Holding Down Load Peaks on the St. Paul

By Automatic and Manual Means a Load Factor of Nearly 60 Per Cent Is Obtained—Load-Totalizing Instruments Play an Important Part

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THE power limiting and indicating system constitutes one of the many novel features developed and installed as part of the original equipment furnished by the General Electric Company to the Chicago, Milwaukee & St. Paul Railroad for the electrification of its Rocky Mountain and Missoula Divisions. The railway desired to obtain an equipment which, with heavy trains comparatively few in number, would give the highest load factor consistent with good railroading. The Montana Power Company, which furnishes power to this section of the railroad, desired to prevent excessive peaks, which might cause serious voltage variations which would require the installation of excess-generating apparatus to take care of the railway load. The power company desired also to obtain means by which the total power supplied to the railway transmission line at a number of points could be accurately recorded at one place and on one meter and to obtain proper peak-load data upon which to base the price of power.

The apparatus described below was built, installed and tried out on the 220-mile Rocky Mountain Division before similar equipment was supplied to the 220-mile Missoula Division.

The equipment for the Rocky Mountain Division as first inst as based on metering the power at the five feed-in points. It was later changed to meter the power at the low-tension side of the motor-generator set step-down transformers in each substation, in order that the high-tension transmission line of the railway company might be employed for emergency power transfer, by the power company. This was not necessary on the Missoula Division, with but two feed-in points.*

NINE FUNCTIONS OF THE CONTROL EQUIPMENT

All of the indicating and recording apparatus for both divisions is installed in the dispatcher's office at Deer Lodge, Mont., the center of the 440-mile electrification. The complete system comprises the distinct functions of limiting the maximum power demand at the will of the train dispatcher and of indicating and recording the total net power. The combination of these two functions accomplishes the following results:

1. Independent of the number of feed-in points, it indicates to the train dispatcher at all times the total net amount of energy being delivered to his division and it makes a permanent record for future study and as a basis for power bills.

2. It automatically deducts regenerated power if returned to the power company's lines or transfer of power from one line to another over the railway company's transmission line.

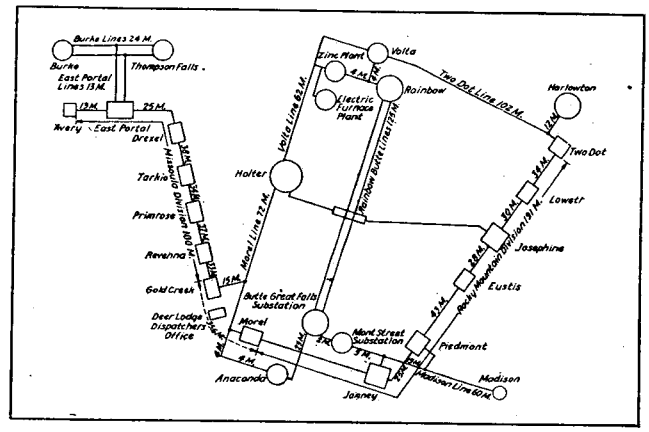
3. It automatically limits the amount of power supplied to the division by lowering the trolley voltage and slowing down the trains so that the maximum peak load on the system cannot exceed a certain predetermined maximum.

4. Its maximum limit can be changed instantly, easily, accurately and directly by the dispatcher without the necessity of notifying substation operators.

5. It is capable of reducing the peak-power demand by 30 per cent.

6. If desired, the equipment can be adjusted so that the lightly loaded substations will not be affected, thereby providing the highest possible voltage for the operation of passenger trains.

7. If desired, the equipment can be adjusted to reduce the voltage on the most heavily loaded substations at the time of peak demand (above the maximum limit)



CONNECTION DIAGRAM FOR ST. PAUL ELECTRIFICATION, ROCKY MOUNTAIN AND MISSOULA DIVISIONS

Showing connections of the 100,000-volt system of the Montana Power Co. and transmission lines of the railroad, with location of the 3,000-volt direct-current railway substations.

slightly in advance of the other stations, thereby tending to equalize the load on all the stations.

8. If an excessive demand for power occurs near any one substation the voltage of that substation is automatically lowered without affecting the voltage of the other substations, dividing the load between the substation affected and the stations on either side.

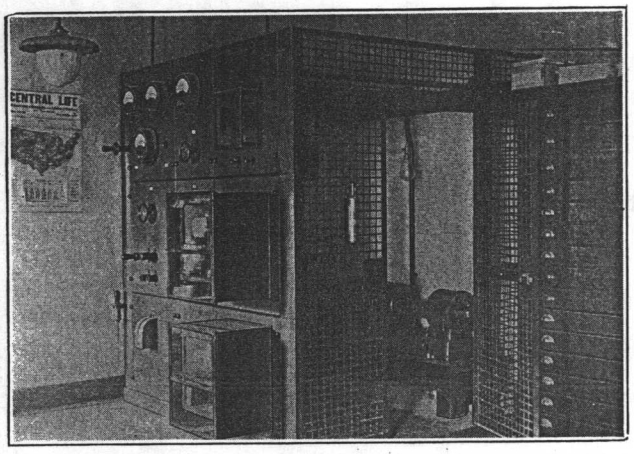
9. The total power fed in at any point or transferred from one power line to another or the amount returned due to regeneration can be easily taken care of by a change in the ratio of the current transformers or by an adjustment of the wattmeter rheostats.

CONTROL CIRCUIT A GIANT OHM-METER

The system is essentially an ohm-meter on a large scale, consisting of a two-wire pilot circuit, extending the length of the division, connecting in series all of the substations and the train dispatcher's office, with contact-making wattmeters and suitable rheostats at the incoming power points, and contact-making ammeters, with voltage-lowering generator rheostats in each substation.

*A brief reference to this system will be found in the abstract of the 1920 report of the committee on electricity of the American Railway Engineering Association in the issue of this paper for April 3, page 695.

A constant source of direct-current potential is applied across the two ends of the pilot wire loop at the dispatcher's office, power being obtained from a 2-kw. 1,200-volt direct-current motor-generator set, the voltage of which is held constant by a standard voltage regulator. The voltage applied to the pilot wire is determined by the length of the division, the resistance of



DISPATCHER'S OFFICE AT DEER LODGE, SHOWING POWER LIMITING AND INDICATING EQUIPMENT

the pilot wire, the number of substations and the power feed-in points.

The indicating and limiting feature is obtained by inserting or removing a certain number of ohms of resistance for a definite change in the kilowatt demand, which causes a definite decrease or increase in the current flowing in the circuit when a constant voltage is held across the pilot wire.

The contact-making wattmeter resistances and the pilot-wire contact-making ammeters are connected in series with the pilot wire, as shown in an accompanying diagram.

The apparatus is designed to hold certain definite peak limits in 2,000-kw. steps from 10,000 to 25,000 kw. as indicated.

The power-indicating apparatus in the dispatcher's office consists of a 2-kw. motor-generator set, a milliammeter calibrated in kilowatts, a curve-drawing ammeter, also calibrated in kilowatts; a curve drawing voltmeter, to give a permanent record of the pilot-wire voltage, and suitable indicating instruments and switchboard to control the motor-generator set.

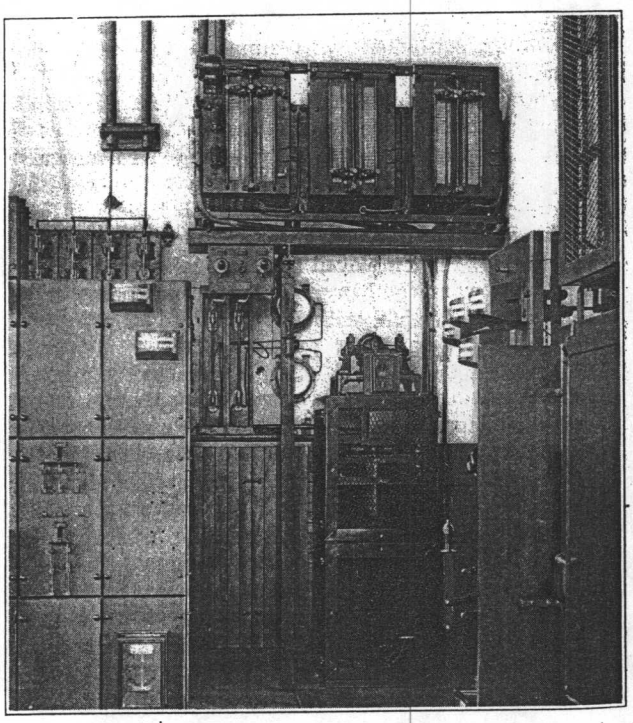
Due to the simplicity of the indicating wattmeters, two of these have been installed for each division, one on the switchboard and the other in front of the trick train dispatcher. With this arrangement the dispatcher can tell at a glance the exact amount of power being taken in his division at any instant, and also can watch the power demand resulting from his orders to the train crews in charge of trains ascending or descending the mountain grade.

Variation in resistance of the pilot wire due to change in temperature is taken care of in the dispatcher's office by a rheostat which can be easily inserted and the total resistance adjusted to 2,000 ohms (the approximate resistance of the pilot-wire loop and the coils of the contact-making ammeters), by holding 1,200 volts and adjusting the rheostat for 0.6 amp.

The contact-making wattmeter equipment consists of a contact-making wattmeter built along standard meter lines, with an indicating pointer equipped with contacts and moving between the two stationary contacts. The spiral spring of the pointer is connected to the shaft of the pilot-wire rheostat located immediately above the wattmeter. This shaft is driven by the motor-driven clutch mechanism at the top of the supporting framework. When contact is made on one side, due to an increase in incoming power, the circuit is completed through the clutch coils, causing the rheostat gearing to engage and inserting a certain amount of resistance in the pilot wire. At the same time the wattmeter spring is wound up due to the movement of the shaft. This action continues until the torque of the wattmeter is offset by the torque of the spring, when a balance is obtained and the clutch circuit is interrupted, thereby causing the rheostat to come to a standstill. This operation is continued for any increase or decrease in the incoming power.

How the Peaks Are Held Down

The power-limiting scheme in connection with the indicating equipment consists of a contact-making ammeter for each substation, with its coil connected in series with the pilot-wire circuit, so that when the current in the pilot wire decreases to a certain predetermined point contact is made and resistance is inserted in the exciter circuits supplying excitation to the separately excited direct-current generators by means of a motor-operated rheostat. The rheostats have sufficient resistance to lower the substation voltage to a minimum of 2,100. When contact is made by the contact-making



POWER LIMITING AND INDICATING EQUIPMENT INSTALLED IN JANNEY SUBSTATION, SHOWING PLUG-SWITCH PANEL

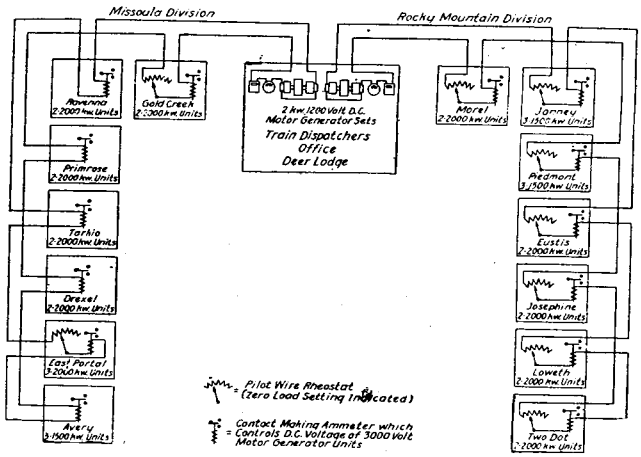
ammeter the voltage of the substation is decreased, and the resulting slowing down of the trains reduces the total input of the substation to a value below the predetermined peak setting. When the total load becomes less than the peak setting the contact-making ammeter will make contact on the other side and bring the voltage of the substation back to normal. A secondary current coil forms part of the contact-making ammeter and is

energized with current from a direct-current shunt in the ground or negative side of the 3,000-volt substation, so that the heavily loaded substations have their voltage decreased slightly before those with lighter loads.

If the total alternating-current input is beyond that covered by the power contract, or limit determined by the train dispatcher, the voltage of all of the substations will be decreased until the total input reaches the amount decided upon.

An overload and an underload relay are also connected across the current shunt. The latter is calibrated to make contact at about one-half load on a substation, so that the limiting equipment is inoperative until the load is greater than this amount. The overload relay is set to take control of the motor-operated rheostats at three times load and prevents the load going above this amount by lowering the voltage independently of the power-limiting equipment which transfers some of the load to the substations on either side.

If the power demand should be greater than the peak limit while a locomotive is regenerating through a sub-



CONNECTION DIAGRAM FOR THE PILOT-WIRE CIRCUIT AND LOCATION OF CONTACT-MAKING WATTMETERS

station the reverse-current relay in each substation (primarily used to give correct field connections of the synchronous motor exciters) is also arranged to open one of the control circuits so that the voltage-lowering rheostats are inoperative. With this arrangement the potential is held constant at 3,000 volts. If the voltage should be below normal, due to operation of the power-limiting equipment, and regeneration should occur, the voltage is automatically brought back to 3,000 and held at this value.

The maximum kilowatt peak limit, or kilowatt setting, can be changed at any time by the train dispatcher to take care of unusual congestion or other requirements.

Due to the necessity of reducing the pilot-wire current to the same value, the kilowatt totalizing meters, which are ammeters calibrated in kilowatts, must record correctly the total kilowatts, although finally carrying the same amperes. This is accomplished by gearing the several rheostats together with a common rheostat handwheel. This changes the voltage through the regulator by definite steps and also changes, at the same time, by definite increments the resistance across the coils of the two kilowatt meters, thus altering the current required to give any definite scale indication in the ratio of the change made at the same time in the pilot-wire voltage. By this means the current at which the contact-making ammeter makes contact can be made to represent 10,000 kw., 12,000 kw., etc., up to 20,000 kw., by simply turning the rheostat handwheel to definite points plainly marked, correctly connecting the three different circuits.

Load Factor Is Now Practically 60 Per Cent

The lowering of the trolley voltage in the substation is accomplished slowly enough, by proper speed of the motor-operated field rheostat, so as not to affect the operation objectionably, the only result being a gradual slowing down of the trains.

Additional power limiting is also obtained by instructing the freight engineers to drop back to series connection of the locomotive motors if very low trolley voltage is indicated by the voltmeters in each locomotive cab.

The peak limit was set at 14,000 kw. for the Rocky Mountain Division on April 1, 1919, and operation has been very satisfactory on this basis. The average load factor from April to September, 1919, inclusive, was 56.8 per cent.

The railway pays 0.536 cent per kilowatt-hour for 60 per cent of the peak, irrespective of whether this amount is actually used or not. The load factor maintained is so nearly 60 per cent that the increase in cost of power, or the cost of power not used, is very slight. With increase in the number of trains the load factor will be raised and no difficulty should be experienced in holding a load factor of 60 per cent or better. If the power-limiting feature is removed peaks as great as 21,000 kw. to 22,000 kw. would result.

One of the great indirect benefits obtained is the valuable assistance the indicating equipment gives the train dispatcher in dispatching trains in such a manner as not to give excessive peaks, and thereby lower the voltage due to the power-limiting equipment. By careful train dispatching, so that one train is ascending the mountain grade while another train is descending, it is possible to assist the automatic equipment in maintaining a good load factor very materially and greatly to increase the efficiency of the general operation of the railroad.

In the development of the apparatus described above great credit is due E. S. Johnson, J. R. Craighead, J. B. Taylor and E. J. Thiele for valuable suggestions, improvements and assistance in working out the details of the great number of new and untried features.

Kansas City Railway Installs Its Own Printing Plant

THE Kansas City (Mo.) Railways has installed a complete composition, printing and binding plant which is adequate to supply all of the company's printing needs except tickets and transfers. It is installed in a modern fireproof building with high ceilings and natural light and occupies 3,400 sq.ft. of floor space. The composing room is equipped with all sizes and faces of type and the necessary type cases, form stones, etc. The equipment of the press room includes a 35 x 47-in. bed Whitlock cylinder press for printing the weekly and monthly editions of the *Railwayan* and other large forms, a 12 x 18-in. Gordon press having a Miller automatic feeder and a 10 x 15-in. Gordon press for small forms. There is also a semi-automatic power paper cutter. The bindery is equipped with a wire stitching machine, a punching machine and a folding machine.