Research Article

Research on Optimization of Power Emergency Material Dispatching for Beijing Winter Olympics

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The Beijing Winter Olympic Games is an extremely important event, and the supply of electricity is the basis for it. In order to prevent the sudden loss of power to the event, it is necessary to carry out power repair and restore normal power supply in the shortest possible time. Contemporary research is less focused on the emergency repair of power systems. This thesis studies the dispatching of power emergency materials in two stages and in the first stage, the minimum gap rate and the shortest time for material dispatching and transportation are mainly considered, and the required types of power emergency materials are dispatched from the storage near the Olympic venues to various power failure points. In the second stage, aiming at the shortage of power emergency materials at each fault point, the power emergency materials will be dispatched from the rear national power grid regional material reserve to the power emergency materials reserve near the Olympic venues and then dispatched to each power fault point through the power emergency materials reserve. Finally, this paper verifies the effectiveness of the combination of the primary and secondary dispatching models in an example, providing a reference for further improving the emergency response capability of the Olympic venues and improving the safety system of the power system.

1. Introduction

Beijing Winter Olympics is a major sports event to show China's image, which is of great significance for coordinating the development of Beijing-Tianjin-Hebei, inspiring the national spirit, and promoting international cooperation. In order to ensure the smooth convening of Beijing Winter Olympic Games, ensuring power supply is the basis of the event. The main methods to ensure power supply are to improve the reliability of power equipment and timely replacement of equipment failure. In the practical process of restoring electricity, the reliability of power electronics plays a more important role in the safety of the power system, so that faults due to it may have an impact on our restoration process. Many scholars are devoted to the study of how to improve the electrical equipment. To solve the midpoint voltage unbalance problem, Wang et al. [1] proposed a closed-loop midpoint voltage balancing method based on carrier overlapping pulse width modulation (COPWM); to

ensure the reliability and safety of power semiconductor device gate drivers, Zhang et al. [2] designed a 10 kV silicon carbide MOSFET high-voltage insulated GDPS for medium voltage (MV) applications; Zhang and Ruan [3] address the transient input and output power imbalance in two-stage single-phase converters, which leads to second harmonic currents (SHC) in DC-DC converters, DC sources, or DC loads; a closed-loop design-based, virtual impedance-based and power decoupling-based control scheme is reset; and Sun et al. [4] propose a novel distributed coordination controller combined with a multiagent-based consensus algorithm and it is applied to distributed generating units in the energy Internet; and to reduce the second harmonic current (SHC), Zhang et al. [5] designed a virtual series impedance. Wang et al. [6] propose a reduced-order aggregate model based on balanced truncation approach to provide the preprocessing approach for the real-time simulation of large-scale converters with inhomogeneous initial conditions in DC microgrid. However, in the actual process,

it is difficult to completely avoid the failure of power equipment, so it is also the premise and basis to ensure the power emergency supplies scheduling for the Beijing Winter Olympic Games. In case of sudden power failure, how to complete the dispatching and supply of power emergency materials in the shortest time and restore the smooth power supply line is very important for restoring the normal operation of the power supply system. Therefore, it is imperative to build an efficient and scientific emergency distribution system of power materials. Most of the existing related studies need to consider the shortest total scheduling time to reduce the loss of accidents or disasters, to achieve the fastest emergency response, and to optimize the rescue effect [7–9]. Some scholars also consider the scheduling of emergency supplies based on time window [10, 11]. This project is aimed at large-scale competitions, especially putting the dispatching time in the highest priority position, reducing or alleviating the problem of long waiting time, and ensuring the normal operation of power systems in major venues. Also, to describe the completion effect of power emergency material dispatching, it is necessary to introduce appropriate indicators. However, the consequences of different disasters and accidents and the demand for materials are different, and the satisfaction indicators are not uniform. When Hwang [12] studied famine; they used minimal response satisfaction to the degree of pain and hunger. Yang et al. [13] and Maghrebi et al. [14] take the comprehensive utility based on the utility value of different relief materials to different disaster points as the objective function, aiming at maximizing the total utility of the disaster points. Similarly, this thesis introduces the concept of “gap ratio” to complete the dispatching of power emergency materials in two stages. The previous stage is to strive to minimize the gap between the demand and supply of emergency materials caused by power outages in venues. In the latter stage, the materials are dispatched twice for the gap until the demand is completely extinguished. Aiming at the complex power material comprehensive dispatching problem, it is divided into multiple stages and multiobjective, or introducing new description concepts is also a common research method. Scholars such as Saeideh et al. [15] designed a two-stage randomized planning plan for emergency distribution based on initial blurring scenarios. The location and inventory levels of the reserve centers are determined based on the need to stay in point and then distribute and plan materials. Irohara et al. [16] built a trilevel programming model for disaster relief planning. Duhamel et al. [17] have established a multicyle postdisaster emergency material reserve center positioning, demand, and distribution model. Many scholars have laid a good foundation for the study of reserve location and path optimization [18–20]. Based on the characteristics of electric power emergency materials, this thesis proposes to achieve the comprehensive goal of shortest emergency response time and satisfaction of emergency materials dispatching at the same time under the condition of determining the location of emergency materials reserve and emergency materials warehouse, to ensure that electric power emergency materials can be delivered on-demand and accurately distributed after sudden accidents.

1.1. Problem Description. During the Winter Olympics, large-scale power accidents will lead to power outages in large-scale Olympic venues, and power outages in Olympic venues will directly interrupt the holding of Olympic events, which will seriously affect the normal holding of the Olympic Games. It should be noted that the longer the power outage in Olympic venues, the greater the loss caused by the power outage. Therefore, to restore the power supply to the Olympic competition venues as soon as possible, it is necessary to detect the power failure points as soon as possible and send a power emergency material dispatching request to the power emergency material reserve of the Winter Olympics according to the specific power failure causes. Specifically, external force major factors cause a large-scale power outage in the Winter Olympics venues, that is, there are I power emergency materials demand points, and the power experts send material dispatching requests to J power emergency materials reserves near the Olympic venues [21]. The dispatching request specifically includes the location of the power failure point, the type of material demand, the quantity of material demand, and other information. There are power emergency materials stored in the power emergency materials reserve near the Olympic venues. How to quickly deliver the required materials in the dispatching request to the power emergency materials demand points is the problem to be solved in this paper. The primary dispatch of power emergency materials mainly considers the time and gap rate and only considers the dispatch of materials from the power emergency materials storage near the Olympic venues to the power failure point. The transportation means used in the dispatch process are special vehicles in the Olympic Park.

To solve this problem, due to the limited storage capacity of the power emergency materials reserve near the Olympic venues, it is impossible to meet the material dispatching request of each demand point at one time, so the material reserve in each region of the State Grid must supplement the material gap and carry out the secondary dispatching of power emergency materials. The main difference between one-time scheduling and secondary scheduling is the different sources of emergency supplies due to the difficulty of supply to fully meet demand. The main source of emergency supplies in Phase 1 was the electricity emergency supplies depot near the Olympic venues, while the main source of emergency supplies in Phase 2 was the collection of supplies stored in the National Grid region. To ensure the smooth hosting of the Olympic Games, China, as the host country of the 2022 Beijing Winter Olympics, has made great efforts to provide an all-round guarantee for the Olympic Park. In the face of one dispatch that cannot meet the demand for power emergency materials at each power fault point, sufficient materials will be dispatched from the material reserves in H national power grid areas to extinguish the demand gap at each fault point. When one dispatch finds that the material demand at each demand point cannot be met at once, it immediately sends a dispatch request for demand gap information to the material reserve in Area H of the National Grid and immediately initiates a second dispatch. How to quickly and accurately extinguish the demand gap at each

fault point is the purpose of secondary scheduling. The secondary dispatching of power emergency materials mainly considers time; according to the relevant regulations of the International Olympic Committee, power emergency materials need to be dispatched from the material reserve in the State Grid area to the power emergency materials reserve near the Olympic venues, and then the power emergency materials are dispatched from the reserve to the power failure points that need power emergency materials, that is, the power emergency materials demand points. In the process of dispatching power emergency materials, the means of transportation used from the material reserve in the State Grid area to the power emergency material reserve near the Olympic venues are the same type of vehicles. The means of transportation used from the power emergency materials storage near the Olympic venues to the power failure points are special vehicles in the Olympic Park.

2. Mathematical Models

2.1. Problem Assumptions. Based on the research problems in this paper, the following assumptions are made:

- (1) The power emergency material dispatching request sent by the power experts includes information such as the location of the power failure point, the type of material demand, and the quantity of material demand, as well as the storage information of the power emergency material storage warehouse near the Olympic venues and the information of the means of transportation. It is known and cannot be changed before dispatching. This thesis does not consider changes in demand and supply.
- (2) The vehicles involved in the Olympic Games are special and there is no shortage of transportation capacity. The driving speed of this type of special vehicle is consistent and can meet any demand for transportation capacity for power emergency material dispatching. The dispatching model in this paper does not consider the load limit of vehicles.
- (3) The dispatch cost is not considered in the dispatch process of electric power emergency materials, only one-way transportation is considered in the dispatching process of materials between each node, and there is no congestion on the dispatching road of electric power emergency materials.
- (4) The second dispatch uses the same type of vehicles for material transportation at the same speed, regardless of multimodal transport, cost, and road congestion, and does not consider the material loading and unloading and transfer time of the power emergency material storage near the Olympic venues.
- (5) The power emergency materials in the regional reserve of the State Grid can meet the needs of each power failure point; that is, the three-layer network studied in this paper can meet all the needs of the demand points.
- (6) Due to the characteristics of the power grid, without a single part, the normal power supply capacity of the power grid cannot be restored; therefore, this thesis assumes that the supply urgency of all kinds of power emergency materials is the same, and because the power failure occurs in the Olympic Park, to restore power supply as soon as possible and try our best to reduce the adverse impact on the holding of the Olympic Games, it is assumed that the supply urgency of all kinds of power emergency materials is the highest level.
- (7) After a power failure occurs in the Olympic Park or outside the scope of the Olympic venues, the demand for power emergency materials will be summarized to the demand for power emergency materials at the failure point of the Olympic venues according to the principle of proximity.
- (8) From the State Grid Regional Reserve to the Power Emergency Material Reserve near the venue and then to each power failure point, the materials to be dispatched in each stage are integer pieces.
- (9) Loading and unloading time is not taken into account when dispatching from the regional storage of State Grid to the storage of power emergency materials near the venue and then to each power failure point.

2.2. One-Time Scheduling Model

2.2.1. Parameter Description

$I = \{i | i = 1, 2, \dots, m\}$ represents a set of power failure points, i.e., demand points (or disaster points)

$J = \{j | j = 1, 2, \dots, n\}$ means that the power emergency materials storage near the Olympic venues is the collection of supply points

$A = \{a | a = 1, 2, \dots, e\}$ indicates the collection of types of power emergency materials stored in the power emergency materials reserve

SS_{ja} indicates the number of type A electrical emergency supplies in reserve at the point j of supply of electrical emergency supplies

Q_{ia} indicates the demand for type A electrical emergency material at an electrical failure point i after the use of electrical emergency materials stored in the Olympic stadium

D_{ji} indicates the distance between power emergency supply point j and power emergency material demand point i

V_1 indicates the driving speed of the means of transport used at the point of supply j to point of demand;

$T_{\max}^i$ indicates the maximum response time of a demand point i to obtain electrical emergency supplies at a time of dispatch

G_{jia} indicates the number of type A electrical emergency supplies dispatch to point of demand i at point of supply of electrical emergency supplies j

Θ_{ia} represents a type A electrical emergency material satisfaction rate of a demand point i

X_{jia} is a 0-1 variable; when this value is 1, it indicates that type A electrical emergency supply is a dispatch from power emergency supply point j to demand point i ; when the value is 0, the power emergency supply point j has no dispatch of type A electrical emergency to point of demand i

2.2.2. Model Building. The electrical accident caused a wide power outage in Olympic Park. After rapid testing power experts sent a request for power failure point i to the electrical emergency supplies reservoir j near the Olympic stadium. Information such as the location of power failure points, types of a power emergency materials demand, and the specific quantity of various power emergency materials demand included in the dispatching request are known. Through the rapid collection and processing of information, the number of nodes and material supply information of the power emergency material storage near the Olympic venues and the distance from the power emergency material storage near the Olympic venues to each power failure point are known. On this basis, a one-time scheduling model is constructed to minimize the material gap rate and the shortest material dispatching and transportation time.

The objective function of the primary dispatching model of power emergency materials for the Winter Olympics is

$$\min Z_1 = \left\{ \sum_{i=1}^m \sum_{a=1}^e \frac{(Q_{ia} - \sum_{j=1}^n G_{jia})}{Q_{ia}} \right\} (\text{me})^{-1}, \quad (1)$$

$$\min Z_2 = \max \left(\frac{D_{ji} \cdot x_{jia}}{v_1} \right). \quad (2)$$

Constraints are

$$\sum_{j=1}^n G_{jia} \leq Q_{ia}, \forall i \in I, a \in A, \quad (3)$$

$$\sum_{i=1}^m G_{jia} \leq SS_{ja}, \forall j \in J, a \in A, \quad (4)$$

$$\sum_{j=1}^n \frac{G_{jia}}{Q_{ia}} \geq \theta_{ia}, \forall i \in I, a \in A, \quad (5)$$

$$\frac{D_{ji} \cdot x_{jia}}{v_1} \leq T_{\max}^i, \quad (6)$$

$$x_{jia} \in \{0, 1\}, \forall i \in I, j \in J, a \in A. \quad (7)$$

Model objective function: formula (1) indicates that the sum of the gap rates for all demand points to obtain power emergency materials from the power emergency materials reserve near the Olympic venues is the smallest. Formula (2) indicates that the longest transportation time from dispatching power emergency materials from the power

emergency materials reserve near the Olympic venues to the demand point is the smallest.

Model constraints: formula (3) indicates that the electrical emergency supplies dispatch from the electrical emergency material reserve near the Olympic stadium to the demand point is not greater than the sum of the demand for the required type A electrical emergency supplies at that demand point. Formula (4) indicates a transfer from the reserve of electrical emergency supplies near the Olympic stadium degree to point of demand of the type of electricity emergency supplies equals the electrical emergency supplies reserve near the Olympic stadium, the corresponding type of power emergency material reserve. Formula (5) indicates that the satisfaction rate of electrical emergency supplies obtained by each demand point is not less than a certain number. Formula (6) indicates that the maximum transportation time of dispatches materials from the power emergency material storage warehouse j near the Olympic venues to each power failure point i shall not exceed the maximum response time of the failure point i ; formula (7) indicates that when the value of 0-1 variable x_{jia} is 1, dispatching type A electric emergency supplies from supply point j to demand point i of electric emergency supplies occurs; when the value of x_{jia} is 0, power emergency supplies supply point j does not dispatch type A power emergency supplies to power emergency supplies demand point i .

2.3. Secondary Scheduling Model

2.3.1. Parameter Description

$I = \{i | i = 1, 2, \dots, M\}$ represents a set of power failure points, i.e., demand points (or disaster points)

$J = \{j | j = 1, 2, \dots, n\}$ means that the power emergency materials storage near the Olympic venues is the collection of supply points

$K = \{k | k = 1, 2, \dots, h\}$ indicates the collection of material reserves in the State Grid area, i.e., rear supply points

$A = \{a | a = 1, 2, \dots, e\}$ indicates the collection of types of power emergency materials stored in the power emergency materials reserve

SS_{ka} represents the reserve of type A electrical emergency supplies in reserve at a rear supply point k

Q_{ia} indicates the demand for type A electrical emergency material at an electrical failure point i after the use of electrical emergency materials stored in the Olympic stadium

Q'_{ia} indicates a demand gap for type A electrical emergency supplies at a power failure point after a dispatch

D_{ji} indicates the distance between power emergency supply point j and demand point i

D_{kj} represents the distance from a rear supply point k to a supply point j

V_1 indicates the speed of the vehicle from the supply point j to the point of demand

V_2 indicates the travel speed of the vehicle from the rear supply point k to the point of supply j

$T_{\max}^i$ indicates the maximum response time of a demand point i to obtain electrical emergency supplies at a secondary dispatch

G_{kja} indicates the quantity of type A electrical emergency supplies dispatch to supply point j at a rear supply point k

G'_{jia} indicates the number of type A electrical emergency supplies dispatch to a demand point i in the secondary dispatch of electrical emergency supplies at the Winter Olympics

x'_{jia} as of variable 0-1: when this value is 1, it indicates that type A electrical emergency supplies are dispatched from power emergency supply point j to demand point i in the secondary dispatch of electrical emergency supplies for the Winter Olympics; when the value is 0, it indicates that the secondary dispatch supply point did not dispatch electric emergency supplies to demand point i

y_{kja} as a 0-1 variable: when the value is 1, it indicates that type A electrical emergency is a dispatch from the rear supply point k to supply point; when the value is 0, it indicates that the rear supply point k did not dispatch electrical emergency supplies to supply point j

2.3.2. Model Building. Since one dispatch does not meet all the power emergency materials requirements of each power fault point, to restore the normal power supply in the Olympic Park as soon as possible and reduce the adverse impact on the normal holding of the Olympic Games, when a dispatch finds that the material demand of each demand point cannot be met at one time, it immediately sends a dispatch request to the material reserves in H national power grid areas for the demand gap information and immediately starts the second dispatch. Through the rapid collection and processing of information, information such as the number of nodes and material supply information of the material storage depots in the State Grid region and the distance between the material storage depots in the State Grid region and the power emergency material storage depots near the Olympic venues are known. Therefore, the secondary dispatching model of power emergency materials for the Winter Olympics is constructed, which aims at the shortest dispatching and transportation time of power emergency materials.

The objective function of the secondary dispatching model for power emergency materials for the Winter Olympics is

$$\min Z = \max \left\{ \left(\frac{D_{kj}}{v_2} \right) \cdot y_{kja} + \left(\frac{D_{ji}}{v_1} \right) \cdot x'_{jia} \right\}. \quad (8)$$

Constraints are

$$\sum_{k=1}^h \sum_{j=1}^n \sum_{a=1}^e G_{kja} = \sum_{j=1}^n \sum_{i=1}^m \sum_{a=1}^e G'_{jia}, \quad (9)$$

$$\sum_{j=1}^n G_{kja} \leq SS_{ka}, \forall k \in K, a \in A, \quad (10)$$

$$\sum_{k=1}^h \sum_{j=1}^n G_{kja} = \sum_{i=1}^m Q'_{ia}, \forall a \in A, \quad (11)$$

$$\sum_{j=1}^n G'_{jia} = Q'_{ia}, \forall i \in I, a \in A, \quad (12)$$

$$\sum_{k=1}^h SS_{ka} \geq \sum_{i=1}^m Q'_{ia}, \forall a \in A, \quad (13)$$

$$\sum_{i=1}^m G'_{jia} = \sum_{k=1}^h G_{kja}, \forall j \in J, a \in A, \quad (14)$$

$$\left(\frac{D_{ji}}{v_1} \right) \cdot x'_{jia} + \left(\frac{D_{kj}}{v_2} \right) \cdot y_{kja} \leq T_{\max}^i, \quad (15)$$

$$x'_{jia} \in \{0, 1\}, \forall i \in I, j \in J, a \in A, \quad (16)$$

$$y_{kja} \in \{0, 1\}, \forall k \in K, j \in J, a \in A. \quad (17)$$

Model objective function: formula (8) indicates that the longest transportation time of power emergency materials dispatched from the material storage warehouse in the State Grid area to the power emergency material storage warehouse near the Olympic venues and then to the demand point is minimized.

Model constraints: equation (9) indicates that all electrical emergency supplies dispatch from the rear supply point k to all power emergency supply points j equals all electrical emergency supplies supply point j dispatch to all demand points with the number of electrical emergency supplies of i ; formula (10) indicates that the sum of type A electrical emergencies dispatched from a rear supply point k to a supply point j is less than or equal to that rear supply point k reserve level of type A electric emergency supplies in reserve; formula (11) indicates dispatch from all rear supply points k to category A at all supply points j ; the sum of electrical emergency supplies is equal to the gap in total demand for type A electrical emergency after all demand points i once dispatched; formula (12) indicates the secondary dispatch from all supply points j to a point of demand i ; the sum of type A electrical emergency is equal to the gap in demand for type A electrical emergency after a

dispatch at that point of demand; formula (13) indicates the reserve of all rear supply points; the sum of electrical emergency supplies is greater than or equal to the sum of the gap in the demand gap for type A electrical emergency after a dispatch at all demand points; formula (14) indicates the secondary dispatch from a supply point j to all demand points i ; the sum of type A electrical emergency is equal to the sum of all rear supply points k received at that supply point j ; formula (15) indicates the secondary dispatch from the rear supply point k to point of supply j to point of demand i ; the sum of the maximum time for transporting electrical emergency supplies cannot be greater than the maximum response time for secondary dispatch at point of demand i ; equation (16) indicates when 0-1 variable x'_{jia} is 1, during the secondary dispatch of electrical emergency supplies of the Winter Olympics from power emergency supply point j , with type A electrical emergency supplies to demand point i ; when the value is 0, there is no dispatch of type A electrical emergency supplies from power supply point j to point of demand i ; equation (17) indicates that with 0-1 variable y_{kja} type A electrical emergency is a dispatch from the rear supply point k to supply point j ; when the value is 0, the rear supply point k does not dispatch electrical emergency to supply point j .

2.4. Model Solving. According to the characteristics and types of the power emergency material dispatching model for the Winter Olympics constructed in this thesis and the good performance of LINGO in solving this type of problem, this paper uses LINGO software to solve the model constructed in this paper. The primary dispatching model for the winter Olympic Games power emergency supplies is a multiobjective optimization problem, and therefore this study adopts a multiobjective optimization algorithm based on a decomposition strategy. The multiobjective function is transformed into a single objective function in the solution, and the dimensionality is eliminated by first optimizing the single objective function and then summing it. Although the setting of weights is an important part of this algorithm, in contrast to complex high-dimensional optimization problems, there is no apparent conflict between the two optimization objectives in this paper, so no weight setting is performed. This algorithm has obvious advantages for low-dimensional multiobjective optimization problems such as ours. Although the overall optimal is not guaranteed, satisfactory results can be achieved in the absence of obvious conflicts between the optimization objectives [22].

To eliminate the influence of dimensions, the two objective functions are added after eliminating dimensions, as shown in the following equation:

$$\min Z = \left\{ \sum_{i=1}^m \sum_{a=1}^e \frac{(Q_{ia} - \sum_{j=1}^n G_{jia})}{Q_{ia}} \right\} (me)^{-1} + \left\{ \max \left(\frac{D_{ji} \cdot x_{jia}}{v_1} \right) \right\} \bullet (T_{\max}^i)^{-1}. \quad (18)$$

Since the quadratic scheduling model is a single objective function, it can be solved directly by using LINGO code.

3. Case Analysis

3.1. Basic Data. Yanqing, as one of the three major competition areas of Beijing 2022 Winter Olympics, is located in Xiaohaituo Mountain area in the northwest of Beijing, 74 kilometers away from Beijing's urban area. As an important part of the competition area of the 2022 Winter Olympics, the core area of Yanqing Division is located in Xiaohaituo Mountain with an altitude of 2,199 meters; two competition venues, the National Alpine Skiing Center and the National Snowmobile and Sled Center, and two non-competition venues, Yanqing Winter Olympic Village and Mountain Media Center, will be built at the southern foot of Xiaohaituo Mountain. Three major events (alpine skiing, snowmobile, and sled), four subevents (alpine skiing, snowmobile, steel frame snowmobile, and sled), and 20 minor events will be held. Among them, the National Alpine Skiing Center will host the Winter Olympics downhill, super giant slalom, giant slalom, slalom, and other events in 2022; the Snowmobile Sled Center will host the Winter Olympics snowmobile, steel frame snowmobile, sleigh, and other competitions; Yanqing Winter Olympic Village can provide about 1,430 beds for athletes and team officials, including international area, operation area,

residential area, and other functional areas. All functional areas and venues in the competition area need electricity as the energy power for all activities such as lighting, heating, and snowmaking.

The core area of Yanqing competition area is the mountain area, with complex terrain, steep mountains, high mountains, and dense forests, the vertical drop of the venue is nearly 1,000 meters, and the high altitude and low temperature always test the power facilities and equipment in Yanqing Division.

During the Winter Olympics, a sudden power failure occurred in a venue in Yanqing District, which affected the normal power supply of the venue. At this time, the power system automatically started the power emergency response procedure and instantly started UPS uninterruptible power supply (refers to power supply equipment that will not be interrupted due to short-term power failure and can always supply high-quality power supply and effectively protect precision instruments) and generator car (standby power supply). At the same time, due to the limited continuous power supply capacity of UPS uninterruptible power supply and standby power supply, to ensure the normal, stable, and continuous power supply capacity of the Winter Olympics venues, the faulty venues were immediately overhauled, and three power failure points were found out (power emergency materials demand points I_1 , I_2 , I_3), respectively, required

power generation vehicles (A1), UPS uninterruptible power supply (A2), cable (A3), and cable connector (A4), and other power emergency materials are shown in Table 1.

There are two power emergency supply points near the faulty venue, namely, the power emergency supplies supply points, which are J_1 , J_2 , and the number of prestored electrical emergency supplies corresponding to the demand of each point of failure is shown in Table 2.

It is known that the material transportation distance from each storage warehouse to each fault point is shown in Table 3.

The material transportation means used in this competition area is snow press (as shown in Figure 1), and its transportation speed is 20 km/h. The maximum response time of power emergency materials at three fault points in one dispatch is 2 h. The minimum satisfaction rate of all kinds of power emergency materials required by each fault point in one dispatch is shown in Table 4.

Due to the limited materials stored in the power emergency materials storage warehouse near the fault venue, it is impossible to fully meet the power emergency materials demand of each fault point at one time. The gap of power emergency materials at each fault point after one dispatch is shown in Table 5. In this situation, it is necessary to start the secondary dispatching immediately, that is, to dispatch the material gap of each demand point after the primary dispatching from the material reserve warehouse in the State Grid area (i.e., the rear supply point). According to the relevant regulations of the International Olympic Committee, power emergency materials should be dispatched from the material reserve in the State Grid area to the power emergency materials reserve near the Olympic venues and then from the power emergency materials reserve near the Olympic venues to each power failure point. The material reserve situation of the State Grid Regional Material Reserve, which can provide emergency materials for the Yanqing Division, is shown in Table 6.

It is known that the distance from the material storage warehouse in the State Grid area to the power emergency material storage warehouse near the faulty venue is shown in Table 7. The required power emergency materials are transported by car from the material storage warehouse in

TABLE 1: Power emergency material demand at each power failure point.

Q	I1	I2	I3
A1 (set)	4	3	2
A2 (set)	2	2	2
A3 (shaft)	2	1	1
A4 (unit)	5	3	2

the State Grid area to the power emergency material storage warehouse near the faulty venue at a speed of 60 km/h. The maximum response time of power emergency materials in the secondary dispatching of the three fault points is 4 h. All kinds of power emergency materials required by each fault point in the secondary dispatching must be met; that is, the material satisfaction rate must reach 100%.

3.2. Solution Results

3.2.1. One-Time Scheduling. The purpose of one-time dispatching is to enable each power failure point to quickly obtain emergency materials. This mode first calls the power emergency materials from each storage warehouse in the Olympic venues to meet some needs of each power failure point. Provided that, within 2 h, all electrical emergency supplies in the reserve will be allocated to each point of failure and that the satisfaction rate is not less than the minimum material satisfaction rate of each power failure point, for the sum of the gap rate of each failure point and the sum of the maximum transit time of all kinds of electrical emergency materials, these two subgoals are reached minimally. Through the one-time dispatching model constructed in the second chapter, the one-time dispatching simulation of power emergency materials for the Winter Olympics is implemented. Using LINGO software, the optimal target result can be obtained; Table 8 shows the results of optimal scheme for primary dispatching.

When solving, the double objective function of the primary dispatching model of power emergency materials for the Winter Olympics is transformed into a single objective function after eliminating the dimensional influence:

$$\min Z = \left\{ \sum_{i=1}^m \sum_{a=1}^e \frac{(Q_{ia} - \sum_{j=1}^n G_{jia})}{Q_{ia}} \right\} (me)^{-1} + \left\{ \max \left(\frac{D_{ji} \cdot x_{jia}}{v_1} \right) \right\} \bullet (T_{\max}^i)^{-1}. \quad (19)$$

The purpose of one dispatch is to enable each power material demand point to quickly obtain the required materials. It is stipulated that all emergency materials in the power emergency material reserve of Olympic venues will be distributed to each power failure point within 2 hours. When calculating the gap rate of each power fault point, according to the field investigation, it is found that all kinds of emergency materials dispatched by the power emergency materials reserve near the venue to each power fault point

can meet the minimum material satisfaction rate of each fault point, to ensure that emergency materials will be delivered at the first time after a power failure at each fault point, and some demands will be solved first.

After a scheduling case calculation, it is possible to know the best solution; power emergency material requirements points I_1 , I_2 , and I_3 can get the supply of electric tram (A1), UPS uninterruptible power supply (A2), cable (A3), and cable connector (A4) as shown in Table 9; satisfaction rate is

TABLE 2: Power emergency material reserve of each power emergency material reserve warehouse.

SS	J1	J2
A1 (set)	2	3
A2 (set)	2	2
A3 (shaft)	2	1
A4 (unit)	5	3

TABLE 3: Material transportation distance from power emergency material reserve to power fault point (unit: km).

D	J1	J2
I1	20	15
I2	18	9
I3	6	19

FIGURE 1: Snow compressor.

TABLE 4: Minimum material satisfaction rate at power failure point.

θ	I1	I2	I3
A1	50%	50%	50%
A2	50%	50%	50%
A3	40%	40%	40%
A4	60%	60%	60%

TABLE 5: Shortage of power emergency materials at each fault point after primary dispatching.

Q'	I1	I2	I3
A1 (set)	2	1	1
A2 (set)	1	0	1
A3 (shaft)	1	0	0
A4 (unit)	2	0	0

TABLE 6: Material reserve of material reserve warehouse in State Grid area.

SS	K1
A1 (set)	5
A2 (set)	4
A3 (shaft)	8
A4 (unit)	5

TABLE 7: Distance from the State Grid area material reserve to the power emergency material reserve near the fault venue.

D	K1
J1	135
J2	168

shown in Table 10; the demand for four kinds of materials can be obtained with reference to the power failure point; the specific results are shown below.

In the first half of the objective function, the sum of the average gap rates of each power fault point is 26.94%, and the average gap rate of each fault point is shown in Table 11. In the second half of the objective function, the maximum average transportation time is 0.45 h, which is less than the maximum average transportation time limit of 1 h for the four kinds of power emergency materials transported to each power failure point. The transportation time of various kinds of power emergency materials at each demand point is shown in Table 12.

According to the results of the above two objectives, it can be learned that each power emergency material reserve will deliver all the emergency materials to the power failure point within the specified maximum response time, thus alleviating the adverse situation caused by the shortage of materials to a certain extent. The results show that the electrical emergency supplies reserve J_1 was finally shipped to the power emergency supply-demand point I_2 and the time is 0.9 h longer, but less than the prescribed 2 h. The lowest satisfaction rate is the demand point I_1 , which has a satisfaction rate of 50%, 50%, 50%, and 60% for four items, respectively, but above the minimum material satisfaction rate for each point of failure. At this stage, the rapid response of power emergency materials was solved, and all emergency materials in each storage depot in Olympic venues were dispatched to each power failure point.

3.2.2. Secondary Scheduling. Quadratic dispatching is to implement simulation according to the quadratic dispatching model to ensure that all power fault points are met after completing the primary dispatching, aiming at the demand gap of each fault point. It is stipulated that all kinds of power emergency materials will be transported from the emergency materials storage warehouse in the rear State Grid area to the emergency materials storage warehouse in the Olympic venues within 4 hours and finally transported to various power failure points. The distribution purpose of this stage is to extinguish the gap at each power failure point and carry out the accurate dispatch of insufficient materials, to minimize the sum of the longest transportation time of power emergency materials from the State Grid area to the material storage of Olympic venues and the longest transportation time from the material storage of Olympic venues to each power failure point. After analyzing the calculation results of the secondary scheduling case, the best scheme is shown in Tables 13 and 14.

The target function includes the transit time from the State Grid Reserve to the Olympic Stadium Reserve and then the power failure point. The transport time for electrical emergency supplies from the State Grid Reserve to the Olympic Stadium

TABLE 8: Results of optimal scheme for primary dispatching.

G	J1				J2			
	A1 (set)	A2 (set)	A3 (shaft)	A4 (unit)	A1 (set)	A2 (set)	A3 (shaft)	A4 (unit)
I1	0	0	0	0	2	1	1	3
I2	1	0	1	3	1	1	0	0
I3	1	2	1	2	0	0	0	0

TABLE 9: Supply situation of power fault point in primary dispatching.

G	A1 (set)	A2 (set)	A3 (shaft)	A4 (unit)
I1	2	1	1	3
I2	2	1	1	3
I3	1	2	1	2

TABLE 10: Satisfaction rate of power failure points in primary dispatching.

θ	A1 (set)	A2 (set)	A3 (shaft)	A4 (unit)
I1	50.00%	50.00%	50.00%	60.00%
I2	66.67%	50.00%	100.00%	100.00%
I3	50.00%	100.00%	100.00%	100.00%

TABLE 11: Average gap rate of power fault points in primary dispatching.

Z1	Average gap rate
I1	47.50%
I2	20.83%
I3	12.50%

TABLE 12: Transportation time from power emergency material reserve to power failure point (unit: H).

T	J1	J2
I1	1	0.75
I2	0.9	0.45
I3	0.3	0.95

Bold indicates material transportation.

TABLE 13: Results of optimal scheme for secondary dispatching State Grid Reserve Bank to Olympic venue Reserve Bank.

G	K1			
	A1 (set)	A2 (set)	A3 (shaft)	A4 (unit)
J1	3	2	1	2
J2	1	0	0	0

TABLE 14: Results of the optimal scheme for secondary dispatching of Olympic venue reserves to power failure points.

G'	J1				J2			
	A1 (set)	A2 (set)	A3 (shaft)	A4 (unit)	A1 (set)	A2 (set)	A3 (shaft)	A4 (unit)
I1	2	1	1	2	0	0	0	0
I2	0	0	0	0	1	0	0	0
I3	1	1	0	0	0	0	0	0

Reserve is 3.25 h, 2.55 h, and 3.1 h, respectively, which were less than the specified maximum time limit of 4 h. Therefore, the objective function value, that is, the cumulative shortest transportation time, is 3.25 h, and the specific solution results are shown in Tables 15 and 16 below.

The purpose of secondary dispatching is to meet all the emergency materials requirements of each power failure point, to minimize the sum of the longest transportation time of power emergency materials from the State Grid area to the material storage of Olympic venues and the longest

TABLE 15: Transportation time from State Grid Reserve Bank to Olympic venue Reserve Bank (unit: H).

T	K1
J1	2.25
J2	2.8

TABLE 16: Cumulative transportation time from State Grid Reserve Bank to power failure point via Olympic venue Reserve Bank (unit: H).

Route	K-J transportation time	J-I transportation time	Cumulative transportation time
K1-J1-I1	2.25	1	3.25
K1-J1-I3	2.25	0.3	2.55
K1-J2-I2	2.8	0.3	3.1

transportation time from the material storage of Olympic venues to each power failure point.

The results show that the transportation time of power emergency materials from the State Grid Reserve Bank to the Olympic venues Reserve Bank is 2.8 h, and the cumulative maximum transportation time from the Olympic venues Reserve Bank to each power failure point is 3.250.75 h, which is less than the specified maximum response time of 4 h. At this stage, all the gaps in the demand for power emergency materials were extinguished, and the problem of quick response was better solved under the constraints of the existing environment.

4. Conclusion

In this thesis, according to the demand of power emergency materials dispatching in Winter Olympics, combined with the actual power emergency materials dispatching and the characteristics of supply and demand in Winter Olympics, the primary dispatching model and the secondary dispatching model of power emergency materials are established, respectively, and the validity of the models is tested by using the relevant data of Yanqing competition area. The results show that the established model is realistic and feasible and provides a feasible and effective scheme for the optimization of power emergency materials dispatching in the Winter Olympics. When building the model, this thesis does not consider the vehicle speed change and the loading and unloading time of electric emergency materials and can further consider the speed change and loading and unloading time of vehicles in the future.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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