Research on Rail Potential While Many Trains Are Starting at the Same Time

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Abstract: The value of traction current affects rail potential. In real life, if many trains start at the same time, the traction current may increase, and so is the rail potential. The excessive rail potential would seriously threaten people's lives. The paper states briefly that many trains start at the same time will increase the traction current and the rail potential, and it is verified by the Matlab/simulink model and the field test data. Lastly, an optimization measure of traction current based on locomotive schedule is proposed to reduce the rain potential.

1 UNTRODUCTION

The rapid development of urban rail transit brings a lot of convenience to people. However, some new problems such as stray current corrosion and high orbital potential were on the way. Once the rail potential is too high, people will have electric shock hazard. Therefore, the reason of studying orbital potential, which proposes the inhibitory measures of orbital potential is particularly important.

Research shows the magnitude of locomotive traction current can affects the height of orbital potential. With larger locomotive traction current comes higher orbital potential (YANG Gang, 2010). In real life, different execution mode of locomotives can affects the size of traction current. When the train is in an accelerated stated, absorbing current from the power grid. When multiple columns of locomotive starts at the same time, also causes the increase of traction current (WANG Jia, 2012).

2 UNDER CERTAIN CONDITION OF MULTIPLE LOCOMOTIVES START AT THE SAME TIME, THEORETICAL CALCULATION AND ANALYSIS OF TOTAL TRACTION CURRENT SIZE

Regard the time of the first locomotive left the departure station as zero hour, set the traction current which comes from the locomotive's parking time at each station are all zero seconds to i(t,0), where t is the running time. According to the actual situation, the duration of the locomotive's stay at each station can be adjusted (LI Guoxin, 2010). Assume the time range of the locomotive's adjustable action at the No.m station is $[a^m, b^m]$ seconds, the traction current for the first vehicle at this time can be expressed as

$$f_1(t,T) = i(t,T_1) \tag{1}$$

In this formula, $T_1 = [t_1^1, t_1^2, \ldots t_1^N]$ is the vector of the residence time of the first vehicle at each station. N is the total number of stations,I (t,T_1) is a function about time and locomotive traction current based I (t,0) on and T_1 . The Fixed D-value to i(t,0) can be made in accordance with the parking time per station at the time of the specific calculation. (Because the

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locomotive lighting, signal, door and other systems are still in working condition when parking, the traction current is not zero).

Set the departure interval to n seconds, the traction current of the P vehicle can be expressed as

$$f_p(t,T_p) = i(t - pn, T_p) \qquad (2)$$

Set the maximum number of locomotives running at the same time on the running route is P, these steps allow you to get the total current value of the whole line at any time.

$$f(t,T) = \sum_{p=1}^{P} f_p(t,T_p) \qquad (3)$$

As the locomotive quickened its advance, it absorbs electricity from the grid. Therefore, $f_p(t,T_p) > 0$. According to formula (3), when there are multiple locomotives increase the speed of start-up at the same time on the line, the total traction current will be increased (M. Brenna, A. Dolara,S. Leva, D, 2010).

3 MATLAB/SIMULINK SIMULATION ANALYSIS AND FIELD RECORD DATA WAVEFORM VERIFICATION

This article selects the “Rail-Exhaust network-Groung-Buried metal” model that is closest to the actual. Separately in One-way Feeding style and Two-way Feeding style, making simulation analysis to the model, used to study the effects to rail potential under a certain state when multiple locomotives increase the speed of start-up at the same time.

(1) “Rail-Exhaust network-Groung-Buried metal” equivalent circuit when in the One-way Feeding style as shown in the figure 1:

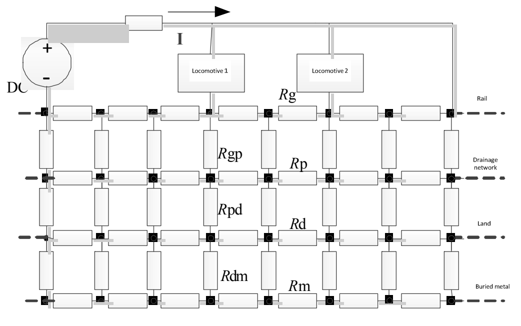

Figure 1: Equivalent circuit under unilateral power supply.

Combining with the actual situation, setting simulation parameters: Set the 3 substation spacing to a power supply range, then establish a power supply range.

Take part of the parameter to a specific value: DC=750V, Rail longitudinal resistance=0.03 $\Omega \cdot \text{km}$, Earth longitudinal resistance=0.001 $\Omega \cdot \text{km}$, Exhaust network=0.001 $\Omega \cdot \text{km}$, Buried metal longitudinal resistance=0.005 $\Omega \cdot \text{km}$, Transition resistance between track and exhaust network=15 $\Omega \cdot \text{km}$, Transition resistance between the exhaust network and the earth=3 $\Omega \cdot \text{km}$, Transition resistance between the earth and buried metal=3 $\Omega \cdot \text{km}$.

Replace the the locomotive with the controlled current source, refer to relevant information (M. Brenna, A. Dolara,S. Leva, D, 2010), set the absorbed current curve during locomotive operation, as shown in the figure 2:

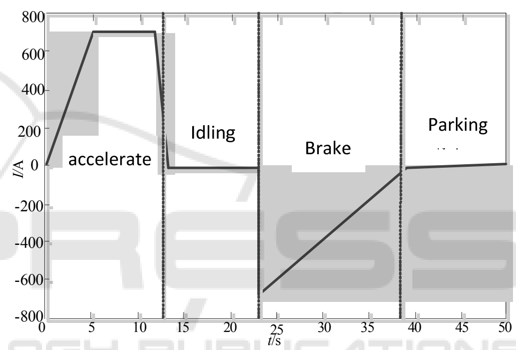

Figure 2: Diagram of the absorbed current by locomotive during running.

Because this paper mainly studies the influence of track potential when locomotive speed up startup, choose a simulation time of 0 to 25 seconds, to ensure that locomotives operate faster during this time period.

Regard the position of the substation is 0($L = 0\text{km}$). Locomotives begin to accelerate from $L = 0\text{km}$ at zero of the relative time, the locomotive starts to accelerate at a $L = 1.2\text{km}$ seconds later, mapping within the same coordinate system. When two locomotives are individually accelerated and simultaneously accelerated, a curve in which the orbital potential changes over time at a certain point of $L = 0.6\text{km}$ in the interval as shown in the following figure 3:

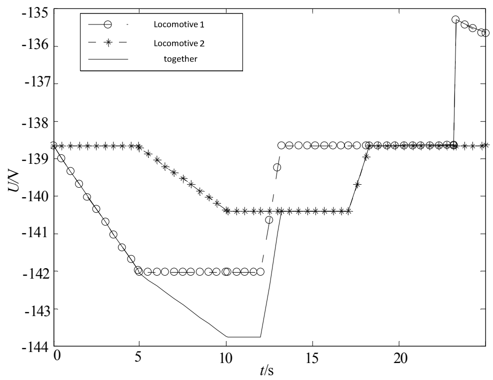

Figure 3: Diagram of the rail potential located at $L = 0.6\text{km}$ changing by time when two locomotives accelerate separately and simultaneously.

(2) Equivalent circuits in “Rail-Exhaust network-Groung-Buried metal” model under bilateral are shown in the figure 4:

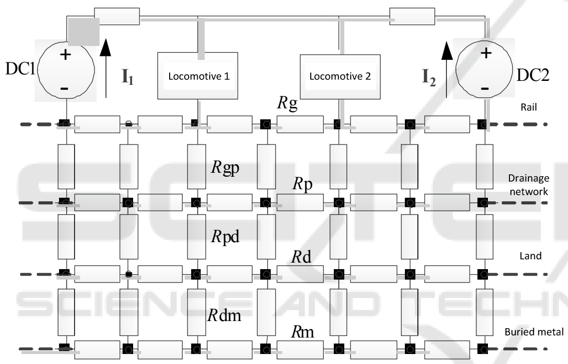

Figure 4: Equivalent circuit under bilateral power supply.

Parameter settings are the same as parameter settings under unilateral power supply mode.

Set the location of substation 1 is $L = 0\text{km}$. The first vehicle speed up from $L = 0\text{km}$ at the moment of relative time, the locomotive starts to accelerate at $L = 3.6\text{km}$ in 25 seconds. Mapping within the same coordinate system, when two locomotives are individually accelerated and simultaneously accelerated during operation, the change curve of orbital potential at a certain point of $L = 1.8\text{km}$ in the interval is shown in the figure 5 respectively:

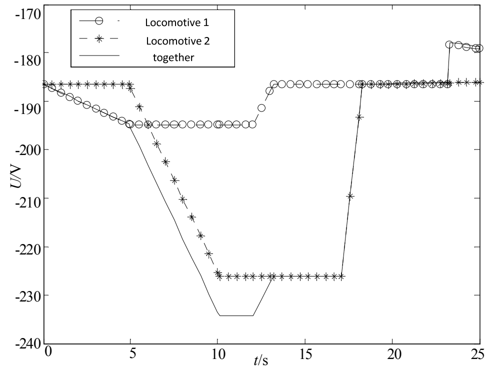

Figure 5: Diagram of the rail potential located at $L = 1.8\text{km}$ changing by time when two locomotives accelerate separately and simultaneously.

Comparing the above modes of power supply, it can be seen from the waveform diagram of the influence of locomotive startup acceleration operation on rail potential, when two locomotives accelerate operation at the same time, relative to the case of each locomotive running alone, the orbital potential will all increase, there’s just a difference in a value. Therefore we can conclude that the simultaneous start of the train will cause the traction current to increase, which causes an increase in orbital potential.

The following is a waveform based on the measured data in the field. In both cases, when a locomotive starts to accelerate operation and multiple locomotive start to accelerate operation at the same time, the curve of orbital potential changing with time at a certain point along the route is shown in the figure 6 and 7:

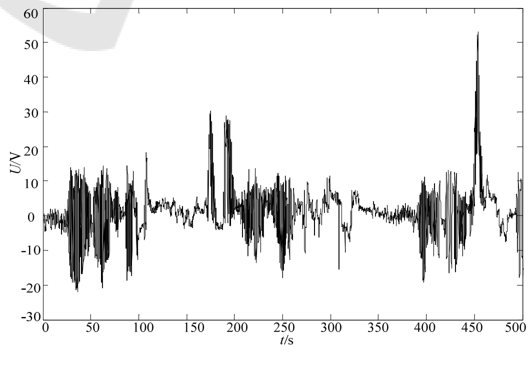

Figure 6: Diagram of the rail potential located at a point changing by time when one locomotive accelerate.

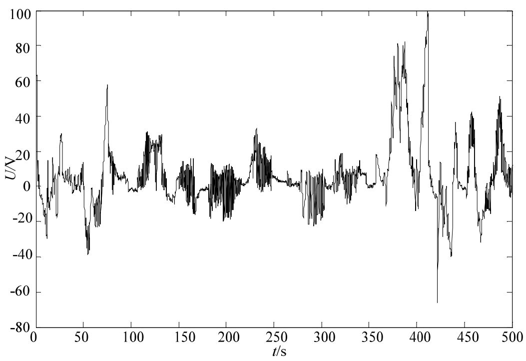

Figure 7: Diagram of the rail potential located at a point changing by time when several locomotive accelerate.

Comparing figures 6 and 7, we can see that the orbital potential increases when multiple locomotives accelerate operation at the same time, as opposed to a single locomotive starting the accelerated operation alone.

Therefore, in order to reduce the orbital potential, we can adjust the locomotive scheduling time, reducing the probability of simultaneous start-up operation of multiple locomotives, making some optimization of the traction current.

4 OPTIMIZATION OF TRACTION CURRENT BASED ON LOCOMOTIVE DISPATCHING

When the locomotive is running, the residence time of the locomotive at each station can be adjusted according to the allowable range. Therefore, the time of station stay along the route can be reasonably optimized to reduce the simultaneous start-up operation probability of multiple locomotives. According to the above ideas, traction current optimization based on locomotive dispatching can be realized by the following two methods:

1) Calculate the total value and take the minimum. For each set of locomotives can be achieved at each station residence time, Calculating the corresponding scheduling schedule separately, and using it as the final scheduling schedule. Due to the long running time of the locomotive throughout the day, the calculation of this method is too heavy, so it's not feasible.

2) Establishing the mathematical model of using locomotive residence time to reduce total traction current, solving the minimum values. At the same time, up to

$$P = \frac{M}{n} \tag{4}$$

Locomotives were running at the same time, in the above formula, M is the maximum time allowed for a locomotive from the point of departure to the end, and N is the fixed departure interval for locomotive dispatching. Also, from the beginning of the P-1 vehicle, a loop is formed at the NP time interval, so it is calculated only within the [N (P-1), N (P-1) +NP] time frame. Make the running schedule of the P vehicle, and the subsequent locomotives recycling uses this schedules.

The impact model used to reduce the total traction current by adjusting the residence time of each station can be expressed as:

$$\min_{T} \ \max_{t} \{f(t,T)\} \tag{5}$$

$$s.t. \quad n(P-1) \leqslant t \leqslant n(2P-1) \tag{6}$$

$$a^m \leqslant t_p^m \leqslant b^m \tag{7}$$

$$\sum_{m=1}^{M} t_p^m \le c \tag{8}$$

In formula (8), C is the maximum allowable time for stays along the locomotive, which is a nonlinear and extremely small problem. By calculation, the value of the minimum traction current can be solved.

5 CONCLUSION

Based on the actual situation, this paper establishes a "Rail-Exhaust network-Groung-Buried metal" four-layer model, and under the two power supply modes of unilateral power supply and bilateral power supply, the model is simulated and verified by the actual test data, and the results show that the rail potential is increased by the simultaneous start-up operation of multiple locomotives. By establishing the mathematical model of locomotive residence time to reduce the total traction current, it is a measure to reduce the rail potential by reasonably optimizing the station residence time along the locomotive.

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