch, stand and hold switch in until the machine is up to speed; it can then be let out and thrown again. If you attempt to let it back while motor is starting, there is danger of burning the switch contacts by reason of the extreme high current required while the motor is starting.
- 7 Before changing over selector switch from one transformer to the other, be sure that the transformer is on the line, as the signal circuit is served by this switch.
- 8 Do not energize a dead trolley feeder without consulting the dispatcher.
- 9 Do not put any lubrication on the commutator; this is taken care of by the brushes.
- 10 Do not let yourself or clothing come in contact with any live or moving parts.



PART II

DESCRIPTION OF SUBSTATIONS EQUIPPED WITH GENERAL ELECTRIC APPARATUS

The following description incorporates various typical photographs and one line diagrams introduced to assist the operator in the understanding of the instructions in Part I. Since the arrangement of the apparatus in the several stations varies somewhat, this description may not check exactly with the layout of some stations. An operator should observe the apparatus and circuits in the substation which he is to operate so that he may be thoroly familiar with them.

Note should be taken that the one line diagrams are illustrative only and do not show the circuits complete. In tracing trouble or in other work requiring a knowledge of the complete circuits, the operator should use the station wiring diagram supplied to each substation.

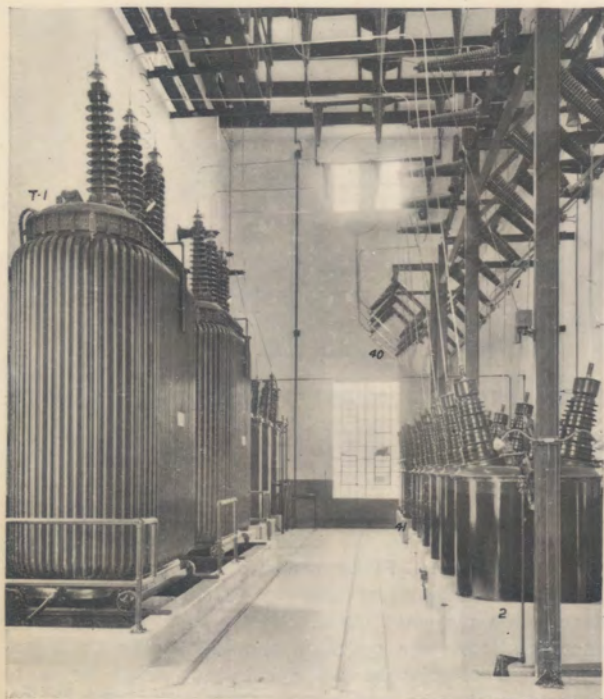
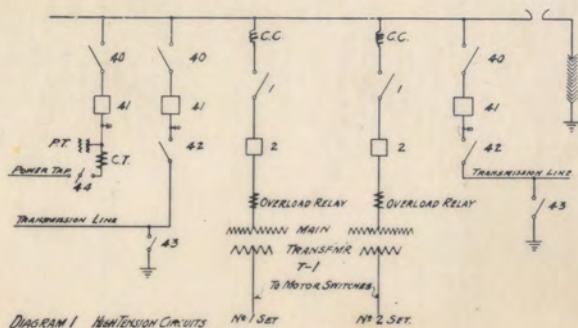


PLATE I



High Tension Room (Plate I). Apparatus in the substation used in 100,000 volt circuits is known as high tension and all apparatus used on the transformed or 2300 volt circuits and others of lower voltage is known as low tension apparatus. All high tension apparatus and circuits inside the substation are in the high tension room.

Main Transformers (T-1). Used for changing the voltage from 100,000 to 2300 volts.

High Tension Switches are of four general types, oil switches, air-break switches, disconnecting switches, and grounding switches.

High Tension Oil Switches (2 and 41) are used in switching operation in the high tension circuits and for connecting the main transformers to the high tension buses. The oil switches are used because it is much safer to break under oil a heavy arc generated by the high tension voltage.

Each set consists of three tanks containing switch contacts submerged in oil. They are operated by rods and levers connected to an operating handle on panels in the motor generator room. The oil switches used in the high tension lines coming from a power company are called Power Company switches. Those used where the Railway high tension lines enter the station are called Railway switches.

Air-Break Switches (44, Plate III) are installed instead of the more expensive oil switches when the service required of them permits. They can be opened in emergency with power on the line, but whenever possible the opening of these air-break switches should be done with the high tension line dead. The switches are mounted on the roof of a substation or on a transmission pole or tower.

Disconnecting Switches (1 and 40). The purpose of the disconnecting switches is to open the circuit between the high tension bus and the oil switches so that work can be done on the latter, also to give visual means of determining that the circuit is open.

Grounding Switches (43, Plates III and IV), used only on the Coast Division, provide means of grounding and short-circuiting the high tension wires when men are called to work on these lines. They are located outside the buildings and on the line side of all other switches.



PLATE II

Power Company's Switch at Cedar Falls. This switch is controlled from the panel shown on Plate V. The small wires on wall go to the synchronism indicator on that panel.

Apparatus:

40. —Disconnecting switches.

41. —High tension oil switches.

PT-4.—Potential transformers for Power Companies' meters.

CT-9.—Current transformers for Power Companies' meters.

VD.—Voltage detectors. These give a snapping sound when full voltage is on the wires to which they are attached.

In addition to the oil switch the Power Company has at each tap an air-break switch outside the station (No. 44, Plate III).



PLATE III



PLATE IV

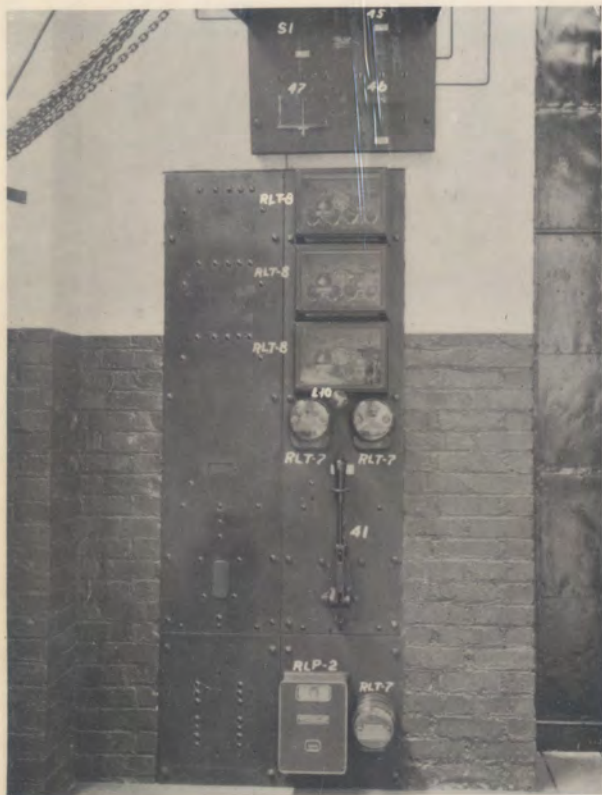


PLATE V

High Tension Line Panels. Located against middle wall at each end of motor-generator room. These panels are equipped with switches and relays for controlling the high tension lines entering building at east and west end of station. The Plates V and VI show the Power Company control panel at Cedar Falls substation and is typical of other power taps. This panel controls the switch shown in Plate II.

Apparatus:

- 41. —Operating handle for oil switch (41).
- L-10. —Light which burns when oil switch trips out automatically.
- RLT-7. —Inverse time limit relays.
- RLT-8. —Inverse time limit relays.
- RLP-2. —Reverse power relay.
- SI. —Synchronism indicator.
- 45-46-47. —Switches in indicator circuits.

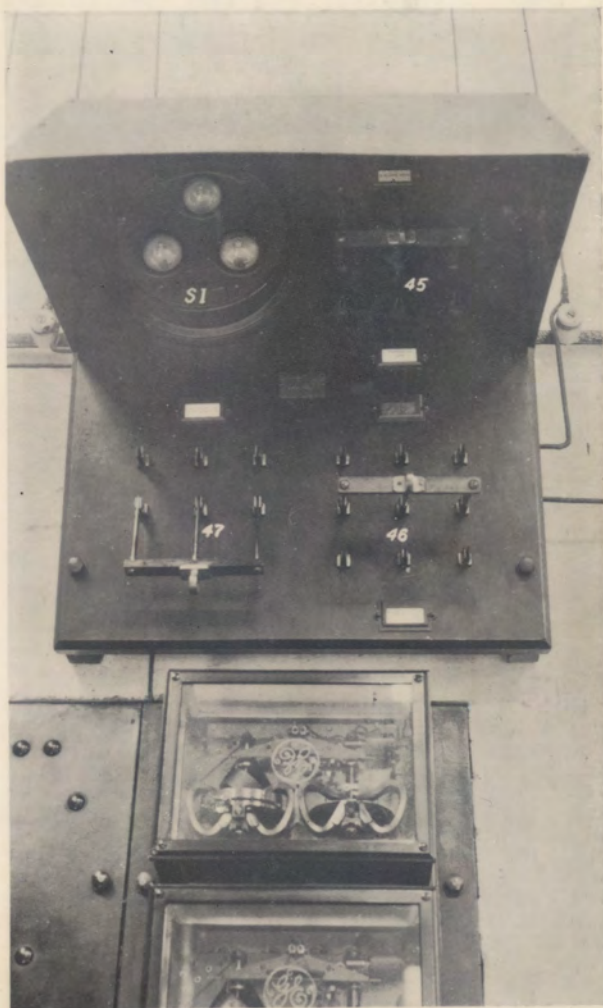


PLATE VI

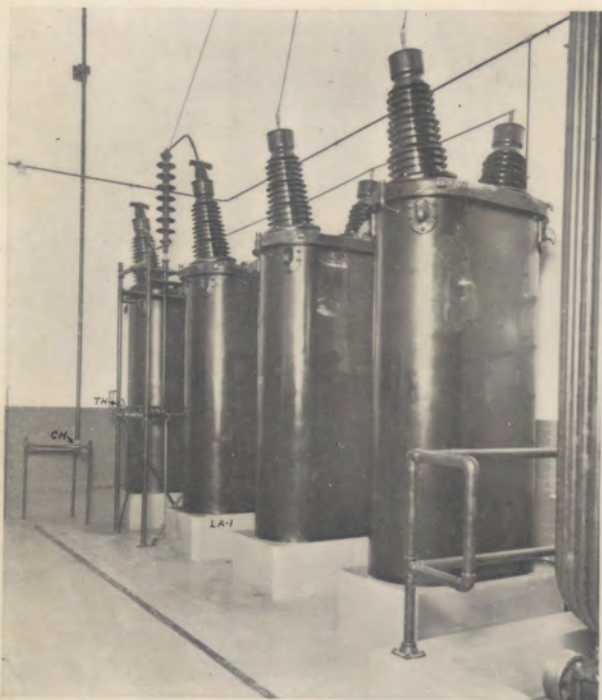


PLATE VII

High Tension Lightning Arresters. The protection of the high tension apparatus against lightning or high voltage surges is accomplished by allowing the lightning or surges to pass across horn gaps (Plate VIII) down thru electrolytic resistance to ground. The horn gaps are located on the roof of the substation at all stations except Drexel, East Portal, Avery, Cle Elum, and Hyak, where, due to snow conditions, they are mounted on pipe work in the high tension room. The electrolytic resistance is contained in the four large tanks. These tanks and the handles for operating the apparatus in charging are in the high tension room.

Apparatus:

LA-1.—Lightning arrester tanks.

TH. —Transfer handle for reversing the contacts.

CH. —Charging handle for operating the horn gaps.

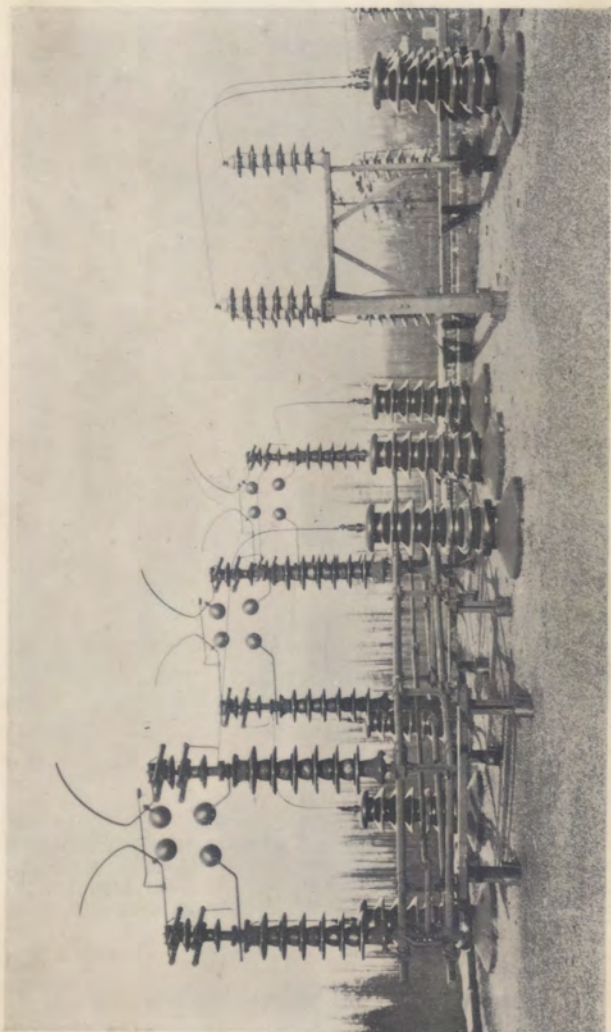


PLATE VIII

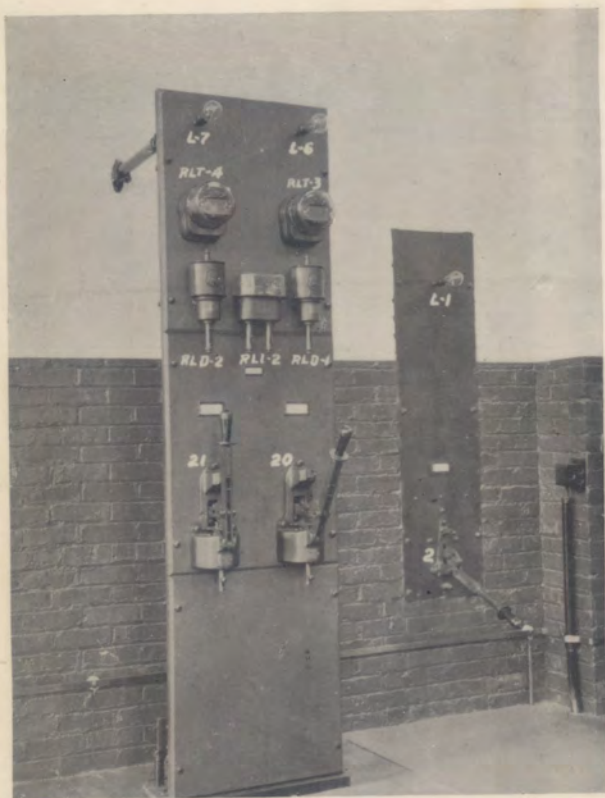


PLATE IX

Transformer Panel. Located on the motor-generator room side of the center wall opposite the transformer oil switch which it operates. Th oil switch connects the main transformer to the high tension bus, or, in other words, energizes the main transformer.

Apparatus:

- 2. —Transformer oil switch handle.
- L-1.—Indicating light which burns when the oil switch automatically trips out due to overload or trouble.

Selector Panel. Located in the motor-generator room against the wall between No. 1 and No. 2 motor panels. This panel is equipped with switch handles and protective devices controlling the oil switches that connect the selector bus to the 2300 volt side of one or the other of the main transformers.

Apparatus:

- 20. —Switch handle for connecting selector bus to No. 1 transformer.
- 21. —Switch handle for connecting selector bus to No. 2 transformer.
- L-6. —Indicating light which burns when switch No. 20 trips out automatically.
- L-7. —Indicating light which burns when switch No. 21 trips out automatically.
- RLD-1 & 2. —Definite time limit relays.
- RLT-3 & 4. —Inverse time limit relays.
- RLI-2. —Instantaneous relays.

At some stations the arrangement of the apparatus is the reverse of that illustrated, the No. 1 switch being always toward the same end of the building as the No. 1 transformer.

On Rocky Mt. and Missoula Divs. there is only one pilot light serving both selector switches.

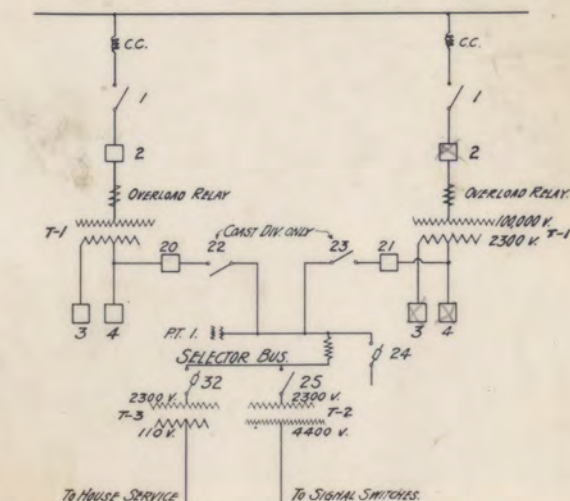


DIAGRAM 2. TRANSFORMER AND SELECTOR CIRCUITS

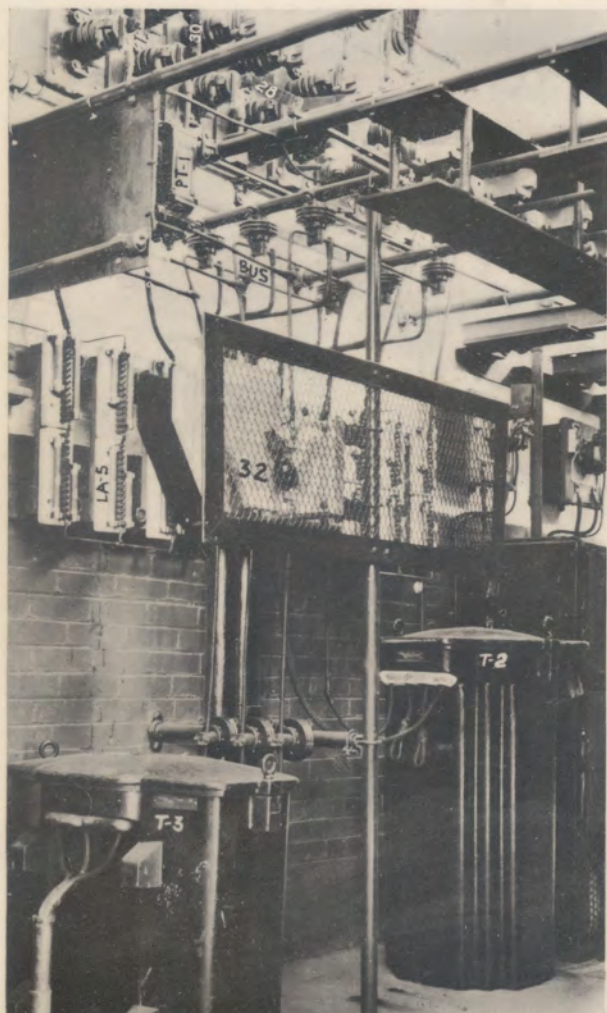


PLATE X

Selector Bus, Rocky Mountain and Missoula Divs. Located back of main switchboard. These wires are energized at 2300 volts from one of the main transformers thru the selector panel and supply power to the signal and house service transformers. These supply power at 4400 volts to signal circuits and at 110 volts to various services about the station such as lights, pumps, etc.

Eus.—2300 volt bus.

T-2. —Signal transformer.

T-3. —Lightning transformer.

25. —Disconnecting switch in signal transformer circuit. This switch is back of the fuse 32 and not seen in this illustration.

32. —Expulsion fuse in lighting transformer circuit.

PT-1.—Potential transformer on bus.

This illustration also shows the signal disconnecting switches 28 and 29 and the signal lightning arresters LA-5 and LA-6 with their disconnecting switches 30 and 31. See Diagram 7.

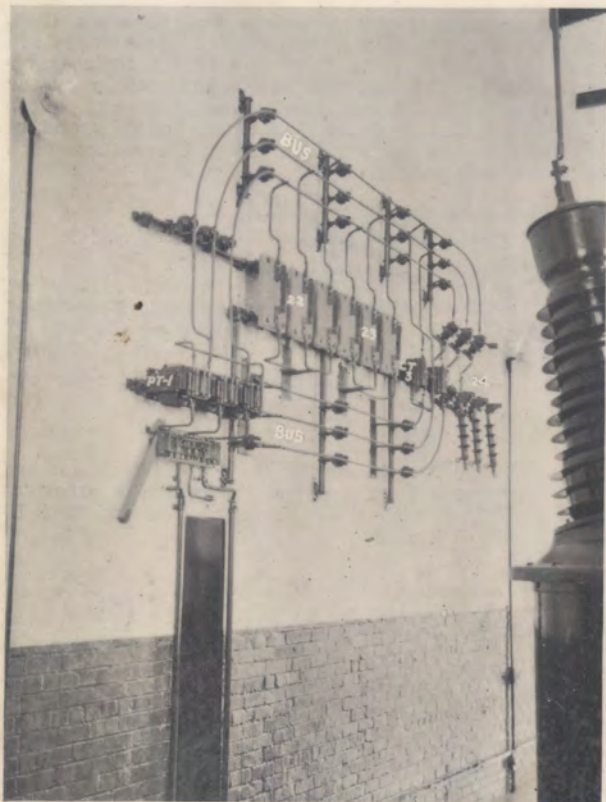


PLATE XI

Selector Bus, Coast Division. Located on middle wall in high tension room. These wires are the circuits which supply power at 2300 volts to the transformers which supply power at other voltages to the signal circuits and to the various services about the substations, such as light, pump, etc.

Apparatus:

Bus.—2300 volt bus.

CT-3.—Current transformer in bus.

22.—3 pole disconnecting switches in series with oil switch for No. 1 transformer

23.—Disconnecting switch for No. 2 transformer

PT-1.—Potential transformer for obtaining A. C. voltage for relays.

24.—Fuse-switch for transformer drying.

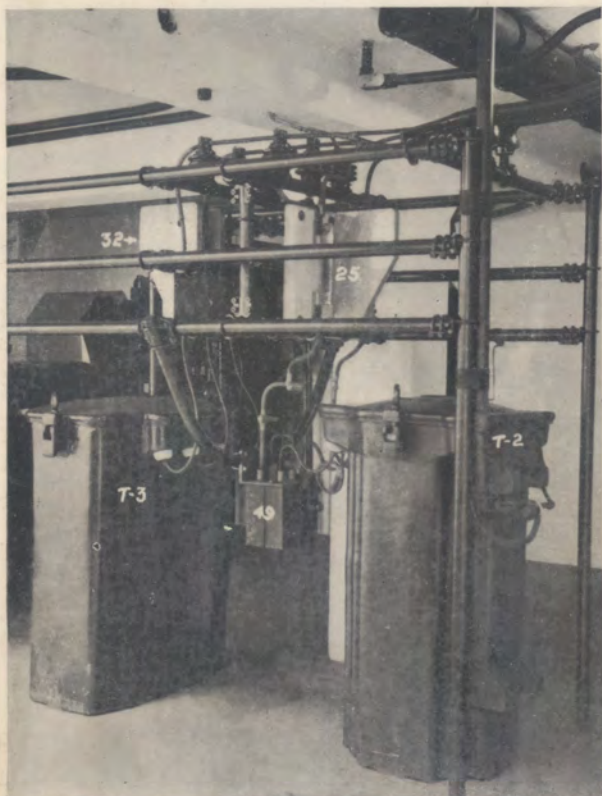


PLATE XII

Lighting and Signal Transformers, Coast Division. Located in basement. These are fed from the selector bus and supply power to the house service and signal panels on the main switchboard.

Apparatus:

- T-2.—Signal transformers.
- T-3.—Lighting transformers.
- 25. —Disconnecting switch in signal transformer circuit.
- 32.—Expulsion fuse in lighting transformer circuit.
- 49. —Switch for varying voltage in signal circuit. Used only at Cedar Falls.

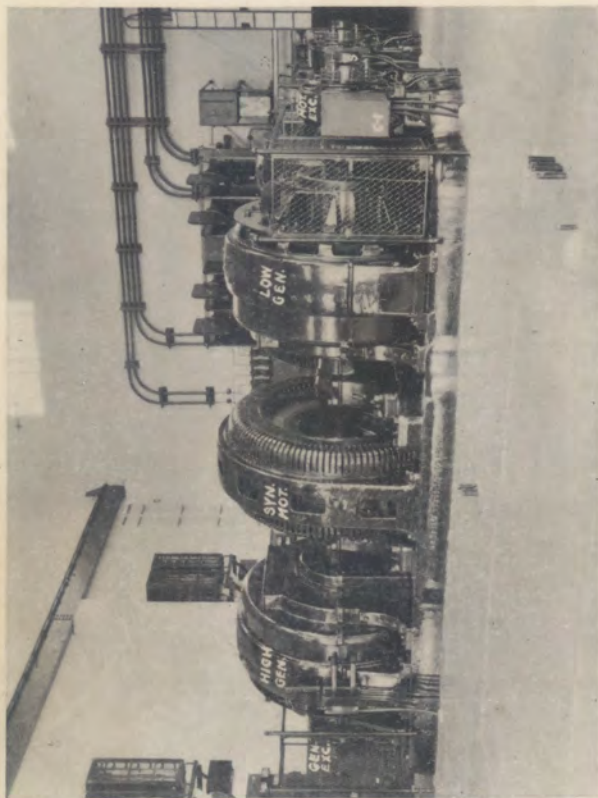


PLATE XIII

Motor-Generator Set. This machine converts power from 2300 volts Alternating Current to 3000 volts Direct Current, or if the substation is receiving power from locomotives in regenerative braking, it converts the 3000 volt D.C. to 2300 volt A.C. Sets of two capacities are in use, 2000 KW and 1500 KW. The small sets are used only at Janney, Piedmont, and Avery. The M.G. set consists of one synchronous motor, two 1500 volt generators, and two exciters on one shaft.

The synchronous motor furnishes the motive power for the whole set. It receives thru the main transformer electrical energy from the transmission line and converts it into mechanical energy to drive the two d.c. generators. The motor in the larger sets is rated as a 2500-k. v. a., 2300-volt, three-phase, 60-cycle,

514 r. p. m. synchronous motor. That in the smaller sets in 1900 k. v. a., 600 r. p. m.

The two main generators are driven by the synchronous motor and supply the power to the trolley system. Each generator is rated as a 1000 Kw. (or 750 Kw. in the small sets), compound wound, 1500-volt direct current generator. The two are connected in series to deliver power at 3000 volts. The fields of the sets on the Coast Division are compounded to give practically constant voltage with varying loads. On the Rocky Mt. and Missoula Divisions the series fields are shunted out in order to decrease the tendency of the commutators to flash over. The voltage of the latter machines decreases somewhat as the load increases. The generator connected to the negative bus is called the low generator, as its voltage to ground is but 1500 volts. The other generator is called the high generator, as its voltage on the positive side is 3000 volts above ground potential. The generators are designed to carry their rated load continuously; a 150 per cent. load for two hours; or a 300 per cent. load for five minutes. The current output would be from the 2000 Kw. sets for rated load, 666 amps.; for 150 per cent. load, 1000 amps.; or for 300 per cent. load, 2000 amps. per set.

The generator exciter is a 125-volt D. C. self excited generator and supplies the shunt field of the generators, charges the storage batteries, and in conjunction with the batteries supplies power for contactors, relays, indicating lights, etc. It also supplies part of the field of the motor exciter.

The motor exciter is a D. C. generator supplying the field of the synchronous motor. Its voltage varies up to 80 volts, depending on the requirements of the motor. Besides its main field, supplied by the generator exciter, it has a shunt and a commutating field energized from its own commutator and two opposing fields excited by the line current from the main 3000-volt generators. These fields are so related as to give the most economical excitation for the synchronous motor and satisfactory power factor on the high tension lines for all loads both when the generators are supplying power and in reversed operation. Contactor C-1 is across one of the two last mentioned fields shorting out this field when regenerated current is received by the station. This makes the necessary adjustment in the field of the motor exciter which would otherwise be adversely affected by the reversal of the line current.

The speed limit device (S), by opening the generator breakers when the set exceeds a certain limit, prevents damage to the set from this cause.

In all stations No. 1 motor-generator set is the one next to the main switchboard. The panel controlling this motor is adjacent to it against the middle wall. A motor-generator can be run only from its own main transformer and high tension oil switch. The No. 1 transformer is in the same end of the station as the No. 1 set.

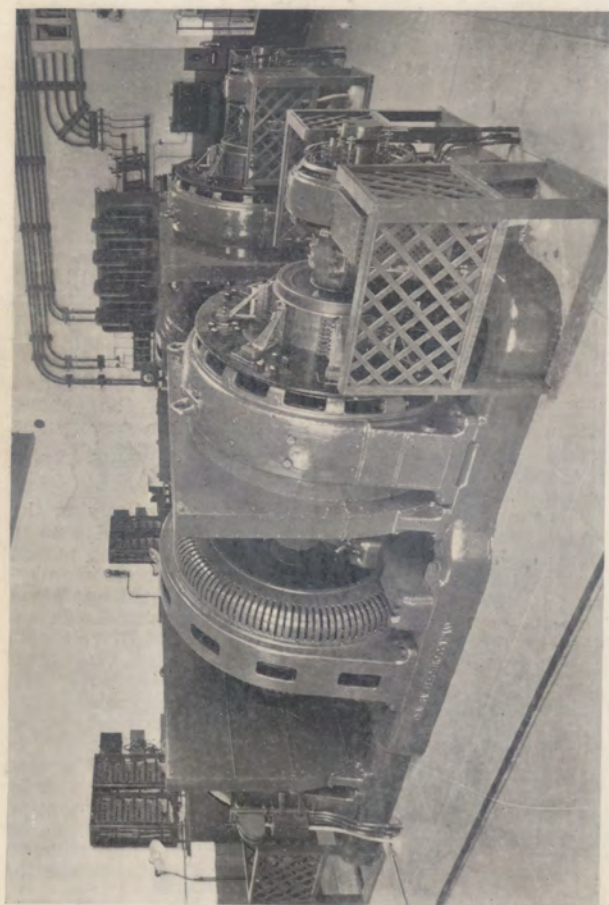


PLATE XIV

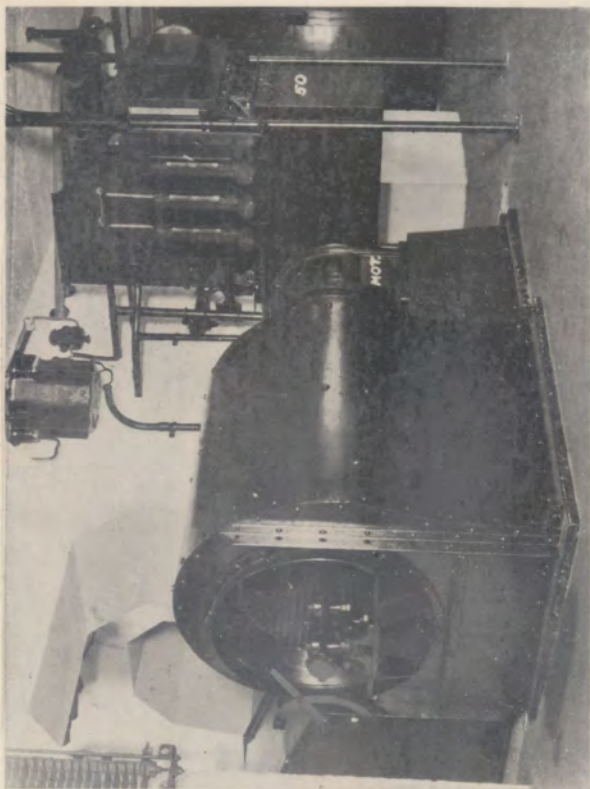


PLATE XV

Blower. Located in basement below the motor-generator room. These fans force air thru the windings of the main generators to prevent the temperature rising to a value which would be injurious to the insulation. The blower is driven by an induction motor (MOT) receiving its power from the leads to the synchronous motor. The induction motor is controlled by a thermostat mounted in the main lead from the generator. The thermostat actuates the automatic starting switch (50) starting the blower when the temperature of the winding reaches a certain value. In addition to the thermostat control, the motor may be started by the knife switch (48) on the side of the equalizer panel. Blowers are not used in the Rocky Mt. Division, these sets being self-ventilated. (See Plate XIV).

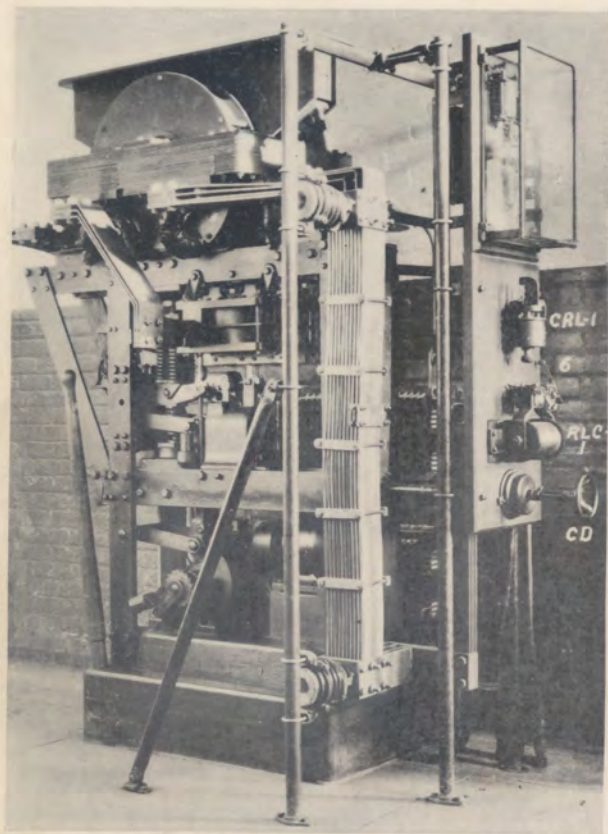


PLATE XVI

High Speed Circuit Breaker and Panel, Rocky Mt. and Missoula Divs. Located near end of main switch-board. One breaker serves all motor-generator sets in the station and is connected between the negative bus and the rail. It affords a very quick and automatic means of opening the main power circuit in case of excessive overloads. It is mechanically closed by an electric motor and held closed by a latch. The closing motor is started by the switch 6. It is tripped by the load current when this exceeds the amount of the breaker setting. The breaker is adjusted for the required tripping current by means of the calibrating dial (CD). On the panel is mounted also the reverse current relay RLC-1 and control relay CRL-1 (See description of Plate XXII).

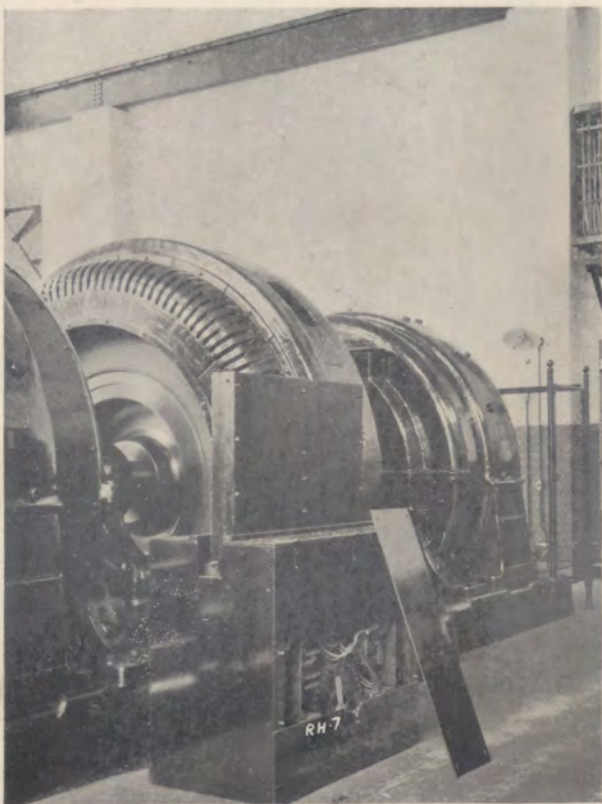


PLATE XVII

High Speed Circuit Breaker, Coast Division. Located on floor beside low main generator of the set it serves, connected in the circuit between the low generator and the rail or negative. See diagram No. 4. This switch affords a very quick and automatic means of opening the main power circuit in case of trouble. It is closed by operating its control switch on the generator panel. Power for closing is furnished by current from the generator exciter and it is held closed against heavy springs by an holding coil energized from the same source. Power current from the main generators passes thru a coil, the magnetism of which opposes that of the holding coil. When, due to excessive line current, the magnetism equals or overcomes that of the holding coil, the springs pull the breaker open.

In the illustration the breaker has the side cover removed showing the rheostat (RH-7) by which the value of the tripping current is adjusted.

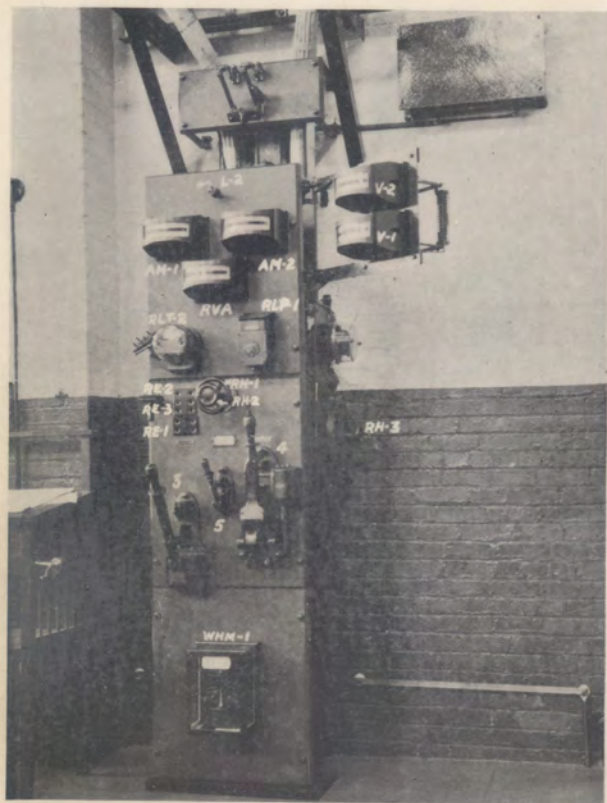


PLATE XVIII

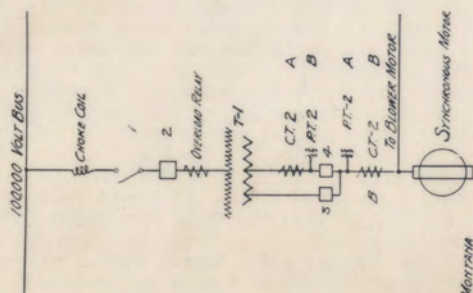


DIAGRAM 3. MOTOR PANEL

A-MONTANA
B-COAST DIV.

No. 1 Synchronous Motor Panel. Located against wall near end of motor-generator set. This panel is equipped with the necessary switches, meters, and rheostats for controlling the synchronous motors of No. 1 set.

Apparatus:

- 3. —Starting oil switch handle.
- 4. —Running oil switch handle.
- 5. —Field switch handle.
- RH-1. —Rheostat handle for regulating field of motor.
- RH-2. —Rheostat handle for self excited differential shunt field of motor exciter.
- RH-3. —Rheostat handle for separately excited shunt field of motor exciter.
- AM-1. —A. C. ammeter which indicates the current taken by the motor armature.
- RVA. —Wattless component indicator, which indicates whether the motor has the proper field strength.
- AM-2. —D. C. ammeter for indicating current of the motor field.
- V-1. —A. C. voltmeter for indicating voltage on the low side of the power transformer. This reads only when the potential plug is in receptacle RE-1.
- V-2. —D. C. voltmeter for reading the voltage of the motor exciters and generator exciters. By plugging in at receptacle RE-2, the voltage on the generator exciter is secured; and by plugging in at receptacle RE-3, the voltage on the motor exciter.
- L-2. —Indicating light which burns when running switch (4) trips out automatically.
- RLT-2. —Inverse time limit relay.
- RLP-1. —Reverse power relay.
- WHM-1. —Watt-hour meter registering power taken by set.

The panel for No. 2 set is the same except that it does not have meters V-1 and V-2. If it is desired to read the voltage on No. 2 motor-generator set, the operator plugs in at the proper receptacle on No. 2 motor panel and reads the meters V-1 and V-2 on No. 1 panel.

The synchronous motor panel on the Rocky Mountain and Missoula Divisions does not have the voltmeter V-2 with its receptacles RE-2 and RE-3 for the D. C. exciters. (See Plate XX).

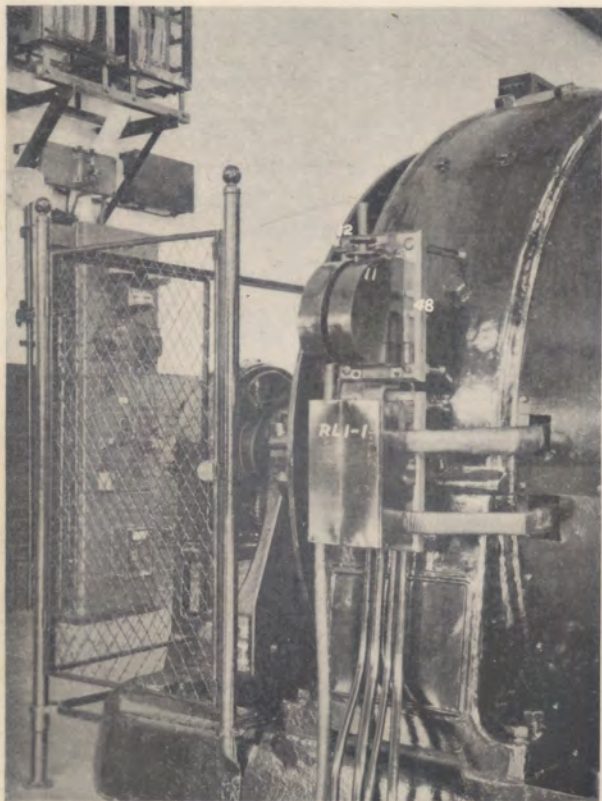


PLATE XIX

Equalizer Panel. Mounted on the magnet frame of the high generators. On this panel are switches which could be more conveniently located there than on the main switchboard.

Apparatus:

11. —Equalizer switch for connecting together the generator series field of No. 1 and No. 2 sets in order that the machines may divide the load equally.
48. —Switch for hand control of blower motor.
12. —Switch in the circuit of the motor exciter field contactor, C-1.
- RLI-1.—D. C. overload current relay.

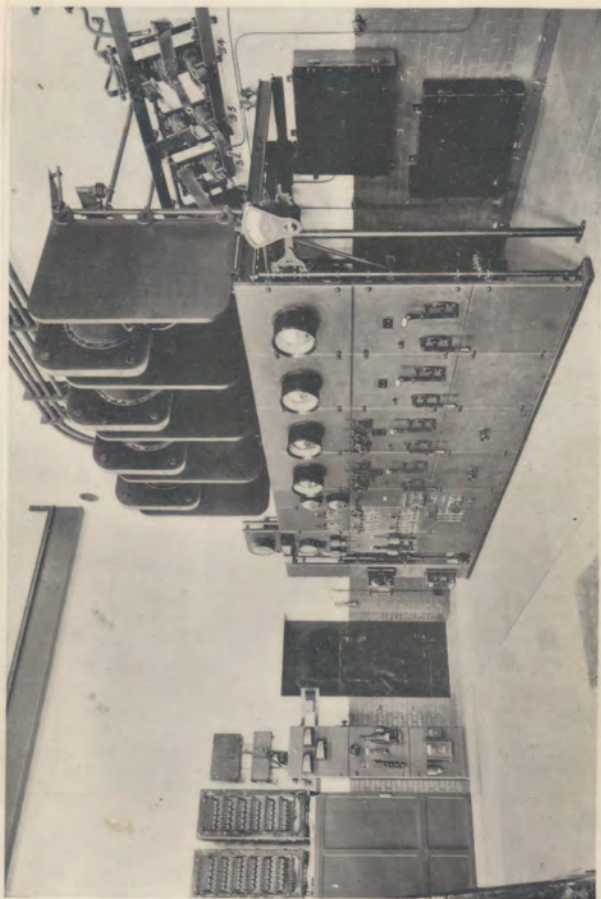


PLATE XX

Main Switchboard. Located in motor-generator room. This board controls the main generators, trolley feeders, signal feeders, batteries and lighting circuits.

The individual panels on the particular board illustrated are, reading from the left:

- Power Company Panel,
- Signal Panel,
- House Service Panel,
- Battern Panel,
- No. 1. Generator Panel,
- No. 2 Generator Panel,
- East Feeder Panel,
- West Feeder Panel,
- Voltmeter on Swinging Bracket.

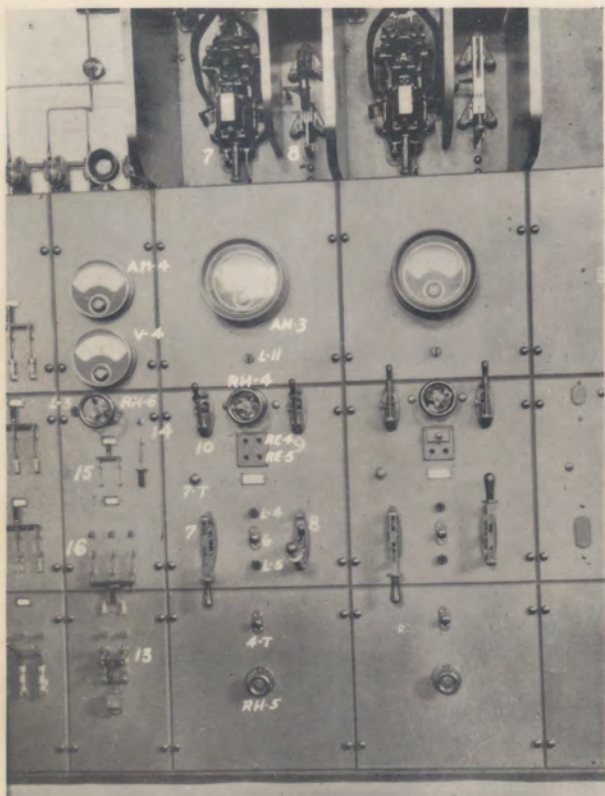


PLATE XXI

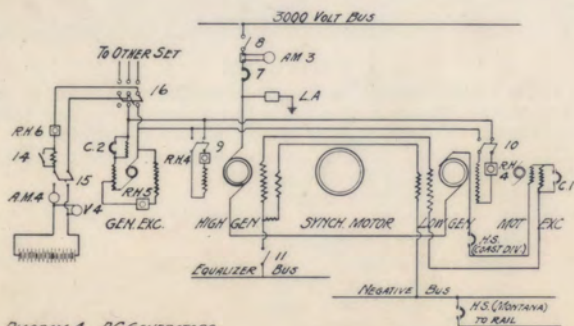


DIAGRAM 4 D.C. GENERATORS

Battery Panel. This panel is equipped with the necessary switches, meters, and rheostats, for controlling the storage battery. The storage battery supplies power for tripping relays, alarm signals, pilot lamps, and emergency station lights.

Apparatus:

- AM-4.—D. C. ammeter which indicates the battery charge or discharge in amperes.
- V-4. —D. C. voltmeter which indicates the voltage across the battery.
- L-3. —Pilot light which when out indicates no voltage on the control circuit.
- RH-6.—Rheostat handle by which the charging current to the battery can be regulated.
- 14. —Switch for regulating the charging current to the battery.
- 15. —Switch for connecting the battery to the charging source; i. e., exciter circuit.
- 16. —Double throw switch for putting the battery on either No. 1, No. 2, or No. 3 exciter. Used in conjunction with switch No. 17 on house service panel.
- 13. —Automatic throwover switch which connects certain lights distributed thruout the building to the battery circuit when the main power supply goes off.

Generator Panel. There is one panel for each motor-generator set. The panels are equipped with the necessary operating handles, meters, and rheostats, for controlling the two generators of each set. The generator circuit breakers and disconnecting switches are immediately above these panels.

Apparatus:

- 7. —Handle for operating the generator circuit breaker.
- 8. —Handle for operating the disconnecting switch.
- 9. —Handle for controlling the field switch of the high generator.
- 10. —Handle for controlling the field switch of the low generator.
- 7-T. —Pull button for tripping the generator circuit breaker.
- 4-T. —Pull switch for opening the running switch on motor panel (Coast Division only).
- 6. —Pull switch for closing the high speed circuit breaker (Coast Division only).
- RH-4.—Rheostat handles for controlling the generator fields.

- RH-5.—Rheostat handle for controlling the field of the generator exciter.
- RE-4.—Receptacle for connecting the voltmeter across both high and low generators.
- RE-5.—Receptacle for connecting the voltmeter across the low generator.
- L-11.—Light which when burning indicates that the blower apparatus is operating.
- L-4.—Light which burns red when high speed breaker is closed. (Coast Division only).
- L-5.—Light which burns green when high speed breaker is open. (Coast Division only).
- AM-3.—Ammeter which indicates the current delivered or received by the high and low generators.

Feeder Panel. This panel is equipped with switch operating handles and meters for controlling the feeder circuits. There are two identical panels, one feeding the east feeder and the other the west.

Apparatus:

- 18.—Operating handle for closing the feeder circuit breaker.
- 19.—Operating handle for closing and opening the feeder disconnecting switch.
- 18-T.—Pull button for tripping feeder circuit breaker.
- RE-6.—Receptacle for connecting the voltmeter to the feeder and trolley.
- AM-5.—D. C. ammeter for indicating the current entering or leaving the station thru the switches.

Reverse Current Relay Panel, Coast Division. This panel is equipped with relay and contactor for adjusting the field of the synchronous motor so that it may operate as a synchronous generator when the power is being returned from the trolley. The D. C. generators automatically motor, but in order that the synchronous motor may operate satisfactorily as a generator, it is necessary to make certain changes in its fields. These changes are accomplished by the equipment on this panel and contactor C-1 on the M. G. set.

- CRL-1.—Contact closing relay which controls contactor C-1 on the motor-generator set.
- RLC-1.—D. C. reverse current relay which closes relay CRL when the current in the line is reversed from normal direction.

Voltmeter. On this meter (V-3) is read the voltage of the generators or of the east or west feeders, depending on in what receptacle the potential plug is placed.

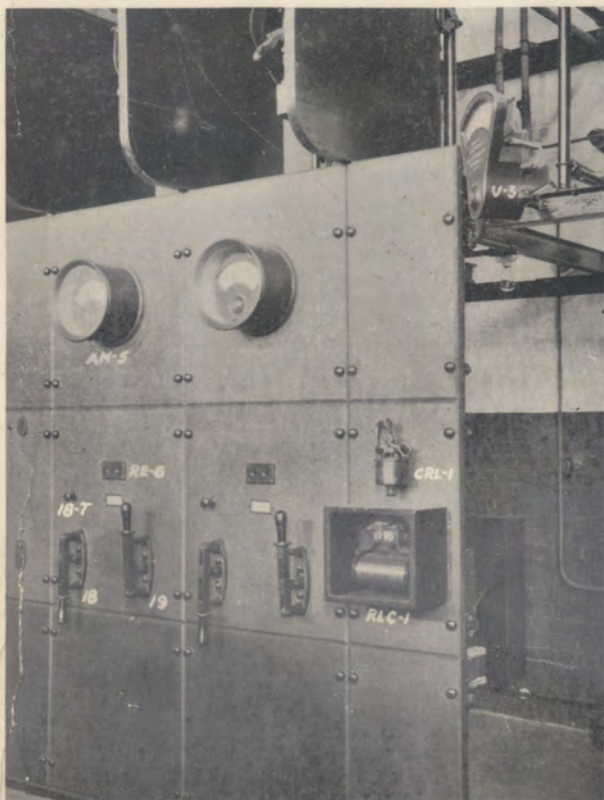


PLATE XXII

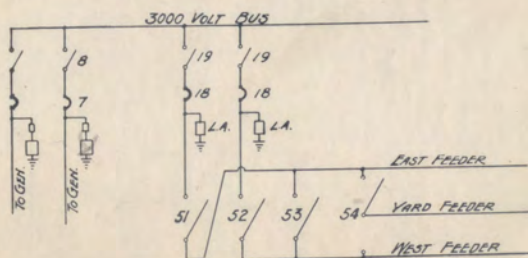


DIAGRAM 5 FEEDERS. ROCKY MOUNTAIN AND MISSOULA DIVISIONS

3000 Volt Feeders. The feeder and the trolley lines are connected together by taps spaced approximately 1000 feet apart. The east and west lines are sectionalized in front of or near each substation by an air gap, being connected together only by the switches at the substation. The trolley wires over the yard tracks are separated from the main lines and are also controlled from the substation.

The trolley feeders are connected to the substation bus first thru a set of disconnecting switches No. 51 to No. 55 and then thru the circuit breakers and the disconnecting switches on the feeder panels. The first set of disconnecting switches allows for various possible connections. For example, the east and west feeders and yard trolleys may be tied together without connection to the station bus, or both main feeders may be connected to one station feeder panel. Connection made by these switches can be determined by a study of the wiring diagrams and of the switches themselves. Normally the east and west feeders are not connected together by the switches, but are fed separately thru their individual panels. The yard trolleys are connected to either the east or west feeder.

On the Rocky Mt. and Missoula Divs. switches No. 51 to No. 55 are located inside the building on the wall back of the main board. They are of ordinary disconnecting type and cannot be opened under load. (See Plate XX).

On the Coast Division the corresponding switches are mounted outside of the building and are of the air-break type so that they can be opened under load. In case of serious trouble on the main switchboard, the trolleys and feeders may be disconnected from the substation circuits by these switches. (See Plate XXIII).

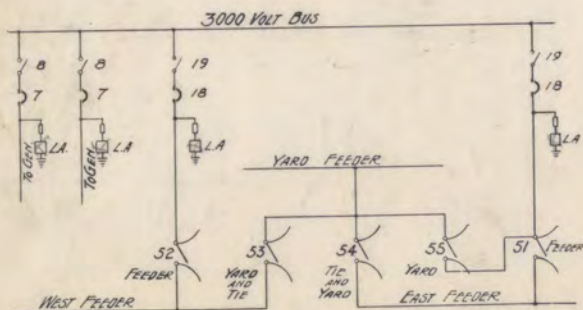


DIAGRAM 6. FEEDERS COAST DIVISION. (EXCEPT RENTON)

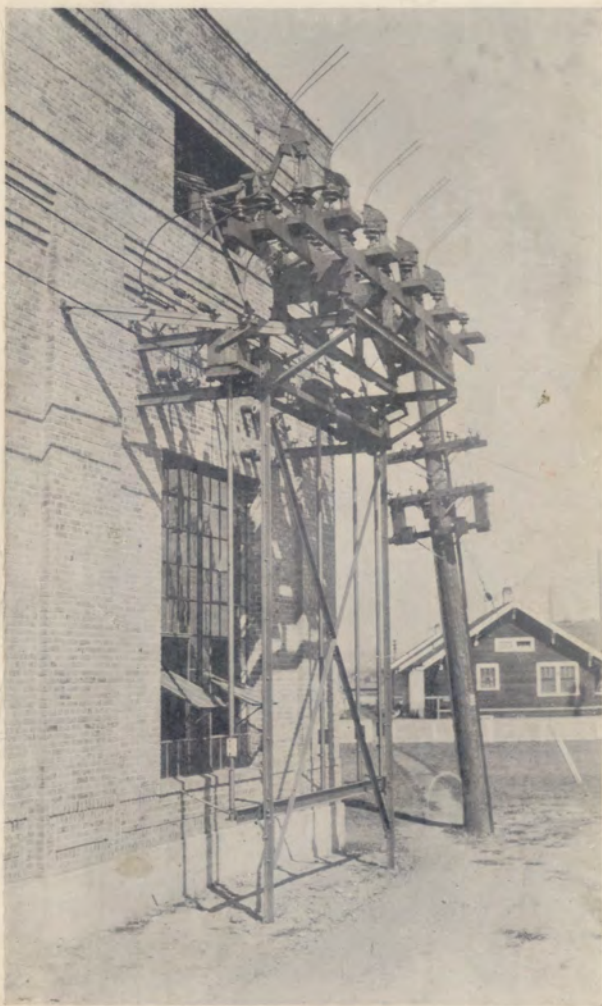


PLATE XXIII

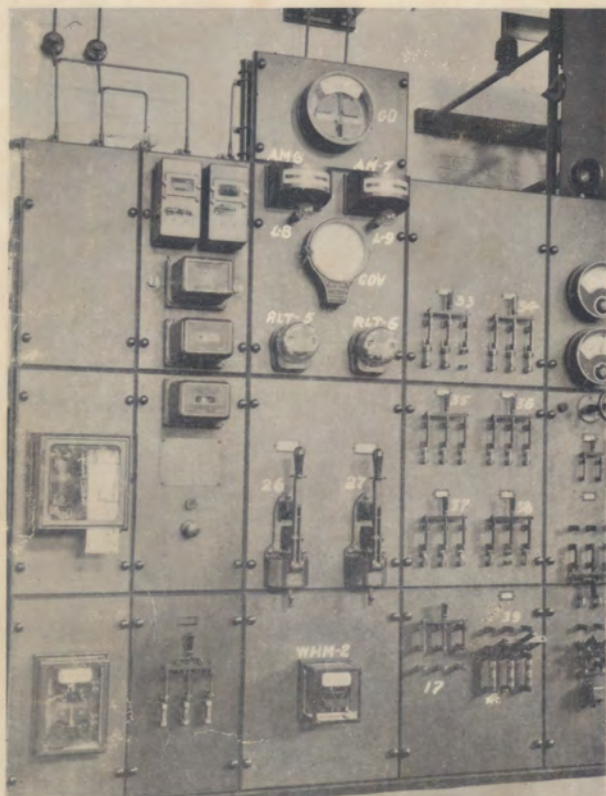


PLATE XXIV

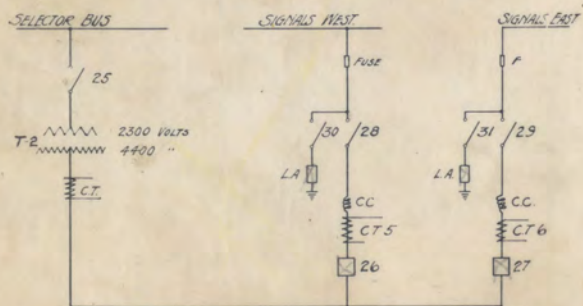
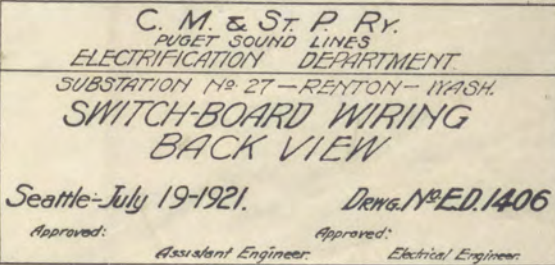
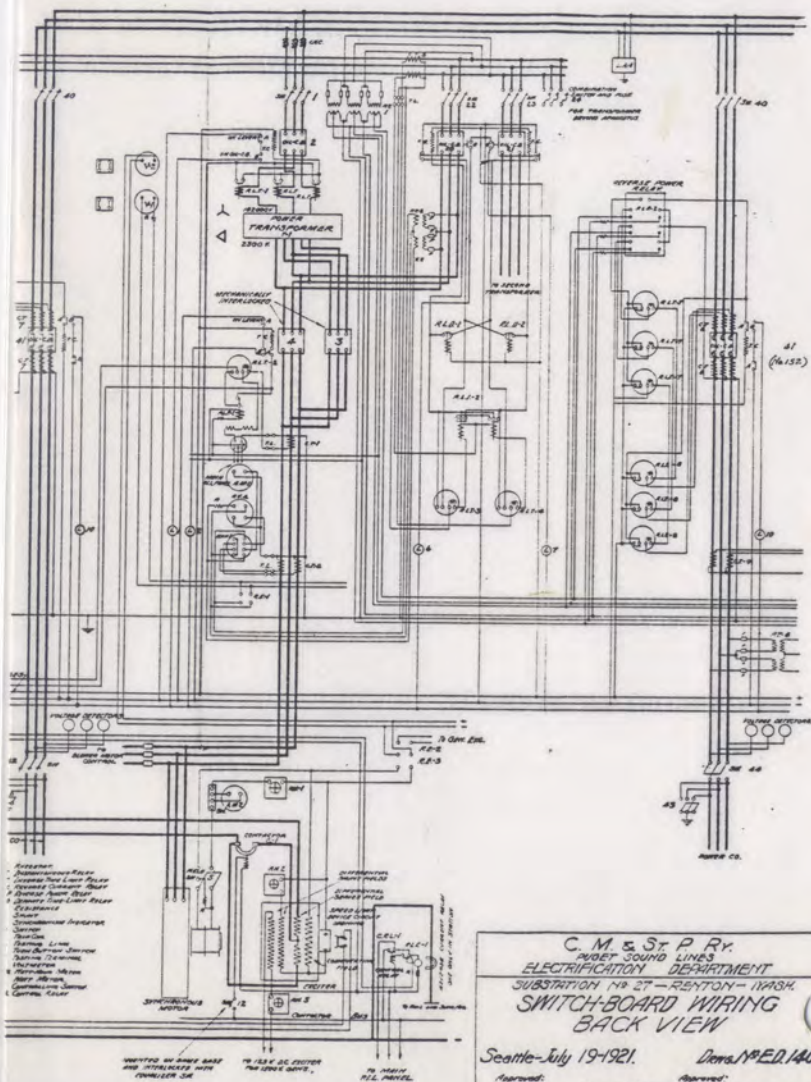


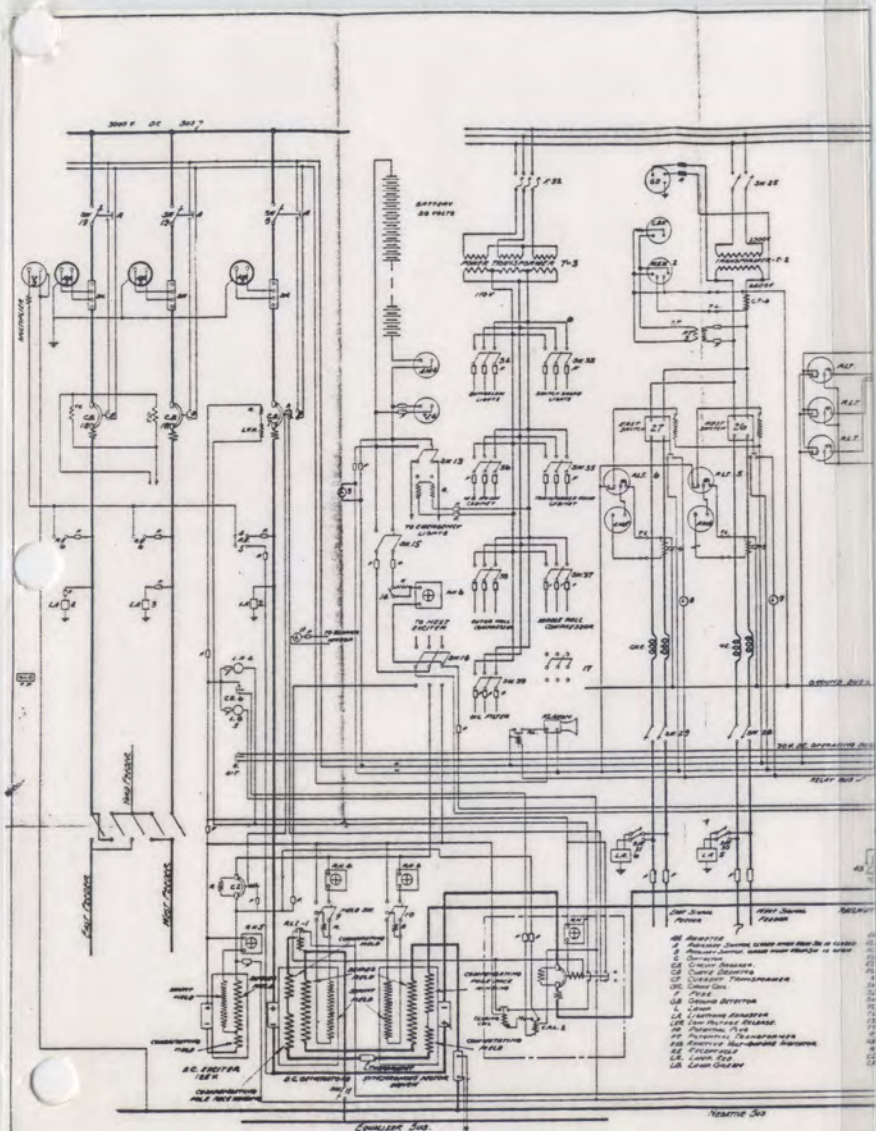
DIAGRAM 7 SIGNAL PANEL







C. M. & ST. P. RY.
 PORT SOUND LINES
 ELECTRIFICATION DEPARTMENT
 SUBSTATION NO. 27 - RENTON - WASH.
 SWITCH-BOARD WIRING
 BACK VIEW
 Seattle-July 19-1921. Drawn M.E.D. 1406
 Approved: Assistant Engineer Electrical Engineer



Equine Soc.

Negative 300