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Improving the Quality of Power in Tehran Metro Line Two Using Ant Colony Algorithm

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ABSTRACT

In order to put Tehran on the road of sustainable development, it is essential to find a solution for dealing with air pollution. The use of public transport, especially metro is one of the options to achieve this goal. Since the highest share of pollutants in Tehran belongs to cars and mobile sources, relative statistical indicators are estimated through assuming the effect of metro lines development and subsequently reduction of traffic on power quality index. Hereupon, power quality in metro line 2 of Tehran is analyzed using the ant colony algorithm. In general, power quality is one of the most magnificent electrical systems issues. The power quality within the metro area is analyzed through various approaches and numerous studies within this context; which using predictor control is one of them. However, in this paper we put our efforts to study this issue by the ants' colony algorithm.

Keywords: *Improvement of power quality, Tehran metro line 2, ant colony algorithm, power quality index.*

I. INTRODUCTION

Today, establishing the subway lines in metropolises and big cities is one of the necessities of sustainable development of public transport systems. The effect of this means of transportation in urban traffic solutions and its significant place is clearly visible. In particular, remain unresolved traffic issues has negative effects such as increased environmental pollution, waste of valuable resources and above all, adverse effects on human health. Improvement of power quality means that power quality determines the proportion of electrical power delivered to the consumer equipment. Synchronization of frequency and voltage phase makes it possible for electricity network to have a favorable performance without significant loss of quality. Without an appropriate electrical power, perhaps the electrical equipment does not work properly or even does not work completely. There are several reasons and ways for the loss of electric power quality. Power industry includes power generation, transmission, and distribution to the final consumer. Electricity passes from the wires to feed the ultimate load. Electric power transmission from production to consumption depends on various parameters such as weather, production, demand, etc. which provide many opportunities for quality loss. Power quality depends more on the voltage rather than the power or flow. This research aims to survey the improvement of power quality in Tehran metro line 2 using ant colony algorithm and to investigate the all factors affecting the achievement of this goal.

1. Underground Rail Transportation System

In the last two decades, a remarkable growth in rail transport systems has occurred. So that the new century can be called the century of stunning surprises and important developments in rail transport. Now, the world's fastest passenger rail vehicles are made in France and Japan (Shiee,S. Omidi,M., 2015).

New rail lines in transport and fleet (vehicles and operating them) are important in terms of the dynamic interaction. Type and quality of rail lines play a significant role in this field. Rail lines range from various groups of low power, average power, high power and high power divided. Trains' power of movement is a decisive parameter from the aspect of mobility comfort of resisting forces and dynamic interaction of wheel and rail. In addition, it should be mentioned that any range of power requires its own necessities of control systems (Montazeri,M. Rahnavard, B., 2014).

1500s was the beginning of the trains' working. At first, the railways were made of wood and carriages were pulled by powerful horses. Steam trains were invented in the early 1800s. When Richard Trevithick moved the first locomotive powered by a steam engine on the steel rails, today trains' era began. This action was performed in 1804 and in South Wales but English George Stephenson was who played a critical role in changing the train to a public transport. He manufactured a pretty big train and equipped it with a locomotive with steam engine for the passengers inside (Niksirat, M. et al., 2012).

Heavy rail transit systems usually refer to the underground rail (metro) and airlines (Air Metro). In these lines, electric trains move on routes separated from other transport systems and carry high capacity of passengers in most hours of day. Subway stations have great length and height and electric energy consumption is usually supplied through the third rail. It should be mentioned that referring the term heavy to such line simply is because of the heavy capacity of carrying the passengers and does not relate to the properties of stations. Consultants, suburban transport system are constructed between urban rail transportation systems and residential and commercial centers (e.g. railroad of Tehran-Karaj); hence they are also called Metro Link Seifi, H. &Sepasian, M. S., 2011). Cars usually are two floors and their actuator system can be electric or diesel motors. In suburban lines, the distance between the stations is high (3 to 6 miles); therefore, the power of movement is more than urban rail systems and about 80 km/hr. The suburban trains are usually scheduled for peak commute hours.

Usually any rail transportation system using only one independent Rail is called Monorail. In this system, wagons move only by means of one rail. Commonly the rails are in height, but they also can be intersection or in the underpass (tunnel) (figure 1). The wagons can be hung from the rails or move on rails (Straddle). In terms of movement and control, monorail system is in the category of Automated Guideway Transit (AGT) Almasi, M. H. et al., 2016).

Fig. 1: Intersection monorail (Ibid)

Introduction to Tehran Metro Line 2

Tehran Metro line 2 is a completely urban line with 26 km length and 22 stations. This line starts from the Farhangsara located in Jashnvareh Street next to the FarhangsaraEshragh and is extended to Sadeghiyeh located in the southwest corner of the second square of Sadeghiyeh. This line in ShahidBagheri Station links to eastern extension of line 4, in Imam Hossein Station links to under construction line 6, in DarvazehShemiran links to line 4, in Imam Khomaini Station links to line 1, in Daneshgah-e Emam Ali Station to line 3, in ShahidNavabSafavi to under construction line 7, in Shademan intersects with line 4, and finally at the end of line and in Sadeghiyeh connects to line 5. With operation of line 2, the move time from East of Tehran to the West decreased to 40 minutes.

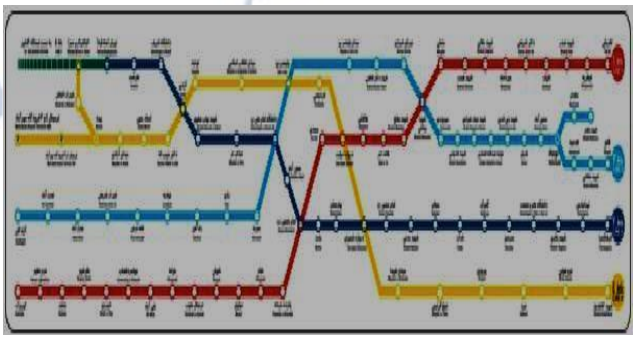

Fig. 2: Schematic map of the Tehran Metro (line 2 is marked with blue) (Ibid)

II. IMPROVEMENT OF POWER QUALITY

The quality of power is one of the most important issues of electric loads. In case that any noise in voltage, frequency, and current losses and damage the electrical equipment. (Dehini, R. &Sefiane, S. 2011). Retail markets must set the natural transmission of electricity (transmission and distribution) and other services that are contracted with the consumers in order to supply their demand. The subject is the improvement of power quality indexes, better voltage regulation and modification of power factor from the advantages of DGs usage which is not possible in central systems of production.

There isn't any voltage adjustment in the power systems because of the enhancement of the transmission power. There are also other parameters such as economic problems, biological problems which influence the structure of power network. There are many factors which affect the inclination of using smart networks. These factors are as the following: reduction of lines losses, enhancement of voltage profile, reducing the issuance of emissions, development of network security, enhancement of power quality, development of efficiency, increasing the security of the sensitive loads and enhancing the capacity of transmission and distribution system (Parpinelli, R. S. et al., 2015).

It is important to prepare some information about the consumers. The next aim is achieving to the powerful system which has high quality and reliability. One of the most important problems is supplying the quality which is accepted by the consumers (Song, Y. H. et al., 2014). Frequently, the following reasons are presented about the electronic quality discussion:

- Gradual development of general output of the power networks.
- The possibility of distortion the low quality
- The electronic devices are sensitive towards the electronic quality changes

In addition, customers are more aware about the problems which are related to the electronic quality than the past

Analysis Method

First, we should review the power equations to analyze the power quality in the train.

$$P_M = \frac{1}{2}\rho_{Air} V^3 \pi R^2 C_P(\lambda, \beta)$$

$$P_M = \omega_M T_M$$

$$C_P = \frac{P_M}{P_V}$$

$$\lambda = \frac{\omega_M R}{V}$$

Where P_m is the mechanical power of train, P_{air} is the air density, V is the wind power, ω_m is the power of rotation, β is the blade angle, T_M is the mechanical torque, and R is the radius of the turbine. Curve Power (CP) for a given peak power and also $\lambda = \frac{\omega mR}{V}$ are given by manufacturer. Note that CP should not exceed the upper limit theory (Parpinelli, R. S. et al., 2012).

$$C_P^{MAX} = 16/27 \cong 0.59$$

Introducing the Ant Colony Algorithm

Clone (mass) of ants, bees and/or all kind of social insects is a distributed system that despite the simplicity of each of them creates a highly structured social organization. For example, the ant colony sometimes can perform complex tasks which are beyond the capabilities of individual ants (Niu, D. et al. 2014). The subject of "ant colony" reviews the derived samples of the actual behavior of ants and uses these samples as a source of inspiration for the design of new algorithms (Dorigo, M. et al., 2013).

The algorithm was suggested by Marco Dorigo for solving the vendor issue with 75 cities in 1991 and called it ant system which was the prototype Ant Colony Algorithm. Dorigo indicated this algorithm with three features:

1. Versatility: same issues could be solved with the algorithm such as using the vendor symmetric algorithm (Dij = Dij) for solving vendor asymmetric issues (Dij ≠ Dij).
2. Capabilities: with modifying algorithm, other problems can be solved in Hybrid Optimization. The algorithm is not affected by parametric changes.
3. Population-based: allows the algorithm to have a positive feedback mechanism for finding correct answer rapidly. It also allows for parallel execution. In addition, it will prevent convergence and get caught in

the initial optimal solution due to the decentralized computing.

Ant Colony Algorithm developed and other models emerged such as AntNET, Ant-Q, MMAS, and ACS. The process of the algorithm is as follow:

1. Determine the initial value for pheromone function and innovative function
2. Insert the city of origin on the blacklist for each ant
3. Calculate the probability function to select the next town for each ant in each city
4. Modify urban populations for each course
5. Adding the selected city to blacklist for each ant
6. Determine the best route
7. Update

Functions and Elements of Ant Colony Algorithm

1) The function of pheromones

$$\Delta\tau_{ij}^{k}(t, t+1) = Q/d_{ij}$$

$$\Delta\tau_{ij}(t, t+1) = \sum_{k-1}^{m} \Delta\tau_{ij}^{k}(t, t+1)$$

In the first equation, the pheromones amount of *k-th* ant is calculated on *dij* and in second equation the total pheromone is calculated on the edge with the passage of *m* ants.

Routing algorithm based on ant colony

This algorithm shows the details of routing scheme for MANETS which includes route discovery and support mechanisms. The route discovery will be completed by reaching the pioneer ant and reverse links to the destination. This mechanism looks like the AODV algorithms. Routes primarily are kept by data packets. This means that if a path fails, temporarily creates a package and sends it to alternate links. Otherwise, it returns to the previous hop for simulation. If the package eventually returns to the origin, finding the new direction has been created sequentially.

Ant routing algorithm

The unofficial report of the Ant Net algorithm is stated as follow:

Each node in the grid keeps a record of destination package which passes through the node.

According to the information in the table, the first movement of pioneer ant makes a decision for next hop which wants to take the node. The pioneer ant collects all information about the nodes and time. In future, this information will be updated. The next move to reach the neighbor node is calculated by a simple formula:

$$D_{ij} + (q_{ij} + s_a)/ B_{ij}$$

For reaching the destination, the score of the trip is calculated and the pioneer ant becomes a secondary ant.

The secondary ant comes back through the captured path and uses the queue of the data packet. The secondary ant uses priority queues.

The simulation can be summarized as follow:

The topology shows the origin and then calculates the time delay. After confirming the ant algorithm on the current topology, the likelihood will be applied on routing tables, and it will recalculate the delay (Slimani, L.&Bouktir T., 2014). If the new delay was better, it will change the origin node for pioneer ant. Then it accepts the new solution due to the time of the process. The comparison between the delays indicates the best one. When T_{ant} is over but T_{simul} is not over yet, the new topology of the grid will be simulated based on mobile models of RWM and BSAM till the T_{simul}gets over.

Problems Optimization by Ant Colony

Ant colony optimization algorithm inspired from the behavior of natural ants. It is highly efficient in combinatorial optimization problems (Yu, B. et al., 2015). All other algorithms, which are based on Ant algorithm, are Multi-Agent Systems. Artificial ants act just like real ants. Ant algorithm is a good example of collective intelligence where agents with low capabilities work together and create very good results. This algorithm is useful to solve optimization problems.

- Studying the train movement behavior for the distance between two stations:

We want to study the power profile of a train movement for a route of Tehran subway line 2

In order to study we need route information which is as follows:

The start point of train movement in first station: x_{min}=200m

The endpoint of the route in second station: x_{max}=1450m

With respect to the information we have, line slope of the start and end of the route is 0 and in the

distance between start and end the slope is 0.03 percent.

The point that the slope changes after train starts movement: x_1=430m

The point that the slope becomes 0 before the train reaches to final station: x_2=1315m

With respect to the route information mentioned above, the train has 0 slope from the movement start point in x_{min}=200m to the first point that slope changes in x_1=430m, and from this point to the distance of x_2=1315m the slope is 0.03%, and from this point to the end of the route the slope is again 0 (slope 0 means that the train continues movement in a horizontal path).

Horizontal path that are at the start and end of the path shows the platforms in which the train reaches to passengers platforms.

The other information that we need to study the train power profile is the limitation of train movement power:

Power limitation from the start point to the point x=505m is equal to: v=65km/h

Power limitation from the point x= 505m to the point x=705m is equal to: v=50km/h

Power limitation from the point x=705m to the end of the path x_{max}=1450m is equal to: v=65km/h

The optimal time that the train passes the distance between these two stations is equal to 110 seconds.

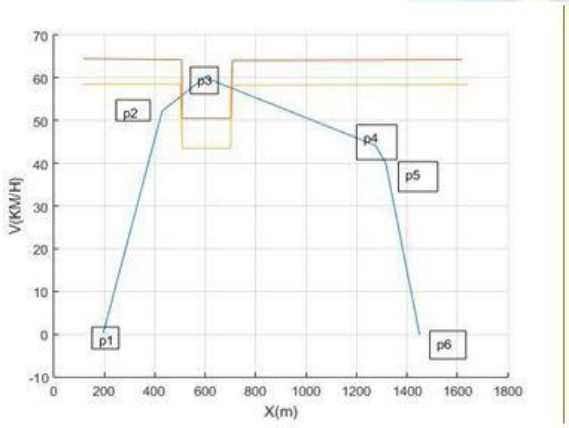

Fig. 3: Power profile for determined path with the first repetition with one variable.

In figure 3 p_1 shows the start moment of train movement which has the power 0. P_2 shows the point of the path slope change; it is apparent that the train power decreases after reaching to this point because it enters a steep path. P_3 is the path strategic point in which the train changes from acceleration state to neutral state. P_4 is the point that the train experiences the slope change again. In p_5 the train brakes while entering the station to stop in p_6 which shows the platforms.

The blue diagram is related to the train movement and the yellow diagram shows power limitation and it is obvious that in the first repetition using Imperialist Competitive algorithm the power limitation is not observed and the train power exceeds the allowed power, therefore we need the other operations of this program to observe the power range. With the second repetition the results in figure 4 is obtained for train power profile.

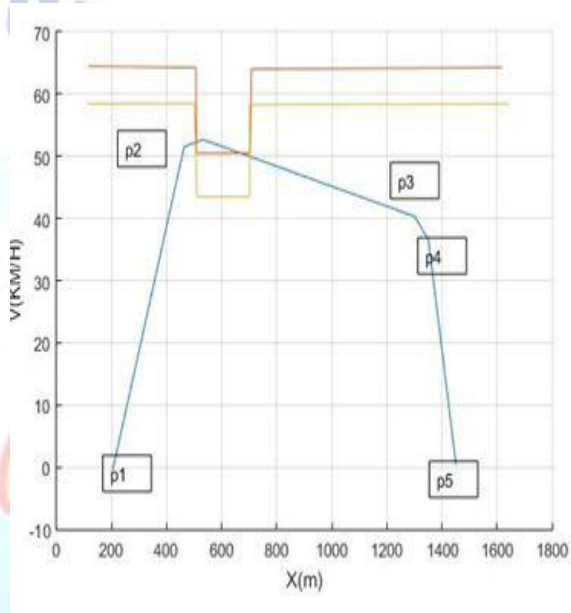

Fig. 4: Power profile after applying second repetition with one variable.

In figure 4 the profile of the train movement power is decreased and the total cost is decreased with this change, but again the power limitation condition is not observed in second repetition, therefore the program enters its third repetition.

Using the following relationship energy consumption for train movement is obtained:

The total energy consumption= the time of acceleration / required electrical power for acceleration.

Path Acclivity

The third path that we consider for train movement to obtain its power profile is an acclivity path. On the contrary to previous state when the train reaches to acclivity, its power is decreased. The specification of this path is as follows:

The point after commence of movement that the train experiences the acclivity. x_1=7000m

The point before reaching final station that the slope becomes 0: x_2=9000m

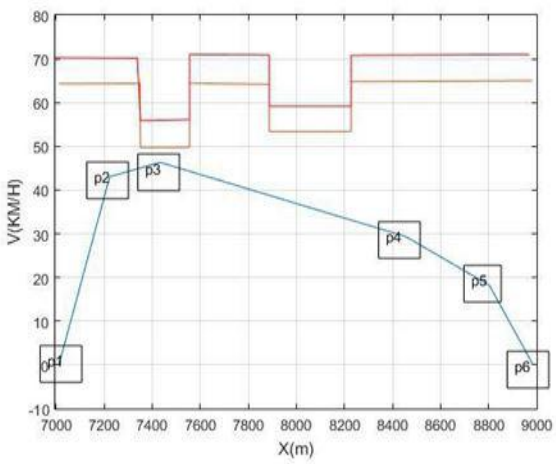

Fig. 5: Power profile for the third acclivity path with one variable

In figure 5 considering three variables power profile are obtained.

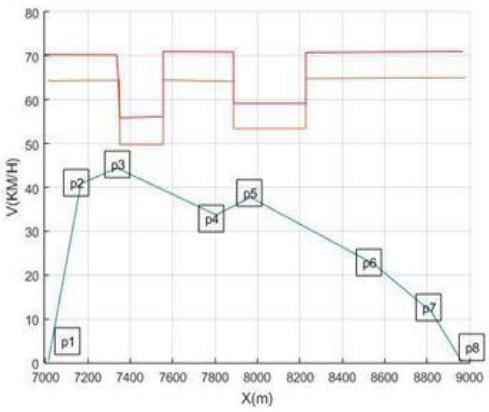

Fig. 6: Power profile for the third acclivity path with three variables.

III. CONCLUSION

In order to find an optimal power profile we have to look for points to modify strategy. Numerous points could be effective in regards of profile optimization. In other words, we study each path using different numbers of variables and finally we choose the highest response. In this article we used ant colony algorithm to compare thegathering results. To find in previous sentence means to determine numbers in allowed range for strategy change variables that optimize the power profile. In fact, we changed the train problem into a mathematical issue to find a minimum point in 'n' dimensions environment for an anonymous function. By generating random numbers and combining them, colony algorithm method tries to find the optimal point to create new numbers. Due to the cooperation between ants, this method has more convergence in comparison with other algorithms. Therefore, it is utilized to implement the article.

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