UNIVERSITI TEKNOLOGI MARA

EMPIRICAL CHARACTERIZATION OF GEOMAGNETICALLY INDUCED CURRENTS AT EQUATORIAL REGION DUE TO SPACE WEATHER PERTURBATIONS IN SOLAR CYCLE 24

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ABSTRACT

Geomagnetically Induced Currents, which significantly impact the functionality and safety of power grids and electronic communication systems, are of growing concern within equatorial due to the escalating intensity of solar events during Solar Cycle 24. This study investigates the causes and characteristics of intense Geomagnetically Induced Currents (GICs) in the equatorial region, with a focus on the influence of space weather parameters during solar cycle 24 where three core objectives were pursued which are analyzing the ground magnetic response to space weather events through the temporal variation of the geomagnetic field (dB/dt), characterizing the key parameters in interplanetary shock waves that trigger GIC, and developing an empirical model to characterize the equatorial dB/dt in response to these events. Methodologically, the study leverages SuperMAG Ring index values to categorize geomagnetic storms and correlates geomagnetic field variations with solar wind parameters such as speed and dynamic pressure, uncovering a predominant occurrence of GICs during the initial phases of severe geomagnetic storms. These findings provide foundational insights into how Earth's magnetosphere is influenced by solar activity, thereby provide indication for the prediction of potential geomagnetic storms and substorms. Additionally, a comprehensive analysis revealed that high speeds and angles in interplanetary shock waves are directly correlated with increased equatorial GIC activity. A statistical approach confirmed that when both parameters are high, a substantial increase in GICs can be expected, highlighting their mutual importance for equatorial GIC activities induced by space weather events. The resulting empirical model, utilizing the linear regression model was developed to characterize equatorial GIC activity attributed to space weather events in solar cycle 24. This empirical characterization incorporates key variables such as IP shock angle, IP shock speed, Rise Time, ΔSMR, GMD, and GML. From the established empirical characterization, region-specific sensitivity was observed, with different sector having different vulnerability to geomagnetic disturbances. Moreover, diurnal fluctuations in GIC activities were also examined, revealing significant variations based on Earth's relative position to the Sun as well as evolving geomagnetic and ionospheric conditions. In conclusion, the study offers a comprehensive understanding of the mechanisms influencing equatorial GIC activities, and their correlation with interplanetary shocks and other geomagnetic variables. The insights gained have crucial implications for both space weather forecasting and the overall stability of Earth-based electrical infrastructures, marking a significant advancement in the field.

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1.1 Overview

Space weather disturbances, such as solar storms and other space events, can have significant effects on the Earth's magnetosphere, especially in the equatorial region. One of the main consequences of these interactions is geomagnetically induced currents, which have the potential to disrupt our technological systems. In this area, specific geomagnetic conditions intensify these impacts and increase infrastructure vulnerability. This study begins by examining how the electromagnetic interaction between the Earth's magnetic field and incoming solar wind leads to Geomagnetically Induced Currents (GIC) generation. This complex interplay causes variations in geomagnetic field strength, resulting in surface currents that pose a direct threat to critical infrastructure integrity and functionality. An accurate understanding of GIC behaviour in the equatorial region is crucial for assessing associated risks comprehensively. By investigating and documenting how GICs respond to space weather events, this work aims to facilitate an effective assessment for developing modelling systems against geomagnetic disturbances. This initial chapter provides essential foundational knowledge required for understanding GIC mechanism and impacts specifically at equatorial latitudes. It sets the stage for subsequent chapters that will explore more detailed methodologies, empirical findings, and strategic implications for mitigating risks from space weather phenomena. Therefore, the introduction provides an overview of the importance of studying geomagnetically induced currents in the equatorial region due to space weather perturbations. Furthermore, it highlights the potential impact of these currents on critical infrastructure, such as power distribution systems and communication networks.

1.2 Research Background

1.2.1 Space Weather Event and Earth's Magnetic Field Variation

The rapid expansion of technological advancements across several industries