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CALCULATION OF PASSENGER ELEVATOR LOADING BASED ON THE MAXIMUM PASSENGER FLOW RATE

РОЗРАХУНОК ЗАВАНТАЖЕННЯ ПАСАЖИРСЬКИХ ЛІФТІВ НА ОСНОВІ ВРАХУВАННЯ МАКСИМАЛЬНОГО ПАСАЖИРОПОТОКУ

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Abstract. *The paper considers a simplified methodology for calculating the load and performance of passenger elevators. It is emphasized that the actual average daily load of the elevator differs from the calculated one. The necessity of development of new methods of consideration of elevator parameters and technical and economic comparison of applied solutions in the design of lifting electromechanical systems is emphasized.*

Key words: *passenger elevator, passenger flow, load calculation, elevator electric drive*

Анатація. *У роботі розглядається спрощена методика розрахунку завантаження і продуктивності пасажирських ліфтів. Акцентується увага, що фактичне середньодобове завантаження ліфта відрізняється від розрахункового. Наголошено на необхідності розроблення нових методів урахування параметрів ліфтів і техніко-економічного порівняння застосовуваних рішень під час проектування підйомних електромеханічних систем.*

Ключові слова: *пасажирський ліфт, пасажиропотік, розрахунок завантаження, ліфтовий електропривод*

Introduction.

The elevator industry is a powerful component of the global technology and economy. It consists of dozens of large corporations and thousands of different enterprises and organizations designing, manufacturing and operating elevator equipment, which provide millions of jobs. In its importance, this field reflects one of the most important features of modern civilization [1].

The main task of all passenger elevators is to provide transport in the vertical plane in buildings and structures for various purposes. They not only facilitate the daily physical movement of people, but are often the only means of such movement. In large cities, the total daily volume of transport by passenger elevators exceeds the volume carried by all modes of urban transport [2]. Classification of elevators is very ramified and differentiates them by purpose, load capacity, speed, design features of the lifting mechanism, types of automation systems, the level of comfort provided, determined by the design of cabins, lighting and controls. The present work is devoted to the solution of separate problems of synthesis of electric drives of the lifting mechanism of passenger elevators of mass application.

Main text.

Calculation and selection of lifting electromechanical systems of passenger elevators, it is suggested to base on the account of maximum passenger flow. During the day passenger flows vary in direction and grandeur. In the morning and evening there are ‘peak’ periods of elevator loading, between which there is a more even distribution of load [3]. In most cases in the design of passenger elevators design period is taken equal to five minutes. Such choice is justified by the fact that at longer time intervals the intensity of passenger flow fluctuates significantly. If average values are used for calculations, it can lead to the formation of queues and increase the waiting time of passengers at certain moments. If the occupants are evenly distributed on the floors, the five-minute passenger flow is determined as follows.

$$Q_s = \frac{A\left(N-a\right)}{N\,100} \tag{1}$$

and at uniform population

$$Q_s = \frac{Ai'}{100} \tag{2}$$

where A - the total number of residents; N - the total number of floors of the building; a - the number of floors whose population does not use the elevator (1-2 floors of a residential building); i'/100 - passenger flow intensity indicator, characterizing the number of passengers (in percent) to be transported up and down in the continuation of the calculated five-minute peak. The values of ‘five-minute’ peaks, depending on the functional purpose of the building, are given in Table 1 [3].

Table 1 - Values of ‘five-minute’ peaks of passenger elevator loading

Type of building	Peak (as a percentage of the total number of people served by the elevator)
Residential buildings	4 - 6 %
Hotels	7 -10%
Administrative and business buildings	12 - 20%
Educational institutions	20 - 35%

The magnitude of the five-minute peaks is also influenced by the location of the building in the city. When selecting the number of elevators, the time that a elevator takes for a complete round trip is taken into account. The hourly capacity of a elevator (total number of passengers transported in one direction per hour) can be calculated [1].

$$P = \frac{3600E}{2H/V_H + \sum t_n} \tag{3}$$

where E = Q/80 is the capacity of the cabin (people); Q - is the capacity of the elevator; 80 kg is the average mass of one passenger; Σt_n - the time taken by the elevator cabin to stop.

This time can be determined by

$$t_n = (t_t + t_s + t_d)(N_v + 1) + t_{en} + t_{ex} + t_{ad} \tag{4}$$

For passenger elevators with a capacity of 320, 500 and 1000 kg at a speed of 0.71 and 1.0 m / s, the total time spent on acceleration and deceleration (t_t), start (t_s), as well as door operations (t_d), is 10.0-12.0 seconds. For cargo-passenger elevators this time increases to 12-14 seconds. If the width of the door opening does not exceed 1000 mm, the time for entry (t_{en}) and exit (t_{ex}) of one passenger is 1.5-2.0 seconds. If the width of the opening is more than 1000 mm, it is reduced to 0.8-1.2 seconds. The additional time (t_{ad}) spent on accidental delays is expressed as a percentage of the total round trip time [5]. For passenger flows travelling in one direction, it is 5-10% of the total round trip time, and for two-way flows it is 10-15% of the round trip time in one direction [4].

The number of probable stops of the elevator cabin is determined [3]

$$N_v = N_1 - (N_1 - 1)\left(\frac{N_1 - 1}{N_1}\right)^{\gamma} \quad (5)$$

where N_1 - number of possible stops on the floors above the first floor; γ - design coefficient (recommended value - 0.8).

Other recommendations for calculating the load and performance of passenger elevators are also proposed [6-8]. However, all the proposed calculation methods mainly allow to determine the passenger flow in general for a day or an average hour, but do not allow to calculate the actual load of the elevator (for example, the number of calls, stops, the number of passengers, the distribution of passengers when moving up and down). For example, at a elevator speed of 2.0 m/s, a full cycle of operation for a five-minute maximum passenger load in a 40-storey building and a capacity of 1,600 kg is 303 seconds round trip, carrying 28 people. This corresponds to an estimated five minute interval. Assuming this is 5% of the total number of people living in the building and using the elevator, the total number of passengers per day is 560. When calculating the passenger flow based on peak hour load, this number would be 993 people. However, the elevator, operating at the maximum five-minute intensity, is capable of making 235 full trips and carrying 7,934 passengers per day.

Comparison of the obtained data shows that the actual average daily load of the elevator differs practically by an order of magnitude from the calculated load, on the basis of which it is recommended to choose the elements of the elevator electromechanical system.

Conclusions.

1. A simplified method for calculating the load of passenger elevators was proposed based on the maximum passenger flow. Its application allows for the preliminary selection of electric drive elements and lifting mechanisms for mass-market passenger elevators.

2. It has been determined that for synthesizing the parameters of elevator electromechanical systems, assessing energy characteristics and performing other technical and economic calculations, it is important to have data on the actual load of elevators based on statistical studies.

3. It has been determined that in the absence of statistical data, it is necessary to develop and use new methods of technical and economic comparison of the options and technical solutions used in the design of elevator systems.

Literature:

1. Shuangchang F., Jie C., Xiaoqing C. Analysis of the hidden danger for old elevator safety. 2020 3rd International Conference on Electron Device and Mechanical Engineering (ICEDME), 605-608. (2020)
http://doi.org/10.1109/ICEDME50972.2020.00143

2. Talwandi, N., Walia, N. Optimising Vertical Mobility: Using Machine Learning to Reduce Passenger Wait Time in Elevators. 2024 IEEE International Conference on Computing, Power and Communication Technologies (IC2PCT), 1034-1048 (2024).
http://doi.org/10.1109/IC2PCT60090.2024.10486445

3. Nguyen, T., Miura, N., Sone, A. Analysis and control of compensation rope response in elevator system with timelyly length. 2019 11th Asian Control Conference (ASCC), 905-910 (2019).
http://doi.org/10.1109/ASCC.2017.8287291

4. Boiko, A., Naidenko, E., Besarab, O., Bondar, O. Vibration Damping of Elevatoring Mechanisms for Elevators Using Control Systems. Proceedings of the 6th International Conference on Design, Simulation, Manufacturing: The Innovation Exchange, DSMIE-2023. Volume 2: Mechanical and Materials Engineering, 13-23 (2023)
http://doi.org/10.1007/978-3-031-32774-2

5. Naidenko, E., Bondar, O., Boiko, A., Fomin, O., Turmanidze, R. Control Optimization of the Swing Mechanism. Grabchenko's International Conference on Advanced Manufacturing Processes. InterPartner 2021: Advanced Manufacturing Processes III, 14-21. (2021)
http://doi.org/10.1007/978-3-030-91327-4_2

6. Bernard, P., Deaconu I., Popescu, S. PLC controlled elevator drive system.

2015 9th International Symposium on Advanced Topics in Electrical Engineering (ATEE), 783-796 (2015)
http://doi.org/10.1109/ATEE.2015.7133775

7. Benyao, C., Licheng, R., Jian, Ye., Jianzhong, B. Elevator Traffic Pattern Recognition Based on Density Peak Clustering. 2018 IEEE International Conference of Safety Produce Informatization (IICSPI), 1722-1731 (2018)
http://doi.org/10.1109/IICSPI.2018.8690418

8. Jiang, X., Namokel, M., Hu, C., Tian, R., Dong, J. Research on Energy Saving Control of Elevator. 2019 International Conference on Control, Automation and Information Sciences (ICCAIS), 1-5 (2019).
http://10.1109/ICCAIS46528.2019.9074551.

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