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Preliminary Analysis on the Interplanetary Cause of Geomagnetically Induced Current and Its Effect on Power Systems† ⋆

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Abstract Using the detected events of geomagnetically induced current (GIC) in the Ling'ao nuclear power plant from 2004 to 2005, and focusing on the interplanetary cause of GIC and its effect on power systems, we have analyzed the corresponding solar driving sources and interplanetary solar wind structures, and performed spectral analysis on the most intense GIC event by means of wavelet transform. The results of this study show that: (1) Most GIC events were driven mainly by the halo coronal mass ejections, the interplanetary cause of GIC events includes the shock sheath, magnetic cloud, and multiplex interplanetary solar wind structure. (2) Based on the strongest GIC event on 2001 November 9, we find that the fluctuation of GIC in the earlier stage was related to the magnetic cloud boundary layer, and the variation of GIC intensity in the later stage was caused by magnetic cloud itself. (3) Compared to the frequency of the power system (50 Hz), the GIC can be equivalent to a quasi direct current. The energy of the GIC is embodied in the two time intervals in the wavelet power spectrum: the first interval is shown as an impulsive type and with a weaker intensity, and the second one is stronger. Regarding to the cumulative time of the transformer temperature rise caused by GIC, the second interval has a longer duration than the first one. Hence, during the second interval, it is more harmful to the power systems and devices. (4) With a correlation analysis, the correlations of the SYM-H index and dB_x/dt with the GIC are significantly stronger than those of other geomagnetic indices with the GIC.

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1. INTRODUCTION

As one of the factors to affect the safety of power systems, the geomagnetically induced current (GIC) is one of the most important phenomena of space weather during large magnetic storms. When the magnetic field and material erupted by solar activities move to the vicinity of the Earth, the magnetosphere is compressed to cause interference or damage of power systems and other modern facilities. The resulted GIC may damage the transformers, to produce a permanent damage of the equipment, or even a breakdown of the whole power system[1−4]. When the value of GIC is too large, it may cause a DC magnetic biasing of large transformers, thus to trigger a series of secondary disasters, such as the harmonics, reactive fluctuation, the temperature rise of transformers, the malfunction of protective devices, etc., and even to produce the power cut in a large area[5]. A remarkable feature of the effect of solar activities on the power systems is that the larger the scale of a power system, the easier the power system to be interfered by the solar activities.

In high-latitude regions (such as North America, and North Europe), the variation of geomagnetic field is more violent, the power cuts over a large area were caused by the GIC for many times[3,5−6]. With a continuous extension of the scale of power systems, in the regions of medium and low latitudes, such as in South Africa, Brazil, and Japan, the accidents of GIC to damage the power systems appeared also many times[7−9]. Due to the large scale of the present power systems in our country, there were also the GIC interference events in the power transmission systems of Guangdong, Jiangsu, Zhejiang etc., and to cause a series of negative effects of the anomalous temperature rise of transformers etc.[10]. Meanwhile, in the constructing power systems with an extra-high voltage (1000 kV) in the north, east, and central China, the unit resistance of transmission cables is much smaller in comparison with the main power systems of 500 kV as mentioned above, and it is more possible to cause some large accidents of power cuts due to the strong GIC events driven by solar storms, thus to cause very severe influence on the society, and to affect directly the human work and life. Hence, it is urgently required to keep the safe and reliable operation of the power systems, which is concerned with the development of the society and the safety of the country[11].

Because that not only the effect of GIC on the power systems is accumulative, but also the effects of GIC on the reactive fluctuations and harmonics of the overall power system are clustered and abrupt[12−13], it is necessary to describe the feature of GIC and the possible influence on the power systems in detail. Pirjola et al.[14] confirmed that the data of the particles and geoelectric fields detected in the near-earth space are the primarily concerned problem for building the physical model of GIC, hence, the key point to solve the effect of GIC on the power systems is to analyze the space parameters associated with the feature of GIC from the origin, and to explore the response mechanism of the large-scale power systems. In addition, the action of GIC on the power systems has a time-delay feature, a