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Feasibility Analysis of Conventional Settings for Distance Relay (21) and Line Differential Relay (87L) in an Inverter-Based Resource-Integrated Transmission System
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INTISARI

Integrasi *inverter-based resources* (IBR) pada sistem transmisi mengubah karakteristik arus gangguan yang menjadi dasar kerja proteksi saluran. Perubahan tersebut dapat memengaruhi relay jarak atau relay 21 yang bekerja berdasarkan impedansi tampak, serta relay diferensial saluran atau relay 87L yang bekerja berdasarkan perbandingan arus pada kedua ujung saluran. Penelitian ini bertujuan menganalisis karakteristik operasi relay 21 dan relay 87L pada sistem transmisi terintegrasi IBR, membandingkan pengaruh *wind turbine type 3*, *wind turbine type 4*, dan *photovoltaic*, serta mengevaluasi kelayakan penggunaan setting proteksi konvensional pada skenario yang diuji. Penelitian dilakukan melalui simulasi DIgSILENT PowerFactory menggunakan sistem *modified two-area Kundur*. Saluran TL89 antara Bus 8 dan Bus 9 digunakan sebagai objek proteksi. Kondisi dasar tanpa IBR digunakan sebagai acuan, kemudian dibandingkan dengan kondisi sistem yang terintegrasi WT Type 3, WT Type 4, dan *photovoltaic*. Setting relay 21 disusun berdasarkan kondisi sistem konvensional, sedangkan relay 87L menggunakan setting *default* pada model. Evaluasi dilakukan pada skenario gangguan internal DLG di TL89 serta gangguan eksternal DLG, tiga fasa, dan SLG di TL79 dengan kondisi TL78 *out of service*. Parameter yang diamati meliputi status operasi, zona dan impedansi tampak relay 21, serta hubungan arus diferensial dan arus *restraint* relay 87L. Hasil simulasi menunjukkan bahwa relay 21 dengan setting konvensional masih bekerja sesuai acuan pada gangguan internal DLG di TL89. Namun, pada gangguan eksternal di TL79 dengan TL78 *out of service*, relay 21 sisi Bus 8 berulang kali tidak memenuhi syarat *starting* karena arus gangguan yang terbaca rendah, sehingga responsnya dikategorikan sebagai *misoperation*. Sisi Bus 9 umumnya tetap tidak trip karena gangguan tidak terbaca berada di arah depan relay. Pada skenario dengan *photovoltaic*, impedansi tampak elemen ZBG sisi Bus 9 sempat masuk zona 1, tetapi operasi tertahan oleh elemen *phase directional*. Sebaliknya, relay 87L menunjukkan respons yang lebih konsisten. Pada gangguan internal, arus diferensial berada pada daerah operasi sehingga relay memberikan perintah trip, sedangkan pada gangguan eksternal titik arus tetap berada pada daerah penahan sehingga relay tidak memberikan perintah trip. Berdasarkan hasil tersebut, setting konvensional relay 21 hanya layak secara terbatas pada sistem dan skenario yang diuji, khususnya ketika arus gangguan, impedansi tampak, dan arah gangguan masih mendukung kerja relay. Evaluasi ulang diperlukan untuk gangguan eksternal, konfigurasi saluran *out of service*, kecukupan arus *starting*, dan pembacaan arah gangguan. Relay 87L menunjukkan kelayakan yang lebih konsisten pada kombinasi skenario penelitian, tetapi kesimpulan ini tetap terbatas pada model sistem, jenis dan level IBR, lokasi gangguan, konfigurasi jaringan, kontrol inverter, serta setting yang digunakan.

Kata kunci : *inverter-based resources*, relay 21, relay 87L, proteksi transmisi, setting konvensional

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ABSTRACT

The integration of inverter-based resources (IBR) into transmission systems changes the fault-current characteristics used as the basis for transmission line protection. These changes can affect distance relay or relay 21, which operates based on apparent impedance, and line differential relay or relay 87L, which operates based on current comparison at both ends of the line. This study aims to analyze the operating characteristics of relay 21 and relay 87L in an IBR-integrated transmission system, compare the effects of wind turbine type 3, wind turbine type 4, and photovoltaic resources, and evaluate the feasibility of conventional protection settings under the tested scenarios. The study was conducted through DIgSILENT PowerFactory simulations using a modified two-area Kundur system. The TL89 line between Bus 8 and Bus 9 was used as the protected line. The base case without IBR was used as the reference and was compared with systems integrated with WT Type 3, WT Type 4, and photovoltaic resources. Relay 21 settings were arranged based on the conventional system condition, while relay 87L used the default settings available in the model. The evaluation considered an internal DLG fault on TL89 and external DLG, three-phase, and SLG faults on TL79 with TL78 out of service. The observed parameters included operating status, zone and apparent impedance of relay 21, and the relationship between differential current and restraint current of relay 87L. The simulation results show that relay 21 with conventional settings still operates according to the reference for an internal DLG fault on TL89. However, for external faults on TL79 with TL78 out of service, relay 21 on the Bus 8 side repeatedly fails to satisfy the starting requirement because the measured fault current is low, so its response is categorized as a misoperation. The Bus 9 side generally remains untripped because the fault is not detected in the forward direction of the relay. In the photovoltaic scenario, the apparent impedance of the ZBG element on the Bus 9 side temporarily enters zone 1, but operation is blocked by the phase directional element. In contrast, relay 87L shows a more consistent response. For the internal fault, the differential current is located in the operating region and the relay issues a trip command, while for external faults the current points remain in the restraint region and the relay does not issue a trip command. Based on these results, the conventional setting of relay 21 is feasible only in a limited manner for the system and scenarios tested, particularly when the fault current, apparent impedance, and fault direction still support relay operation. Re-evaluation is required for external faults, out-of-service line configurations, starting-current adequacy, and directional fault detection. Relay 87L shows more consistent feasibility across the tested scenario combinations, but this conclusion remains limited to the system model, IBR type and level, fault location, network configuration, inverter control, and settings used in this study.

Keywords : inverter-based resources, relay 21, relay 87L, transmission protection, conventional settings