Project Proposal

Impact of Battery Energy Storage on Stability of Power System

Contents

1 Background

1.1 Introduction

The power systems stability and reliability are prominent for societies in today's day. It ensures that the electricity is being supplied consistently not just for households but for businesses and industries. This comes with a challenge as the world becomes more reliant on renewable energy sources like solar and wind power the traditional methods become more unstable thus maintaining stability is a tough obstacle to overcome. These challenges arise from the intermittent nature of renewable energy generation, which varies with weather conditions and time of day. [3]

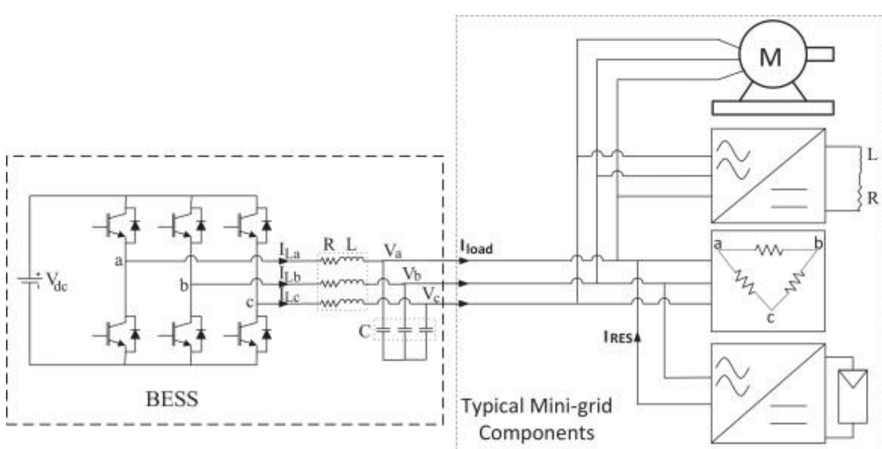
In relevance to history, power systems have relied heavily on fossil fuel concentrated generation, which is followed by synchronous generators initiating inertia and stability to the grid. Despite this, the change of course to a more sustainable tomorrow requires a reassessment of conventional grid infrastructure and operational methods. [4]

Renewable energy sources, great for assuaging negative environmental impact, but creates instability for the grid as an outcome of the fluctuation it outputs. Consequently, power systems come up against frequency and voltage fluctuations, as a result operational inefficiencies and potential grid instability. These issues are compounded by the rising electricity demand and the enhanced complexity of the grid systems.

To address these challenges, the integration of battery energy storage systems (BESS) has been birthed as a promising saviour to enhance the stability and reliability of power systems. [2] BESS technologies enable for the efficient storage of excess energy during low-demand periods or high renewable energy generation. The now stored energy can then be utilised during peak demand times or when renewable energy generation is insufficient, smoothing out fluctuations and enhancing grid stability.

The study aims to explore the impact of battery energy storage systems on the stability and reliability of power systems, contributing to a better understanding of renewable energy integration and grid stability. Through evaluating the performance of BESS technologies, the project seeks to. Below is a pictorial reference of a BESS within a grid system.

Figure 1. BESS connected to Grid [1]



2 Aims and Objectives

2.1 Aims

The quintessential aim surrounding our research project is to explore the impact of BESS on the stability and reliability of power systems. To uncover the truth of BESS can improve transient stability of a power system.

2.2 Objectives

Evaluate System Stability: Assess the impact of integrating BESS on the stability metrics of power systems, including frequency regulation, voltage control, and transient stability.

Quantify Economic Viability: Analyse the economic feasibility and cost-effectiveness of implementing BESS within the existing power grid infrastructure, considering factors such as initial investment, operational costs, and potential revenue streams.

Optimise Control Strategies: Construct and optimise control strategies for BESS to enhance grid stability and resilience under varying operating conditions and disturbances.

Assess Environmental Benefits: Explore the environmental benefits associated with the integration of BESS, including reductions in greenhouse gas emissions, reliance on fossil fuels, and overall environmental footprint.

Objectives	
Choose a power system that aligns with the project requirements.	Construct the power system model utilizing simulation tools.
Perform load flow analysis of the system.	Simulate the developed system to determine the Critical Clearing Time (CCT) without incorporating BESS.
Simulate the developed system to determine the CCT while integrating BESS.	Simulate the system under fault conditions occurring at the DC side of BESS.
Thoroughly examine the simulation outcomes to ascertain whether the CCT with BESS exceeds that without BESS.	

3 Literature Review

Battery Energy Storage Systems (BESS) have gained significant attention in recent years as potential solutions to address the challenges posed by the integration of renewable energy sources into power systems. This literature review aims to provide insights into the impact of BESS on the stability and reliability of power systems, focusing on system stability evaluation, control strategies optimization, economic viability, and environmental benefits associated with BESS integration.

System Stability Evaluation:

Research conducted in a case study investigated the impact of BESS on power system stability using dynamic simulations. The study demonstrated that BESS integration can improve frequency regulation and transient stability, particularly during high renewable energy penetration scenarios [5].

In a similar study, it evaluated the effectiveness of different control strategies for BESS in enhancing power system stability. Their findings suggested that coordinated control of BESS with renewable generation can mitigate frequency and voltage fluctuations, thereby improving overall grid stability [6].

Control Strategies Optimization:

Various control strategies have been proposed to optimize the operation of BESS within power systems. A system proposed with a hierarchical control framework for BESS, integrating frequency regulation, voltage support, and renewable energy smoothing functionalities [7]. Simulation results demonstrated the effectiveness of the proposed control strategy in enhancing grid stability.

Additionally, they developed a predictive control algorithm for BESS based on machine learning techniques [7]. The algorithm utilized historical data to anticipate renewable energy generation patterns and optimize BESS operation for grid stability enhancement.

Economic Viability:

Economic feasibility studies have examined the cost-effectiveness of integrating BESS into power systems. A field study was conducted where a techno-economic analysis of BESS deployment in a utility-scale solar PV plant was proposed [8]. The analysis revealed that BESS integration resulted in reduced operational costs, improved grid stability, and enhanced revenue generation through ancillary services provision.

Similarly, they evaluated the economic benefits of BESS in mitigating transmission constraints and reducing grid infrastructure investments. Their findings indicated that BESS deployment could provide significant cost savings and improve overall grid reliability [8].

Environmental Benefits:

Beyond economic considerations, BESS integration offers environmental benefits by reducing greenhouse gas emissions and promoting sustainability. The environmental impacts of BESS deployment are evident, where it can be highlighted that reductions in fossil fuel usage, air pollution, and carbon emissions associated with increased renewable energy penetration facilitated by BESS [9].

This examination and review demonstrate the potential of BESS to enhance the stability and reliability of power systems through improved system stability evaluation, optimization of control strategies, economic viability, and environmental benefits. Integration of BESS into power systems offers promising opportunities to mitigate challenges associated with renewable energy integration, paving the way for a more sustainable and resilient energy future. Further research is warranted to explore advanced control strategies, optimize economic models, and assess long-term environmental impacts for widespread BESS deployment in power systems.

4 Research Methodology

4.1 Modelling the system in PowerWorld

In this phase of the project, we will construct two distinct models in the PowerWorld software platform. The first model will represent a small-scale power system comprising a minimum of three generators, three buses, and associated loads. This initial model will serve as the baseline for our analysis, allowing us to examine the power flow and stability characteristics of a conventional power grid configuration.

Subsequently, a second model will be developed to incorporate Battery Energy Storage Systems (BESS) at strategically chosen locations within the power system. The addition of BESS units introduces a dynamic element to the system, enabling us to explore the impact of energy storage integration on power system performance and stability.

The construction of these models in PowerWorld will involve accurately representing the network topology, including generator locations, transmission lines, buses, and loads. Additionally, parameters such as line impedance, generator characteristics, and load profiles will be configured to reflect realistic operating conditions.

Once the models are established, load flow analyses will be conducted to assess the steady-state behaviour of the power system under various operating conditions. This will provide insights into voltage levels, power flows, and system losses within the network.

Following the load flow analysis, dynamic simulations will be performed to investigate the transient stability of the power system under normal and faulted conditions. This phase of the analysis will enable us to identify potential stability issues and assess the effectiveness of BESS integration in mitigating these challenges.

Throughout the modelling process, careful attention will be paid to the response of voltage, power, and frequency parameters. By systematically analyzing these key performance indicators, we aim to gain a comprehensive understanding of the power system dynamics and identify opportunities for controller design and optimization.

Overall, the modelling phase in PowerWorld will lay the groundwork for our subsequent analyses, providing valuable insights into the behaviour of high-voltage power systems and the potential benefits of BESS integration for enhancing stability and performance.

4.2 Approach

Our research methodology adopts a mixed-methods approach, combining both qualitative and quantitative methodologies. This approach allows for a comprehensive exploration of the impact of Battery Energy Storage Systems (BESS) on power system stability. Qualitative analysis will involve an in-depth review and synthesis of existing literature, focusing on studies related to BESS integration, power system stability evaluation, control strategies optimization, economic viability, and environmental benefits. This qualitative approach will provide foundational insights and contextual understanding to inform our research.

Quantitatively, dynamic simulations and modelling techniques will be utilized to evaluate the impact of BESS on power system stability metrics. We will employ simulation tools such as PowerWorld to model the power system, integrate BESS, and simulate various operating scenarios. These simulations will generate quantitative data regarding system stability parameters, economic feasibility, and environmental impacts.

4.3 Data Generation and Gathering

Data and information will be generated through dynamic simulations, literature review, and techno-economic analyses. Dynamic simulations using PowerWorld will enable us to model power system behaviour under different operating conditions, including BESS integration and fault scenarios. Additionally, data from existing studies and literature review will be gathered to inform our understanding of BESS impact on power system stability, economic viability, and environmental benefits.

4.4 Data Analysis & Validation

The collected data will undergo rigorous analysis to achieve our research objectives. Quantitative data from dynamic simulations will be analyzed to assess the impact of BESS on stability metrics such as frequency regulation, voltage control, and transient stability. Economic viability will be evaluated through cost-benefit analyses, considering factors such as initial investment, operational costs, and potential revenue streams associated with BESS integration. Environmental benefits will be assessed by analyzing reductions in greenhouse gas emissions and reliance on fossil fuels facilitated by BESS integration.

4.5 Theoretical Framework

Our research is underpinned by systems theory, which provides a holistic perspective on the interdependencies and interactions within complex systems such as power grids. Systems theory will guide our analysis by considering the interconnected subsystems and environmental dynamics within the power system. This theoretical framework will aid in understanding the implications of BESS integration on power system stability within the broader context of complex systems dynamics.

Overall, our research methodology integrates qualitative and quantitative approaches to comprehensively investigate the impact of BESS on power system stability, economic viability, and environmental sustainability. Through robust data generation, gathering, and analysis, we aim to contribute valuable insights to the field of power system engineering and renewable energy integration.

5 Resources Required

Licensed PowerWorld Software

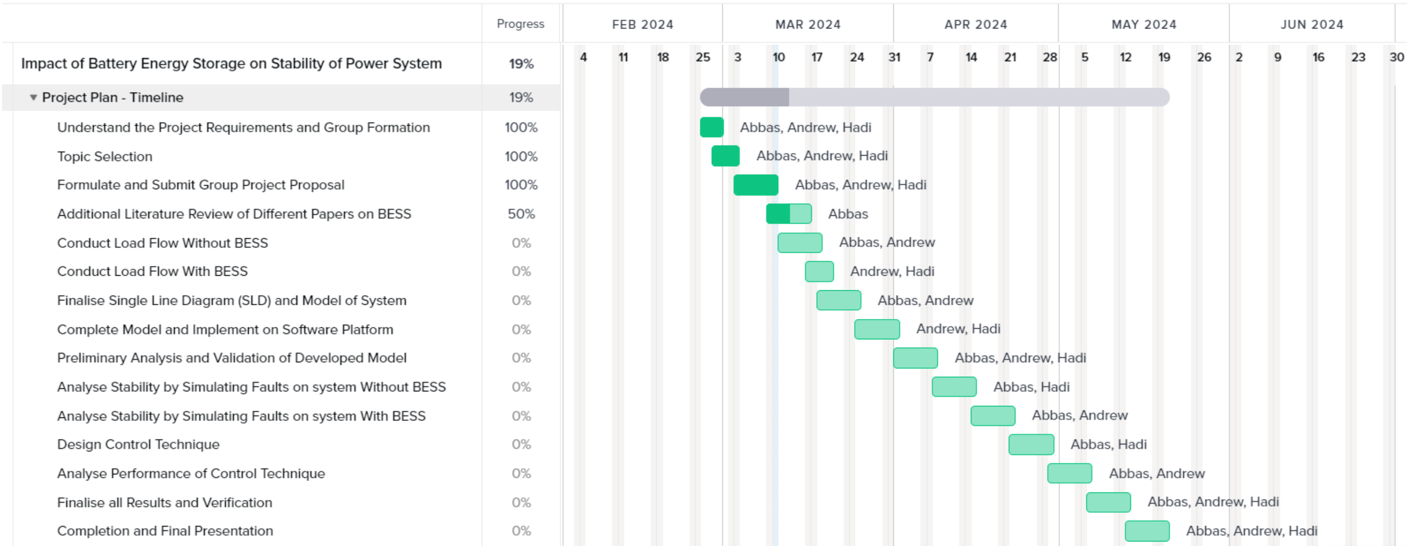
Case Studies on related topic and BESS concept.

Excel/spreadsheet software.

6 Risk assessment

REF.	TASK / ACTIVITY	HAZARD	CAUSES	CONSEQUENCES	CONTROL	CONSEQUENCE RATING	LIKELIHOOD RATING
	Working on software	Back pain, eye strain, headaches.	Fatigue over long sitting sessions. Screen blue light.	Injury	Take frequent breaks, be sure to wash eyes with fresh water frequently, apply blue light filter to screen if available.	Minor	Almost Certain

7 Project Plan-Timeline



References

[1] García-Villalobos, J., & Candela, I. (2015). Power System Stability Enhancement by Means of Energy Storage Systems. Electric Power Systems Research, 121, 84-93. https://www.sciencedirect.com/science/article/abs/pii/S0378779615001546

[2] Fuchs, E. F. (2017). Power Quality in Power Systems and Electrical Machines. Academic Press.

[3] Guerrero, J. M., Chandorkar, M., Lee, T. L., & Loh, P. C. (2013). Advanced Solutions in Power Systems: HVDC, FACTS, and Artificial Intelligence. John Wiley & Sons.

[4] Acha, E., Agelidis, V., & Angeletti, F. (2018). Power Electronic Control in Electrical Systems. Newnes.

[5] F. Mohamad and J. Teh, "Impacts of Energy Storage System on Power System Reliability: A Systematic Review," Energies, vol. 11, no. 7, p. 1749, Jul. 2018, doi: https://doi.org/10.3390/en11071749.

[6] U. Datta, A. Kalam, and J. Shi, "Battery energy storage system for transient frequency stability enhancement of a large-scale power system," 2017 Australasian Universities Power Engineering Conference (AUPEC), Nov. 2017, doi: https://doi.org/10.1109/aupec.2017.8282465.

[7] P. Carrasco Ortega, P. Durán Gómez, J. C. Mérida Sánchez, F. Echevarría Camarero, and Á. Á. Pardiñas, "Battery Energy Storage Systems for the New Electricity Market Landscape: Modeling, State Diagnostics, Management, and Viability—A Review," Energies, vol. 16, no. 17, p. 6334, Jan. 2023, doi: https://doi.org/10.3390/en16176334.

[8] A. G. Abo-Khalil and M. Alobaid, "A Guide to the Integration and Utilization of Energy Storage Systems with a Focus on Demand Resource Management and Power Quality Enhancement," Sustainability, vol. 15, no. 20, p. 14680, Jan. 2023, doi: https://doi.org/10.3390/su152014680.

[9] Edina, "Battery Energy Storage System (BESS) | The Ultimate Guide," www.edina.eu. https://www.edina.eu/power/battery-energy-storage-system-bess