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Multi-Scenario and Multi-Objective Collaborative Optimization of Distribution Network Considering Electric Vehicles and Mobile Energy Storage Systems

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ABSTRACT Due to the short-term large-scale access of renewable energy and residential electric vehicles in residential communities, the voltage limit in the distribution network will be exceeded, and the quality of power supply will be seriously reduced. Therefore, this paper introduces the mobile energy storage system (MESS), which effectively solves the problem of overvoltage limit caused by the large number of distributed power sources and household electric vehicles in the distribution network. This paper proposes an optimal scheduling model for distribution network based on mobile energy storage system. First, the space-time energy transfer model of mobile energy storage is established, and the transfer cost of MESS and the income of peak shaving and valley filling are considered. According to daily driving data of household electric vehicle (EV), a prosumer group electric vehicle charging and discharging model is established; After that, by establishing a target model for maximizing MESS operating income and penalizing voltage overshoot under different scenarios such as low peak load of electric vehicles and different initial capacities of MESS, a multi-scenario multi-objective collaborative optimization model for the distribution network is established; Finally, an improved IEEE33-bus system is used to analyze the calculation example. The results of the calculation example show that the optimal scheduling model in this paper can improve the photovoltaic consumption capacity and improve the voltage limit problem, which verifies the effectiveness and economy of the scheduling model.

INDEX TERMS Electric vehicle (EV), mobile energy storage system (MESS), distribution network, collaborative optimization.

I. INTRODUCTION

As global fossil reserves may be reduced by about two-thirds in the next 50 years, from about 39 trillion US dollars to 14 trillion US dollars in value, oil, natural gas and coal businesses are becoming increasingly unprofitable. The resulting trend in the future is that oil supply is surplus and demand is declining, and the renewable energy market is gradually expanding [1]. Renewable energy is characterized by its wide distribution of resources and low energy density, which is more suitable for small-scale dispersed development. Therefore, photovoltaic power generation is mostly distributed. However, new energy resources have the characteristics of intermittent and randomness. Photovoltaic power generation depends on the weather, and it is difficult to predict power generation. This makes it difficult to absorb new energy power generation. It is easy to cause voltage fluctuations after being connected to the distribution network. The light phenomenon is more serious [2], causing a great waste of resources.

At the same time, as an important clean energy power, electric vehicles have received great attention and large-scale investment in various countries. Electric vehicles are gradually entering families, and more and more families are

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gradually buying electric vehicles instead of traditional fuel vehicles, large-scale charging infrastructure are put into operation. Electric vehicle load has the characteristics of large current and strong time domain. For residential electric vehicle users, people often start charging in the evening, which aggravates the peak-to-valley difference of the distribution network, causing harmonic pollution and voltage fluctuations. The challenges faced by power systems in peak shaving and frequency modulation will become more and more severe. Therefore, a large number of innovative technologies such as cheap, environmentally friendly, and safe energy storage technologies are needed as strong support [3].

On the power generation side, energy storage facilities can smooth output fluctuations and improve power quality; adjust power station output to reduce wind and light abandonment in new energy power plants; participate in system auxiliary frequency modulation, etc. On the grid side, energy storage facilities can reduce the peak-valley difference of the system, improve the load curve, reduce the construction of some peak-load units and power transmission and transformation projects; participate in system frequency modulation; as a black start power supply and a security power supply for important loads. On the user side, energy storage facilities can use the peak-to-valley price difference to reduce electricity costs; reduce peak power supply loads and reduce capacity electricity costs; provide backup power for their own sensitive equipment [4].

Different from the traditional energy storage power station that requires special workshops, long construction period and fixed and immovable characteristics, mobile energy storage systems can be produced in factories and have the characteristics of strong environmental adaptability, easy installation and high scalability [5], The modular design of the container energy storage system adopts internationally standardized container sizes, allowing ocean and road transportation, and can be hoisted by overhead cranes, with strong mobility and no geographical restrictions. In addition, the container energy storage system can be produced in a factory and assembled and debugged directly in the workshop, which greatly saves the cost of construction and operation and maintenance of the project.

At present, many researches have been conducted on the optimal scheduling of MESS at home and abroad. Literature [6] proposed an elastic distribution network disaster recovery strategy that considers the interactive optimization of portable energy storage and network reconstruction. The strategy proposed in the article can maximize the use of renewable energy on the basis of meeting the safe operation of isolated islands; Literature [7] proposed a mobile energy storage optimization configuration model in the distribution network. This model optimizes the number and rated capacity of mobile energy storage vehicles, and improves the economics of mobile energy storage. Literature [8] discusses the important role of mobile energy storage devices in power emergency, and discusses in detail the optimization and configuration of mobile energy storage sites, introduced the grid connection method and grid technology of mobile energy storage; Literature [9] proposed a method for electric vehicle charging load prediction based on the driving and parking characteristics of electric vehicles, considering the temporal and spatial distribution. The parking generation rate model is used to predict parking demand, predict the temporal and spatial distribution characteristics of electric vehicle charging load; Literature [10] reviews the impact of electric vehicle access on the power grid and the current research status of electric vehicle load forecasting, and analyzes the influencing factors of charging load forecasting. Literature [11] proposes a hybrid energy storage system with batteries and supercapacitors added to the photovoltaic system, which realizes the capacity optimization configuration under the schedulable grid-connected photovoltaic power station, and minimizes the total system cost.

The main contributions of this paper can be summarized as follows:

1) This article comprehensively considers the energy storage characteristics of MESS and the transfer space-time location, and establishes a mobile energy storage system space-time dynamic transfer model based on MESS charge and discharge constraints and path transfer costs.
2) According to the characteristics of multiple centralized charging of household electric vehicle loads in residential areas, an EV load model based on normal distribution mileage is established based on the historical travel data of residential EVs in the residential area, combined with the access of renewable energy such as photovoltaics in the distribution network to establish MESS, and the residential EV load of the cell is dynamically constrained in multiple scenarios.
3) With the goal of maximizing peak-shaving and valley-filling capacity, maximizing the benefit of preventing voltage overruns, and maximizing photovoltaic consumption coordinated optimization, a multi-scenario and multi-objective dynamic optimization scheduling model of the distribution network considering the joint constraints of MESS and household EVs is established.

II. MOBILE ENERGY STORAGE SYSTEM MODEL

A. MESS SPACE-TIME DYNAMIC ENERGY TRANSFER MODEL

(1) The main function of the mobile energy storage system is to meet the demand of peak shaving and valley filling of the distribution network, and its capacity should be able to improve the power flow distribution of the distribution network and prevent the voltage from exceeding the limit [12]. The sum of the MESS capacity should be greater than the voltage regulation demand capacity of the distribution network.

$$\sum_{m=1}^{M} P_{mt}^{MESS} \geq P_{it}^{vl}, \quad \forall i \in I, t \in T \tag{1}$$

where, $\mathrm{P}_{\mathrm{mt}}^{\mathrm{MESS}}$ is the charging and discharging power of the m-th MESS at time t, M is the number of MESS, I is the set of nodes, T is the set of time, and P_{it}^{vl} is the required capacity for voltage regulation.

(2) In order to reduce battery consumption and improve battery life, the charging and discharging power of the MESS should not exceed its rated power, and the access of mobile energy storage should not cause the new voltage to exceed the limit. In addition, MESS cannot be charged and discharged when switching between nodes [13].

$$P_{mt}^{MESS} \le P_{rated}^{MESS}, \quad \forall m, t \tag{2}$$

$$\sum P_{mit}^{MESS} \le P_{it}^{\lim}, m \in i, \quad \forall t \in T, i \in I \tag{3}$$

$$P_{mt}^{MESS} = 0, \quad \text{if } M_{\mathrm{mt}}^{MESS} = 1, \ \forall m \tag{4}$$

where, MMESS m is the 01 variable, 0 means that the m-th MESS has not moved the node at time t, and 1 means that the node has moved.

(3) The transfer model for MESS.

For any two nodes, during a move of MESS, the product of the time required to move and the speed should be greater than the distance between the nodes to be moved.

$$\sum_{t=t_{ms}}^{t_{me}} M_{mt}^{MESS} \times v_m \ge l_{ij}, \quad \forall m \tag{5}$$

where, l_{ij} is the distance between the transfer nodes ij, v_{m} is the moving speed, t_{ms} and t_{me} are the starting and ending moving moments, respectively, and MMESS m tis the 01 variable, indicating whether the MESS transfers the node at time t.

B. MESS OPERATING COST MODEL WITH ELECTRICITY PRICE

The main operating cost of mobile energy storage vehicles is the cost of charging electricity and the mobile cost of energy storage vehicles. When dispatching, it is necessary to consider the impact of the health status of the mobile energy storage vehicle and the number of charging and discharging times on the life, so as to extend the service life of the mobile energy storage vehicle and improve the utilization efficiency of the energy storage vehicle. When calculating the cost, the peak and valley electricity price is used to calculate the operating cost of the mobile energy storage vehicle, and the low electricity price is used to charge during the low period and discharge during the peak period [14]. The real-time price can be obtained by the local power dispatching department, or the historical price can be used to simulate the change trend of the current electricity price.

The operation and maintenance of MESS will generate maintenance costs and benefits. Maintenance costs include two parts. The first part is the depreciation cost of MESS caused by charging and discharging, and the second part is the cost of MESS transfer between nodes. The income of MESS is the income brought by charging at a lower price when the load is low, and discharging at a higher price when the load is peak.

$$C1_{mt}^{MESS} = \omega_{dc}(F_{mt}^{cha} + F_{mt}^{dis}) \tag{6}$$

$$C2_{mt}^{MESS} = \begin{cases} \omega_{mv}, t \in [t_{ms}, t_{me}] \\ 0, \text{other} \end{cases} \tag{7}$$

$$\mathrm{G}_{m}^{MESS} = \sum_{t=1}^{T} (F_{mt}^{dis} \times \omega_{it} - F_{mt}^{cha} \times \omega_{it}) \tag{8}$$

where, C1MESS mt is the charge and discharge depreciation cost of the m-th MESS at time t, and ω_{dc} is the depreciation coefficient. C2MESS mt is the transfer cost of the m-th MESS at time t, ω_{mv} is the transfer cost coefficient, and ω_{it} is the electricity price of node i at time t.

III. ORDERLY CHARGING COORDINATION OPTIMIZATION MODEL FOR HOUSEHOLD ELECTRIC VEHICLE GROUP

A. CHARGING LOAD MODEL OF HOUSEHOLD ELECTRIC VEHICLE GROUP IN RESIDENTIAL DISTRICT

The daily driving mileage of household electric vehicle users in residential areas approximately obeys a lognormal distribution, and its probability density function is [15]:

$$f(d) = \frac{1}{\sqrt{2\pi} d\sigma_d} \exp\left[-\frac{(\ln d - \mu_d)^2}{2\sigma_d^2}\right] \tag{9}$$

D in the formula is mileage, μ dis 3.019, σ dis 1.123.

The battery power of a household electric vehicle and its mileage d satisfy an approximately linear relationship,

$$E^v = \frac{d - \mathrm{D}}{\mathrm{D}} \times 100\% \tag{10}$$

In type: E^{v} is the battery power of the electric vehicle; D is the maximum mileage of the electric vehicle in the pure electric state.

Combining the above formula, the probability density function of the battery power before charging the electric vehicle can be obtained as

$$f(E^v) = \frac{1}{\sqrt{2\pi} D(1 - E^v)\sigma_d} \times \exp\left\{-\frac{[\ln(1 - E^v) + \ln D - \mu_d]^2}{2\sigma_d^2}\right\} \tag{11}$$

The end time t_{e} of the last trip of the residential EV in the community approximately obeys the Weibull distribution, and its probability density function is

$$f(t_e) = \begin{cases} \frac{k1}{k2}\left(\frac{t_e}{k2}\right)^{k1-1} \exp\left[-\left(\frac{t}{k2}\right)^{k1}\right], \\ \quad 4 < t_e \le 24 \\ \frac{k1}{k2}\left(\frac{t_e + 24}{k2}\right)^{k1-1} \exp\left[-\left(\frac{t_e + 24}{k2}\right)^{k1}\right], \\ \quad 0 \le t_e \le 4 \end{cases} \tag{12}$$

where, k1 and k2 are the shape parameter and scale parameter of Weibull distribution, k1 = 5.427, k2 = 18.618.

The charging mode of residential electric vehicles and the charging start time t0 depend on the charging control strategy [16] The charging methods mainly include battery replacement mode, normal charging mode and fast charging mode. If the electric vehicle user starts to charge at the end of the last trip, the control strategy is a random charging control strategy. If the electric vehicle user delays ΔT on the basis of a given time before charging, the control strategy is a delayed charging control strategy. Among them, ΔT can be obtained by the uniform random number back off algorithm. Assuming that there are N household electric vehicles in the cell node, the daily mileage d of electric vehicle users and the charging start time t0 are independent of each other, and each charge is fully charged, then the electric vehicle charging power at t ($t \geq t0$). The expected value is

$$P^V(t) = N\int_0^1 f(E)p^s(t)\mathrm{d}E \tag{13}$$

in type: ps(t) is an electric vehicle with a power charge at the t-moment.

$$P_t^s = \begin{cases} P_v^{cha}, t_0 \leq t \leq t_s \\ 0, other \end{cases} \tag{14}$$

$$t_s = t_0 + d \times E_{per}^V / P_v^{cha} \tag{15}$$

where, t_s is the time when the charging ends, P_v^{cha} is the rated charging power of an electric vehicle, and EV per is the power consumption per kilometer of the electric vehicle.

From the above formula, the load charging demand model of household E^V groups in residential communities can be obtained. Electric vehicle charging load adopts unit power factor control, so the expected value of reactive power demand is zero [17].

B. CHARGE AND DISCHARGE CONSTRAINT MODEL OF HOUSEHOLD EV GROUP IN RESIDENTIAL DISTRICT

The charging and discharging capacity of household electric vehicle batteries must meet the following constraints [18].

(1) The capacity of the EV battery is related to the charge and discharge capacity. The charge capacity increases while the discharge capacity decreases. In addition, the capacity of the electric vehicle should remain unchanged before the electric vehicle ends its use and starts charging.

$$E_t^V = E_{t-1}^V + (V_{t-1}^{cha} - V_{t-1}^{dis})P_{t-1}^V \tag{16}$$

$$V_t^{cha} + V_t^{dis} \begin{cases} \leq 1, t \leq t_e, \mathrm{t} \geq \mathrm{t}_0 \\ = 0, t_e < \mathrm{t} < \mathrm{t}_0 \end{cases} \tag{17}$$

where, EV t is the battery power of the electric vehicle at time t, and V_t^{cha} and V_t^{dis} are variables of 01, which represent charging and discharging respectively [19].

(2) In order to ensure the safety of charging and discharging of residential EVs in the community, its charging and discharging capacity should be within a certain margin and not overcharge and overdischarge.

$$E_{Min}^V \leq E_t^V \leq E_{Max}^V, \quad \forall t \tag{18}$$

where, EV Max and EV Min are the upper and lower limits of the charge and discharge capacity of electric vehicles.

(3) In order to meet the travel needs of residents in the community the next day, the charged capacity of the day should be greater than the travel demand capacity, and the remaining capacity should be greater than the minimum discharge capacity. The demand capacity is obtained indirectly according to formula 9 and formula 10, the probability of EV trip mileage.

$$E_s^V - E_{per}^V \geq E_{Min}^V \tag{19}$$

where, EV per is the predicted demand capacity of the next day trip [20].

IV. MULTI-SCENARIO AND MULTI-OBJECTIVE OPTIMIZATION SCHEDULING CONSIDERING ELECTRIC VEHICLES AND MOBILE ENERGY STORAGE

Based on the charging and discharging models of MESS and EV, this paper comprehensively considers the mobile cost and peak-shaving and valley-filling benefits of MESS, and establishes establish the optimization scheduling model of the distribution network MESS with the goal of maximizing photovoltaic output, minimizing operating costs and minimum voltage overruns.

A. OBJECTIVE FUNCTION

The objective function consists of three parts. The first part is to maximize the output of all photovoltaics connected to the distribution network and reduce the waste as much as possible; the second part is to minimize the operating cost of MESS, which includes the cost of moving between nodes and the cost of charging electricity, the income includes the income of peak shaving and valley filling [21].

$$Max\ F = f_1 - f_2 - f_3 \tag{20}$$

(1) Maximize photovoltaic output.

$$f_1 = k_1 \times \sum_{t=1}^{T}\sum_{i=1}^{I} P_{it}^{PV} \tag{21}$$

(2) Minimize operating costs.

$$f_2/k_2 = \sum_{t=1}^{T}\sum_{m=1}^{M}(C1_{mt}^{MESS} + C2_{mt}^{MESS}) - \sum_{m=1}^{M}\mathrm{G}_m^{MESS} \tag{22}$$

(3) Minimize voltage overlimits.

$$f_3 = k_3 \times \sum_{t=1}^{T}\sum_{i=1}^{I}(V^U + V^L) \tag{23}$$

where, k1, k2 and k3 are the weight coefficients of each target, which P_{it}^{PV} is the active power of the PV at the i t-moment under the i node. V^U and V^L are voltage relaxing factors [22].

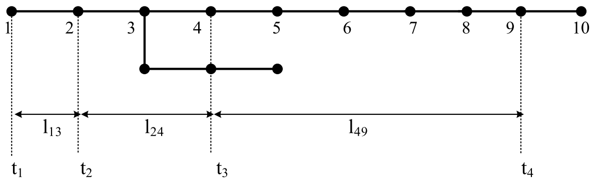

FIGURE 1. MESS space-time transition constraint model.

B. CONSTRAINTS

(1) Current constraints

$$P_{it} = \sum_{j\in i} P_{jt} + p_{it} + P_{it}^{V} + (F_{mt}^{cha} - F_{mt}^{dis}) \sum_{m\in i} P_{mt}^{MESS} - P_{it}^{PV}, \quad \forall i.t \quad (24)$$

$$Q_{it} = \sum_{j\in i} Q_{jt} + q_{it}, \forall i, t \quad (25)$$

$$V_{it} = V_{jt} + \frac{P_{jt}r_{ij} + Q_{jt}x_{ij}}{V_{jt}}, \forall i.t \quad (26)$$

$$V_{it} \geq V^{Min} - V^{L}, \quad \forall i, t$$
$$V_{it} \leq V^{Max} - V^{U}, \quad \forall i, t \quad (27)$$

where, P_{it} and Q_{it} are the injected active and reactive power of node i at time t, the load of node p_{it} at time t, V_{it} is the voltage of node i at time t, V^{Max} and V^{Min} are nodes the upper and lower limits of the voltage, r_{ij} and x_{ij} are the resistance and reactance between node i and node j.

(2) MESS and electric vehicle charging and discharging constraints.

$$E_{mt}^{MESS} = E_{m(t-1)}^{SUESS} + (F_{m(t-1)}^{cha} - F_{m(t-1)}^{dis}) P_{m(t-1)}^{MESS}, \quad t \geq 2 \quad (28)$$

$$E_{m\_\min}^{MESS} \leq E_{mt}^{MESS} \leq E_{m\_\max}^{MESS}, \quad \forall m, t \quad (29)$$

$$F_{mt}^{cha} + F_{mt}^{dis} \begin{cases} = 0, M_{\mathrm{mt}}^{MESS} = 1 \\ \geq 1, M_{\mathrm{mt}}^{MESS} = 0, \end{cases} \quad \forall m, t \quad (30)$$

$$(16) - (18) \quad (31)$$

where, E_{mt}^{MESS} is the electric quantity at time t, $E_{m\_\min}^{MESS}$ and $E_{m\_\max}^{MESS}$ are the margins of MESS charging capacity, F_{mt}^{cha} and F_{mt}^{dis} are the 01 variables, which are the mth MESS charge and discharge flag at time t.

C. OPTIMAL SCHEDULING PROCESS CONSIDERING MESS MULTI-SCENARIO PARTICIPATION

Based on the MESS and EV models, this paper considers the multi-objective coordination optimization problem under different scenarios such as low peak load of electric vehicles and different initial capacities of MESS, and establishes multi-scenario multi-objective coordination optimization model of the distribution network by maximizing MESS operating revenue and penalizing voltage overruns, the distribution network optimization scheduling process is shown in Fig. 2. First, the MESS energy space transfer model is established according to the charge and discharge constraints and the transfer cost of the MESS between nodes is calculated, and then the charging load model of the household electric vehicle group is established according to the driving model of the residential electric vehicle, and then input the distribution network voltage, impedance, photovoltaic output and node load and other parameters, and then coordinate and optimize according to the MESS model and the electric vehicle model and combine the input distribution network parameters to maximize the photovoltaic output. Minimize the operating cost and minimize the voltage limit as the goal. Solve the optimal scheduling of the MESS at T time in the future, and execute the scheduling at the first time, and check whether the voltage limit has occurred at the next time [23]. If there is no limit violation, then Then execute the scheduling at the next moment until all T have been executed, otherwise, re-input the distribution network parameters such as voltage over-limit to solve the new MESS optimal scheduling.

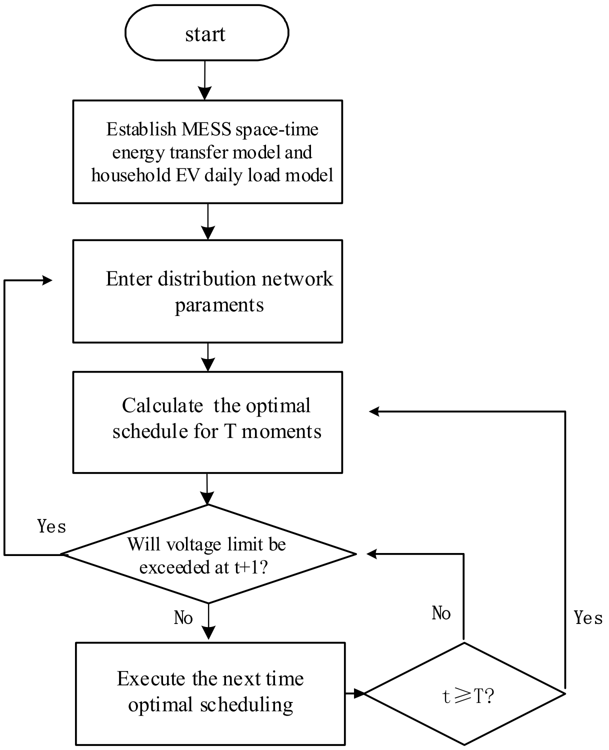

FIGURE 2. Flow chart of MESS optimization scheduling.

V. CASE ANALYSIS

A. CALCULATION PARAMETERS

In order to verify the correctness and effectiveness of the optimized configuration of the distribution network considering electric vehicles and mobile energy storage systems proposed in this paper, this paper uses the improved IEEE33-node system as an example. The system contains 4 photovoltaics, 6 MESSs, and 0 time. The initial position of MESS is shown in Fig. 3. Nodes 4, 15, 22, and 29 are connected to distributed photovoltaics with capacities of 1.43MW, 2.25MW, 3.17MW and 2.64MW respectively. The typical solar power curve of node 4 is shown in Fig. 3. The electricity price of the calculation example adopts the seasonal peak electricity price, which is divided into four stages: peak, peak, flat, and valley. The typical daily electricity price is shown in Table 1.

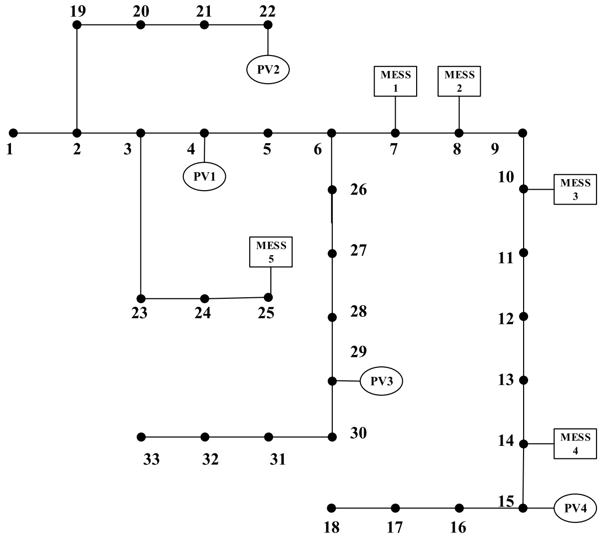

FIGURE 3. Improved IEEE33-node distribution network system.

TABLE 1. Typical daily electricity price.

The time periods.	Electricity price ($/ MW. .*.h).	The time periods.	Electricity price. ($/MW*h).
0-8	53.2	16-18.	72.4
8-10	72.4	18-20.	81.2
10-12	63.5	20-22	72.4
12-14	63.5	22-24	53.2
14-16	72.4		

When the MESS is not connected, the photovoltaic output reaches its peak around 12 noon, causing some node voltages to be too high. At this time, light must be discarded to stabilize the node voltage. At 18:00, the distributed photovoltaic output drops sharply while the load is at a peak, the power supply is difficult to meet the load demand, resulting in the voltage of node 30 is too low, the voltage curve of node 30 is shown in Fig. 5.

1) CONFIGURATION RESULTS

The optimal allocation model in this paper is a mixed integer nonlinear programming problem. The CPLEX and CONOPT solvers are used to solve the model, and the optimal scheduling of MESS and the optimal solution of charging and discharging power at each time are obtained. The optimal scheduling of MESS1 at 7-13 points is shown in Table 2. MESS1 is charged at 7 and 8 points. Since the electricity price rises from 8 points, the charging power at 8 points is reduced and the transfer starts at 9 points. The discharge power is all zero. MESS1 reaches the 3 nodes at 10 o'clock. Because the load rises at this time, MESS1 begins to discharge [24]. At 11 o'clock, the PV output increases. At 12 o'clock, the PV output becomes excessive. MESS1 starts to charge to maintain voltage stability. The SOC of MESS1 is shown in Fig. 6.

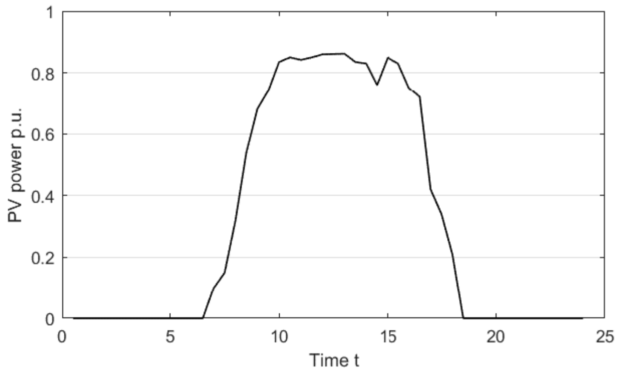

FIGURE 4. PV1 typical sunrise force curve.

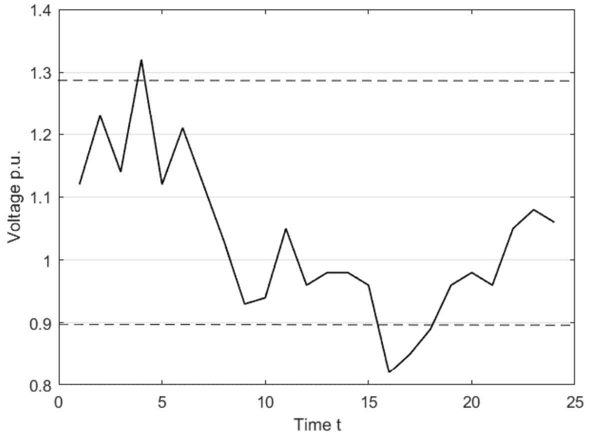

FIGURE 5. The voltage time curve of node 30.

TABLE 2. Optimal scheduling of MESS1.

	node	Power. MW	F^{cha}	F^{dis}
7	7	1.42.	1	0
8	7	0.75.	1	0
9		0	0	0
10.	3	0.64.	0	1
11.	3	0	0	0
12.	3	0.58	1	0
13	3	0	0	0

MESS can effectively cut peaks and fill valleys, absorb PV output, and MESS can move between nodes, which has the advantages of economy and convenience that conventional energy storage does not have. However, MESS scheduling is often more complicated. If MESS uses a fixed configuration, it will not be able to take full advantage of its peak shaving and valley filling. It can be seen from Fig. 7 that when the MESS is not optimally scheduled, it can only keep the voltage of the connected node stable, and the node voltage

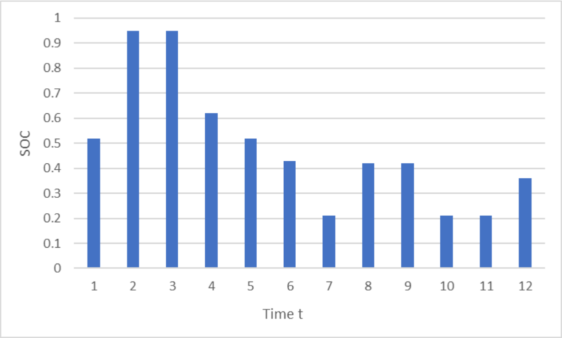

FIGURE 6. SOC time chart of MESS1.

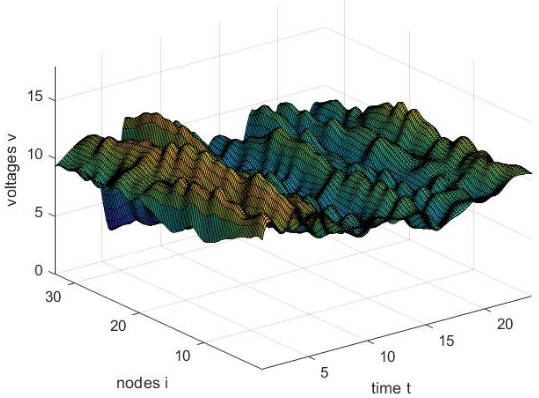

FIGURE 7. MESS is not optimally scheduled.

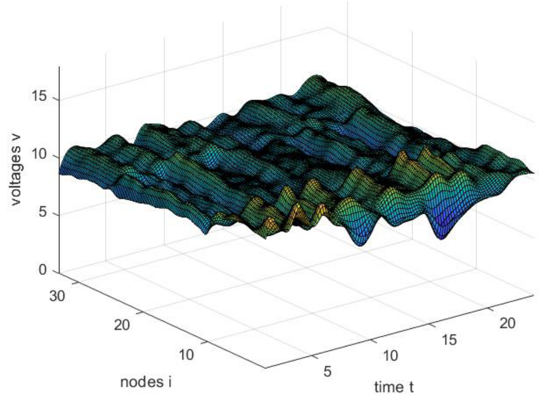

FIGURE 8. After MESS optimized scheduling.

of the end node drops severely. The node voltage-time curve of optimized scheduling is shown in Fig. 8. It can be seen that the optimized configuration model proposed in this paper can optimize the dynamic scheduling of MESS between different nodes, and the effect of peak shaving and valley filling under the premise of achieving optimal economy significant [25].

VI. CONCLUSION

This paper establishes the spatiotemporal energy transfer model of mobile energy storage and the charging and discharging model of the residential electric vehicle group, and considers the access of new energy sources such as photovoltaics to optimize the joint optimization of MESS and EV, and proposes that photovoltaic output is the highest in multi-scenario and multi-objective collaborative optimization model with the goal of minimizing voltage overruns and minimizing MESS operating costs. The main contributions of this paper are as follows.

1) Comprehensively considering the characteristics of energy storage and space-time position transfer of MESS, the space-time dynamic transfer model of mobile energy storage system based on MESS charge and discharge constraints and path transfer cost is established, and the path transfer model and cost model are proposed.
2) Considering the coordinated optimization of the mobile energy storage system and the charging and discharging constraints of residential EVs in multiple scenarios, the MESS scheduling is used to solve the voltage limit problem, and the access to renewable energy such as photovoltaics is also considered.
3) A multi-scenario and multi-objective dynamic optimization scheduling model for distribution network considering the joint constraints of MESS and household EVs is proposed to maximize the peak-shaving and valley-filling capacity, maximize the prevention of voltage over-limit revenue, and maximize the coordinated optimization of photovoltaic consumption. Multi-objective joint optimization to achieve global optimal economy.
4) The MESS optimal dispatch model proposed in this paper can effectively solve the problem of voltage overruns in the distribution network. With limited MESS input, it can reduce peaks and fill valleys by optimizing dispatch between different nodes, which solves the load of household electric vehicles and photovoltaics. The voltage fluctuation problem caused by the uncertainty of the output significantly improves the voltage quality and power supply stability of the distribution network under the premise of achieving optimal economy.

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