Physica C 209 (1993) 335–336
North-Holland

PHYSICA C

Application of high temperature superconductive magnetic energy storage (SMES) system to an electric utility grid - a demonstration plant

S. Velner[a], D. Weiner[a], M. Blau[a] and Y. Yeshurun[b]

[a] Research & Development Division, The Israel Electric Corporation, Haifa, Israel

[b] Department of Physics, Bar-Ilan University, Ramat Gan, Israel

As a preliminary part of a proposed demonstration plant of a SMES made of high-temperature superconductors we present calculations of frequency transients for four SMES units incorporated in the Israeli electric system.

The Israel Electric Corporation (IEC) supplies electric power to an isolated power grid, i.e. there is no interconnection to neighboring power systems. Other main features of the system are:
- Peak demand of 4800 MW.
- Load factor of about 61 percent (updated in 1991).
- Installed capacity of the whole system - 5800 MW (end of 1992).
- The system consists of :
- 2x550 MW and 4x350 MW coal fired units.
- 2170 MW oil fired units, that consist of 17 units ranging from 50 to 228 MW.
- 6x100 MW industrial gas turbines.
- Relatively short transmission lines in the power grid.

In addition, two coal fired units of 550 MW are under construction and are to be commissioned in 1996 and 1997.

There are considerable economical benefits due to the installation of relatively large generating units in the system but on the other hand this has a negative impact on an isolated system. In an isolated system a trip of a large generating unit would affect many consumers at the same time and the imbalance between load and generation would have a considerable effect on the network's frequency that would be reduced within a short period of time. Such events have, of course, non-desirable impact on the reliability of the power system. In order to avoid the collapse of the power system after a severe sudden imbalance, utilities use an under-frequency automatic load shedding system. The purpose of it is to restore the power balance between load and generation and to prevent the frequency from dropping to dangerous low levels. However this automatic protection system causes the disconnection of a large number of consumers. The goal is to improve the level of reliability of supply to the consumers everywhere in the grid. This aim can be achieved by introducing storage facilities into the system [1].

There are many ways to store electric energy. Anyone of them has its advantages and limitations but in this case we are interested in the quick response of the system. This can be achieved only by using either batteries or Superconducting Magnetic Energy Storage (SMES), because only these two means store electricity directly and have response time of order of milliseconds, i.e. quick enough to prevent automatic load sheddings and thus they can be used as immediate spinning reserve.

Of the two means SMES has some advantages compared to Battery Energy Storage (BES) [2,3]. These are:
- High return efficiency - up to 95% for a large unit, i.e. about 20% more than BES.
- Relatively large storage capacity. It is accepted that SMES units will potentially run over a wide range of energy capacity - from Joules to GWh, when this device will be commercially realized. This is not practical for BES.

- Easy treatment and maintenance compared to BES.

In order to evaluate the impact of SMES on the Israeli electric system we simulated a theoretical model of the system including a SMES unit. The power system's frequency (rated at 50 Hz) and load shedding were calculated for different SMES powers. Table 1 shows the SMES power against load shedding and minimum frequency after the forced outage of a 550 MW generating unit. The systems basic parameters (with no SMES) are given below theTable. Clearly, the larger the power of the SMES, the smaller is the frequency deviation, requiring a smaller response from the generating units. Graphic description of the results is given in Fig. 1 which shows the frequency transients for four SMES units within the first 12 seconds after the fault.

Table 1. Results summary for different SMES ratings

SMES Power (MW)	Load Shedding (MW)	Minimum Frequency (Hz)
0	355.8	48.72
20	355.8	48.74
40	355.8	48.77
60	237.4	48.81
80	237.4	48.85
100	237.4	48.88
120	237.4	49.90
150	237.4	48.93
180	203.1	48.90
200	89.4	49.04

Pre-fault load = 2840 MW
Power of the tripped generation unit = 550 MW
Pre-fault available capacity = 3268 MW
Total load shedding = 355.8 MW
Initial frequency = 49.90 Hz
Minimum Frequency= 48.72 Hz at time=1.620 sec
Immediate reserve in generating units (after 2.5 sec) = 177.66 MW

The main benefit of SMES as an immediate spinning reserve unit is that it allows for reduction of the spinning reserve kept in generating units while the reliability of supply is improved. A reduction of the spinning reserve requirement would allow a more economical loading of the most efficient units.

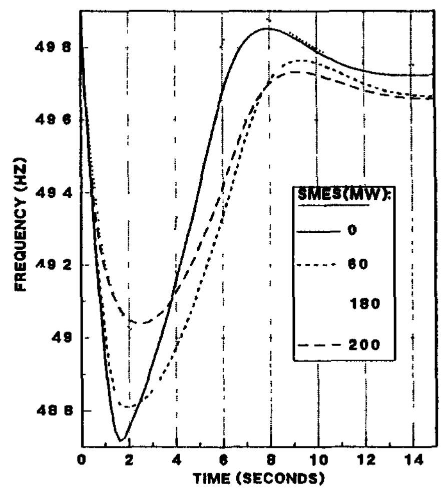

Figure 1. Frequency transients for four SMES units

This project is partially supported by the Ministry of Energy and Infrastructure

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