4.03.1

Of Interest to Electric Locomotive Enginemen and Power Substation Operators
Rocky Mountain and Coast Divisions

We realize that most of the enginemen and substation operators are familiar with the comments on electric operation which follow herewith, but a discussion of the subject will do no harm as we will have a lot of traffic to handle with electric locomotives, and we all want to do the best job possible with the equipment we have to work with.

The electrification system on the Rocky Mountain and Coast Divisions is known as a 3000 volt direct current system, as this is the designation of the electric power normally fed to the trolley system at substations. Most of the substations now supply power at from 3100 to 3300 volts for locomotives while motoring and steps are being taken to increase this voltage at most stations to 3400 volts. This will also give higher voltage at the locomotives, and higher voltage means more horse power. With higher voltage the locomotives will not pull any more cars, but they will move cars at a higher rate of speed than they will with low voltage. In some cases, voltage at substations is reduced for locomotives handling heavy trains in regeneration. In this way the speed of the train is reduced, high voltage at the locomotive is eliminated, and better operation of locomotives and trains is obtained.

Even though the voltage at the substations is 3000 volts or more for locomotives while motoring, voltage at the locomotive will be less than 3000 volts. The difference between voltage at the locomotive and voltage at the substation, for instance 3000 volts at the substation and 2400 volts at the locomotive, is called "Line Drop" and indicates loss in the trolley system to transmit power from the substations to the locomotives. "Line Drop" is a tax imposed by the line for transmitting power. The voltage at the substation and the voltage at the locomotive can be compared to the money you earn and the figures shown on your check. The tax deduction accounts for the difference.

The resistance of the combined trolley and rail circuit at the midpoint between substations, and with the power being fed from both substations, as for instance, between Gold Creek and Morel, is about .6 of one ohm. Since voltage drop is the product of resistance multiplied by the current, voltage drop at Deer Lodge will be 100 x .60 or 60 volts for each 100 amperes taken from the trolley wire at that location. For 1000 amperes, the drop would be 600 volts.

The current required to pull a train depends on grade, tonnage, and train speed. For example, take a two unit EF-4 locomotive and a 5500 ton train, eastward leaving Deer Lodge. In the first motor combination each unit will draw about 250 amperes, or 500 for both units, line drop 300 volts, and trolley voltage about 2700. In the second motor combination, each unit will have two circuits with each circuit drawing 250 amperes, and the total current will then be 1000 amperes, the voltage drop 600, and the trolley voltage 2400. In the third motor combination, or full parallel, each unit will have four circuits, the total current will be 2000 amperes, the voltage drop 1200, and trolley voltage 1800. If other locomotives are taking power in the same section, voltage will be still further reduced.

In case of low voltage at the locomotive due to line drop, there is nothing the substation can do to improve the situation at the locomotive, but there are several things the locomotive engineer can do to help both the substation and locomotive equipment, and at the same time may even be able to improve his train speed.

Substations:-

At substations 100,000 volt, 60 cycle, alternating current is stepped down by transformers to 2300 volts, alternating current. Electric power at this voltage is used to drive a synchronous motor, with two direct current generators mounted on the same shaft with the motor - one on either side of the motor. Each generator can furnish direct current at 1500 volts (more or less) and both generators are connected in series to give 3000 volts. The positive lead is carried through a switch and circuit breaker to the trolley feeder, and the negative is connected to the rail or return circuit.

With a locomotive motoring, current flows from the positive bus in the substations, through the feeder and trolley wires, through the pantograph and traction motors and back to the negative side of the substation generators through the track rails and negative return circuit.

With a locomotive regenerating, power flows from the locomotive to other locomotives which are motoring, or back to the substations, driving the DC generators as motors, causing the synchronous motor to operate as a generator and forcing power back through the transformers to the 100,000 volt transmission line, and in which case the substation KWH meters are reversed and the Railroad is thus given credit for the regenerated power.

Since there is at all times one or two substations at the other end of the trolley system, and also in many cases, one or more electric locomotives, defective equipment or rough handling of one locomotive will often cause tripouts or flashovers at the substations or on other locomotives.

Substations have generating equipment with capacity as follows:

Stations	No. of Motor Generator Sets	Continuous Capacity - KW Each Set	Continuous Capacity - KW Station	Two Hour Capacity Each Set	Two Hour Capacity Station	Station Current Capacity (Amperes) Continuous	Station Current Capacity (Amperes) 2-Hour
Two Dot	2	2000	4000	3000	6000	1334	2000
Loweth	2	2000	4000	3000	6000	1334	2000
Francis	2	2000	4000	3000	6000	1334	2000
Eustis	2	2000	4000	3000	6000	1334	2000
Piedmont	3	1500	4500	2250	6750	1500	2250
Janney	3	1500	4500	2250	6750	1500	2250
Morel	2	2000	4000	3000	6000	1334	2000
Gold Creek	2	2000	4000	3000	6000	1334	2000
Ravenna	2	2000	4000	3000	6000	1334	2000
Primrose	2	2000	4000	3000	6000	1334	2000
Tarkio	2	2000	4000	3000	6000	1334	2000
Drexel	2	2000	4000	3000	6000	1334	2000
East Portal	3	2000	6000	3000	6000	2000	3000
Avery	3	1500	4500	2250	6750	1500	2250
Taunton	2	2000	4000	3000	6000	1334	2000
Doris	2	2000	4000	3000	6000	1334	2000
Kittitas	2	2000	4000	3000	6000	1334	2000
Cle Elum	1	2000	2000	3000	3000	667	1000
Hyak	2	2000	4000	3000	6000	1334	2000
Cedar Falls	2	2000	4000	3000	6000	1334	2000
Renton	2	2000	4000	3000	6000	1334	2000
Tacoma Jct.	1	2000	2000	3000	3000	667	1000

Note - 1 KW = 1.34 H.P.

The substation operators are instructed to take necessary steps to protect their generating and switching equipment. When locomotives are closely spaced or so handled as to cause an overload on their generators, the substation operator reduces voltage. This reduction in voltage results in a decrease in current being taken from that station. If the current again builds up to overload values, the substation operator must make further reduction in voltage. The following example will show what effect overload and voltage reduction has on substation capacity and train operation.

Assume that a freight train with a two unit EF-4 locomotive is to follow train No. 15 out of Harlowton. Since there is a twelve-mile stub end feed from Two Dot to Harlowton, all of the power for both trains must be furnished by Two Dot. Two Dot can furnish 2000 amperes at 3400 volts, for two hours, but can not furnish more than 2000 amperes under any normal conditions for any sustained period. 2000 amperes at 3400 volts equals 6500 KW or 8600 H.P.

Train No. 15 will require about 750 amperes, leaving 1250 amperes for other locomotives. The engineer on the freight train at Harlowton is going to get out of town in a hurry, so he goes into full parallel as quickly as possible, or perhaps into second combination, and shunts the motor fields. In either case his locomotive will draw a total of 1500 amperes or more. Now, since the resistance of the distribution system between Two Dot and Harlowton is 1 ohm, he will have line drop of 1500 volts. The 1500 amperes his locomotive takes, added to the 750 amperes for train No. 15, gives Two Dot 2250 amperes, so that the substation operator must reduce voltage. The overload caused by the freight locomotive at Harlowton still persists, so the substation makes another reduction in voltage, and finds that when substation voltage is reduced to 2000, current will not be more than 2000 amperes. So far everything is fine, except that the freight train at Harlowton is practically stalled and train No. 15 is operating at about half speed. The total output of Two Dot substation now is 2000 amperes at 2000 volts = 4000 KW or 5380 HP instead of 8600 HP, and the reduction was caused by the over ambitious engineer on the freight train at Harlowton.

What could the engineer on the freight train at Harlowton do to avoid the condition described above? He could start his train slowly, as he will find out that is the only way he can start it under the conditions described above. He can run in second combination, full field, keeping locomotive current at a reasonable value, allowing train No. 15 to operate at maximum speed and get out of his way, and allowing the substation operator at Two Dot to put out 8600 HP instead of 5380 HP or less.

The above is only one example of many with which you are no doubt familiar. The following suggestions will indicate how the best operation can be obtained in handling heavy trains with the electrification system which we now have.

1. Operate your locomotive carefully, and make changes in current gradually, keeping in mind that another locomotive or a substation may have to take the rap for your rough handling, or that power may be cut off altogether.

2. Where another train is involved, give the passenger train or a train ascending a grade the preference. There is only so much power to be had, and if the fellow with the big locomotive hogs the power, the substation will have to do the voltage reducing act and both trains will get nowhere, fast.

3. From your cab ammeters and your motor combination and controller position, figure out how much current is being drawn by your locomotive, and estimate how much is being drawn by other locomotives near you. If both trains are near a substation, that substation will have nearly the total load of both locomotives, and may have to reduce voltage. To avoid this, back off to a lower motor combination, reducing total current to your locomotive, allowing line voltage to rise and permitting both trains to move at reasonable speed.

4. Do not use shunt field position except when required by instructions or necessity, or when you have good line voltage. Use of shunt field position greatly increases motor and total locomotive current, increases line drop, and may cause substation to reduce voltage or to trip out. In many cases you will get more H.P. output from your locomotive, and therefore the best possible train speed, in some full field running position.

We will have our own instruction car in electrified territory in the near future and will go into the matter of electric and diesel-electric operation and other matters incident to railroad operation in which you may be interested. In the meantime, send us any questions you have to ask, and we will furnish you an answer or explanation.

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