Dynamic Brake Regulator And Protection System in Locomotive

F.Takbiri

Dr.S.Frashad

Iran university of Science and technology

Email: fa_takbiri@rail.iust.ac.ir

Abstract

In this paper, dynamic braking system of locomotive is simulated by ORCAD software. Locomotive dynamic braking is a system which is used to retard locomotive speed through the conversion of kinetic energy to electrical energy. This energy conversion is accomplished by connecting the traction motors as separately excited generators with field current being provided by the main generator. This system consists of two modules DR and DP. Excitation current to the motor fields is controlled by the braking lever position and by the dynamic braking regulator module DR. The dynamic brake protection module DP provides backup protection for the traction motor fields and the dynamic braking resistor grids in case a fault develops in the dynamic braking regulator module DR.

Key words: Dynamic braking system, Regulator, Traction motor, Resistor grid.

1. Introduction

Locomotive dynamic braking is a system which is used to retard locomotive speed through the conversion of kinetic energy to electrical energy. This energy conversion is accomplished by connecting the traction motors as separately excited generators with field current being provided by the main generator. The motor armatures are geared to the axels and rotate whenever the locomotive is moving. Loading is provided by connecting the traction motor armature circuits to dynamic braking grids. Armature current is determined by the speed at which the armature rotate and by the amounts of excitation applied to the motor fields.

With maximum field excitation braking effort increases from minimum at zero miles per hour to maximum at approximately 24 miles per hour. Maximum braking effort for the lower braking lever position is progressively lower and is attained at progressively higher track speed as the braking lever position is decreased. After maximum braking effort is attained, an increase in track speed results in a decrease in braking effort.

The amount of kinetic energy that is converted into electrical energy is proportional to RI^2 Where I is braking grid current and R is the effective resistance of the braking grids. The increase in braking effort from zero to maximum results from increased motor armature grid current as track speed increases. This results in an increase of RI^2 and consequently an increase in braking horsepower.

Excitation current to the motor fields is controlled by the braking lever position and by the dynamic braking regulator module DR. The DR module operates to limit the excitation current to a value that prevent armature or grid current from increasing above the maximum safe current carrying capacity of the braking grid. The dynamic brake protection module DP provides backup protection for the traction motor fields and the dynamic braking resistor grids in case a fault develops in the dynamic braking regulator module DR.

2. Dynamic brake protection

The motor field protection circuit, Fig 1, is connected across the main generator, in parallel with the traction motor field, during dynamic braking. Therefore the motor field protection circuit detects any changes in excitation voltage applied to the traction motor field.

During dynamic braking, zener diode Z8, in series with resistor R15 and R19, maintain 6.2 volts on the emitter of transistor Q5. Current flows from terminal 3 of DP module through the voltage divider consisting of resistor R19, R16, R17,R18

Q5 is reverse biased during normal operation. However, if a fault develops in the dynamic braking regulator module DR, the excitation voltage applied to the traction motor fields may tend to rise above a safe value. Transistor Q5 will become forward biased if the excitation voltage rises above a safe value. The collector of Q5 is connected, through R23, to the base of transistor Q6. Turn on of Q5 causes Q6 to be forward biased. Turn on of Q6 causes current to flow through the LED portion of opto-isolator O11. This increases the collector current of photosensitive transistor portion of O11. This collector current is applied to the base of transistor Q7, causing Q7 to be forward biased. Turn on of Q7 energizes the motor field protection relay MFP. Pickup of MFP drops the feed to the equipment protection relay EQP and recalibrates the motor field protection circuit by shorting out resistor R16. Pickup of MFP also provides a positive feed to the motor field announciator relay MFA and to the time delay circuit consisting of R21, R22, C5, and C6.

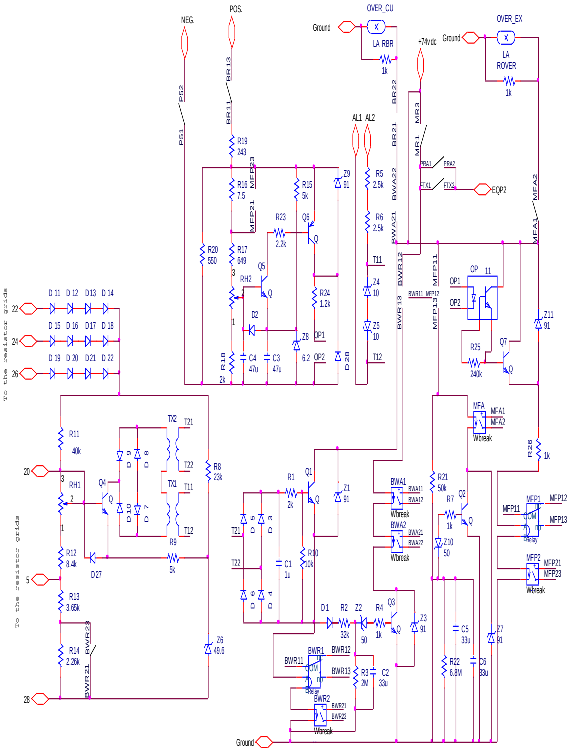

Fig1. DP module

Drop out EQP drops the feed to the generator field contactor GFC which removes excitation voltage from the main generator field and this decreases the main generator output voltage. The inductance of the main generator field windings prevents an immediate collapse of current through the field. The decrease in main generator output Voltage results in a reduction in the voltage applied to the base of Q5. This reduction in voltage causes Q5 to become reverse biased. Reverse bias on Q5 causes MFP to drop out. Dropout of MFP reestablishes the feed to EQP and results in reapplying excitation voltage to main generator field.

3. Dynamic brake regulator

Voltage signals proportional to current through grids with basic dynamic brakes, Fig 2, are applied to left port of circuit. The larger of these signals is applied between receptacles 1 and 13 of the DR module. The signal applied between terminal 13 and 1 is applied to a voltage divider consisting of rheostat RH1 and resistor R1, R2, R3, and R4. This same voltage is also applied to resistor R7 in series with zener diodes Z1 through Z9. The zener diodes provides a constant reference signal to the emitter of Q2.

A signal proportional to braking grid current is applied to the base of transistor Q1 by a voltage divider consisting of R5 and R6 connected between the wiper arm of RH1 and the emitter of Q2. When braking grid current rises above 600 amperes, the voltage at the wiper arm of RH1 is larger than the reference signal applied to the emitter of Q2. This causes current flow from the wiper arm of RH1 to the zener diodes. This current flow results in placing forward bias on Q1 and Q2. With forward bias on Q1 and Q2, current flows through the secondary winding of transformer T1-A and the primary winding of transformer T2-A, then from collector to emitter of Q1 and Q2. This current induces a voltage into the secondary T2-A. this voltage is rectified and applied to a voltage divider consisting of R8 and R9. Transistor Q3 is forward biased by the voltage developed across R9.

With forward bias on Q3, the braking lever signal is removed from the circuit of field. As a result, excitation to main generator field decreases. When braking grid current decreases below 600 amperes, the signal at wiper arm of RH1 decreases and place a reverse bias on Q1 and Q2.

4. Basic dynamic brakes with trainlined grid current control

Output voltage of companion alternator is applied to the primary of transformer T4 in series with brake current transductor BCT. When braking current is low, the reactance of BCT is high and the voltage applied to primary of T4 is low. As braking grid current increases, the output voltage of T4 is applied between terminal 9 and 11. A voltage which is proportional to the braking lever signal, as determined by the braking lever position, is applied to terminal 7 of DR module.

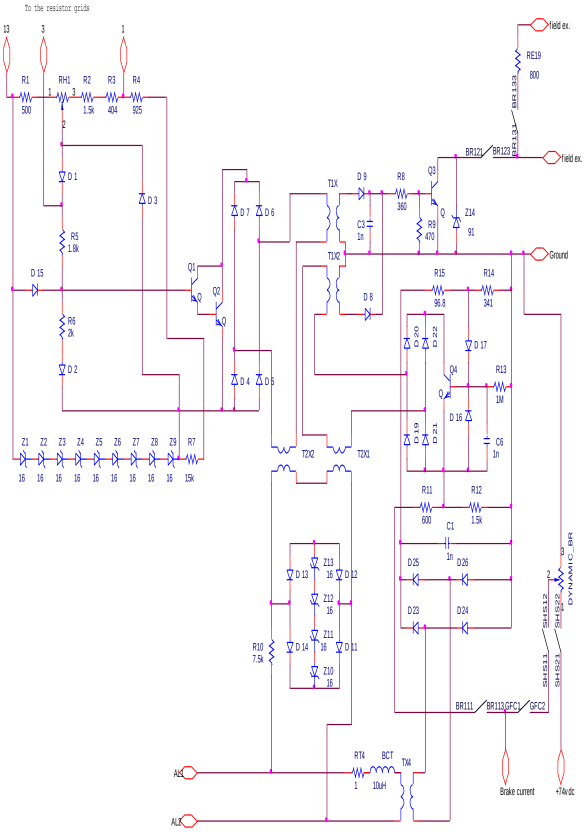

Fig2. DR module

Transistor Q4 compares the braking lever signal with the braking grid current signal. Q4 is forward biased if braking grid current increases above the braking lever signal. Turn on of Q4 provides a path for current flow through transformer T1-B secondary and T2-B primary. The output of T2-B is rectified and applied to a voltage divider consisting of R8 and R9. Forward bias on Q3 results in decreasing of excitation to the main generator field.

5. Simulation results

The simulation results applying voltage to the modules are shown in following figures:

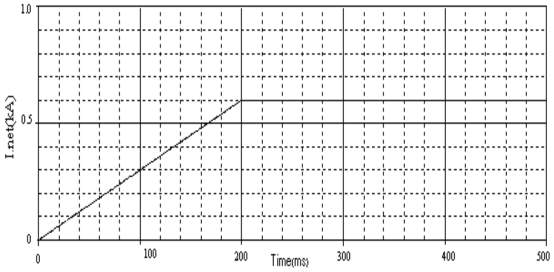

Fig3.resistor network current

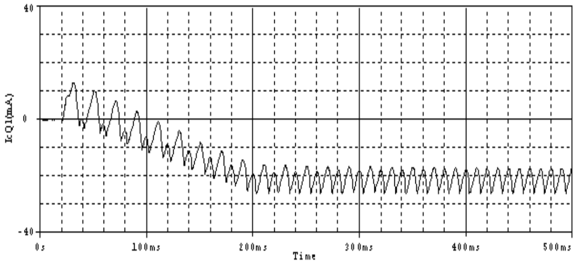

Fig4. Collector current of Q1

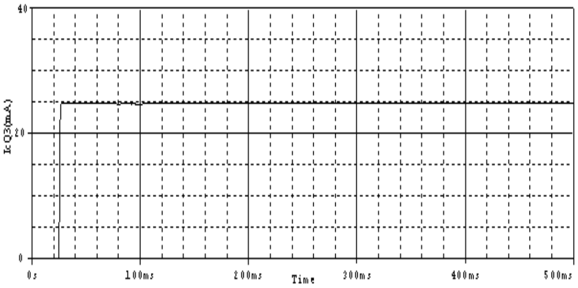

Fig5. Collector current of Q3

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