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Geomagnetically Induced Currents (GICs) Related to Ionospheric Sq Currents in Mid-Latitude Regions: A Case Study in Japan

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Geomagnetically induced currents (GICs) are electric currents induced near the Earth's surface due to fluctuations of the Earth's geomagnetic field, which are caused by variations of currents in the magnetosphere and ionosphere. GICs, possessing properties like direct current, are known to significantly affect transformers, which are designed for alternating current. The main causes of geomagnetic fluctuations that cause GICs are equatorial ring currents in the magnetosphere and ionospheric Sq currents caused by the tidal winds due to the solar heating of the thermosphere. These current changes in the upper atmosphere induce variations of geomagnetic fields, subsequently causing GICs. Much research has been conducted on GICs caused by equatorial ring currents because of their potential risk to significantly damage the safety of power transmission systems. On the other hand, GICs associated with ionospheric Sq currents occur every day, and their fluctuations may impact the stability of power supply, potentially causing power losses. However, research on this topic has not yet been adequately advanced. Particularly, very little research on long-term analyses of GIC measurements possibly related to ionospheric Sq currents in mid-to-low latitude regions like Japan have been performed. In this study, we have analyzed a long-term data set of GIC measurements recorded in a specific region in Japan. Utilizing statistical methods, specifically the Seasonal-Trend Decomposition using LOESS (STL), we have attempted to isolate and remove fluctuations in GICs caused by equatorial ring currents to identify variations of GICs during geomagnetic quiet periods. We compared the derived GICs with ionospheric Sq currents. We also compare with variations of the geomagnetic indices to validate the reliability of our model. Our research contributes to understanding the underlying causes of power irregularity related to GICs and provides insights into the mitigation of potential adverse impacts on power transmission systems.