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**Skema Load Shedding Optimal Untuk Meningkatkan Stabilitas Frekuensi Saat Operasi Island di Sistem
Kelistrikan Bali**
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ABSTRAK

Sistem kelistrikan Bali memiliki kerentanan tinggi terhadap gangguan lepasnya transfer daya dari Jawa melalui Saluran Kabel Laut Tegangan Tinggi (SKLT) yang dapat menyebabkan *island operation*, defisit daya, penurunan frekuensi, dan risiko *blackout*. Skema pelepasan beban eksisting berbasis *Adaptive Defense Scheme* (ADS) masih berpotensi menimbulkan *overshedding* karena besarnya pelepasan beban mengikuti transfer daya pra-gangguan tanpa mempertimbangkan karakteristik dinamik sistem secara eksplisit. Penelitian ini mengembangkan strategi optimal *load shedding* berbasis Mixed-Integer Linear Programming (MILP) untuk meningkatkan stabilitas frekuensi sistem kelistrikan Bali pada kondisi *island operation*. Metode yang digunakan meliputi simulasi gangguan N-4 SKLT Gilimanuk–Banyuwangi, analisis respons frekuensi, estimasi parameter dinamik sistem, perhitungan gain governor efektif (Kgov) dari parameter model DEGOV aktual, pembentukan model frekuensi agregat menggunakan *linearized classical generator model* dan *swing equation*, serta validasi menggunakan DIgSILENT PowerFactory. Pada kondisi beban rendah, total *load shedding* hasil optimisasi sebesar 234,30 MW atau lebih kecil 39,18 MW (14,34%) dibandingkan ADS, dengan frekuensi *steady-state* sebesar 50,00 Hz. Pada kondisi beban puncak, total *load shedding* sebesar 239,45 MW atau lebih kecil 21,04 MW (8,08%) dibandingkan ADS, dengan frekuensi *steady-state* sebesar 49,66 Hz akibat keterbatasan *headroom* governor. Hasil validasi menunjukkan bahwa nadir frekuensi pada kedua kondisi operasi tetap berada di atas batas minimum 49,5 Hz. Selain itu, ADS eksisting terindikasi mengalami *overshedding* yang ditunjukkan oleh penurunan output governor pasca-shedding. Dengan demikian, hasil optimisasi MILP dapat digunakan sebagai acuan penyempurnaan tabel defense scheme agar pelepasan beban menjadi lebih selektif, proporsional, dan sesuai dengan karakteristik dinamik sistem Bali.

Kata kunci— Optimal Load shedding, MILP, Stabilitas Frekuensi, Island Operation, Sistem Kelistrikan Bali.

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ABSTRACT

The Bali power system is highly vulnerable to disturbances involving the loss of power transfer from Java through the High Voltage Submarine Cable, which may lead to island operation, power deficit, frequency decline, and blackout risk. The existing load shedding scheme based on the Adaptive Defense Scheme (ADS) still has the potential to cause overshedding, as the amount of load shed follows the pre-disturbance power transfer without explicitly considering the dynamic characteristics of the system. This study develops an optimal load shedding strategy based on Mixed-Integer Linear Programming (MILP) to improve the frequency stability of the Bali power system under island operation. The proposed method includes the simulation of an N-4 disturbance on the Gilimanuk–Banyuwangi submarine cable, frequency response analysis, estimation of system dynamic parameters, calculation of the effective governor gain (Kgov) from actual DEGOV model parameters, development of an aggregated frequency model using the linearized classical generator model and swing equation, and validation using DIgSILENT PowerFactory. Under low-load conditions, the optimized load shedding is 234.30 MW, which is 39.18 MW (14.34%) lower than ADS, with a steady-state frequency of 50.000 Hz. Under peak-load conditions, the optimized load shedding is 239.45 MW, which is 21.04 MW (8.08%) lower than ADS, with a steady-state frequency of 49.66 Hz due to limited governor headroom. The validation results show that the frequency nadir under both operating conditions remains above the minimum limit of 49.5 Hz. In addition, the existing ADS is indicated to experience overshedding, as shown by the reduction in governor output after load shedding. Therefore, the MILP optimization results can be used as a reference for improving the adaptive defense scheme table so that load shedding becomes more selective, proportional, and aligned with the dynamic characteristics of the Bali power system.

Keywords— *Optimal Load shedding, MILP, Frequency Stability, Islanded Operation, Bali power system*