International Journal of Research
Available at https://pen2print.org/index.php/ijr/
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 23
December 2018

# Numerical Calculation of Electrical System of A Metro

Mehmet Sait Cengiz[1]
[1]Department of Technical Vocational School, Bitlis Eren University, 13000 Bitlis, Turkey

***Abstract**:*

*Nowadays, electric transport vehicles are needed in urban-intercity passenger and freight transportation. For this reason, power supply systems are installed in order to provide continuous, high quality and safe energy to railway vehicles. Transport activities are continued by providing energy to the electric train sets with conductive lines. Electric rail systems are safely operated by providing a continuous flow of energy due to the principle of providing uninterrupted energy to the vehicles, braking energy and ensuring the required voltage levels by means of conductive wires or rails. In this study, the re-arrangement of the metro transportation system as a subway was carried out.*

***Keywords***

*Electric rail systems, electric transport vehicles, metro, LRT, energy.*

## 1. Introduction

Transportation encompasses the movements of passengers and goods that are carried out in order to maintain the daily activities of the rapidly growing urban population globally [1-4]. The 50 million-level journey that takes place in cities in one day is about twenty times the number of trips between cities in a day by road, rail, sea and air. The increase in the global population, the rapid increase in the rate of urban population and the daily economic activities and the daily travel rates per person increase. Accordingly, the size of the urban transport sector is increasing rapidly while its scope is expanding, the length of journeys in urban areas, which are spreading more and more every day, increases and the pedestrian journey becomes a motor vehicle journey [5-9].

## 2. Rail Public Transport

The level reached by travel demands in large cities necessitates service by rail systems. In cities, the delay in the implementation of rail systems constitutes the basis of traffic problems in big cities. Urban railways, which have started to be constructed in recent years, will facilitate the solution of traffic problems.

Many problems arise during the development and implementation of new rail systems and development of existing rail public transportation systems in cities. Due to the fact that new rail systems have not been activated in the city for many years, the necessary experience and accumulation can be reached new. Due to the lack of close monitoring of rapidly developing technologies and lack of such technological applications in the cities, it causes a lack of information in countries with developing economy in urban rail systems [10-12].

The deficiencies in urban rail systems are not only in technical matters, but also in the uncertainty of the methods and procedures in the planning, projecting, construction and operation of rail systems, and in the financing of construction and operation [13-19].

Rail public transportation systems bring new advantages with increasing population and increasing urban traffic.

• The participation of new users is 30% to 50% of the rail system users, who prefer the rail system instead.

• Reduction of transport costs: The cost per passenger-kilometer decreases by 50% in most cases when compared with bus transportation. This reduces operating costs and subsidy costs.

• Security: The rail system is very safe for transportation. A train set is equivalent to 100-150 cars in traffic. Signal and automatic control / stop systems ensure safety.

• Reduction of pollution: There is no doubt that the harmful environmental impact of electric transport is almost negligible alongside road vehicles.

• Facility and infrastructure construction: Metros are underground, Light metros can travel above or below ground in all axes or channels. The stations are compact and functional. Thus it may be possible to connect to every point of the city.

• Real estate appraisal: Real estate prices increase in the vicinity of the station. With increasing value, quality services and products spread to various points of the city, new trade and settlement focuses occur.

## 3. Light Metro Systems

Light Metro System has an important place among city rail transportation systems. Systems with higher travel capacity than tram systems. Maximum travel capacities on the clock are 40.000 passengers/ direction. Although these systems are preferred as the main transportation systems in the transportation corridors where the travel demands are high, they can also be constructed as secondary transportation systems which work integrated with higher capacity systems in very crowded cities [20-21]. Light metro lines are safe systems with full isolation. They can be constructed as a level, viaduct or tunnel. Because the system is isolated, it allows for high commercial speeds. In light rail systems, the average commercial speed is 50-60 km/h and the maximum cruising speed is 90 km / h. Energy supply can be provided by catenary (conventional system), rigid catenary or bottom rail systems. Commonly, 750 $V_{DC}$ or 1500 $V_{DC}$ current is preferred. Figure 1 shows the light rail transport system [21-24].

**Figure 1. Light rail transportation system**

## 4. Example of Existing Metro System

In this study, a sample metro system was examined. Table 1 shows the features of the existing metro system.

Nowadays, metro systems, which are considered as transportation systems with the highest travel capacities among urban public transportation systems, are operated as the main public transportation system in many big cities of the world. [25-27]. In major cities, metro systems are preferred on the lines where the highest travel demands are determined. Metros, which are fully isolated rail transport systems, are generally constructed underground by deep tunnel methods to mitigate the traffic loads on the surface. Depending on the structure of the land, the tunnel lines that can be constructed as open and tunnel or drilling are sometimes built on the surface in the form of a level or on the viaduct. Commercial speed is higher in subway systems than in other systems, average commercial speed is 50-60 km/h. The maximum speed is 90 km/h. Metros are also referred to as the ”Heavy Rail System Met. As the travel volumes are high, all facilities are built accordingly. Energy supply can be made from overhead feed lines in the form of catenary or rigid catenary, as well as light rail systems, as well as from the bottom feeding systems installed in the form of 3.ray. A voltage of 750-1500-3000 $V_{DC}$ can also be used. Figure 2 shows the Metro transportation system [28-31].

**Figure 2. Metro transportation system**

A 10-km-long metro bus line runs with 10 stops. If this line is to be built as a metro, all lines and stations will be taken under the ground with the acceptance of the constant slope of the line and the rail system will comply with the rail system standards. Accordingly, the number of stops will also change [32-34]. The alternative features of this subway system are shown in Table 1.

| **Route Features** | |
|---|---|
| Route length ***S (km)*** | 10 |
| Average slope imi ***(s%)*** | 0% |
| **Business Terms** | |
| Average train speed ***V (km/h)*** | 50 |
| Train range ***t (minute)*** | 2 |
| Passenger Load ***k (passenger/vehicle)*** | 300 |

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 23
December 2018

| | |
|---|---|
| Number of vehicles in the train ***D*** | 10 |
| The curb weight of the wagon is ***G (Ton)*** | 20 |
| The loaded weight of the wagon is ***G (Ton)*** | 24+(300×70×0,001)=45 |
| Load weight of the train set ***G (Ton)*** | 10×45=450 |

The work is shown in Equation 1.

$$A_{kgm} = 1000 \times Z_{kg} \times S_{km} \quad (1)$$

The average power produced per second is shown in Equation 2.

$$P_{(kgm/s)} = 1000 \times Z \times S = 1000 \times Z \times V \quad (2)$$

$$P_{(ps)} = 1000/75 \times Z \times V$$

$$P_{(ps)} = (1000 / (3600x75)) \times Z \times V = Z \times V / 270$$

The power of the movable vehicle η and the power of the moving vehicle is shown in Equation 3.

$$P_{(ps)} = (Z \times V / 270) .\eta \quad (3)$$

If 1 kW = 1.36 ps, the value in kW is shown in Equation 4.

$$N = (Z \times V) /(270x1.36 )x\ \eta \quad (4)$$

If the average yield in rail systems is accepted as 0.75, the power obtained is shown in Equation 5.

$$N = Z \times V / 275 \quad (5)$$

The relation between Z cer power and the total weight G of the operated train is shown in Equation 6.

$$Z = W \times G \quad (6)$$

Here W is the sum of the friction forces. If the investigated road is at the slope of% s, the power of the train operated with V velocity in G weight can generally be written as in Equation 7.

$$N = [(W + s) \times G \times V] / 275 \quad (7)$$

W rail total strength (Friction) becomes N Equation 8.

$W = 2.5 + 0.0005 \times V^2$ is,

$$N = [(2,5 + (0.0005 \times V^2) + s) \times G \times V] / 275 \quad (8)$$

The train uses cooling, air conditioning, compressor, lighting and so on. If we add auxiliary internal forces, the total power becomes the same as seen in Equation 9.

$$N_{TOTAL} = [(2,5 + (0,0005 \times V^2) + s) \times G \times V] / 275 + N_{inner} \quad (9)$$

Arrival -Granding Time = 2 × S × 60 / V

Number of trains = Track time / Train range

Number of trains = 2 × S × (60 / V) × t = TS

The electrical power demand for the entire line is shown in Equation 10.

$$Q_{(kW)} = N_{TOTAL} \times TS \quad (10)$$

Calculating the power of the subway line created as an alternative to this route;

The power to be towed by the 10-set train;

$$N = [(2.5 + (0.0005 \times V^2) + s) \times G_t \times V)] / 275$$

$$N = [(2.5 + 0,0005 \times 50^2 +0) \times 450 \times 50] / 275$$

N = 306.81 kW

The total power required for the train set is about 30.681 kW for each vehicle as internal power:

$N_{TOTAL}$ = 306.81+30.681 = 337.5 kW

The duration of the course is;
2 × 10 × (60/50) = 24 min.

Number of train: 24 / 2 = 12 train set

Energy required for the entire line:

Q = 12 × 337.5 = 4050 kW

In addition, if the overcurrent currents drawn at 10% take off are added, a total of 4.445 MW will be generated.

## 5. Conclusion

This study describes the design of an existing rail system as a subway line with a different view to the academic scientists working in rail systems and the engineers who make application work. The main aim here is to determine the electrical load in engineering applications. In the study, a metrobus line was designed in terms of electricity demand in accordance with the metro system.

## 6. References

[1] Ocak, İ., Metro Tüneli Kazılarında, Kazı Hızı, Tasınan ve Konverjansa Kayaç Özelliklerinin Etkisi Üzerine İstatistiksel Bir Yaklaşım, *Doktora Tezi, Osmangazi Üniversitesi Fen Bilimleri Enstitüsü,* Eskişehir, (2004).

[2] İETT, http ://www.iett.gov.tr/section.php?sid=39#, (2005).

[3] Acar, I. H., Kent İçi Trafik Sorunlarının Hafifletilmesinde Güncel Yöntemler ve Talep Yönetimi", *4. Toplu Taşıma Kongresi,* Ankara, (1994).

[4] Kancabaş, E. S., 'Urban Transportation Planning Applications in Developed and Developing Countries and Analysis of Transportation System in Ankara on The Basis of Rail Transit, *Yüksek Lisans Tezi, ODTÜ Fen Bilimleri Enstitüsü,* Ankara, (1998).

[5] Cengiz Ç., Yapıcı İ., Cengiz MS. 2018. Fourier Analysis in Rail Systems, *International Conference on Multidisciplinary Science, Engineering and Technology (IMESET'18 Dubai)* Oct 25-27, 2018, Dubai. BAE.

[6] Cengiz MS., Yapıcı İ. 2018. Mathematical Design of Bipolar Rail Systems, *International Engineering and Natural Sciences Conference (IENSC 2018),* Nov. 2018

[7] Yapıcı İ., Cengiz MS. 2018. Rail Transport Systems, *International Engineering and Natural Sciences Conference (IENSC 2018),* Nov. 2018

[8] Yapıcı İ., Cengiz MS. 2018. Mathematical Analysis of Voltage Drop In Single Ended Feeding In Rail Systems, *International Engineering and Natural Sciences Conference (IENSC 2018),* Nov. 2018

[9] G. Poetsch, J. Evans , R. Meısınger , W. Kortüm , W. Baldauf, A.Veıtl ve J. Wallaschek 1997. Pantograph/Catenary Dynamics and Control, *Vehicle System dynamics,* 28:2-3, 159-195.

[10] Kölük E., 2005 Demiryollarının Ülkemizde ve Dünyadaki Gelişimi, *TCDD Eğitim Merkezi yayınlanmamış ders notları,* Ankara

[11] [Erdelikara Ü., Raylı Sistem Bilgisi, TCDD Eğitim Merkezi.

[12] İnce N., Raylı Sistem Bilgisi, TCDD Eğitim Merkezi.

[13] Levinson, 2003, H.S., Zimmerman, S., Clinger, J., Gast, J., Rutherford, S. and Bruhn, E., Bus rapid transit, Vol 2: 233, *Implementation Guidelines, TCRP (Transit Cooperative Research Program) Report 90.*

[14] Betts, A. I., Homes, R. ve Hall, J. H 1987. Defining and Measuring the Quality of Current Collection on Overhead Electrified Railways9+. *I.E.E. Conference 'Electric Railway for a New Century.*

[15] Ambrósio J., Pombo J., Facchinetti A., Bruni S., Massat J.-P. ve Dupuis H., 2010. Key parameters for pantograph/catenary numerical models, *PantoTRAIN Technical Report D1.1, UNIFE,Brussels*, Belgium

[16] Ambrósio J., Pombo J., Pereira M., Antunes P. ve Mósca A., 2012. "Recent developments in pantograph-catenary interaction modelling and analysis", International Journal of Railway Technology,1, 1, 249-278

[17] Ambrósio J., Pombo J., Rauter F. ve Pereira M., 2008." A memory based communication in the co-simulation of multibody and finite element codes for pantograph-catenary interaction simulation", *[In:] Multibody Dynamics,* C.L. Bottasso (Ed.), Springer, Dordrecht, the Netherlands

[18] Collina A. ve Bruni S., 2002. Numerical simulation of pantograph-overhead equipment interaction, *Vehicle System Dynamics,* 38, 4, 261-291

[19] Collina A., Lo Conte A. ve Carnevale M., 2009. "Effect of collector deformable modes in pantograph-catenary dynamic interaction, Proceedings of the Institution of Mechanical Engineers, Part F, *Journal of Rail and Rapid Transit,* 223, 1, 1-14

[20] EN50317 standard, 2012. Railway applications– Current collection systems–Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line, *CENELEC European Committee for Electrotechnical Standardization, Brussels,* Belgium

[21] EN50367 standard, 2006. Railway applications – Current collection systems – Technical criteria for the interaction between pantograph and overhead line, *CENELEC European Committee for Electrotechnical Standardization, Brussels,* Belgium

[22] Poetsch G., Evans J., Maisinger R., Kort¨um W., Baldauf W., Veitl A. and Wallaschek J., 1997. Pantograph/catenary interaction and control, *Vehicle Systems Dynamics*, 28, 159-195

[23] Seo J.-H., Sugiyama H. ve Shabana A., 2005. Three-dimensional deformation analysis of the multibody pantograph/catenary systems, *Nonlinear Dynamics,* 42, 199-215

[24] Öncü E., 1978, Kentsel ulaşımda raylı sistemler, *1. Toplu Taşım Kongresi, Ankara Büyükşehir Belediyesi EGO Genel Müdürlüğü,* sayfa 298-326

[25] J. Ambrosio, J. Pombo ve M. Pereira,2013. "Optimization of high-speed railway pantographs for improving pantograph-catenary contact, *Theoret_cal &Appl_ed Mechan_cs Letters* 3, 013006

[26] Özdirim M., 1990, Ulaşım konusunda yerel yönetimlerin uygulamaları, *3. Toplu Taşım Kongresi, Ankara Büyükşehir Belediyesi EGO Genel Müdürlüğü,* 101-140

[27] Toprak, R. ve Aktürk, N., 2001, Raylı toplu taşım sistemleri ve raylı toplu taşım sistemlerinde güvenliği tehdit eden tehlikeler, *3. Ulaşım ve Trafik Kongresi Sergisi*

*Bildiriler Kitabı, Makina Mühendisleri Odası*, sayfa 280, 99-108

[28] S. H. Kia, F. Bartolini, A. M. Mabwe. ve R. Ceschi, 2011. Real-Time Simulationof Pantograph-Catenary Interaction, *37th Annual Conference on IEEEIndustrial Electronics Society* IECON, pp. 258-264.

[29] Kumar, P., Bierlaire, M., Gallay, O., Generalized Algorithms for Crew Planning: Survey and Future Directions for Railways, *10th Swiss Transport Research Conference*, Ascona, Switzerland, 1-3, September, 2010.

[30] Suyabatmaz, A.Ç. ve Şahin, G., Railway Crew Capacity Planning Problem with Connectivity of Schedules, *Transportation Research Part E: Logistics and Transportation Review*, 84, 88-100, 2015.

[31] Kohl N. ve Karisch S. E., Airline Crew Rostering: Problem Types, *Modeling, and Optimization, Annals of Operations Research*, 127, 223-257, 2004.

[32] C. O'Donnell, R. Palacin ve J. Rosinski, 2006. Pantograph Damage And Wear Monitoring System, *The Institution of Engineering and Technology International Conference on Railway Condition Monitoring*, 178 – 181.

[33] A. Bobillot, J.P. Massat, ve J.P. Mentel, 2011. Design of Pantograph-Catenary Systems by Simulation, *9th World Congress on Railway Research (WCRR).*

[34] W. Wang, A. Dong ,G. Wu, G. Gao, L. Zhou, B. Wang, Y. Cui ,D. Liu,D. Li ve T. Li, 2011. "Study on Characterization of Electrical Contact Between Pantograph and Catenary," Electrical Contacts (Holm), 2011 *IEEE 57th Holm Conference on*, pp. 1-6.