DESIGN STRATEGY AND NEW CONVERTER TOPOLOGY FOR THE RECOVERY OF KINETIC ENERGY ON RAILWAYS SYSTEMS,

The increasing concern with energy saving and efficiency has a clear application in the regenerative braking capacity common to most rolling-stock. This possibility crashes with the non-reversible characteristics of the substations of direct-current catenary-based rail systems. It is estimated that the amount of kinetic energy lost and unable to be reused represents approximately 30% of the traction energy.

We present the design strategy of a new converter topology based on the connection in cascade of a DC/DC elevator to a three-phase inverter and a particular application on a subway system. With this new topology, it is possible to maximize the total energy recovered as the system is freed from the limitations imposed by voltage fluctuations in the grid, allowing for energy recovery at minimum catenary voltages under any circumstances. At the same time, by using the existing transformer, the required investment and impact on the substation are minimized.

The solution presented proposes a cascade connection between an elevator chopper and an inverter. The chopper increases the existing voltage in the catenary by generating sufficient voltage for the inverter to return power to the distribution grid. This way, the catenary voltage margin with which the power recovery system is able to function is the maximum for any grid voltage situation, optimizing power recovery in all circumstances. The recovery system works connected to an already existing transformer in the substation.

The proposed solution minimizes the problems of the “zero sequence current” due when an inverter and a six-pulse rectifier are connected in parallel. This has been achieved by combining the effect of the converter´s topology, the integration of a coupled inductancy that means an impedancy for the “zero sequence current” current, and finally by optimizing the converter´s triggering.

Specific dimensioning.
The study, design and construction of the first prototype have been carried out for a particular subway system in Spain.
The prior study involved acquiring on-board real traction and braking-power profiles, as well as the velocity data of an Electrical Multiple Unit covering the round-trip distance through all the existing lines. The next step was to determine the characteristics of the equipment to be installed at each of the substations, the required power capacity and the resulting work cycles. For dimensioning purposes, we created a simulation tool capable of calculating the interaction between the different substations and the different trains linked to the same catenary. We created a model of the substations, as well as the catenary impedances. Using the data obtained from the real measurements taken of each unit, the program was able to successively calculate the evolution of the trains’ position, the evolution of the impedances in the catenary sections between the different components, and the resulting power flows for each instantaneous configuration.
The program was first validated by carrying out a simulation of the real installations and comparing the results obtained with real values. We then calculated the recoverable power profiles for each substation.
With the results obtained, we were able to determine the optimal current capacity values for a recovery system, as well as the thermal requirements derived from the resulting work cycle. With the limits assigned to each substation, the resulting savings were calculated with the possibility of estimating the amortization and viability of the system.

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