§34. Improvement of 250 MVA Motor-Generator System

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To feed pulse high-power to the plasma heating devices in the Large Helical Device (LHD), the motor-generator (MG) was constructed [1] in 1993. Since then, continuous effort has been devoted to improve its performances. The main items of them are summarized in this report.

i) Computer control system

In the first step, the computer system was composed of one MG computer and two load computers, Each of load computers sets operating condition for a single load. They operate for feeding energy to the apparatus for research and development of neutral beam injection (NBI), and electron cyclotron heating (ECH) or ion cycrotron range of frequency (ICRF) in the plasma heating building. These three computers are connected by a metallic Ethernet cable of 500m long.

The second cycle of LHD experiment starts in the middle of 1998. Then three types of high-power heating devices (ECH, ICRF and NBI) are simultaneously utilized to obtain high-beta plasmas. To adapt this situation, a work station is introduced as a load computer. It is placed in the control room of the LHD control building, and can set operating conditions of the MG for seven loads. Linkage to the MG computer is done through a pair of optical fiber cables of 650m. It is of course that two existing load computers can be utilized in the new system.

As a result, the duty of the MG computer has much increased. To grade up its processing speed an operational computer has been newly equipped. The existing one mainly deals with logical operation for control of the whole MG system, and communication with the whole load computers. The new one graphically displays operating status of both the MG and loads, and serves as interface for page printer and hard copy.

Two new functions are mounted for the computer system. The one is operational simulator, which enables to check the availability of any operations without rotation of the MG. This function offers valuable imformation on inexperienced operating conditions. The other one is display of one-line diagram on the load computer. It indicates the operating loads and open/close status of all the current breakers of the MG and loads. Operational errors will be decreased when operators carefully watch this diagram.

ii) Special sequence for pre-shot of NBI

The ion source of NBI contains cesium to obtain enormous negative ions. Fine powder of Cs, however, adheres on the accelerating electrodes when they cool down, which causes premature breakdown. Warming-up of them is dispensable a prior to NBI injection in the LHD experiment, because its interval exceeds 5 minutes and then their temperature surely lowered. To avoid this defect, a new sequence has been added, which starts to energize the power supplies for both filament and arc 3 minute before the injection and continues for 30 seconds. The usage of this 'pre-shot' function is voluntarily selected.

iii) Operation by LHD central control system

The MG is demanded to prepare, start and terminate its operation by the central control system for the LHD experiment. It has to transfer the answer-back signals, and also to be operated by the timing signals from the LHD central timing control system. To attain these requirements, the control system of the MG has been modified and interconnected with the LHD central control system by metallic cables.

iv) Automatic control of reactive power

The operation of the MG causes high reactive power (RP) in the 6 kV power line. A phase advance capacitor of 3 MVA is equipped to compensate the RP. It is surely effective in the starting-up phase (0-435 rpm), but it is insufficient for the acceleration phase (435-901rpm). Another 3 MVA capacitor is, therefore, adopted to intensify the effect. In this case, the latter capacitor is switched-on when the RP is detected to exceed 4.5 MVAR. After the RP becomes over -2 MVAR, the former capacitor is then disconnected, the latter capacitor remaining contacted. The RP is thus reduced automatically.

v) Reduction of overshoot in output voltage

In the early phase, the overshoot of 14% has been observed in the output voltage. After the control constants for excitation have been adjusted, its value is suppressed below 10%.

vi) Measurement of voltages and currents

Waveforms of output voltage and current are roughly displayed on computer system. However, accurate records of various waveforms are necessary for diagnostics of the MG system, including apparatus in output sides. For this purpous, an eight-channel digital recorder is equipped, the output data of which can be precisely analyzed by a computer with processing programs.

Reference

1) Kitagawa, S. et al.: Fusion Eng. and Des. 26 (1995) 539.