TELKOMNIKA, Vol. 11, No. 9, September 2013, pp. 5018~5029
ISSN: 2302-4046

Analytical Method of Distributed Generation on Static Voltage Stability

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Abstract

It can't be ignored that the impact of distribution network to the static voltage stability of the distributed generation. In this paper, we first introduce the stability indices of the traditional grid on static voltage and the analytical method, at the same time, we put forward the corresponding advantages, disadvantages and applicable scope. Then, we present a summary of the current research on the impact of distribution network to the static voltage stability of the distributed generation at home and abroad from the two aspects of the static voltage stability indices and analytical methods. At last, the paper points out a new way to improve the distribution network static voltage stability that with the consistency theory to achieve coordinated control of distributed generation, microgrid, as well as virtual power plants, which will be more advanced. This article has a reference value for the analysis of the impact of distributed generation on static voltage stability of the distribution network, as well as researches the measures to improve the static stability.

Keywords: *distributed generation, static voltage stability, FACTS, microgrid, virtual power plant*

1. Introduction

As the main form of decentralized power supply, the proportion of the Distributed generation (DG) in the distribution network will be increasingly larger. The access of the DG will change the original flow distribution, the transmission line power, etc, which will be a great impact to the static voltage stability of distribution network. Therefore, the static voltage stability indicators and stability analysis are the premise and basis of measures to improve stability. In this regard, widely used in the traditional power grid stability indicators and analytical methods are worth learning. However, due to the presence of DG, there are new features as follows.

Different types of DG have a different type of interface with the distribution network [1], including asynchronous generators, synchronous generators and power electronic converters, etc. Different types of DG will have different impacts on the voltage stability of distribution network when they access to the grid.

When some DGs (such as wind generations) connect to the Grid, they will absorb reactive power from the distribution network while giving the active power. As a result, the voltage stability of the distribution network will deteriorate. So when such devices access to the Grid will require the reactive power compensation devices [2], for instance, FACTS devices such as SVC, STATCOM. In the previous distribution network voltage stability studies, the load is treated as a static load. However, the motor-type load will exhibit different characteristics to the distribution network voltage stability [3]. So the effect of the motor-type load and the FACTS devices can't be ignored when research the static voltage stability of the distribution network with the DG.

In the study of improving the static stability of the distribution network with the DG, the traditional control will be still useful. On the other hand, the role of the DG is important. In this aspect, the use of microgrid (MG), virtual power plant (VPP) coordinated control is noteworthy development direction.

In this paper, we first introduce the stability indices of the traditional grid on static voltage and the analytical method. We made a detailed analysis of the current research on the impact of distribution network to the static voltage stability of the distributed generation at home and abroad, especially the effect of the motor-type load and the FACTS devices. Finally, we

Received April 4, 2013; Revised May 31, 2013; Accepted June 14, 2013

propose a new way to improve the static voltage stability of the distribution network, which with the coordinate control of the MG, VPP and the FACTS devices.

2. The Static Voltage Stability Indices of the Traditional Grid and the Analytical Method

2.1. Static Voltage Stability Indices

The commonly used static voltage stability indices including the sensitivity indices, eigenvalue index, singular value index, margin index, VIPI indicators based on multi-trend solution method and the energy function indicators, etc.

2.1.1. Sensitivity Indices

Sensitivity indices can be divided into the node sensitivity, branch sensitivity and generators sensitivity when classified by the physical significance. In addition to use to judge the voltage stability of the system, they could also be used to judge the weak areas, weak branch and key generator, and determine the reactive power compensation installation location [4-6]. However, a lot of sensitivity indices don’t involve the load static/dynamic characteristics and generator reactive power constraints. Therefore, there are still some limitations when the sensitivity indices are used as the voltage static stability criterion.

2.1.2. Eigenvalue Index and Singular Value Index

The singular value and eigenvalue belong to the voltage collapse towards index [7, 8]. And as the increase of the scale of the system, the result of the voltage stability will be consistent when analyse with the both. The shortage of the singular value and eigenvalue are the bad antecedence and the heavy computation. Now there already developed some fast algorithm, such as the *LU* decomposition with flow calculation to the singular value, with which can calculate the minimum singular value quickly [9].

2.1.3. Voltage Stability Towards Index

(1) Voltage stability index L based on the general power flow solution

The index L can be expressed as follow:

$$L = \max_{j\in\alpha_L} L_j = \max_{j\in\alpha_L} \left| 1 - \frac{\sum_{i\in\alpha_G} F_{ji} V_i}{V_j} \right| \quad (1)$$

In the above equation, F_{ji} stands for load participation factor, and the proximity degree of L to 1 represents the trend of divergence degree. L is the maximum value of the L_j. L is a quantitative indicator characterization the distance between the actual state and the stability limit. The local index L_j indicates which nodes prone to voltage collapse. The index L is simple structured and accurate calculation, and can be used for online analysis. However, the index L cannot provide any information about the participation of the branch and the generator, and it can only be used to the traditional flow model. Meanwhile, the generator reactive power limit is not considered in the calculation of the index L [10].

(2) Voltage Instability Proximity Indicator *VIPI*

The power flow equations are usually present multiple solutions, and the closer the operating point to the collapse point, the less the number of solutions. While there is only 1 pair of solutions in the vicinity of the collapse point, there is only 1 solution at the collapse point. And the index *VIPI* uses that law to predict the closeness of the voltage instability [11]. Besides, the index is very sensitive to the response of the changes of the operating conditions. Since it is the angle difference between two nodes injected voltage vector, it can not associate with any actual variables of the power system directly.

(3) Voltage Collapse Proximity Indicator *VCPI*

Slightly change the load on a specific bus (i.e. active power ΔP_L and reactive power ΔQ_L), and assume thereby causing the corresponding change of the reactive power output of the entire generator is $\Delta\sum Q_G$. We define *VCPI* by the following equation:

$$VCPI \overset{def}{=} \frac{\partial \sum Q_G}{\partial Q_L} \quad (2)$$

The smaller the value of the *VCPI*, the more stable the system, otherwise the more unstable the system.

VCPI is a good indication of the adjacent voltage collapse. However, due to its strong nonlinear to the load, there are serious limitations as a measure of the margin of safety [12].

(4) The first indicator of the voltage stability

We usually use the equivalent circuit shown in Figure 1 while in the derivation process of the static voltage stability indicator.

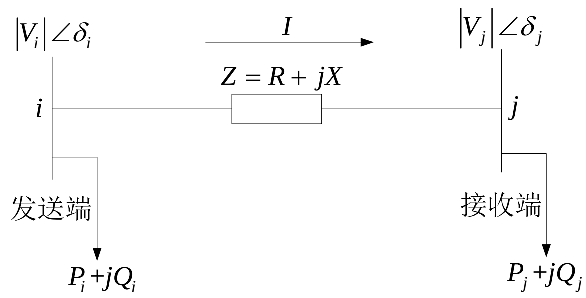

Figure 1. Simple Model of Distribution System Line

In the Figure 1, *R* indicates the resistance of the line while *X* stands for the reactance. P_i/P_j indicates the active power of the node *i/j* while Q_i/Q_j stands for the reactive power.

According to the model in Figure 1, Reference [13] derivation the first indicator of the voltage stability based on the power flow:

$$L_j = 4\left[\left(P_j X - Q_j R\right)^2 + \left(P_j R + Q_j X\right)\right] \quad (3)$$

In the equation, L_j stands for the voltage stability indicator of the branch *j*. The whole system voltage stability indicator *L* is the maximum voltage stability indicator of all the branches, and the corresponding branch is the weakest of the whole system.

(5) Voltage stability index *VSI*

By using the equivalent model shown in Figure 1, References [14, 15] deduce a new kind of voltage stability index *VSI*:

$$VSI_j = \left(P_j R + Q_j X - 0.5|V_i|^2\right)^2 - Z^2\left(P_j^2 + Q_j^2\right) \quad (4)$$

VSI_j stands for the voltage stability indicator of the branch *j*. The whole system voltage stability indicator *VSI* is the maximum voltage stability indicator of all the branches. Usually, the range is 0<*VSI*<0.25, and the closer *VSI* to 0, the more stable the system. References [14, 16] calculate the most sensitive bus of the system and the voltage stability range of the distribution network by using the index *VSI*.

2.1.4. Margin Index

Starting from the given running state of the system and gradually approximate the voltage collapse point by increasing the load or transmission power according to a certain pattern. Then the distance from the current system operating point to the voltage collapse point can be regard as the degree of voltage stability index, i.e. load margin index or margin index [17-19]. Reference [20] treats the margin index as the objective function, and solves the system maximum stability margin by the interior point theory and the continuous power flow genetic algorithm. References [21, 22] propose two new voltage stability margin indicators *VSM* and *VMPI*.

(1) Voltage stability margin index *VSM*

As shown in the Figure 1, voltage amplitude of the node *j* and its connected load apparent power can be expressed as follows:

$$V_j = \frac{V_i Z_L}{\left[Z_L^2 + Z^2 + 2 Z_L Z \cos\left(\theta\text{-}\theta_L\right) \right]^{1/2}} \tag{5}$$

$$S_j^L = \frac{V_i^2 Z_L}{\left[Z_L^2 + Z^2 + 2 Z_L Z \cos\left(\theta\text{-}\theta_L\right) \right]} \tag{6}$$

In the above equations, Z_L is the impedance value of the load, θ stands for the phase angle of the impedance *Z* while θ_L stands for the phase angle of the impedance Z_L. When Z_L=*Z*, the apparent power of the node *j* connecting load will reach the maximum value:

$$S_j^{cr} = \frac{V_i^2}{2Z\left[1+\cos\left(\theta_0\text{-}\theta_L\right)\right]} \tag{7}$$

Meanwhile, the voltage stability of the node *j* will reach its limit value. Reference [22] proposes a new distribution network voltage stability margin index based on the above theory:

$$VSM_j = \frac{S_j^{cr}\text{-}S_j^L}{S_j^{cr}} \tag{8}$$

VSM_j stands for the voltage stability margin index of the node *j*.

(2) Voltage Margin Proximity Indicator *VMPI*

Reference [45] proposes the *VMPI*:

$$VMPI = \begin{cases} \cos^{-1} \dfrac{V' \cdot V_L}{\|V\| \cdot \|V_L\|} & \left(\|V\| > \|V_L\|\right) \\ -\cos^{-1} \dfrac{V' \cdot V_L}{\|V\| \cdot \|V_L\|} & \left(\|V\| < \|V_L\|\right) \end{cases} \tag{9}$$

$V= (|V_1|,f_1,\ldots, |V_i|,f_i,\ldots, |V_n|,f_n)'$ is each node's voltage magnitude and phase angle obtained by the conventional flow calculation. $V_L= (|V'_1|,f'_1,\ldots, |V'_i|,f'_i,\ldots, |V'_n|,f'_n)'$ is each node's minimum voltage magnitude and phase angle obtained by the optimal power flow algorithm.

2.1.5. Energy Function Index

The energy function index (TEF) is built on the basis of the Lyapunov stability theory. And because its calculation is simple and it's been proved that the scalar function has relationship with the area surrounded by the nose-shaped curve under the assumed conditions, we regard the TEF as the voltage stability index. However, this scalar function can hardly contain more complex system model, and the calculation of the second balance point is complex, especially for the heavy load system.

2.1.6. The other Indicators

Some other voltage stability indicators include the reactive power margin index [23], the laboratory function and second order index [24, 25], the local index [26, 27], V/V_0 index, etc.

2.2. Static Voltage Stability Analysis Method

The main purpose of the static voltage stability analysis method is to judge whether the voltage of the system in the given state is stability and how to get the voltage instability critical point as well as the characteristics of the critical point. There are power flow method, singular value decomposition method, and sensitivity method according to different stability indicators. Variety of analytical methods has its own advantages and disadvantages, and the scope of application.

2.2.1. The P-U Curve

The P-U curve is the relationship between the node voltage and the regional load or the power flow of the transmission interface, so that the P-U curve can indicate the regional load level and the degree of closeness of the whole system to voltage collapse caused by the transmission interface power levels [28]. The P-U curve can be used for the analysis of the static voltage stability limit of the complex coupling network [29, 30]. However, the nose of the curve or the flow of the maximum power point is emanative.

2.2.2. The Q-U Curve

The Q-U curve depicts the relationship between a node voltage and its injected reactive power. The bottom of the curve is the voltage collapse point, where $dQ/dU=0$; on the right side, where $dQ/dU>0$, the voltage is stable; on the left side, where $dQ/dU<0$, the voltage is unstable. The distance between the running point and the bottom of the curve is the reactive power margin. The Q-U curve indicates the voltage stability characteristics and require of the reactive power, and it has good convergence and fast calculation speed. But the computation is huge for the Q-U curve needs to be calculated for each power level and accident. For a given operating condition, the Q-U curve indicates the need of partial compensation, rather than the global optimum compensation requirements.

2.2.3. Sensitivity Analysis

Voltage stability analysis of the sensitivity is based on the flow equations, and uses the changes of some certain physical quantities to study the system stability [28]. The sensitivity analysis methods have been widely used. References [31, 32] use the sensitivity index to judge weak buses; References [31, 33] use the sensitivity index to locate position of the reactive power compensation, and provide the basis for the installation of reactive power compensation devices. Meanwhile, the sensitivity analysis methods have some drawbacks [34, 35]. Most of References do not take the dynamic load effects into account when calculating the sensitivity. Ignore the effect of physical restriction such as limitation of generator reactive power and active power economic dispatching. Without taking into account the non-linear characteristics of the system, thus the distance between the critical point and system can not been reflected accurately.

2.2.4. Eigenvalue-Eigenvector Analysis

Eigenvalue-Eigenvector analysis is the kind of method to determinate the voltage Stability margin by calculating the minimum eigenvalue and its respective left and right eigenvector of the load flow Jacobin matrix. Reference [35] presents a new method for the determination of voltage collapse areas in large scale power systems, basing on Eigenvalue-Eigenvector analysis of the extended load flow Jacobin matrix. Reference [36] proposes a new index to estimate the voltage stability weakness of nodes and a method to judge the transmission line with weak voltage stability, taking the modulus minimum eigenvalue of power flow Jacobin matrix as the criteria to weigh the weakness of power system.

2.2.5. Singular Value Decomposition Method

The sign of the power flow Jacobin matrix determinant determines the system being studied is stable or unstable. The minimum singular value of the power flow Jacobin matrix represents the static voltage stability index, and the magnitude of the minimum singular value indicates the distance between the researched operating point and the static voltage stability limit [37]. Reference [38] puts forward a genetic degradation comprehensive optimization algorithm of the minimum singular value by using the minimum singular value as the stability margin index. Reference [39] proposes the singular value method to measure node voltage stability, and discusses the relationship between the voltage stability margin index signified by minimum singular value and the voltage stability margin index signified by physical quantities.

2.2.6. Model Analysis

In order to simplify the Jacobin matrix, we need to calculate the minimum eigenvalue and its eigenvector by using the system static model, and that method is called model analysis technology. Each eigenvalue relates to the change mode of the voltage/reactive power and the magnitude provides the relative measure of the unstable voltage. Reference [40] proposes the node participation factors and branch participation factors to identify voltage stability. Reference [41] gives the information about the voltage stability from the point of view of the system by the modal analysis method, and points out the area where there has potential problem. The modal analysis method can be well positioned the weak areas of voltage stability, and provide effective guidance for the implementation of control measures.

2.2.7. Bifurcation Analysis

Static voltage stability analysis mainly considers two types of voltage collapse: the saddle-node bifurcation (SNB) and the limitary induced bifurcation (LIB). There are mainly three ways to solve the voltage collapse point [42]: direct method [43], continuous power flow [44] and OPF-based method [45]. The direct method is invalid to the LIB voltage collapse and the initial is highly required. The continuous power flow need to calculate the power flow solution and requires specialized technology to identify voltage collapse type. The OPF-based method can consider a variety of constraints, but the way of the generator output growth and the order of constrains are different with the continuous power flow. Therefore, the calculation results have some differences with the first two ways.

Based on the above, References [46, 47] propose different ways to calculate the voltage collapse point; Reference [46] provide the calculation method of SNB point based on the direct method; Reference [47] uses the direct method to locate the SNB point; Reference [48] proposes a way to solve the static voltage stability critical point based on optimal multiplier power flow.

3. The Research of the Impact of DG on Voltage Stability of Distribution Network

So far, many scholars have been researched on the impact of DG on voltage stability of distribution network. The main idea is analysis based on the existing static voltage stability indicators and the traditional, such as the P-U curve, sensitivity analysis [49], modal analysis method [50], eigenstructure decomposition method, etc.

Reference [51] represents the voltage stability of the distribution network by the P-V curve, and then improves the system voltage stability by genetic algorithm to optimize the DG as well as the location of reactive power compensation. Reference [52] proposes a way to analysis by using the sensitivity analysis method according to the impact of DG on voltage of the system. Analysis the impact of DG output as well as DG location to system voltage. Reference [53] determines the system eigenvalue by modal analysis method, then work out the system modal participation factors by the eigenvectors, and pick out the bus with the maximum modal participation factor (i.e. the bus which its voltage is closest to voltage collapse point) as the access point of DG.

Reference [54] uses the voltage stability first index in the Equation (3) to the analysis of the impact of DG on voltage stability of distribution network. Reference [55] discusses the impact of different types of DG and the access location and the capacity to the index L, and concludes that the three above factors will have a great effect to the index L. Reference [56] uses the voltage stability index in the Equation (4) to the analysis of the impact of DG on voltage stability of distribution network, and regards the index VSI and active power loss as the objective function to optimize the location and capacity of DG. Reference [57] uses VSI to evaluate each node’s voltage stability of the distribution network and checks this impact by variety of locations and capacity. And reaches a conclusion that the location of DG has the mainly impact to the distribution network voltage stability. Reference [58] uses VSI to evaluate each node’s voltage stability of the distribution network. And proposes the line stability index based on the distribution network equivalent model in Figure 1.

$$LQP_{ij} = 4\left(\frac{X}{V_i^2}\right)\left(-\frac{X}{V_i^2}P_i^2 + Q_j\right) \quad (10)$$

$$SLQP = \max\left\{LQP_{ij}\right\} \quad (11)$$

LQP_{ij} indicates the line between node *i* to node *j*. Regard the two indicators and active power loss as the objective function to optimize the location and capacity of DG.

Reference [59] uses the voltage stability index in the Equation (8) to the analysis of the impact of DG on voltage stability of distribution network, and regards the *VSM* [13, 15] and the network less as the objective function to optimize the location and capacity of DG with the modal analysis method and continuous power flow method. Reference [60] proposes a method to evaluate the static voltage stability probability of the power system with DG. After establishing the load stochastic model with wind energy, solar energy and other DG, according to its high-order moment, using point estimation method to construct the corresponding random variables estimation point. Then analyse the deterministic static voltage stability and find out the random variable estimated point corresponding voltage stability critical point. To thereby obtain the corresponding statistical characteristic values. And then apply the Cornish-Fisher series expansion to calculate and the probability distribution. Reference [54] proposes the static voltage stability margin index:

$$V_n = \frac{V_{p,withDG}}{V_{p,withoutDG}} \quad (12)$$

$$Maxmize \quad V_{index} = \frac{\left(\sum_{n=1}^{N} V_n pr_n\right)}{96} \quad n=1,2,\ldots,N \quad (13)$$

In the above equations, *N* stands for the number of load connected generators, *prn* stands for the probability of each connection, $V_{p,with\ DG}$ stands for the voltage of system with DG, while $V_{p,without\ DG}$ stands for the voltage of system without DG, V_i stands for the voltage magnitude of the node *i*. Optimize the location and capacity of DG with the optimization algorithm by regarding V_{index} as the objective function.

4. New Features of the Distribution Network Containing DG Static Voltage Stability Analysis

4.1. The Impact of Induction Motor Load

Different load characteristics will have varying degrees of impact to the power system transient stability, voltage stability, low frequency oscillation. Particularly under critical circumstances, the calculation result may be a qualitative difference.

In the previous analysis of the calculation, the load model is usually an equivalent model with an induction motor plus a static load. However, because the induction motor load weight proportion is heavy, and has a greater impact, this model only has applicability. With the addition of DGs and the increase of capacity of each single DG, the voltage stability of the distribution network will be new changes and the analysis of impact of both DG and load to the system will be needed [62].

Reference [63] proposes the concept of the generalized load model, which means the terminal of the distribution network is not only the load, but also contains a lot of power sources, and this kind of regional grid system which includes both the power as well load and mainly load is called generalized power load. The proposal of generalized power load provides a new approach to the analysis of impact of DG to the distribution network voltage stability.

Reference [64] indicates the static characteristics of the load model and load parameters will be a great impact on the static voltage stability according to the distribution network static voltage stability analysis methods and simulation. Based on this result, reference [65] uses neural network load model for static voltage stability analysis, which accurately describe the impact of load on the voltage stability.

4.2. The Impact of FACTS Devices

In addition to load, the impact of FACTS devices on system static voltage stability can not be ignored.

Reference [66] uses the load margin index and P-U curve flatness index to measure the impact of FACTS devices on system static voltage stability. The continuous flow calculation results show that the FACTS devices such as SVC, STATCOM, and TCSC can improve the system static voltage stability in varying degrees. Reference [67] compares the impact of different kinds of FACTS devices (such as SVC, STATCOM, TCSC, and SSSC) on system voltage stability, voltage distribution and power loss, and provides guidance of choosing the FACTS devices to improve the static voltage stability for the future. Reference [68] uses genetic algorithm to optimize the location of the FACTS devices to improve voltage stability of the system according to the voltage stability index in Equation (1). Reference [69] uses Harmony search algorithm and genetic algorithm to locate the FACTS devices to optimize the voltage stability and power loss according the voltage index in Equation (2) and Equation (3).

4.3. The Impact of Simultaneously Access with DG and other Devices

DG, FACTS and induction motor load will produce different degrees of impact to distribution network voltage stability. And these three devices simultaneously access the distribution network voltage stability is more complex. Besides, there will be a mutual influence between the same type of equipment.

Most existing references analyse only the impact of a single device or a single type of equipment on voltage stability, and do not consider the associate impact of multiple devices on the voltage stability, and do not consider the presence of a variety of devices in the distribution network and their interactions impact.

A few of references consider the co-ordination between different devices. Reference [70] illustrates a way to improve the system voltage stability by the coordination of FACTS devices. Use the coherence control method in the distribution network including DG, FACTS and induction motor load, and divide the impact of DG, FACTS and induction motor loads on voltage stability of the distribution network to two aspects: first, minimize the impact of DG and induction motor loads on voltage stability; second, maximize the support of DG and FACTS on voltage stability. Maximize the voltage stability of the distribution network by designing appropriate protocols and algorithms from these two aspects.

4.4. The Impact of MG and VPP

At present, the research of DG is mainly concentrate in equipment R & D, manufacturing and equipment control. However, the research of grid connected of DG and the grid and the system optimization, coordination and control after the grid connected is still relatively backward. When there is no coordination control, the access of multi-DG will have a great negative impact on the voltage stability of the distribution network because of the DG slow response and small inertia. Compared with the direct grid connected of DG, MG groups the DG and local load and energy storage system as a whole flexible and systematic. And then reduce the impact of DG grid connected on voltage stability of system by flexible technology.

Reference [72] takes droop control of the reactive power inside of MG, and proposes the compensation droop control ring based on the droop control. The simulation results show that the impact of MG to distribution network on voltage stability is smaller compared with DG. Reference [73] establishes a mixed way of AC and DC of MG. And indicates the AC and DC of MG can improve the voltage stability of distribution network by the research of several different control strategies. Meanwhile, reference [73] proposes a way that by using a voltage stabilizer for DFIG exchange part to improve voltage stability, and then use the particle swarm optimization algorithm to optimize control parameters in different control modes to improve voltage stability. After MG access to the distribution network, it will also change the power flow of the distribution network, and the power of MG will permeate to the grid. Reference [74] analyzes the impact of different MG penetration on system voltage stability, and illustrates the different structure of the MG, different access location and capacity of the MG will have different degrees of impact on voltage stability of distribution network.

In the smart grid, in order to achieve the integration and control of DG, scholars have proposed the VPP technology in recent years. The basic concept is combining the DG of distribution network, controllable load and energy storage system as a special power plant through the distributed energy management system. Therefore, we can well coordinated the contradiction between the smart grid and the DG, and fully excavate the value and benefits of the grid and user brought by DG [75-80].

MG is a system including with load and DG. It is performed to be a single controlled unit compared with the external grid, and can meet the user requirements of power quality security of electricity supply at the same time.

Compared to the MG, the VPP not only parallel the DG, controllable load and energy storage system in the distribution network through the PCC point, but also equivalent to a power plant with a transmission system. Besides meet the aspirations of the MG, the VPP is responsible for many other functions in the power transfer process, and the conventional power plant statistics can still be used to measure the effectiveness of the VPP. Therefore, the VPP can schedule the internal DG reasonably as well as reactive output of the energy storage unit. The APP can adjust the voltage distribution network and improve static voltage stability. However, there is no research in this area yet.

5. Conclusion

DG has solved the energy problem but bring many of the adverse effects to the grid as well, especially the voltage stability. This paper summarizes the traditional grid voltage stability analysis method and its indicators, and then makes a comprehensive overview of the analysis method of impact of DG to system voltage stability. This paper focuses on the new features of the static voltage stability analysis of the distribution network with DG, i.e. it's not only need to consider motor load, FACTS and DG, separate distribution network voltage stability, but also need to focus on the interaction of the access of a variety of devices on voltage stability, and should pay attention to the coordinate control of DG, motor load and FACTS devices. Besides, this paper also points out that the operation mode of MG and VPP, and studies the corresponding voltage coordinated control method, and then further enhances static voltage stability of the distribution network. And that is the main way of DG accessing the distribution network.

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