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AASRI Procedia 4 (2013) 2 – 8

AASRI Procedia

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2013 AASRI Conference on Intelligent Systems and Control

The Research of the Transition from Traditional AVC to Smart AVC

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Abstract

This paper first describes the relationship between the smart grid and smart AVC. By some problems of the conventional AVC's practical application connecting with the actual situation of the current grid development, this paper points out that the traditional AVC is unable to adapt to the development needs of the current grid and the tendency of intelligent AVC development.Through the research and the comprehensive exposition of the embedded Smart AVC, including intelligent AVC's new features, it points out that the future development direction of the Smart AVC and some features needs.

Keywords: Smart AVC; Embedded; Multi-objective; New energy; Intelligent alarm and estimation.

1. Foreword

Currently, the intelligent grid is subject to pay a high attention on a global scale. Europe and the United States regard the intelligent grid as an important part of their national strategy. State Grid Corporation of China has put the concept of "strong intelligent grid" forward, and proposed a three-step strategic planning "strong intelligent grid" fully completed by 2020. The intelligent grid is a new transmission and distribution

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doi:10.1016/j.aasri.2013.10.002

system, which is the integration of modern power engineering technology, distributed generation and energy storage technologies, what's more, advanced sensing and monitoring control technology, and information processing and communication technology of new power transmission and distribution system. It is able to provide users with a range of value-added services and to realize the interaction between the grid and the users. Simultaneously it has self-healing and self-adaptive capacity, realizes the flexible access to new energy control, and achieves the intelligent analyses and intelligent decision on mass surveillance information. As a content of the smart grid construction --- intelligent automatic voltage control (Smart AVC) also faces with the need for simultaneous construction of smart grid [1]. Smart AVC answers the problem that the traditional automatic voltage control system has not involved and the future of Smart AVC must involve. Traditional AVC conducts the reactive power and voltage optimization control from the point of view of the whole network. In addition, it made an important contribution to the economic operation of the power grid. However, with the continuous development and growth of the grid and the optimal control of the continuous influx of new energy power generation, traditional reactive power optimization has been difficult to make the grid on a layer of stairs. Therefore, the establishment of intelligent automatic voltage control (Smart AVC) system has been imperative [1] [2].

2 Introduction to traditional AVC

Traditional AVC is a voltage and reactive power optimization control in particular run cross-section. In essence, it is an optimal power flow problem and can be described by a non-linear optimization mathematical model. Usually, the security of the power grid operation is treated as the constraint conditions. And improving the economy is treated as the optimization objective. What's more, traditional AVC realizes the whole network reactive power integrated optimization. The mathematical model can be briefly described as follows:

$$\min f\left(V,\theta,B,T\right) \tag{1}$$

Equality constraints:

$$\begin{cases} P_{Gi}-P_{Li}-\sum\limits_{j\in S_N}P_{ij}\left(V,\theta,B,T\right)=0 & i\in S_N \\ Q_{Gi}-Q_{Li}-\sum\limits_{j\in S_N}Q_{ij}\left(V,\theta,B,T\right)=0 & i\in S_N \end{cases} \tag{2}$$

Inequality constraints:

$$\begin{cases} \underline{Q}_{Gi}<Q_{Gi}<\overline{Q}_{Gi} & i\in S_G \\ \underline{B}_i<B_i<\overline{B}_i & i\in S_C \\ \underline{T}_i<T_i<\overline{T}_i & i\in S_T \\ \underline{V}_i<V_i<\overline{V}_i & i\in S_N \end{cases} \tag{3}$$

Where, $f\left(V,\theta,B,T\right)$ is the objective function. In most cases, it is the active power loss; V_i 、 θ_i 、 P_{Gi} 、 Q_{Gi} 、 P_{Li} and Q_{Li} present the voltage amplitude, voltage phase, power injected into the active, reactive power injected into the active, the active load and reactive load of the node I respectively; B_i is shunt susceptance of the shunt compensation devices i; T_i is per-unit ratio i of the OLTC transformer's tap; S_N is the set of all nodes; S_G is the collection of the unit; S_C is the collection of parallel compensation equipment; S_T is the collection of OLTC transformer's tap [2]. With the grid growing and new energy access increasing, the requirements of the AVC are increasing. Particularly in the run maintenance-free's the standard CIM embedding problem, new energy model for the access problem, and multi-objective optimization modeling issues on the AVC assessment have caused widespread concern.

3. The research of the embedded way for the Smart AVC

The shuttle of traditional AVC and EMS uses plug-AVC model. The model of AVC and data acquisition is realized by making interfaces with EMS. But this method brings a larger workload to run maintenance staff. They often maintain two systems of EMS and AVC, which is repeated labor and whose efficiency is too low. While traditional embedded method can also achieve AVC system embedded in the EMS system, but it also has two drawbacks as follows: 1) data-read uses the API functions provided by the EMS manufacturers good-way package to read the database; 2) opening high-level database permissions may bring the security risks to the EMS system.

So both traditional AVC's connection and embedded method have some disadvantages. Adopting/Using the CIS interface part of the standard IEC61970 to realize the embedding, you can avoid these problems. Concrete embedded methods as follows:

- GDA gets real-time model
- HSDA gets data
- IDL-defined interface achieves temote-control

4 main functions of Smart AVC

Smart AVC achieves the transformation mainly in the following three functions compared with the traditional AVC [5].

4.1 the research of the access to the new energy equivalent model

1) wind turbine model

The randomness of wind speed leads to the uncertainty of wind power. Wind power is directly proportional to wind speed's cubic. But only part of wind energy can be used by wind turbine, which is converted into mechanical power. The expression of the random power:

$$P_m = 0.5 C_P \rho S V^3 \tag{4}$$

where : S is fan blade's sweeping area (m^2); ρ is the air density (kg/ m^3); V is the wind speed (m/s); C_p is wind energy's wind energy utilization coefficient, which is a function of the tip speed ratio λ . The function of the relationship can be obtained by experiment or the existed testing data. And it can use

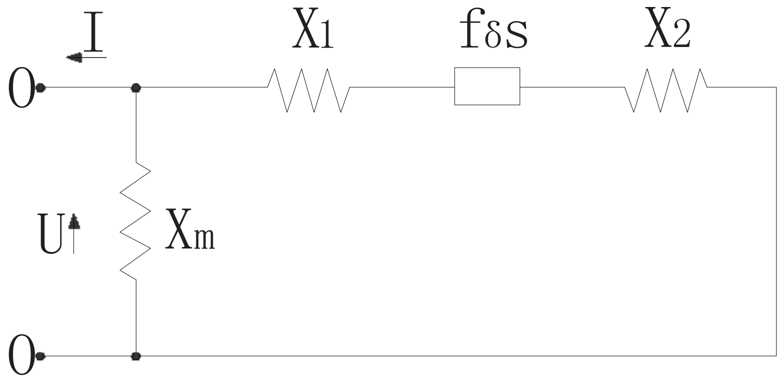

Fig 1. the simplified equivalent circuit model of asynchronous generator

Interpolation method to calculate the wind energy utilization coefficient. When the wind speed is larger than the cut-in wind speed and less than the rated wind speed, using type (4) can calculate the output power of wind turbine; when the wind speed is greater than the rated wind speed and smaller than the cut-out wind speed, output power of wind turbine is the rated power [4].

2) Asynchronous generator equivalent model

In figure 1's equivalent circuit, the circuit relationship can directly obtain the expression of wind power generator reactive power and active power

$$P_e = -\frac{U^2 r_2 / s}{(r_2 / s)^2 + x_k^2} \tag{5}$$

$$Z = \frac{x_m^2 r_2 s + j[(x_m + x_k) x_m x_k s^2 + x_m r_2^2]}{r_2^2 + (x_m + x_k)^2 s^2} \tag{6}$$

Where: Z is the equivalent impedance of asynchronous generator, $x_k = x_1 + x_2$, U is terminal voltage.

3) synchronous generator

In general, the synchronous generator is usually divided into two synchronous generators: the synchronous generator has the ability to regulate the excitation and the excitation regulator does not have the capacity. The former's control method has two kinds, which are named as voltage control and power factor control. But most of the actual synchronous generator is lack in excitation control capacity. In actual production, when the number of poles is short and the speed is high, salient pole structure is adopted.

The power characteristics can be drawn from the equivalent circuit diagram:

$$P = \frac{E_q U}{X_q} \sin \delta \tag{7}$$

$$Q = \frac{E_q U}{X_q} \cos \delta - \frac{U^2}{X_q} \tag{8}$$

Where: P , Q are active output and reactive power output respectively, E_q is load voltage of the synchronous generator. Because there is not excitation regulation system, E_{DGq} is a constant, X_d is the synchronous reactance of synchronous generator, V is the terminal voltage, δ is power angle[5].

4.2 multi-objective optimization modeling studies

Traditional AVC considers the single-objective optimization problem, in reactive power flow optimization

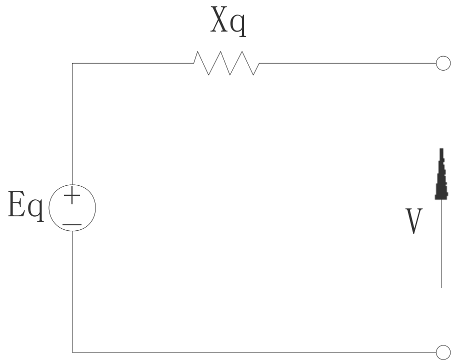

Figure 2. the equivalent circuit of implicit level sync generator

Process, it will inevitably have some impacts on the system voltage stability. Thus, the improvement of the static voltage stability margin as a sub-objective function added reactive power flow optimization model on the basis of the traditional optimization objectives, to improve system voltage stability purposes expectations by optimizing calculation and adjustment. The mathematical model of the power system reactive power flow optimization including variable constraints, the trend of the constraint equations and the objective function is:

The objective function of power system reactive power flow optimization generally includes technical and economic objectives. Economic objectives mainly include minimum active power least of the system; while technical objectives include system load node voltage level best (minimum voltage fluctuations), the system voltage stability margin. Therefore, the objective function can be expressed as:

$$f(x) = \begin{cases} \min(P_{Loss}) \\ \max(\delta_{\min}) \\ \min(\Delta V) \end{cases} \tag{9}$$

1. System's active power loss

$$P_{Loss} = \sum_{i=1}^{N} V_i \sum_{j \in i} V_j G_{ij} \cos\theta_{ij} \tag{10}$$

Where, P_{Loss} is power loss of the transmission system; V is amplitude of the voltage (the generator terminal voltage as a control variable, adjustable); j is a node associated with the node i.

2. System voltage stability margin

This article views the minimum modulus of convergence of the Jacobi matrix eigenvalue maximization as one of the goals of the system reactive power flow optimization, namely:

$$\max(\delta_{\min}) = \max(\min|eig(J)|) \tag{11}$$

Where, J is convergence trend Jacobi matrix, eig (J) means Jacobian matrix eigenvalue mold, min|eig (J)| means the modulus of the smallest eigenvalue of the Jacobian matrix.

3.Voltage offset objective function

The objective function of the voltage offset is to minimize the sum of the offset amount of the voltage of each node and the ideal voltage value range, i.e. to increase the voltage levels of the load node. Function can be expressed as:

$$\min(\Delta V) = \sum_{i=1}^{N} \frac{\Phi(|V_i - V_i^{ideal}| - \delta V_i)}{V_i} \tag{12}$$

Where, V_i is actual voltage of the system load node i; V_i^{ideal} is desired voltage of the system load node i; δV_i is maximum allowable voltage offset of load node i. In this article, V_i^{ideal} is the value of 1, and δV_i is the value of +5% [2].

4.3 The research of smart AVC alarm and assessment methods

Traditional AVC just gives an alarm or unusual information, and does not give a reason for alarm or abnormal in the alarm and abnormal. As a result, traditional AVC leads the users that are unable to position these problems timely and accurately, and brings difficulties to the users when dealing with some extreme cases. In this case, if the cause of the alarm and abnormal real-time accurate is given real-timely and accurately, some unusual faults can take timely and effective solutions to ensure grid more secure and stable.

The inference engine is an important part of the expert system. it uses the knowledge reasoning in expert systems. Using expert experience, knowledge and some reasoning methods, we can introduce the results. By analysis and reasoning of the inference engine, we can use some information through the reasoning problem reasoning and restoring.

1)The reasoning functions of abnormal and alarm

By reversing the reasoning and analysis of abnormal events and completing reasoning exception information, getting the problem and finding the timely detection of problems, such as:reasoning of a communication error alarm condition;reasoning of channel abnormal alarm situation;reasoning of failed equipment and latching alarm.

2)The reasoning function of the control command

As for some systems that do not start or inability to modulate the special case, by inference to verify the correctness of system control, for example:the reasoning of voltage line alarm system without command case; the reasoning of voltage line system control command case.

Intelligent assessment of the main research contents includes the following:

1) By analyzing reactive power compensation curve, we can find the whole network reactive power weak

points and compensation capacity;

2) Nalysis of current equipment network loss variation;

3) The analysis of load variation;

4) Analyses of substation operation mode changes.

5 Conclusions

This article makes some prospects on Intelligent AVC embedding method and functions of the system in the future based on the analysis of the disadvantages of traditional AVC. And on this basis, it elaborates based on the standard CIM intelligent AVC embedding method and intelligent AVC, which differs from some of the new features of the traditional AVC in detail. Then it provides a new train of thought for the future of the development and perfect of Smart AVC.

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