Elevator group control strategy and software design in high-rise office building

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Abstract. Elevators are widely used in high-rise buildings. Especially in high-rise office buildings, multiple elevators are usually installed to meet the commuting needs of a large number of workers. How to dispatch multiple elevators efficiently is particularly important. As a widely used controller in industry, PLC has the characteristics of high reliability, fast calculation speed, and easy programming and installation. The PLC is used to make real-time comprehensive judgments of elevator car position, running direction, load situation and call signals situation. Then the optimal elevator is selected to reduce the waiting and boarding time of passengers.

1. Introduction
With the continuous development of society and the increasing degree of economic activity, high-rise office buildings can be seen everywhere in the current city. Due to the high floors of the current high-rise office buildings, the number of companies and staff that can be accommodated is also large. In order to meet the needs of staff in office buildings, multiple elevators is usually equipped in a single office building. How to efficiently dispatch multiple elevators so that a large number of staff’s calls can be responded and reach the target floor as soon as possible, which has been continuously optimized. And PLC is widely used in production and life because of its high reliability, so the Siemens S7-1200 PLC is used and take the elevator groups with 6 elevators that are all 10 floors as a model to realize the optimal elevator selection strategy.

2. Group control strategy
The elevator group control strategy is mainly designed based on the principle of proximity. However, it is necessary to fully consider the running direction, the call signal direction and the current car location of single elevator to make judgments. And because of the continuous running of the elevator, the call signals change in real time, so the judgment of the optimal elevator also must be carried out in real time.

In addition, the original forward-carrying principle of a single elevator cannot be affected by the group control strategy. For example, when there are internal calls in the elevator, the response of the internal calls must be considered first, and the boarding time of the internal call passengers should not be increased because the nearest responds to the external call. When the elevator is up, it only
responds to the up-call and internal-call signals. And when it is down, it only responds to the
down-call and internal-call signals. When the elevator is fully loaded, the elevator's response to out
calls is cancelled, and no longer participates in the judgment of the optimal elevator. Thereby reducing
the time taken by existing passengers and avoiding unnecessary time waste.

3. Software design plan

3.1. Assumption of the the elevator current state and creation of related units
Assuming that the running directions of No.1-6 elevators and the floors where current cars are located
are as shown in Table 1:

| Elevator No. | Current floor | Running direction | Floor unit | PLC address |
|--------------|---------------|-------------------|------------|-------------|
| No.1         | 1             | ↑                 | 2#0000 0000 0000 0001 | MW0         |
| No.2         | 2             | ↓                 | 2#0000 0000 0000 0010 | MW2         |
| No.3         | 5             | ↑                 | 2#0000 0000 0001 0000 | MW4         |
| No.4         | 7             | ↑                 | 2#0000 0000 0100 0000 | MW6         |
| No.5         | 8             | /                 | 2#0000 0000 1000 0000 | MW8         |
| No.6         | 10            | ↓                 | 2#0000 0010 0000 0000 | MW10        |

No. 1-No. 6 elevators are located on the 1st, 2nd, 5th, 7th, 8th and 10th floors respectively. Store
the corresponding floor number of the car in the MW0-MW10 address unit of the PLC, and the
corresponding bit sets 1 according to the floor number of the car. That is, if the car is on the 1st floor,
the corresponding 0th bit in the address unit sets 1. If the car is on the 2nd floor, the corresponding 0th
bit in the address unit sets 1. The floor unit in the fourth column of the table is obtained. The current
running directions of the 6 elevators are that elevators 1, 3, and 4 are up, elevators 2, and 6 are down,
and elevator 5 is in a stopped state currently.

Assuming that the running elevators all have internal-call signals that are shown in Table 2:

| Elevator No. | Internal-call signal | Internal-call unit | PLC address |
|--------------|----------------------|--------------------|-------------|
| No.1         | 2, 3, 7              | 2#0000 0000 0100 0110 | MW20        |
| No.2         | 1                    | 2#0000 0000 0000 0001 | MW22        |
| No.3         | 6, 10                | 2#0000 0010 0010 0000 | MW24        |
| No.4         | 8, 9                 | 2#0000 0001 1000 0000 | MW26        |
| No.5         | /                    | 2#0000 0000 0000 0000 | MW28        |
| No.6         | 1, 3                 | 2#0000 0000 0000 0101 | MW30        |

The internal-call signals of No. 1 - No. 6 elevators are shown in the second column of Table 2. Except for the elevator No. 5, which has no call signal, the other elevators have different internal-call
signals. Regardless of whether there are out calls, these internal-call signals must be respond and reach
the target floors. A reasonable elevator call design prohibits reverse login. Therefore, the internal-call
signals follow the elevator running direction. That is, internal-call signals of the upward elevators are
all greater than the current floor, and the internal calls of the downward elevators are all less than the
current floor. Store the corresponding internal-call signals of these elevators in the MW0-MW10
address unit of the PLC, and the corresponding bit sets 1 according to internal-call signals number.
That is, the 1st floor internal-call corresponds to the 0th bit in the address unit, and the second layer
internal call corresponds to the first bit 1 in the address unit. Then the internal-call unit in the third
column of Table 2 is obtained.

Assuming that the current out-call signals are generated as shown in Table 3:
Table 3. Current out-call signals

| Out-call signals | Signal floor | Up/down unit | PLC address |
|------------------|--------------|--------------|-------------|
| Up-call signals  | 3, 6, 8      | 2#0000 0000 1010 0100 | MW40        |
| Down-call signals| 3, 9         | 2#0000 0001 0000 0100 | MW42        |

No.1-No.6 elevators are a group-controlled elevator group. 6 elevators share the out-call signals. Therefore, even if only one out-call button is pressed, all the same out-call indicators on the same floor should be on which indicates that there is an out-call signal on that floor. Since out-call signals are divided into up-call signals and down-call signals, the up-call unit and the down-call unit are established respectively. Store the up-call and down-call signals of each floor in MW40 and MW42 address unit of the PLC, corresponding bit sets 1 according to out-call signals number. Then the up/down-call unit in the third column of Table 3 is obtained.

3.2. Calculate the maximum and minimum values of each elevator

To coordinate and dispatch 6 elevators to respond to out-call signals and carry passengers, it is necessary to comprehensively consider the current position of each elevator and the current internal-call and out-call signals. First determine the maximum and minimum values according to the current floors and call signals of each elevator, and then perform subsequent calculations. Take the No.1 elevator as an example.

Perform an OR operation on the up-call unit, the down-call unit and internal-call unit of the No. 1 elevator to determine whether there is a call signal at this time. According to the current state assumption in Section 3.1, then:

\[ MW20 | MW40 | MW42 = 2#0000 0001 1110 0110 \]  \( (1) \)

The result of this operation is not 0, indicating that there is a call currently. And since the lowest bit of “1” in the operation result is the 1st bit in the whole word unit, it means that the minimum call is in the 2nd floor. The current floor of the No. 1 elevator is the 1st floor, which is lower than the lowest call floor. Therefore, the minimum value of No. 1 elevator is the current floors of No. 1 elevator, that is, the minimum value is 1. Since the highest bit of “1” in the operation result is the 8th bit in the whole word unit, it means that the maximum call is in the 9th floor. Therefore, the maximum value of No. 1 elevator is 9.

If the lowest floor of the call is less than the current floor of the car, the lowest floor of the call is the minimum value of the elevator. Then compare the highest floor of the call with the current floor of the car. The larger value is the maximum value of the elevator.

If there is no call signal currently, that is, the OR operation result is 0, the maximum and minimum values of each elevator are assigned to the current floor.

By analogy, calculate the maximum and minimum value of the remaining elevators, which is shown in Table 4:

Table 4. The current maximum and minimum value of 6 elevators

| Elevator No. | OR operation result | Current floor | Maximum value | Minimum value |
|--------------|---------------------|---------------|---------------|---------------|
| No.1         | 2#0000 0001 1110 0110 | 1             | 9             | 1             |
| No.2         | 2#0000 0001 1010 0101 | 2             | 9             | 1             |
| No.3         | 2#0000 0011 1010 0100 | 5             | 10            | 3             |
| No.4         | 2#0000 0001 1010 0100 | 7             | 9             | 3             |
| No.5         | 2#0000 0001 1010 0100 | 8             | 9             | 3             |
| No.6         | 2#0000 0001 1010 0101 | 10            | 10            | 1             |
3.3. Calculation of optimal elevator

The optimal elevator calculation needs to be combined with the current internal-calls, the out-call signals, the running direction and the distance of each elevator to each out-call signal according to the current running direction, and comprehensive judgment is obtained. It can be summarized into 2 situations.

Situation 1: The elevator running direction and the calling direction are both up, or both down, or the elevator is stationary currently.

Taking the running direction and the out-call signal are both up direction as an example. It is judged whether the car floor is lower than or equal to the call floor. If yes, then subtract to get the distance between the up-call signal floor and the car floor of each elevator. That is:

\[ \text{Distance} = \text{Call floor} - \text{Car floor} \]  

(2)

If the car floor is higher than the call floor, it means that the car has passed the call floor. The elevator needs to run up to the highest floor, then down to the lowest internal-call floor or down-call floor, and finally turn back to the up-call floor. That is:

\[ \text{Distance} = (\text{Maximum} - \text{Car floor}) + (\text{Maximum} - \text{Minimum}) + \text{ABS(Up-call floor} - \text{Minimum}) \]  

(3)

Situation 2: The elevator running direction is opposite to the call signal direction.

Taking the running direction is up and the out-call signal is down as an example. At this time, the elevator will turn back down after running up to the maximum number of floors. Then the running distance is:

\[ \text{Distance} = (\text{Maximum} - \text{Car floor}) + \text{ABS(Maximum} - \text{Down-call floor}) \]  

(4)

According to the above description, the running distance from each elevator to each out-call signal is calculated as shown in Table 5:

| Elevator No. | 1st | 2nd | 5th | 7th | 8th | 10th |
|-------------|-----|-----|-----|-----|-----|------|
| No.1↑       | 3   | 12  | 8   | 7   | 12  |      |
| No.2↓       | 14  | 15  | 12  | 8   | 7   | 12   |
| No.3↑       | 5   | 6   | 1   | 11  | 10  | 14   |
| No.4↑       | 7   | 8   | 3   | 1   | 0   | 16   |
| No.5        | 8   | 9   | 6   | 2   | 1   | 1    |
| No.6↓       | 8   | 9   | 6   | 2   | 1   | 1    |

Take the up-call signal of 3 floor response as an example. In the current state, the distance between the No.1 elevator and the 3rd floor is 2, which is the closest car. So the No.1 elevator should respond and carry passengers who pressed the 3rd floor up-call button. Although the elevator car of No. 2 is currently on the 2nd floor, the elevator No. 2 is still going down to send passengers. It needs to turn back to reach the 3rd floor after reach the 1st floor. So the running distance of No.2 elevator is farther than that of the No. 1. By analogy, elevator No. 1 is the optimal elevator to respond the up-call on the third floor currently.
The above process is judged in real time when the program is executed, and the distance is constantly changing with the signal response, so as to ensure the minimum waiting time and the boarding time. If a certain elevator is fully loaded during the process of carrying passengers, the elevator distance is assigned a value of 30 (it is sufficient to exceed the maximum round-trip distance). In order to ensure that the elevator no longer participates in any out-call response, only send the passengers who are in the elevator to their target floors. So that other elevators can determine the optimal elevator to dispatch and respond to out-call signals quickly.

4. Software implementation
According to the previous section, the flow chart in Figure 1 is obtained. Here only take the situation which is the call signal and the running direction are both up as an example. The calculation of other situations are similar to this. In the actual implementation, this section of the program can be written in SCL language instead of ladder language. Through the creation of arrays, FOR loops and other methods, all the situations described are operated in real time to ensure the timeliness of data update.

![Flow chart of optimal elevator calculation](image)

Figure 1. The flow chart of optimal elevator calculation

5. Summary
Through the analysis and design of the elevator group control system in high-rise office buildings, the optimal elevator can be continuously calculated according to the current elevator call signals and floor status. Because of this, each elevator can be dispatched reasonably and improve the running efficiency. At the same time, because the group control system is designed based on the principle of proximity, there is only one optimal elevator to respond to the call. The no-load running of the elevator is avoided, the running distance of the elevator is reduced, and energy consumption is saved.

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