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Increasing the efficiency of power resource management as a solution of issues of the power supply system stability

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Abstract

The paper considers issues of enhancing the resulting stability of the meshed power supply systems containing distributed generation facilities under conditions of large iron and steel enterprises. An improved software suit for studying emergency and post-emergency conditions has been developed; it provides an opportunity to enhance efficiency of the condition control and power resource usage by reducing the downtime of the electric equipment and enhancing the reliability of the whole power supply.

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Keywords power supply system; resulting stability; transient modes; asynchronous power; distributed generation facilities; reliability of electric equipment.

1. Introduction

At present we are experiencing the increase of the additional power units of industrial loads within the power supply systems resulting in energy emergency and determining benefit of building and expanding the base of the distributed generation facilities at the main segments featuring concentrated load. It complicates transient emergency and post-emergency conditions stipulating the need for study of static, dynamic and resulting stability issues. This problem is relevant since emergencies caused by stability loss lead to large-scale damage, outage, lost output and life hazard.

A number of studies concern static stability, including [1] which considers special aspects of static stability under conditions of the industrial meshed system for generators and high-voltage motor load.

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The issues of dynamic stability are presented in papers [2, 3] on the example of acquisition of dynamical characteristics of the complex load.

Within the meshed power supply systems applying the distributed generation one of the severe accident types is a short circuit accompanied by switching to the operation isolated from the power system and following resynchronization. That is why the forecasting emergency and post-emergency conditions should be performed with development of a new improved algorithm of computing transient modes at occurrence of short circuits in the power supply system with auxiliary power plants accompanied by switching to the isolated operation with possibility of resynchronization with the power system.

The performed analysis of studies dealing with estimation of the resulting stability of the electric power systems and systems of electric power supply of industrial enterprises has revealed the absence of the exact analytical dependencies which could be used for practical calculation and reflect the pattern of the transient process under way within the complex multi-machine system at the resynchronization; the proposed methods of asynchronous mode study are not useful at determining change of power balance in the power supply system and changes of the average voltage and frequency levels in comparison with the pre-emergency ones; methods enabling calculation of the three-phase short circuit with following recovery of the parallel operation within the meshed systems have also not developed yet. At present, there are no exact analytical descriptions of events occurring at the generator resynchronization which could reflect behavior details especially in the complex system.

In connection with the above, it should be noted that in order to increase efficiency of the power resource usage and management of modes of the power supply systems the forecasting transient conditions and estimation of resulting stability at short circuits and their trips are required.

2. Increasing efficiency of power resource management

At the study of the resulting stability the calculation of asynchronous operation of the synchronous generators and high-voltage motors is essential. Analysis of the asynchronous power changes are of special interest at the computing transient processes accompanied by the switch of auxiliary power plants to the non-parallel operation with the power systems [4, 5]. At the operation being parallel with the power system the frequency is generally maintained which is close to the rated one; at any transient process the change of the rotor rotation frequency will be followed by generation (at the synchronous generators) or consumption (synchronous motors) of asynchronous power in relation to the infinite power unit. During short circuit rates of the generator rotors are non-uniformly increased. That is why the switch to the non-parallel operation after trip of the damaged element occurs with different rotation rates. Furthermore, the rate of the generator rotors starts changing in the result of the appearing power imbalance due to the downtime of communication with the power system [6]. To maintain the normal unit operation generators and electric drives should be synchronized. Synchronizing process provides an additional electromagnetic torque associated with presence of the asynchronous power. At the separate operation each generator provides its inherent power corresponding to its own rotation frequency. Relating to it, all other generators provide or receive some asynchronous power depending on the rate ratio of the considered generator pair. At the other side, the ongoing generator will also provide (receive) some asynchronous power related to other generators. Mutual sliding of the relevant generator related to the others is determined as follows (1):

$$S_{i,j} = \frac{\omega_{(n-1)}^{(i)} - \omega_{(n-1)}^{(j)}}{\omega_{(n-1)}^{(i)}}. \quad (1)$$

Mutual sliding of other generator related to that one at issue (2):

$$S_{j,i} = \frac{\omega_{(n-1)}^{(j)} - \omega_{(n-1)}^{(i)}}{\omega_{(n-1)}^{(j)}}, \quad (2)$$

where j– number of the relevant generator and $\omega_{(n-1)}$ – rate at *n-1*-the calculation interval.

Under conditions considered emergency control automatics including the non-synchronous automatic restarting (NAR) is used for parallel operation recovery. At its operation the conditions of resynchronization of axillary power