Case Study

Jinko ESS Solution of Micro-grid AC-Coupled System

2.5MW/4.8MWh Li-ion BESS Project, Lagos, Nigeria

Introduction

The Utility-Interactive Hybrid Power Plant under study is in Iganmu, Lagos, Nigeria. Its idea was conceived as part of the renovation of the National Arts Theatre, Nigeria. The National Theatre, Nigeria, is the primary center for the performing arts in Nigeria. The monument is in Iganmu, Surulere, Lagos, Nigeria. Its construction was completed in 1976 during the tenure of the then military Head of State, Chief Olusegun Obasanjo, in preparation for the Festival of Arts and Culture (FESTAC) in 1977. In July 2024, President Bola Tinubu renamed the National Arts Theatre in Iganmu, Lagos, in honor of Nobel Laureate, Prof. Wole Soyinka.

The proposed design for the power plant was a 2.5MWp solar solution, but due to less available rooftop space, a 1.2MWp solar solution was implemented. A 2.5MW Power Conversion System and battery capacity of 4.8MWh were installed. It is a utility-scale project.

Background

Over the years, the Federal Republic of Nigeria was known for actively investing in grid power plants. Still, the long-run cost, losses along the line, and the transmission distance to the consumer end were not desirable. The issue of grid collapse and erosion has also been rampant over the years.

Objectives

Before now, the Nigeria National Theatre depends on the National Grid and the generator for its electrical power. These 2 sources are expensive. Also, the carbon emission from diesel generators has also drastically increased due to unstable grid power supply. This project aimed to reduce energy consumption from the grid, reduce the running time of generators, reduce the carbon emission from burning gas, and provide an uninterrupted power supply. This system will provide at least 50% of the power requirement of the National Theatre, Iganmu. The CO_2 to be offset per annum is 550 tons. The power plant is hybridized with three power sources, and the system is tied to the 11kV grid with the aid of a step-up transformer. The solar panel is set to top priority during the day and the battery at night or when the irradiance is low. In a case where the two sources are not available, the generator and grid are set to come in. One of the major challenges of this project is the unavailability of enough space for solar panels installation. With the successes recorded so far from the system installed, it is necessary to provide an adequate mounting space for the solar modules so that the entire facility can be powered with solar hybrid system.

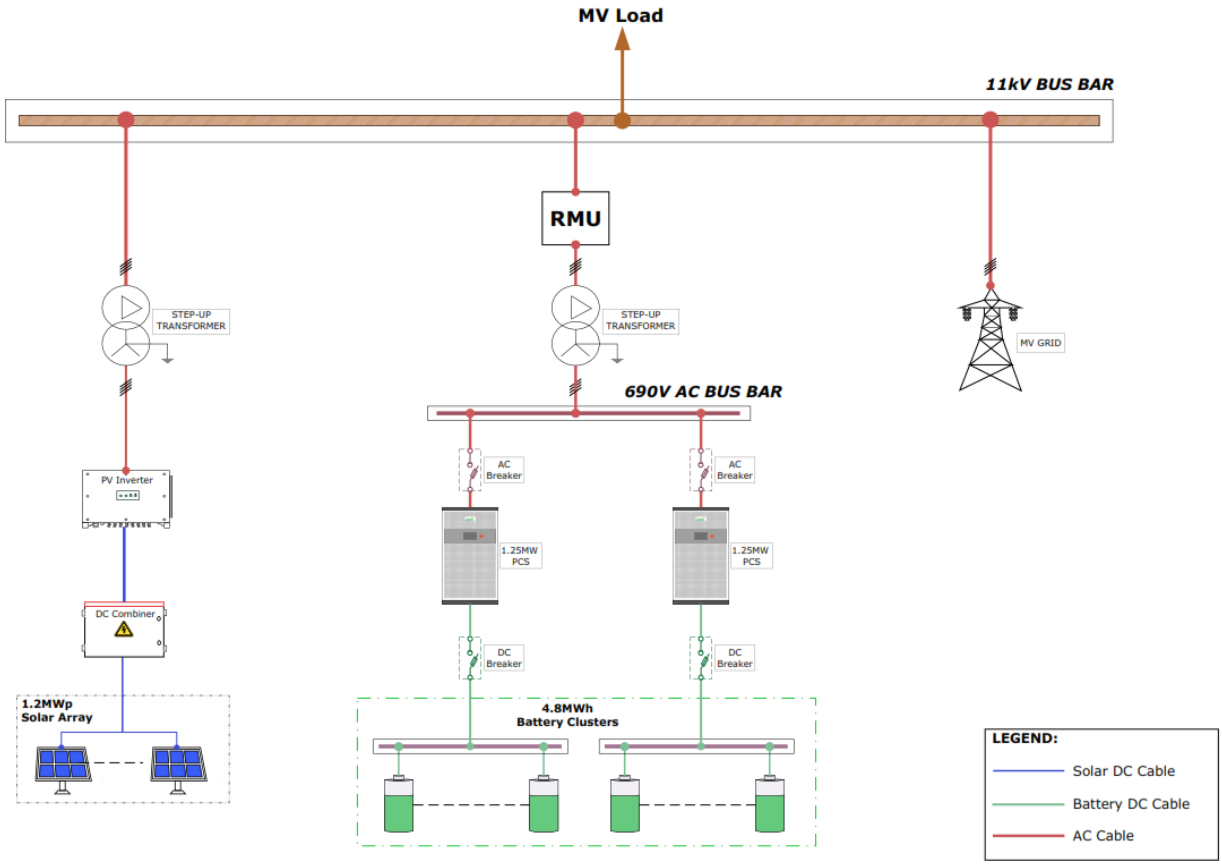

Figure 1: Single Line Diagram of Micro-grid AC-Coupled System

Project Description

System Design

Liquid cooling BESS system: The BESS (Battery Energy Storage System) comprises essential components and devices that work in harmony to deliver optimal performance and safety; among them are battery racks, battery management system (BMS) for efficient monitoring and control, a liquid cooling system to maintain optimal temperature levels, a fire suppression system to ensure safety, and integrated cabinet that provide the necessary infrastructure for seamless operation. The BESS system of 4.8MWh capacity is evenly distributed in two containers of 2.4MWh each. Each container is equipped with its own liquid cooling system to maintain optimal temperature levels. Each container has 7 battery racks (344kWh each), and a rack is made up of eight battery packs and one switch box.

Grid Forming/Following PCS

The PCS demonstrates robust grid adaptability, supporting high/low voltage ride through excelling in various energy scenarios. In a grid forming scenario, it

sets the parameters to be followed by other synchronous machines that are designed to work with it. The major machine that is designed to follow the PCS is the PV inverter. In this scenario, the PCS with the aid of the EMS is to ensure that the PV inverters supply the load and also charge the battery, while the generator is to come-up when the energy demanded cannot be met by both the PV and the BESS that is already drained to a preset threshold voltage. In the grid following scenario, the PCS is smart enough to adapt to the parameters of the grid. The grid will be on standby mode while the load and charging power are taken care of by the PV inverters and the PCS.

Energy Management System (EMS)

The EMS is the central unit that optimizes energy flow, enhances system performance, and enables seamless integration with various applications and energy system ecosystem. The EMS has a user-friendly interface to monitor the SOC, SOH, and power flow. It ensures optimal performance and maximizes energy utilization. The EMS incorporates robust data storage capabilities which serve as a valuable resource for analysis, troubleshooting, and compliance purposes. In off-grid scenario, the EMS optimizes energy usage, manages power loads, monitors battery's SOC, diagnoses system faults, and forecasts energy requirement.

On-Grid Scenario

In an on-grid scenario, the system operates as given below:

1. When the monitoring system senses the grid, it examines its parameters for 2 minutes
2. If the parameters are good after the 2 minutes, the PCS goes to standby mode (No AC output) to allow the grid to connect to the bus bar
3. The grid connects to the bus bar so that it can set parameter for the PCS
4. The PCS comes up and connect to the bus bar after sensing the parameters set by the grid

The above processes are called **Auto black start**

Operation Logic

This utility project is targeted at maximizing the utilization of photovoltaic (PV) power while minimizing the reliance on the national grid and genset. The battery will be charged by the generated power from the PV. The battery charging is achieved by converting the PV power to AC with the PCS designed to charge the battery.

During solar time, the installed PV system caters for the connected loads and uses excess energy to charge the battery storage. The EMS monitors the energy flow and regulates the PCS to maintain a balanced energy flow and charging process. Should the PV output decrease, the PCS will automatically compliment the PV by drawing energy from the battery to satisfy the load demand.

Any time the PV energy is not available or low, the battery supports the load with the stored energy. When the battery's SoC reaches its minimum threshold, the EMS activates the national grid or the genset to assume the load, thereby ensuring uninterrupted power supply.

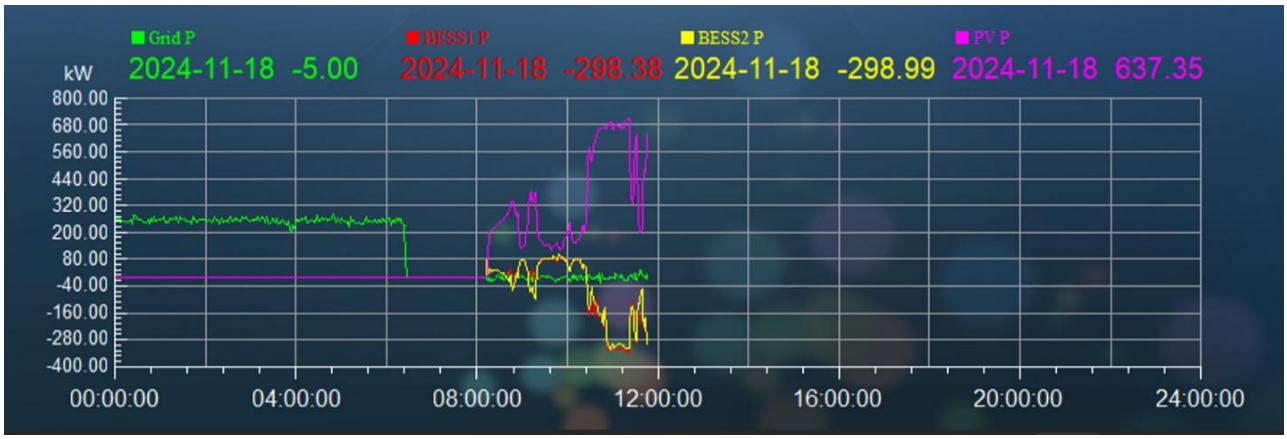

Figure 2: Power Comparison Graph

Customer Benefits

i) Economic Benefits and Cost Savings

Despite requiring substantial financial outlay upfront, AC Coupled PV-ESS projects are cheap to run once they are operational. They have low upkeep, operational, and maintenance costs, making them exceedingly cost-effective eventually.

For the system under study to start paying for itself, it takes between 7 - 10 years . This may seem like a long time but once this period is up, the large-scale project is nothing but upside and will generate green energy for as many years as possible.

Tied into the point above, the low costs associated with operation of solar project mean that the energy generated can typically be sold to National Theater for a lower price than energy derived from fossil fuels. It has been proven that power generated by utility-scale solar shows less LCOE than fossil fuel consistently across time and geographies.

ii) System Stability

One of the major challenges with solar energy is its inherent instability. Generating electricity through solar power requires high levels of irradiance and can be disrupted by inclement weather or location. This PV project is installed with large battery energy storage systems (BESS) which stores energy that can be supplied when generation drops due to factors outside of our control and ensure the connected load is running.

iii) Job Creation

Large PV-BESS systems are huge undertakings, they require enormous amounts of investment, the employment of huge construction teams to build, and finally, many staff to operate and upkeep on a day-to-day basis. All of this creates jobs and drives money into the economy, with many of these employment opportunities being created for both skilled and unskilled labour.

iv) Energy Independence

In addition to creating jobs for both skilled and unskilled labours, this PV-BESS project will also provide power to a commercial Centre in the heart of Lagos, National theatre. The electricity provided will be stable, cost-effective, and removes the facility reliance on the wider grid. The project will increase energy independence and open economic opportunities.

v) Reduced Greenhouse Gas Emission

The main issue with fossil fuels to generate electricity is the release of harmful byproducts, mainly carbon dioxide (CO2). CO2 has been shown beyond argument to damage the environment and contribute to the warming of the planet. This is to say nothing of other toxic byproducts produced by fossil fuel use that directly impact human, animal, and environmental health. This PV-BESS project is aimed at reducing to the barest minimum, the fossil fuels byproducts to escape into the atmosphere.

vi) Renewable Energy Generation

The energy generated from the system installed is renewable in nature. The renewable energy source is the sun. This shows that energy is abundant in nature.

Conclusion

The micro-grid AC-Coupled BESS project demonstrates the feasibility and benefits of large-scale renewable energy deployment. With its 1.2MWp PV capacity, and 2.5MW/4.8MWh PCS and energy storage, this project showcases the potential for solar energy to contribute significantly to the running of 50% electrical load in the National Arts Theatre, and reduce reliance on fossil fuels and national grid.

Recommendations

i) Adequate System Maintenance:

The installed system at the national theatre facility should be sustained and well maintained to enable it serve for the number of years it is designed for. The management should provide necessary support to the maintenance company.

ii) Public Awareness

Educating the staff and the public about the benefits of solar energy and energy conservation is essential. It will make the users understand the best way to use the installed system.