The Researching on Evaluation of Automatic Voltage Control Based on Improved Zoning Methodology

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Abstract: According to the present serious phenomenon of increasing size and structure of power system, hierarchically structured automatic voltage control (AVC) has been the researching spot. In the paper, the reduced control model is built and the adaptive reduced control model is researched to improve the voltage control effect. The theories of HCSD, HCVS, SKC and FCM are introduced and the effect on coordinated voltage regulation caused by different zoning methodologies is also researched. The generic framework for evaluating performance of coordinated voltage regulation is built. Finally, the IEEE-96 system is used to divide the network. The 2383-bus Polish system is built to verify that the selection of a zoning methodology affects not only the coordinated voltage regulation operation, but also its robustness to erroneous data and proposes a comprehensive generic framework for evaluating its performance. The New England 39-bus network is used to verify the adaptive reduced control models’ performance.

1. Introduction
With the continuous development of society science and technology and economy, the scale and structure of power system is becoming more and more complex, the difficulty by controlling the voltage balance of each grid node voltage to control the entire power grid is also increasing. At present, the research direction of automatic voltage control (AVC) has been extended to the hierarchical and sub regional control of network [1-2].

France is one of countries that implement AVC layering earlier, and voltage control mode implemented by EDF company is one of the most advanced control systems in the world. The whole control system is divided into three levels, voltage control [3]. Germany RWE company is the leader in the voltage control system, but its application is two level voltage control, optimal power flow is the core of the optimal control, but because many control variables and high computational complexity, computational cycle is longer, so there are higher requirements on the reliability of [4]. At present, Fujian is the first implementation of AVC, system also uses two level control mode, because the regional controller in order to adapt to the operation state of the power system change is difficult, so the three level control and France compared to the lack of two level voltage control area, control bus hub selection and generator the control layer [5]; Taizhou city has also developed a voltage optimization control system to node voltage as constraint conditions, in order to minimize the power loss, the function of "four remote" to realize the optimization of voltage [6].

According to the AVC partition problem, now has a large number of scholars to conduct research, literature [7] presented a multi population genetic algorithm to improve the voltage control partitioning algorithm of fuzzy c-means clustering of the C, AGC was established in [8] and AVC integrated optimization model based on layered in the time dimension for the frequency and voltage of
decomposition and coordination. The [9] introduces evaluation based on optimal power flow, the power system is divided into several regions, the formation of three level voltage control, but can not reflect the real-time power network topology for partitioning the effects of Shandong power grid AVC system introduced by the literature [10], isolated and EMS means no establishment of communication links, to ensure the stability and reliability of AVC.

In view of the current research situation and development direction, this paper has done a few work: This paper has established a general framework to evaluate the effect of different partition methods on voltage order control, and evaluate the adaptive model in voltage order control In the applicability. This paper introduces the principle and application of single-distance stratification clustering (HCSD), VAr control space stratification clustering (HCVS), spectral K clustering (SKC) and fuzzy C clustering method (FCM) The application of the method is evaluated on the problem of voltage order control. The spatial region is divided and the selection of the dominant node is based on different examples. The adaptability of the adaptive model in the topology change is studied, and the various emergencies are considered The feasibility of each clustering method is verified.

2. Overview of 1 and AVC hierarchical control architecture
At present, hierarchical voltage control can be divided into three stages including voltage control, power system, voltage level control system refers to the voltage change when first need to response, when the system load fluctuation, power grid accident, a first voltage response, the response time of a few seconds in the range of two level voltage control; set in the hub system, is based on regional control, closed-loop control, response time in a minute level, at the level of voltage control, the partition problem is the key to realize the problem of two level control, is also the focus of this paper; three level voltage control system is arranged in the dispatch center, is a kind of prevention and control the response time is about tens of minutes, the target three level voltage control is to ensure the safe operation of the whole network, but also to ensure the economic operation .

The AVC system partitioning general framework diagram is shown in figure 1:

In order to realize the real-time voltage automatic control, it is necessary to optimize all the variables of the whole network in order to obtain the distribution of the optimized power flow. However, the reality is not feasible due to the large and complex network, network partition partition voltage control is the orderly development direction and trends of the day, the first is to obtain the control partition coupled within the region, to reduce the mutual influence between regions, each region has second is the requirement of reactive power balance the basic ability. The current partitioning studies are based on the concept of electrical distance, which can be represented by the sensitivity of the load node, i.e., the Jacobi matrix can be described . After controlling the partition, a dominant node is set so that it can represent the change of the load node in the region. Two regulation as a level of voltage regulation and two regulation of the bridge, the received signal level three voltage control, the voltage amplitude of dominant nodes at a given value, if the shift, by changing a voltage controller parameters of offset voltage offset.
In order to realize the real-time voltage automatic control, it is necessary to optimize all the variables of the whole network in order to obtain the distribution of the optimized power flow [14]. However, the reality is not feasible due to the large and complex network, network partition partition voltage control is the orderly development direction and trends of the day, the first is to obtain the control partition coupled within the region, to reduce the mutual influence between regions, each region has second is requirement of reactive power balance the basic ability. The current partitioning studies are based on the concept of electrical distance, which can be represented by the sensitivity of the load node, i.e., the Jacobi matrix can be described. After controlling the partition, a dominant node is set so that it can represent change of the load node in the region. Two regulation as a level of voltage regulation and two regulation of bridge, the received signal level three voltage control, the voltage amplitude of dominant nodes at a given value, if the shift, by changing a voltage controller parameters of offset voltage offset.

3. Voltage order control frame diagram

In this section, a general framework will be proposed to evaluate the performance of voltage order control. Module A and C are responsible for data acquisition, B, D and E are responsible for evaluating system status, and general framework flow diagram is shown in figure 2.

Fig. 2 flow chart of general framework, load curve provides basic load data for the system, and then considers the safety constraints to optimize the power flow. The module is module B and module C provides the active, reactive and voltage data (P, Q, V) of the power system, providing the voltage reference value and reactive power reference value for the module D, Control range (Vref, Qref, Vmax, Vmin, Qmax, Qmin).

B. module B

The module will be integrated into the different cluster method frame model, the whole network is divided into several weak coupling region, and then select the dominant node for each region, (with methods will be discussed in the fourth part of this article). The system status information collected by module A is transmitted through the module to the D module provides the basis for planning voltage control in the area.

C. module C

Through calculation of the module, module C can obtain the system load and line loss, voltage offset, and provide the basis for the voltage control of the module D. No probability random perturbations in the near normal values by the load fluctuation, the disturbance is temporary, but also will cause random line tripping of reactive load fluctuations, emergency situations should be taken into consideration, so as to control the voltage of the order.

It is assumed that the transient response of the generator reaches a steady state when the voltage is controlled orderly, and the voltage in the middle section can be calculated by the steady-state alternating current flow equation. The number of nodes in the N network, a lot of V voltage offset is a N*1 matrix calculation method, as shown in formula (1):

$$\Delta V = V_{ref} - V_{ad}$$  (1)

Among them, the Vref is the voltage standard value obtained by the module A, and the Vad is the voltage value with perturbation.

From Figure 1, it is assumed that voltage order control is generally based on normal controller can obtain voltage displacement vector Vp of leading node and the reactive power generated by the controllable device such as the generator in the voltage ordered control process Qg.

D. module D

The module includes a voltage control strategy of orderly control, synchronous equipment by adjusting the voltage in each partition to regulate the orderly adjustment of bus voltage of PNset, the ability to control the area of synchronous generator as shown in formula (2):

$$QR_g \cdot C_{pg} \geq a_i$$  (2)

Among them, QRg is reactive capacity of the generator, and Cpg is dominant node in the region. To control the sensitivity of the generator, AC is the smallest controllable volume of K in the first k region. The primary goal of voltage order control is to allow the voltage of the leading node.
PNset can follow the optimal calculated by optimal power flow forecasting module A reference value, a second goal is the rational allocation of regional reactive power distribution, so as to improve the safety of power area, regional reactive power as the reference value of formula (3) shown:

\[ Q_{ref_j} = \frac{\sum_{g=SVR_j} Q_g}{\sum_{g=SVR_j} Q_{g,max}} \]  

(3)

Among them, the SVRJ is a group of generators that participate in the two stage voltage control in the regional J.

The objective function of the two programming problem is shown in equation (4):

\[
\min \{ \sum_{i=PN_{set}} (\Delta V_p)^2 + \mu \sum_{j=SVR_j} (\sum_{g=SVR_j} (Q_{ref} - \frac{Q_g}{Q_{g,max}}))^2) \}
\]

(4)

The constraints are as follows:

\[ V_{p,min} \leq V_p + C_{pg} \cdot \Delta Q_g \leq V_{p,max} \]  

(5)

\[ V_{g,min} \leq V_G + C_{vg} \cdot \Delta Q_g \leq V_{g,max} \]  

(6)

\[ Q_{g,min} \leq Q_g + \Delta Q_g \leq Q_{g,max} \]  

(7)

Among them, is the weight factor of the two objective functions, and Qg is the generator without Work power output, Qg refers to the amount of adjustment obtained by iterative calculation, VP and VG, respectively, bus voltage and generator voltage, Cpg and Cvg respectively refers to voltage sensitivity matrix. Equations (5) and (6) are upper and lower bounds on voltage operation. (7) the upper and lower limits of reactive power operation.

E. module E

The module evaluates the control effect and calculates the correction Qg in each voltage ordered control loop.

In a N bus system, the PI value is calculated based on the mean relative error absolute value in each voltage ordered control iteration, as shown in (8):

\[
PI_i = \frac{1}{N} \cdot \sum_{n=1}^{N} |\frac{V_{ac}(i) - V_{ad}(i)}{\Delta V(i)}| \]

(8)

(9)

Among them, subscript AC is the numerical value after the order control. Ad is the value after the voltage disturbance, and V is calculated by formula (1). That between different voltage levels of the orderly control is a dynamic decoupling, the reactive power control loop time constant is greater than a constant voltage control circuit of power plant, lower than the two level voltage control loop constant, therefore, the dynamic characteristics of voltage can be ignored. If the adaptive simplified control model can be applied to the partitioning method, when \( PI_i \) is less than the threshold \( PI_{three} \), you need to reconfigure the partition and select the dominant node. Then, go back to the B module and update the calculation PIi.

\[
OPI = 1 - E\{PI\}
\]

After each iteration, a non sequential Monte Carlo method is used to update the data. The lower the OPI value, the worse the order control performance of the voltage. Through the comparison of the OPI, we can measure the degree of voltage control scheme for different combinations of modules A, B, C, D and E. In this paper, the influence of the change of the precision of data on the method of partitioning is considered, and then the influence of different partition methods on the performance of voltage order control is studied.

3. Zoning method

In this section, four partitioning methods based on clustering optimization are introduced. In principle, the partition method includes two steps: (1) using the partition algorithm, the area is divided into several voltage for orderly control of weak coupling region; (2) for each small area leading node and bus, the load voltage variation can best represent the region.
3.1 Network partitioning algorithm

Engineering and partition problem is a clustering optimization problem, existing the following definition: A. similarity measure: electrical distance represents the similarity degree of two nodes, most of the electrical distance definition is similar to the actual distance, namely the coupling is stronger, the smaller the distance; B. clustering standard in clustering and classification, need consider the economic objective function; C. clustering evaluation: through evaluation algorithm applicability related clustering method.

1) single distance hierarchical clustering algorithm (HCSD)

The concept of the algorithm and the electrical distance was first proposed. A. similarity measurement: the degree of coupling between the M and the N nodes is affected by the degree of voltage change, as shown in equation (10):

\[
a_{mn} = \frac{\partial V_m}{\partial Q_m} - \frac{\partial V_n}{\partial Q_n}
\]  

However, the use of AMN matrix is not appropriate, the concept of size and electrical distance aspects of AMN is the reverse, on the other hand, amn is not equal to anm, which is not logical, therefore, need to construct new matrix to accomplish the transformation of electrical distance, as shown in Figure 11:

\[
D_{mn} = -\log(a_{mn} \cdot a_{nm})
\]  

B. clustering criteria: a clustering algorithm is merged into the node group, in each iteration, the two clusters CI, CJ similar characteristics such as formula (12) shows, the standard of clustering between clusters as shown in formula (13):

\[
ICD_{i,j} = \max\{D_{mn} : m \in C_i \text{ and } n \in C_j\}
\]

\[
C_i \cup C_j : \min\{ICD_{i,j}\}
\]

The result of the iterative algorithm is a clustering tree, called a tree graph, which shows the correlation between clusters and clusters.

C. clustering verifies that the diameter of a cluster is the maximum distance between any two nodes in a cluster, as shown in equation (14). The relative diameter of the first k cluster can be obtained by formula (15):

\[
diam_{C_k} = \max\{D_{mn} : m, n \in C\}
\]

\[
RD = \frac{\sum_{c=1}^{k} diam_{C_c}}{k}
\]

The quality of the grouping corresponds to the slope of the RD curve. Finally, the optimal number of partitions K can be obtained by formula (16):

\[
k : \max \left\{ \left| RD_2 - RD_1 \right|, \ldots, \left| RD_{\text{max}} - RD_{\text{max}-1} \right| \right\}
\]

2) VAr control space hierarchical clustering (HCVS)

For a reactive power source and a network of L nodes classification, Sij is the node of the I node of J voltage reactive power output sensitivity, VAr control space is defined as the G dimension Euclidean space, each node load are defined by the ordered vector xij:

\[
x_{ij} = -\log \left( |S_{ij}| \right)
\]

Based on the above definition, the ordered vector of the node represents the degree of coupling between the node and the specified reactive power source.

A. similarity measurement: for two load nodes, m{xm1, xm2,... Xm} and n{xn1, xn2,... Xn}, the power distance is shown in equation (18):

\[
D_{mn} = \sqrt{\left| x_{m1} - x_{n1} \right|^2 + \cdots + \left| x_{mg} - x_{ng} \right|^2}
\]
B. clustering criteria: single distance similarity and hierarchical clustering algorithm, also using the agglomerative clustering algorithm, single clustering by iteration, node and a set of passive resources strong coupling of the same will be placed in the same cluster.

\[
ICD_{ij} = \frac{1}{\sum_{m \in C_i} \sum_{n \in C_j} (D_{mn})} \sum_{m \in C_i} \sum_{n \in C_j} (D_{mn})
\]  

(19)

C. cluster verification: using the average intra cluster distance (AD) can determine the most suitable class number in the range of [1 and K max]:

\[
AD = \sqrt{\sum_{i=1}^{k} \sum_{j=1}^{k} ICD_{ij}}
\]

(20)

The larger the AD, the weaker the coupling between the clusters, and the K definition is shown in formula (21):

\[
k = \max \{AD\}
\]  

(21)

3) spectral K clustering (SKC)
The spectral K clustering method is based on spectral analysis, and extracts the global information about the structure of the graph from the eigenvalues of the graph matrix. A. similarity measurement: the relation between weighted proximal matrix and network G is \(A(G) = \text{wij}\). Wij stands for the weights of nodes I and j placed in different clusters, such as the formula (11): (assuming that nodes I and j are adjacent to the G diagram).

The metric matrix of figure D is shown in equation 22:

\[
d_{ij} = \begin{cases} 
0 & \text{if } i = j \\
\sum_{k=1}^{n} W_{ik} & \text{if } i \neq j
\end{cases}
\]  

(22)

The Laplasse operator of G is a \(N \times N\) symmetric matrix, \(L(G) = \text{D}(G) - \text{A}(G)\), and the normalized Blass equation is presented in this paper as follows:

\[
L = \text{D}^{-(1/2)} \cdot \text{L} \cdot \text{D}^{-(1/2)}
\]  

(23)

Laplasse G is the operator for a symmetric matrix \(N \times N\), \(L(G) = \text{D}(G) - \text{A}(G)\), the standard proposed La Blass equation are shown as follows: Blass operator standard is singular, its characteristic value contains 0, the rest of the eigenvalues are also positive. For spectral classification, K characteristic values for nodes in \(R_k\) coordinate arrangements. Vector x standardization publicity, as shown in (24), equivalent to the epitome of k-1 space.

\[
U_i = \frac{x_i}{\|x_i\|} \quad 1 \leq i \leq N
\]  

(24)

B. clustering criteria: the K mean is used to assign N nodes to K clusters. The K mean method iteratively reduces the objective function value:

\[
J = \sum_{j=1}^{k} \sum_{i=1}^{n} \|U_j^i - C_j^i\|
\]  

(25)

Among them, the \(U_j^i\) at C J refers to the node to the geometric center of the distance, the optimization iteration until the center point of the movement down to a certain minimum threshold or below the maximum number of iterations is reached to stop. C. clustering verification: in this paper, eigenvalue analysis is used to determine the most appropriate clustering decision, while feature difference refers to the difference between two consecutive eigenvalues. The values of the eigenvalues Ln are arranged in descending order, relative to eigenvalues, as shown in equation 26:

\[
\gamma = \frac{V_{k+1} - V_{k}}{V_{k}}
\]  

(26)

When the gamma reaches the maximum value, it represents the subarea and the result is optimal. It is worth noting that the relative eigenvalue criterion allows the most appropriate number of clusters to be confirmed prior to the K mean optimization. This will significantly reduce the computation time of the SKC method.
4) Fuzzy K means clustering (FCM)
This paper adds voltage sensitivity research based on similarity measurement, and uses fuzzy statistical method to cluster verification.
A. Similarity measurement: Xij refers to the voltage coupling of load nodes I and J. The formula is shown in equation 11.

\[ J_m = \sum_{i=1}^{N} \sum_{j=1}^{k} u_{ij}^m \cdot \| x_i - C_j \| \quad 1 \leq m \leq \infty \] (27)

Among them, Uij is the membership degree of Xi in J clustering. M determines the ambiguity of clustering. In the simple K mean, Uij converges to 0 or 1 in m=1. The fuzzy clustering is iteratively optimized by formula (27), and the formulas updated by Uij and Cj are shown in formula (28):

\[ u_{ij} = \frac{1}{\sum_{r=1}^{k} \left( \frac{\| x_i - C_j \|}{\| x_r - C_j \|} \right)^{2/(m-1)}} \]

\[ C_j = \frac{\sum_{i=1}^{N} u_{ij}^m \cdot x_i}{\sum_{i=1}^{N} u_{ij}^m} \]

When the conditions shown in the formula (29) are satisfied, the result converges to the minimum or saddle point Jm: 0, epsilon 1.

\[ \left| u_{ij}^{(iter+1)} - u_{ij}^{(iter)} \right| < \varepsilon \quad \text{or} \quad \max \{ \text{iterations} \} \] (29)

C. Clustering verification: Based on the value of K, the quality of the clustering decision can be verified by formula (30). The smaller the VXB, the better the clustering results.

\[ V_{X_B}(k) = \frac{\sum_{i=1}^{k} \sum_{j=1}^{N} u_{ij}^m \cdot \| x_i - C_j \|}{N \cdot \min_{j} \| C_i - C_j \|} \] (30)

3.2 Leading node selection method
After partitioning the area, it should start looking for the dominant node in each region, and the selected leading node needs to be able to replace the voltage level [22] of an area. In the same region, the similarity between the two nodes in the C is shown in listing 31:

\[ L_{mn} = \sum_{m,n \in C} D_{mn} \] (31)

Among them, Dmn refers to the electrical distance between nodes m and n.

The system needs to be able to monitor load disturbances accurately and to keep the voltage from within the proper range. The number of dominant nodes best and clustering the same number of dominant nodes too much though will make cluster more uniform, but also increase the coupling between regions, so they need to control more complex and dynamic interactions to handle loop instability, a good partition method must be able to do a good job in the balance two hand.

4. Simulation results and discussions are presented
4.1 Partition method results are discussed
All partitioning methods use similarity measurement, and only the input Jacobi matrix is needed, and the Jacobi matrix can be periodically updated with conditional changes. Because of the existence of the Jacobi matrix, all partitioning methods are related to state and structure. A good partitioning method can identify different boundary, based on the IEEE-96 system as an example, through the 72 mile 230KV line second and third regions connected by 67 mile 230KV line first and third regions are connected, the system grouping result is shown in Figure 3, the system is divided into three clusters, consistent the partitioning method clustering results, this method can also verify the partition basic ability to confirm the clear boundary.
4.2 Adaptive simplified model zoning method adaptive discussion
This section mainly verifies whether the partitioning method can be applied to the adaptive simplified model, and studies the main factors that affect the applicability of the simplified model partitioning method.

A simplified model of adaptive partition method and the advantage of Jacobi is based on the matrix update can quickly update the voltage control ordered partition model, in order to allow the orderly control voltage can quickly work in the first cycle, the simplified model running time need less than 1 min control. In this paper, Poland 2383 node is used as an example, HCDS and HCVS are all based on agglomerate hierarchical clustering method, and their computational complexity depends on the number of cluster nodes. In order to reduce the computation time, the network needs to reduce the tree nodes and reduce the nodes to 1733 by reducing the tree nodes before clustering.

The computational complexity of SKC and FCM methods is represented by $O(NKI)$ and $O(nk^2i)$, respectively. $N$ is the number of wires to be classified, $K$ is the number of clusters, and $I$ is the maximum number of iterations. For fast clustering, $K$ needs to be limited to range $\{10151\}$, and the reactive margin should be above 20 MVar. For the SKC method, the relative eigenvalue calculation has been introduced in the fourth part of this paper. The SKC method can select the most suitable classification $K$ value, and also increase the computing time.

The results of the relative eigenvalues of the Poland system example are shown in Figure 4, and 17 regions are divided based on the SKC method.

Figure 5 FCM running time curve decided to simplify the control model, HCSD and HCVS are based on agglomerative clustering analysis algorithm, the most potential, SKC can quickly solve the classification problem in about 8 seconds, but in the eigenvalue calculation but increase in computation time.

Figure 6 is the different classification methods of operation of computing time, in the FCM method, the clustering of different $K$ value in this range of $\{10151\}$ can be processed in parallel, unlike FCM, HCSD, HCVS and SKC method can simplify the control online decision model, HCSD, HCVS analysis algorithm based on agglomerative clustering, with the most development the potential SKC can quickly solve the classification problem in about 8 seconds, but in the eigenvalue calculation but increase in computation time.

4.3 example comparison
This paper studied 39 UK bus network based on classic model of network voltage control is ordered, it has 9 synchronous generator, HCSD, HCVS, SKC and FCM methods are to solve a single network state simplified control model problem the most common method, clustering validation parameters are shown in Table 1, each partition the algorithm partitions are shown in Figure 7.

![Figure 3. Regional system topology diagram](image)
Figure 4. Calculation results of eigenvalues

Figure 5. FCM run time diagram

Figure 6. 2383 partitioning time consumption diagram of bus Poland power system

Figure 7. Partitioning and leading node validation diagrams

| Zoning method | Verification standard f(x) | optimal value f | X: optimal value |
|---------------|----------------------------|-----------------|------------------|
| HCSD          | max{ΔRD(k)}                | 0.0265          | 4                |
| HCVS          | max{ΔAD(k)}                | 7.0612          | 4                |
| SKC           | max{γ(k)}                  | 0.4498          | 4                |
| FCM           | Min{V_{XH}(k)}             | 0.0961          | 5                |
The results are highlighted to partition state markers: \{HCSD: [4, 20, 21, 28]\}, \{HCVS: [1, 6, 16, 26]\}, \{SKC: [6, 20, 21, 26]\}, \{FCM: [1, 6, 16, 20, 28]\}. It is not difficult to see, although the network and control objective function is the same, but the results obtained using different classification methods are different, the problem is how to select the most suitable method for voltage control and orderly.

4.4 Static simplified control model and precise measurement evaluation

This section compares the performance of four partitioning methods in voltage order control, and studies the static simplified control based on the New England 39 bus test network. Assume that load obeys the cumulative probability distribution shown in Fig. 8, assuming that the base load deviation obeys the cumulative probability distribution as shown in Fig. 9:

The accurate measurement of the simulation results are shown in Table 2, the performance results show that the classification method affects the choice of order voltage control method. From Table 2 it is not difficult to see, when the spatial classification all can meet the requirements of the time, HCVS and SKC can reduce the loss and improve the voltage distribution, show better performance.

| Spatial classification | HCSD | HCVS | SKC | FCM |
|------------------------|------|------|-----|-----|
| OPI(%)                 | 86.91| 92.09| 91.23| 89.88|

4.5 Static simplified control models and dominant bus noise measurements are evaluated

This section studies the robustness of the measurement error of the spatial classification method, as shown in equation (32):

\[ \Delta V_p = |1 - \epsilon| \cdot \Delta V_p \]

The error of initial value is set to 2%, gradually increasing to find 10% different optimal power flow under the condition of error results as shown in Figure 10, with the increase of the error, the OPI approximation decreases linearly, the slope is small, the robustness of the method of regional classification is stronger, the slope of HCSD decreased significantly, FCM slope is the most slowly, when the error increases, the SKC method is better than HCVS. From the above conclusions, it is easy to see that the selection of the partitioning method needs to be selected according to the expected accuracy of the voltage order control.
Figure 10. optimization results of different partitioning methods based on different measurement errors

Figure 10 based on different measurement error under different partition method based on adaptive topology optimization results of the 4.6 simplified control model will change the adaptive simplified control model is applied to the new England 39 bus network, when the network topology changes, the coupling of space inside and outside will change, the simplified model of adaptive control can maintain good performance. The combination of the partitioning method and the ordered voltage control method, coupled with accurate measurements, can be used to evaluate the most unstable states (maximum load, disturbance reaching 20%). In the actual situation, the accidental occurrence of voltage control in order to control the result will not be ignored. Once the case is lower than the minimum threshold for the E module introduced in the third section of this article, a simplified control model needs to be re run to achieve a steady state for the HCDS, HCVS, and SKC methods with an adaptive simplified model.

Figure 11 compares the performance bias shown by the four partitioning methods in the presence of topological changes OPI.

Partitioning method with adaptive simplified control model has the ability to reduce the attenuation, the effect depends on (PI) thres, the lower the threshold, the better the performance, but the higher the reliability performance requirements. When (PI) thres=1%, the adaptive simplified control model is adapted to HCSD, HCVS and SKC, the network topology has changed, and the corresponding spatial correlation and control characteristics will be improved immediately.

5. Conclusion

In order to improve the voltage coordinated control, a new framework is proposed to evaluate the performance of voltage order control. The framework can select appropriate simplified model configurations for different candidate solutions and for the first time take into account robust characteristics. Although the test results mainly focus on HCSD, HCVS, SKC and FCM four kinds of partition method, but the framework has universal applicability, and can simplify the control model, and any data acquisition technology and matched control scheme. Among the four spatial classification methods, HCSD, HCVS and SKC can quickly and easily decide the simplified control model online. Meanwhile, when the network topology changes, it can improve its status quickly and improve its performance. For the SKC method, the relative eigenvalues have important value, and he needs to calculate the number of clusters by optimizing algorithm before the eigenvalue calculation, so as to improve the operation efficiency. In principle, adaptive simplified control models rely mainly on increased sensing and communication capabilities, and therefore need to be improved in the context of smart grids to enhance online telemetry and infrastructure construction.

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