

PAPER • OPEN ACCESS

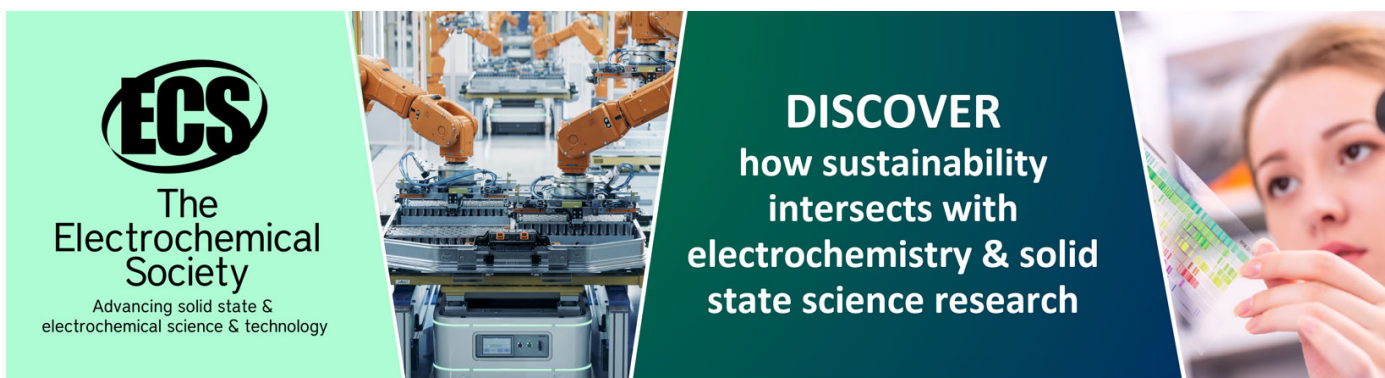
Sensitivity Analysis on the Inter-regional Accommodating Capability of Renewable Energy Based on Time Sequential Simulations

To cite this article: Huichao Wang *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **199** 052029

View the [article online](#) for updates and enhancements.

You may also like

- [A novel beamformer-based imaging of phase–amplitude coupling \(BIPAC\) unveiling the inter-regional connectivity of emotional prosody processing in women with primary dysmenorrhea](#)
Hui-Ling Chan, Intan Low, Li-Fen Chen et al.
- [How will climate change affect the spatial coherence of streamflow and groundwater droughts in Great Britain?](#)
Maliko Tanguy, Amulya Chevuturi, Ben P Marchant et al.
- [Optimization of domestic inter-regional virtual water trade of agriculture products in China](#)
Rong Cai, Mengting Hu, Huiting Guo et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Sensitivity Analysis on the Inter-regional Accommodating Capability of Renewable Energy Based on Time Sequential Simulations

Huichao Wang^{1,a}, Jinhui Ma², Yanan Wang³, Feng Li¹, and Xiaohui Xu¹

^{1,4}Renewable Energy Research Center, China Electric Power Research Institute, Nanjing, 210003, China

²Power Dispatch Department, State Grid Anhui Electric Power Company, Hefei, 230061, China

³Department of Electrical Engineering, Xi'an Jiaotong University, Xi'an, 710049, China

^aCorresponding author: 17600271330@163.com

Abstract. To realize the maximum accommodation of renewable energy of two regions, the paper has studied many influencing factors including renewable energy theoretical output curve, load characteristics, operation constraints of units and operation characteristics of UHV line. The weekly renewable energy inter-regional accommodation model is proposed based on time sequential simulation, considering the reserve of system, maintenance of units, trading power of two regions, power plan of conventional units and so on. An inter-regional system consisting of two IEEE 30 bus systems is used as an example. The sensitivity of influencing factors is analysed to prove the effectiveness and rationality of the proposed model. The research results could be available for dispatching agency to formulate the dispatching plan.

1.Introduction

With the increasing permeability of renewable energy installed capacity, some large-scale energy bases need the ultra-high voltage (UHV) line to realize large-scale, high-efficiency and safe delivery to achieve renewable energy inter-regional accommodation [1]. When the two regions fail to coordinate the scheduling plan reasonably, the plan may cause more serious renewable energy accommodation problems. Therefore, it's necessary to analyse the impact of system reserve, unit maintenance plan, trading power plan, unit power plan and other influencing factors to obtain reasonable inter-regional dispatching plan.

To obtain the maximum accommodation of renewable energy in two regions, the paper comprehensively considers renewable energy theoretical output curve, load characteristics, operation constraints of units and operation characteristics of UHV line, and establishes a weekly renewable energy inter-regional accommodation model based on time sequential simulation, which takes into account the reserve of system, maintenance of units, trading power of two regions and power plan of conventional units. Based on this, the rationality analysis of spare capacity, unit maintenance plan, electricity trading plan and power plan of conventional units in the inter-regional system are carried out.



2. The inter-regional accommodation of renewable energy

The inter-regional accommodation of renewable energy utilizes the UHV line to deliver the renewable energy from surplus area to the power receiving region for further accommodation [2]. Considering the low cost of renewable energy power generation, the trading price will be lower than the benchmark price of the power receiving region, which is beneficial for both renewable energy accommodation and the overall power generation cost reduction. However, the actual situation indicates the renewable energy output has the characteristics of random fluctuations and it's difficult to predict accurately, so it's necessary to use thermal power unit to smooth UHV line. At the same time, in the actual dispatching operation, UHV line is beneficial for large-scale resource optimization configuration across the area without excessive consideration of the frequency modulation requirements and power fluctuations of the two sides of the power grid. Considering the operation control characteristics of UHV line, the transmission power curve generally presents a ladder [3].

In inter-regional system, the equivalent load curve of the power output region is the actual load curve plus the transmission power curve of UHV line. The transmission power plan will increase the equivalent load curve and expand the accommodation space of renewable energy. The equivalent load curve of the power receiving region is the actual load curve minus the transmission power curve of UHV line. The transmission power plan will reduce the equivalent load curve and reduce the accommodation space of renewable energy. Therefore, the dispatching agency can fully coordinate the accommodation space of renewable energy to expand renewable energy accommodation and reduce power generation costs by formulating the plan of reasonable dispatch and transmission power.

3. Time sequence simulation model of inter-regional accommodation

3.1 Objective function

The objective function is the maximum consumption of renewable energy in the two regions with weekly time interval, as follows:

$$\max \sum_{t=1}^T (\sum_{wi=1}^{N_{w1}} P_{wi,t} + \sum_{pi=1}^{N_{p1}} P_{pi,t} + \sum_{wj=1}^{N_{w2}} P_{wj,t} + \sum_{pj=1}^{N_{p2}} P_{pj,t}) \quad (1)$$

Where, T denotes the time period of the model simulation, $P_{wi,t}$ denotes the output of the windfarm wi in the power output region at time t , $P_{pi,t}$ denotes the output of the photovoltaic power station pi in the power output region at time t , $P_{wj,t}$ denotes the output of the windfarm wj in the power receiving region at time t , $P_{pj,t}$ denotes the output of the photovoltaic power station pj in the power receiving region at time t , N_{w1} denotes the number of windfarm of the power output region, N_{p1} denotes the number of photovoltaic power station of the power output region, N_{w2} denotes the number of windfarm of the power receiving region, N_{p2} denotes the number of photovoltaic power station of the power receiving region.

3.2 Constraints

Constraints of the model include the constraints of inter-regional systems operation, the constraints of unit operation, the constraints of UHV line operation, the constraints of unit maintenance, the constraints of power plan and the constraints of renewable energy output. System reserve demand should consider the fluctuation of load and renewable energy [4]. The constraints mainly include transmission power limits, power ramp rate limits, power adjustment time and number [5-8].

(1) System operating constraints

1) The power balance constraints of the power output region

$$\sum_{i=1}^{N_1} u_{i,t} * P_{i,t} + \sum_{wi=1}^{N_{w1}} P_{wi,t} + \sum_{pi=1}^{N_{p1}} P_{pi,t} = \sum_{m=1}^{N_M} P_{m,t} + \sum_{l=1}^{N_L} P_{l,t} \quad (2)$$

Where, $u_{i,t}$ denotes the status of the unit i in the power output region at time t (0 or 1), $P_{i,t}$ denotes the output of the unit i in the power output region at time t , $P_{m,t}$ denotes the power demand of the load node m in the power output region at time t , $P_{l,t}$ denotes the transmission power of the UHV line l at

time t , N_M denotes the number of the load node in the power output region, N_L denotes the number of the UHV line, N_I denotes the number of the unit in the power output region.

2) The power balance constraints of the power receiving region

$$\sum_{j=1}^{N_2} u_{j,t} * P_{j,t} + \sum_{wj=1}^{N_{W2}} P_{wj,t} + \sum_{pj=1}^{N_{P2}} P_{pj,t} = \sum_{n=1}^{N_N} P_{n,t} - \sum_{l=1}^{N_L} P_{l,t} \quad (3)$$

Where, $u_{j,t}$ denotes the status of the unit j in the power receiving region at time t (0 or 1), $P_{j,t}$ denotes the output of the unit j in the power receiving region at time t , $P_{n,t}$ denotes the power demand of the load node n in the power receiving region at time t , N_N denotes the number of the load node in the power receiving region, N_2 denotes the number of the unit in the power receiving region.

3) The reserve demand of two regions

$$\begin{aligned} P_{one,t} &= K_l \times P_{load_one,t} + K_n \times P_{new_one,t} \\ P_{two,t} &= K_l \times P_{load_two,t} + K_n \times P_{new_two,t} \end{aligned} \quad (4)$$

Where, $P_{one,t}$, $P_{two,t}$ denote the reserve demand of two regions at time t , $P_{load_one,t}$, $P_{load_two,t}$ denote the total load demand of two regions at time t , $P_{new_one,t}$, $P_{new_two,t}$ denote the total output of renewable energy of two regions at time t , K_l , K_n denote the fluctuation coefficient of load and renewable energy output respectively[2].

4) The reserve constraints of two regions

$$\begin{aligned} R_{one,t} &\geq P_{one,t} \\ R_{two,t} &\geq P_{two,t} \end{aligned} \quad (5)$$

Where, $P_{one,t}$, $P_{two,t}$ denote the system reserve capacity of two regions at time t respectively.

(2) The constraints of unit operation

1) Unit output constraints

$$\begin{aligned} u_{i,t} * P_{i,min} &\leq P_{i,t} \leq u_{i,t} * P_{i,max} \\ u_{j,t} * P_{j,min} &\leq P_{j,t} \leq u_{j,t} * P_{j,max} \end{aligned} \quad (6)$$

Where, $P_{i,max}$, $P_{i,min}$ denote the maximum and minimum output limits of the unit i in the power output region respectively, $P_{j,max}$, $P_{j,min}$ denote the maximum and minimum output limits of the unit j in the power receiving region respectively.

2) Unit climbing ramp constraints

$$\begin{aligned} R_{i,d} &\leq P_{i,t} - P_{i,t-1} \leq R_{i,u} \\ R_{j,d} &\leq P_{j,t} - P_{j,t-1} \leq R_{j,u} \end{aligned} \quad (7)$$

Where, $R_{i,u}$, $R_{i,d}$ denote the climbing ramp limits of the unit i in the power output region respectively, $R_{j,u}$, $R_{j,d}$ denote the climbing ramp limits of the unit j in the power receiving region respectively.

3) Minimum unit stop time constraints

$$\begin{aligned} \sum_{k=t}^{\min(t+TS_i-1,T)} (1-u_{i,k}) &\geq TS_i (u_{i,t-1} - u_{i,t}) \\ \sum_{k=t}^{\min(t+TS_j-1,T)} (1-u_{j,k}) &\geq TS_j (u_{j,t-1} - u_{j,t}) \end{aligned} \quad (8)$$

Where, TS_i denotes the minimum stop time of the unit i in the power output region, TS_j denotes the minimum stop time of the unit j in the power receiving region.

4) Minimum unit run time constraints

$$\begin{aligned} \sum_{k=t}^{\min(t+TO_i-1,T)} u_{i,k} &\geq TO_i (u_{i,t} - u_{i,t-1}) \\ \sum_{k=t}^{\min(t+TO_j-1,T)} u_{j,k} &\geq TO_j (u_{j,t} - u_{j,t-1}) \end{aligned} \quad (9)$$

Where, TO_i denotes the minimum run time of the unit i in the power output region, TO_j denotes the minimum run time of the unit j in the power receiving region.

(3) The constrains of UHV line operation

1) UHV line power constraints

$$P_{l,\min} \leq P_{l,t} \leq P_{l,\max} \quad (10)$$

Where, $P_{l,\max}$, $P_{l,\min}$ denote the maximum and minimum power limits of the UHV line l respectively.

2) UHV line power climbing ramp constraints

$$\min(R_{l,d}(u_{l,t} - u_{l,t-1}), 0) \leq P_{l,t} - P_{l,t-1} \leq \max(-R_{l,u}(u_{l,t} - u_{l,t-1}), 0) \quad (11)$$

Where, $u_{l,t}$ denotes the status of power adjustment of the UHV line l at time t , $R_{l,u}$, $R_{l,d}$ denote the power climbing ramp limits of the UHV line l respectively.

3) UHV line power adjustment time constraints

$$\sum_{k=t+1}^{\min(t+TA_l, T)} u_{l,k} \geq TA_l (u_{l,t-1} - u_{l,t}) \quad (12)$$

Where, TA_l denotes the maximum stability time of the UHV line l .

4) UHV line power adjustment times constraints

$$\sum_{k=1}^T u_{l,k} \geq T - N \quad (13)$$

Where, N denotes the maximum number of power adjustment of the UHV line l .

(4) Unit maintenance constraints

$$u = u' * M_{k*T} \quad (14)$$

Where, M_{k*T} denotes the unit maintenance schedule (1 means no maintenance, and 0 means maintenance), u , u' denote the status of unit operation before and after maintenance respectively.

(5) The power plan constraints

1) Trading power constraints

$$\sum_{i=1}^T P_i * \Delta t = Q_l \quad (15)$$

Where, Q_l denotes the transmission capacity of the UHV line l during the entire simulation time.

2) Conventional unit power plan constraints.

$$\begin{aligned} \sum_{i=1}^T P_{i,t} * \Delta t &= Q_i \\ \sum_{j=1}^T P_{j,t} * \Delta t &= Q_j \end{aligned} \quad (16)$$

Where, Q_i , Q_j denote the Generating capacity of conventional units of two regions during the entire simulation time respectively.

(6) Renewable energy station output constraints

$$\begin{aligned} P_{w,t} &\leq P_{w,\max} \\ P_{p,t} &\leq P_{p,\max} \end{aligned} \quad (17)$$

Where, $P_{w,\max}$, $P_{p,\max}$ denote the maximum power limits of the windfarm and Photovoltaic power station respectively.

4. Simulation results and analysis

4.1 Parameters

The inter-regional system (A region、B region) consists of two IEEE 30 node systems connected by UHV line. The sensitivity of influencing factors is analyzed by the model of renewable energy inter-regional accommodation, which including the reserve of system, maintenance of units, trading power of two regions and power plan of conventional units.

The unit parameters of inter-regional system are as shown in Table 1, the data in the table is per-unit value and the reference value of system is 100 MW. The conventional units are A-1 and B-1, other thermal power units are flexible units. The number A-5, B-5 units are the wind farm equivalent units. The number A-6, B-6 units are the photovoltaic power station equivalent units. The permeability rate

of A region renewable energy installed capacity is 40%, and 25% in B region. On the other hand, the transmission capacity is 100MW, the power climbing ramp is 50MW/h, and the minimum power adjustment time is 6h of UHV line in the inter-regional system.

The load curve of the inter-regional system, the renewable energy theoretical output curve, the unit maintenance plan, the electricity trading plan, the conventional unit electricity plan and the reserve capacity of two regions are shown below.

Table 1. Power units parameters of inter-regional system

Unit-number	Grid-node	Max output (p.u.)	Min output (p.u.)	Climbing speed (p.u./h)	Min-close-time (h)	Min-Start-time(h)
A-1	1	1.2	0.5	0.375	2	2
A-2	5	0.8	0.3	0.15	2	2
A-3	8	1	0.3	0.3	2	2
A-4	13	0.6	0.2	0.1	2	2
A-5	2	1.6	0	—		
A-6	11	0.8	0			
B-1	1	1.2	0.5	0.375	2	2
B-2	5	0.8	0.3	0.15	2	2
B-3	8	1	0.3	0.3	2	2
B-4	13	0.6	0.2	0.1	2	2
B-5	2	0.8	0	—		
B-6	11	0.4	0			

1) The load curve

The load curves of a province in Northwest China and a province in East China are randomly selected and normalized. Combined with IEEE 30-bus system, the maximum load of A and B areas in a week is set to be 160MW and 300MW, respectively. The week load curves of A and B areas can be obtained, as shown in Figure 1.

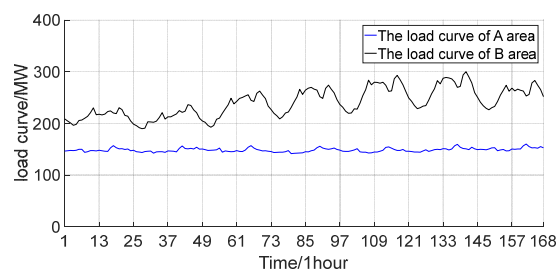


Figure 1. The weekly load curves of A and B areas

2) The renewable energy theoretical output curve

The week renewable energy theoretical power curves of a province in Northwest China and a province in East China are randomly selected and normalized. Combined with the installed capacity of renewable energy in the inter-regional system, the week theoretical power curves of A and B areas are obtained, as shown in Figure 2.

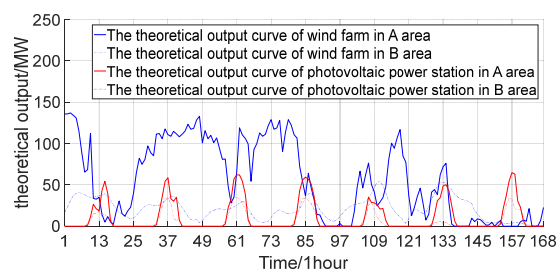


Figure 2. The renewable energy theoretical output curves

3) The reserve demand

Combined with the reserve demand formula (Formula 4), four sets of load fluctuation coefficients K_l and renewable energy output fluctuation coefficients K_n are set up, as shown in Table 2.

Table 2. The parameters of reserve demand for A and B areas

Scene number	K_l	K_n
Scene 1	5%	10%
Scene 2	10%	10%
Scene 3	5%	20%
Scene 4	10%	20%

4) The unit maintenance plan

As shown in Table 3, the week maintenance schedules for the A and B areas maintenance units have two maintenance times to choose.

Table 3. The week maintenance schedules for A and B areas

maintenance unit	maintenance plan	maintenance time
A-3	Plan A1	All day on Wednesday
	Plan A2	All day on Friday
B-3	Plan B1	All day on Wednesday
	Plan B2	All day on Thursday

5) The conventional unit electricity plan

Combined with the unit load rate, the average one-week load rate is set at 50% and 75%, respectively. The week generation plan of conventional units in area A and B areas can be obtained, as shown in Table 4.

Table 4. The week generation plan of conventional units for A and B areas

unit number	plan number	the average one-week load rate	conventional unit electricity plan
A-1	Plan A1	50%	70080MWh
	Plan A2	75%	150120MWh
B-1	Plan B1	50%	70080MWh
	Plan B2	75%	150120MWh

6) The power trading plan

Combined with the utilization ratio of UHV line, the average utilization ratio of line in one week is 20%, 40%, 60%, 80% and 100%, respectively. The power trading week plan between A and B areas is obtained, as shown in Table 5.

Table 5. The power trading week plan between A and B areas

plan number	the average utilization ratio	the power trading week plan
Plan 1	20%	3360MWh
Plan 2	40%	6720MWh
Plan 3	60%	10080MWh
Plan 4	80%	13440MWh
Plan 5	100%	16800MWh

4.2 Simulation results

The solving process of time sequence simulation model of renewable energy inter-regional accommodation is a mixed integer programming problem. The integer 0-1 variable in the problem is the start-stop state of units and the adjustment state of UHV line, which can be solved by CPLEX. With the help of MATLAB and CPLEX, the sensitivity analysis of reserve capacity, unit maintenance plan, power trading plan and conventional unit power plan are carried out with the renewable energy

limitation rate of A and B areas as evaluation indexes.

Without considering the reserve capacity, unit maintenance plan, power trading plan and conventional unit electricity plan, the inter-regional system is solved in two-region independent operation scene and joint operation scene. The limitation power curve of renewable energy in A and B areas are obtained as shown in Figure 3 and Figure 4, and the limitation rate of renewable energy in A and B areas are calculated as shown in Table 6. which can verify the effectiveness of the renewable energy inter-regional accommodation strategy.

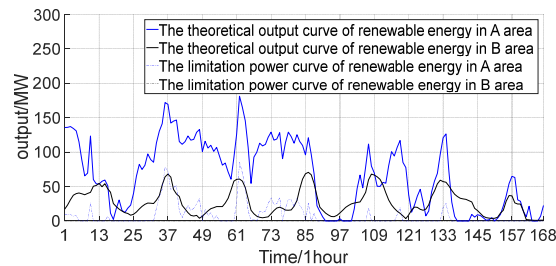


Figure 3. The limitation power curves of renewable energy in A and B areas in two-region independent operation scene

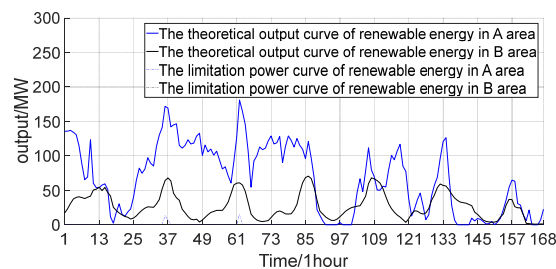


Figure 4. The limitation power curves of renewable energy in A and B areas two-region joint operation scene

Table 6. The limitation rate of renewable energy in A and B areas

Scene number	limitation rate in A areas	limitation rate in B areas	limitation rate in two areas
independent operation	12.36%	0%	8.24%
joint operation	0.32%	0%	0.21%

4.2.1 The reserve demand

Combined with the load curves of A and B systems and the renewable energy output curves, the renewable energy accommodation of inter-regional systems under the four scenarios in Table 2 is calculated, as shown in Table 7.

Table 7. The renewable energy accommodation of inter-regional systems

Scene number	K_l	K_n	limitation rate in A areas	limitation rate in B areas	limitation rate in two areas
Scene 1	5%	10%	1.01%	1.32%	1.10%
Scene 2	10%	10%	1.05%	1.47%	1.17%
Scene 3	5%	20%	1.40%	1.15%	1.33%
Scene 4	10%	20%	1.98%	0.56%	1.51%

Combining with the joint operation scene in Table 6 and comparing the four scenarios in Table 7, it is inferred that the reserve capacity is positively correlated with the renewable energy limitation rates of A system and inter-regional system. With the increase of load fluctuation coefficient and renewable

energy output fluctuation coefficient, the greater the reserve demand, the increase of system startup unit number, the increase of inter-regional system minimum technical output, and the decrease of system renewable energy accommodation capacity. Considering that the transmission power can't be changed at any time, and can't fully coordinate the accommodation spaces of renewable energy of two areas, which may cause the B system can't completely accommodate the local renewable energy.

4.2.2 The unit maintenance plan

Combined with the load curve of A and B system and the renewable energy output curves, the renewable energy accommodation of inter-regional system under the combination of maintenance schemes of A and B system units in Table 3 is calculated, as shown in Table 8.

Table 8. the renewable energy accommodation of inter-regional systems

Scene number	maintenance plan of A areas	maintenance plan of B areas	limitation rate in A areas	limitation rate in B areas	limitation rate in two areas
Scene 1	Plan A1	Plan B1	0.65%	0.71%	0.67%
Scene 2	Plan A2	Plan B1	0.66%	0.69%	0.67%
Scene 3	Plan A1	Plan B2	0.66%	0.68%	0.67%
Scene 4	Plan A2	Plan B2	—	—	—

Combining with the joint operation scene in Table 6 and comparing the four scenarios in Table 8, it is seen that the combination of maintenance schemes of A and B system under scenario 4 is not feasible, and the combination of maintenance schemes in other scenarios only slightly affects the accommodation of renewable energy in A and B areas.

4.2.3 The conventional unit electricity plan

Combined with the load curves of A and B systems and the renewable energy output curves, the renewable energy accommodation of inter-regional systems under the combination of conventional unit electricity plans of A and B systems in Table 4 is calculated, as shown in Table 9.

Table 9. The renewable energy accommodation of inter-regional systems

Scene number	conventional unit electricity plan of A	conventional unit electricity plan of B	limitation rate in A areas	limitation rate in B areas	limitation rate in two areas
Scene 1	Plan A1	Plan B1	0.51%	0.21%	0.42%
Scene 2	Plan A2	Plan B1	0.51%	0.20%	0.42%
Scene 3	Plan A1	Plan B2	0.59%	0%	0.42%
Scene 4	Plan A2	Plan B2	0.55%	0%	0.42%

Combining with the joint operation scene in Table 6 and comparing the four scenarios in Table 9, it is seen that the conventional unit electricity plans of A and B systems only slightly affect the renewable energy accommodation capacity.

4.2.4 The power trading plan

Combined with the A and B system load curves and the renewable energy output curves, the renewable energy accommodation of the inter-regional system under five power trading week plans in Table 5 is calculated, as shown in Table 10.

Table 10. The renewable energy accommodation of inter-regional systems

Plan number	average utilization ratio	power trading week plan	limitation rate in A areas	limitation rate in B areas	limitation rate in two areas
Plan 1	20%	3360MWh	1.02%	0.21%	0.79%
Plan 2	40%	6720MWh	0.42%	0.15%	0.34%

Plan 3	60%	10080MWh	0.23%	0.25%	0.23%
Plan 4	80%	13440MWh	0.25%	0.21%	0.23%
Plan 5	100%	16800MWh	0.94%	0.25%	0.74%

Combining the independent operation scene in Table 6 and comparing the five plans in Table 10, it is seen that the power trading plan between A and B systems will have a great impact on the renewable energy accommodation capacity of A and B areas. Setting a reasonable power trading plan will promote the overall accommodation of renewable energy in inter-regional systems. Compared with the other four schemes, plan 5 aggravates the renewable energy limitation rate for failing to coordinate the changes of renewable energy output at different times because the 100% utilization of the lines.

5. Conclusions

Based on the inter-regional system, the paper analyzes the sensitivity of system reserve demand, unit maintenance plan, conventional unit electricity plan and power trading plan by using the renewable energy inter-regional accommodation time sequence simulation model.

(a) Reserve demand and power trading plan have great impact on the renewable energy accommodation of inter-regional system. The more reserve demand is reserved, the smaller the renewable energy accommodation capacity of the system. Excessive power trading plan will also reduce the renewable energy accommodation space.

(b) Unit maintenance plan and conventional unit electricity plan have slightly weaker impact on the renewable energy inter-regional accommodation of inter-regional system. However, the unreasonable combination of unit maintenance plans of two regions will directly affect the power balance of the inter-regional system, resulting in load shedding.

(c) The renewable energy interregional accommodation time sequence simulation model can verify the rationality of the dispatching plans, such as the system reserve demand, the unit maintenance plan, the conventional unit electricity plan and the power trading plan.

Acknowledgements

Project Supported by State Grid Anhui Electric Power Company Technology Project (Research on the evaluation method and construction plan of the short-term new energy consumption in Anhui).

References

- [1] Liu Z Y, ZHANG Q P, DONG C, et al. (2014) Efficient and security transmission of wind, photovoltaic and thermal power of large-scale energy resource bases through UHVUHV projects [J]. Proceedings of the CSEE, 34(16): 2513-2522.
- [2] Cao Y, LI P, YU Y, et al. (2014) Analysis on accommodating Capability of Renewable Energy and Assessment on Low-carbon Benefits Based on Time Sequence Simulation[J]. Automation of Electric Power Systems, 38(17): 60-66.
- [3] Wang B, XIA Y, XIA Q, et al. (2016) Model and methods of generation and transmission scheduling of inter-regional power grid via HVUHV tie-line[J]. Automation of Electric Power Systems, 40(03): 8-13+26.
- [4] Wang K Y, LUO X J, WU L, et al. (2013) Optimal Dispatch of Wind-hydro-thermal Power System With Priority Given to Clean Energy[J]. Proceedings of the CSEE, 33 (13):27-35.

- [5] Cui Y, ZHAO Y, QIU L J, et al. (2018) Coordinated scheduling method of wind-thermal power transmitted by UHVUHV system for improving peak-shaving margin of receiving-end power grid[J/OL]. Automation of Electric Power Systems, 42(15) :126-132.
- [6] Xu D, WANG B, ZHANG J L, et al. (2016) Integrated transmission scheduling mode for wind-photovoltaic-thermal power by ultra-high voltage direct current system[J]. Automation of Electric Power Systems, 40(06): 25-29+57.
- [7] Han H W, TU M F, ZHANG H L, et al. (2015) Day-ahead generation scheduling method considering adjustable HVUHV plan and its analysis[J]. Automation of Electric Power Systems, 39(16): 138-143.
- [8] Zheng H W, XIA Q, DING M S, et al. (2015) A new mode of HVUHV tie-line operation optimization for maximizing renewable energy accommodation[J]. Automation of Electric Power Systems, 39(03): 36-42.