# Use of Superconducting Devices Operating Together to Ensure the Dynamic Stability of Electric Power System

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***Abstract*—Among the superconducting power devices developed to nowadays first of all should be mentioned superconducting magnetic energy storage (SMES) and superconducting fault current limiters (SFCL) since they have the best test results while operation in real electric power systems. This study is aimed to the development of superconducting magnetic systems of both these devices operating in power system together, what facilitates the solution of two tasks. The first one is to assure the dynamic stability of electric power network itself by the joint operation of SMES and SFCL. The second one is to provide an uninterrupted power supply together with the assurance of stable operation for power system with the synchronous load, e.g., for oil refineries, the main power consumers of which are parallel operating synchronous motors. Under fault event which disturbs the normal operation, we understand here the sudden short-circuit leading to the disconnection of the damaged power transmission line.**

***Index Terms*—Energy storage, fault current limiters, power system dynamic stability, short circuit currents.**

## I. Introduction

As it is known, the general enhancement of electric power systems reliability means an increase of their static and dynamic stability. The static stability is the system's ability to restore its initial operative mode after a low disturbance and/or to ensure a mode close to the initial one, if the disturbance has not been eliminated. The dynamic stability of the electric power system is an ability to restore its initial (or close to the initial) state after large scale disturbances. The latter are understood as short-circuits, disconnection or, on the contrary, connection of any power system elements - loads, transformers, generators, electric power transmissions lines, etc. Here we consider disturbance as sudden three-phase short-circuit at the beginning of power transmission line, which is the most dangerous one, since the power transmission totally interrupts. Also are considered electro-mechanical processes taking place at the power system, the results of the investigations of parameters are given, which determine the relationships between the basic elements of the system together with technical requirements to new devices operating in it- SFCL and SMES [1].

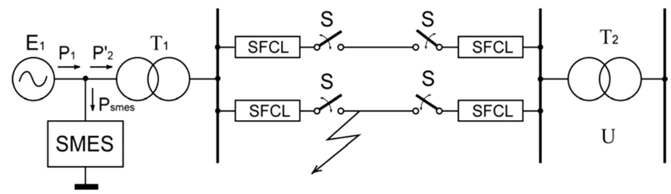


Fig. 1. System under study (instance I).

## II. The Problem Formulation

I. Equation describing the relative generator rotor's motion, without taking into account damping and effect of various adjusting devices, may be written in the following form [2]:

$$\Delta M = M_T - M_G^{II} = T_j \left( d(\Delta\omega)/dt \right), \tag{1}$$

where $M_T$ is turbine torque, $M_G^{II}$ is generator electromagnetic torque in the after-fault mode, $\Delta\omega$ is rotor angular speed change (with respect to the synchronous one), $T_J$ is the inertia constant.

Integration of equation (1) allows to find the rotor angular speed variation as a time function $\Delta\omega = f(t)$, and taking into account that $\Delta\omega = d\delta/dt$ one can find the relative rotor angle $\delta = f(t)$. Variations of these values allow to make conclusion about dynamic stability of electric power transfer when passing from one mode to another.

The change of these units allows to estimate the dynamic stability, by transition of one mode to another.

The most dangerous disturbance is the short-circuit at which the power transmitted to the network rapidly drops and the generators begin to accelerate up to hazardous speeds. In this case, SFCL and SMES could decrease the excessive power produced by the generator, what in its turn enables the easier transfer to new operation mode.

To find the SMES and SFCL parameters ensuring the dynamic stability, the equivalent circuit given (Fig. 1) is used.

II. The power system peculiarity is that power generated at the power plant is transferred via transmission lines to the synchronous load consumption node. At possible sudden short-circuit the damaged power transmission line is disconnected and the synchronous load can fall out of synchronism. We propose to solve this problem by direct connection of the SMES to the substation buses supplying the power node, and the SFCL should be connected to the power transmission line (Fig. 2) [3].

Circuit diagram in Fig. 2 is a typical pattern for the case when power system receives energy from a high-power plant.