# INTISARI

Peningkatan penetrasi VRE menyebabkan banyak energi terbuang akibat sifat intermitennya. Oleh karena itu, diperlukan sistem penyimpanan energi yang tidak hanya mampu mengurangi kerugian biaya tetapi juga menurunkan emisi karbon. Penelitian ini menyelidiki optimasi ukuran dan lokasi VRFB-ESS dalam sistem tenaga listrik yang mengintegrasikan PLTS dengan menggunakan DC-OPF dan metode MIQCP. Model ini bertujuan untuk meminimalkan biaya operasional dan emisi karbon secara bersamaan. Hasil penelitian menunjukkan bahwa integrasi VRFB-ESS yang optimal dapat meningkatkan efisiensi sistem dengan mengurangi biaya *curtailment* dan menurunkan emisi karbon. Pada tingkat penetrasi energi terbarukan sebesar 50%, integrasi BESS mampu menurunkan biaya operasional harian sebesar 5,98% dan emisi karbon sebesar 3,49%. Sementara itu, pada tingkat penetrasi 75%, integrasi tersebut mengurangi biaya operasional harian sebesar 19,84% dan emisi karbon sebesar 9,57%. Temuan ini menegaskan pentingnya peran VRFB-ESS dalam mendukung keberlanjutan energi terbarukan dengan meningkatkan efisiensi biaya dan mengurangi jejak karbon sistem tenaga listrik.

**Kata kunci** : *battery energy storage system, vanadium redox-flow battery, direct current optimal power flow, mixed-integer quadratic constrained programming, multi-period optimization.*

# ABSTRACT

*The increasing penetration of VRE leads to significant energy wastage due to its intermittent nature. Therefore, an energy storage system is required to not only reduce cost losses but also lower carbon emissions. This study investigates the optimization of size and location for a VRFB-ESS in a power system integrating solar power plants using the DC-OPF with MIQCP method. The model aims to minimize both operational costs and carbon emissions simultaneously. The results show that the optimal integration of VRFB-ESS can enhance system efficiency by reducing curtailment costs and lowering carbon emissions. At a 50% renewable energy penetration level, the integration of BESS reduces daily operational costs by 5.98% and carbon emissions by 3.49%. Meanwhile, at a 75% penetration level, the integration reduces daily operational costs by 19.84% and carbon emissions by 9.57%. These findings highlight the significant role of VRFB-ESS in supporting renewable energy sustainability by improving cost efficiency and reducing the carbon footprint of power systems.*

**Keywords** : *battery energy storage system, vanadium redox-flow battery, direct current optimal power flow, mixed-integer quadratic constrained programming, multi-period optimization.*