Grid Code Compliance Studies:

Waste-to-Energy Facility (UK)

- Engineering Recommendation G99 Studies
- P28 Voltage and Flicker Studies
- G5/5 Harmonic Compliance Studies

Introduction

Project Background

Client: Undisclosed
Industry: Waste-to-Energy
Location: Devon, UK (Southwest)
Date: February 2025

Overview

A UK-based renewable energy facility required grid compliance studies after integrating a new 2.9 MVA ORC synchronous generator into its 11kV distribution network. To ensure full compliance with regulatory standards, comprehensive assessments were undertaken, covering G99 Grid Compliance for generations, P28 Flicker and Voltage Fluctuations, and G5/5 Harmonic Studies.

Our team provided expert power system analysis to verify compliance with grid code requirements, enabling seamless generator integration into the existing network while ensuring stable and reliable operation.

Lets Discuss Your Project Requirements

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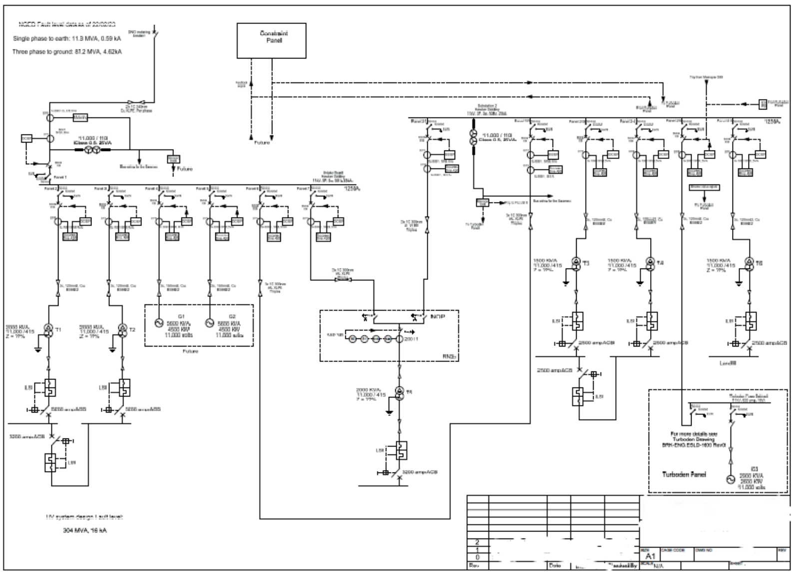
Grid Code Compliance Studies

Site Overview



High Voltage (HV) System

The site is powered by an 11kV infeed at a local substation. The HV distribution network is managed through two main switchboards, ensuring a reliable supply across the facility. The primary switchboard is responsible for distributing power to the energy-from-waste plant and integrating the site's generation assets into the network.

Low Voltage (LV) System

The facility operates a 400V main switchboard, which is supplied by two transformers with a bus section linking them. Under normal conditions, power is provided through one transformer, with the second available as a standby. The main switch panel distributes electricity to various downstream systems that support essential equipment and operations across the site.

Grid Code Compliance Studies

Engineering Recommendation G99 Studies

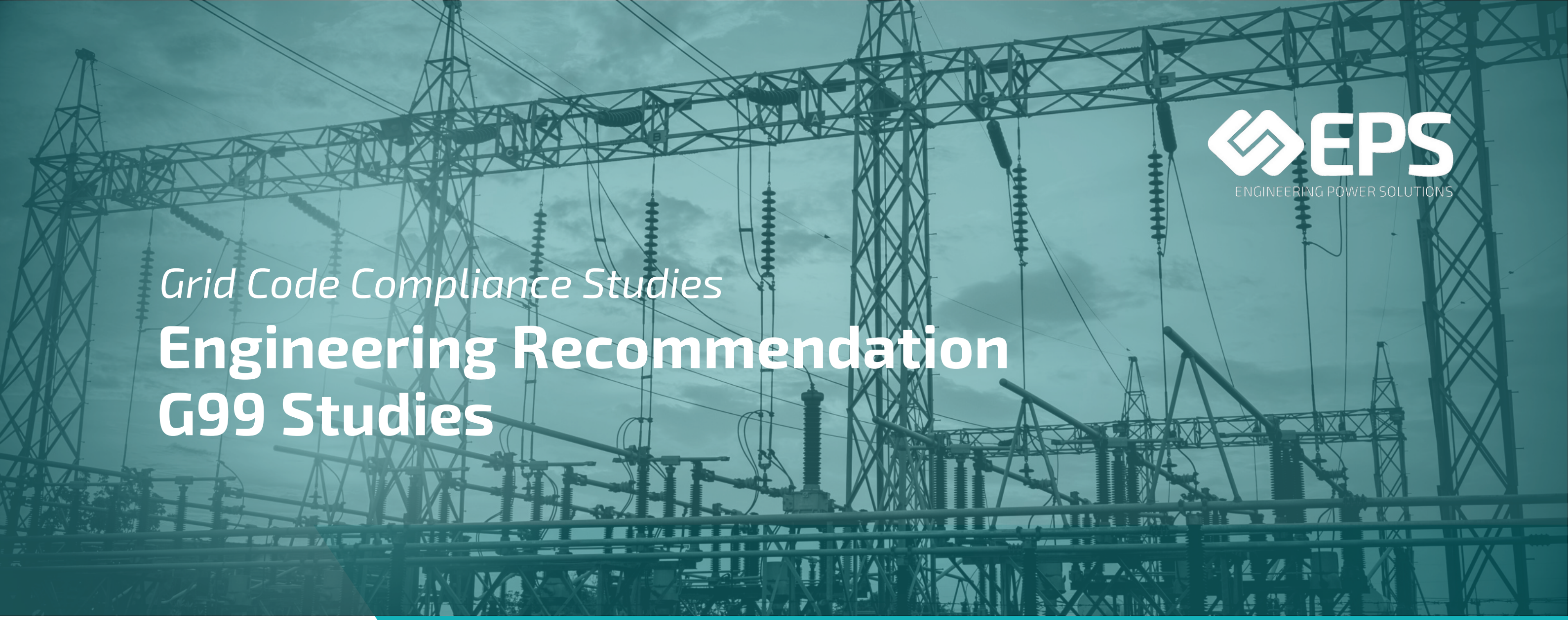
Aims & Objectives

The client was in the process of commissioning a new 2.9 MVA ORC synchronous generator into their 11kV distribution network. They engaged EPS to perform G99 grid compliance studies for their site following the generator's installation. As part of the compliance assessment, our power system engineers developed a dynamic model of the synchronous generator via DIgSILENT Power Factory. We executed various simulations in various operating scenarios to evaluate active and reactive power injections, fault ride through (FRT), and frequency response at the point of common coupling (PoCC). In each scenario, all relevant output parameters were thoroughly assessed to guarantee compliance with the allowable limits specified in (ENA) EREC G99.

Methodology

EPS's scope of work entailed detailed power system modelling in DIgSILENT Power-Factory, taking into account key aspects such as their generator, capability curve, grid transformer, DNO point of connection, DSL dynamic models for turbine / governor, AVR / exciter, PMU, and necessary coding and output channels for plotting the simulations and results. Our work also included:

- An assessment of the generator's reactive capability per **Sections B.4**, **12**, and **13** of the G99 standard.
- Reviewing the generator's response in Limited Frequency Sensitive Mode - Overfrequency **(LFSM -O)**.
- Simulating the generator's response in a wide range of frequency deviations under a Rate of Change of Frequency **(ROCOF)** of 1 Hz/s.
- An evaluation of the generator's compliance for grid connection in each scenario, along with recommendations if any issues are detected.



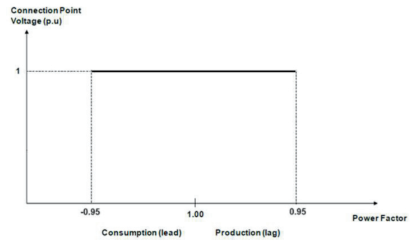
Grid Code Compliance Studies

Engineering Recommendation G99 Studies

Outcomes

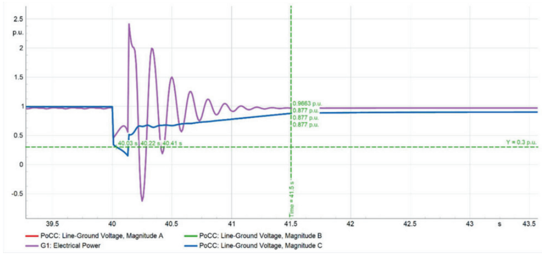
A) Voltage & Reactive Power Capability

The generator demonstrated compliance with G99 standards by operating within the defined reactive power range across voltage and power factor deviations. Load flow simulations confirmed the generator's ability to maintain required reactive power output at various points of operation.



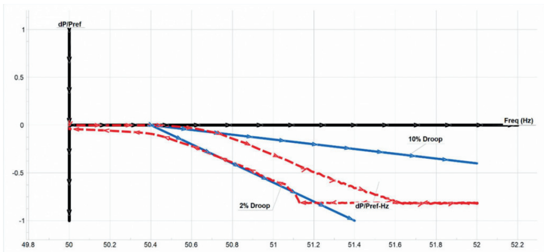
B) Fault Ride Through (FRT)

The generator successfully remained connected and stable during balanced and unbalanced fault scenarios, with active power restored to 100% of the pre-fault level within 0.5 seconds of voltage recovery.



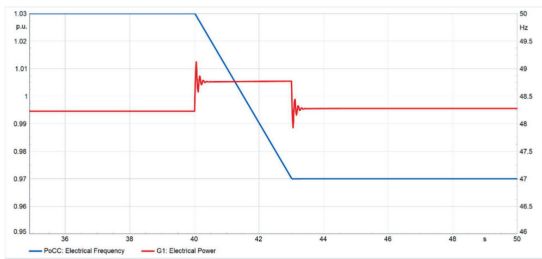
C) Limited Frequency Sensitive Mode – Overfrequency (LFSM-O):

The generator showed a compliant response to frequency excursions up to 52 Hz, reducing active power output as required by the G99 standard.



D) Frequency Response

Continuously maintaining constant active power output for system frequency changes within the range 47 to 52 Hz with 1Hz/s ROCOF and does not decrease by more than 5% for system frequency changes within the range 49.5 to 47 Hz.



Grid Code Compliance Studies

P28 Voltage and Flicker Studies

Aims & Objectives

Along with the G5/5 and G99 studies, the client also engaged EPS to undertake a P28 study to assess the energisation of their waste-to-energy facility. This entailed an in-depth assessment of voltage fluctuations and rapid voltage changes **(RVC)** at the point of common coupling (PoCC). EPS used ETAP power system simulation software to perform these studies.

Methodology

To demonstrate compliance with ENA EREC P28 standards, EPS conducted the following analyses:

- An examination of the transformer/generator energisation principle and its implications on the network.
- ETAP modelling of both the transformer and generator, incorporating transformer core magnetisation curves.
- Simulation of the transformer energisation, generator trip, and motor starting with ETAP
- Plotting of the RVC at the PoCC for each respective scenario related to the Infrequent event based on P28 recommendations.
- Assessment of flicker for events falling within the frequent event envelope.
- Determination of compliance with EREC P28 permissible limits for the identified events.

We evaluated voltage fluctuations for the following switching events at the client's site:

Event	Description	Occurance
1	Grid Transformer Energisation	Infrequent
2	Generator Trip, Grid Recovery	Very Frequent
3	Motor Start-up at a Nominal Load	Frequent

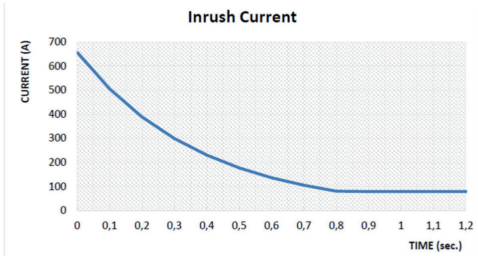
Grid Code Compliance Studies

P28 Voltage and Flicker Studies

Outcomes

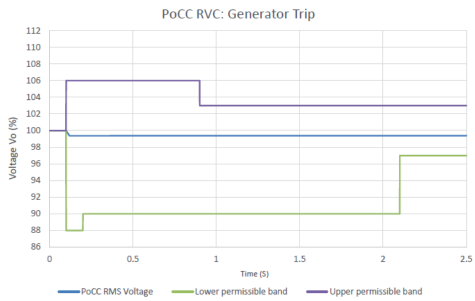
A) Grid Transformer Energisation Analysis

Based on the estimated magnetisation curve and remanent flux percentage of the 1500kVA grid transformer, a peak inrush current of approximately 662A was calculated in ETAP. This inrush caused a maximum voltage dip at the PoCC of 7.5%. This complies with the P28 voltage limits for infrequent events.



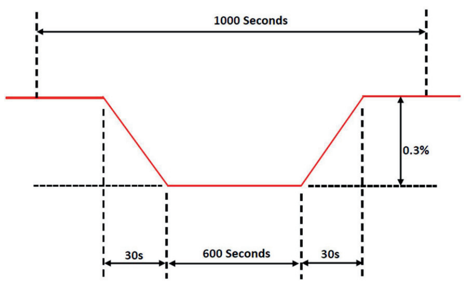
B) Generator Trip Analysis

During ORC generator trip, a minor inrush current was observed at the Point of Common Coupling (PoCC) as the distribution network now should support the nominal network demand. This resulted in a voltage dip of approximately 0.6% at PoCC, which is within acceptable limits for infrequent events.



C) Motor Starting Analysis

The three largest motors were identified and assessed to evaluate motor starting. All motor starting results indicated acceptable RVC at the PoCC, with the worst case being the WF pump, which caused a voltage dip of 0.3% at the PoCC. This is acceptable for frequent events.



All results indicated that the voltage dip and flicker at the PoCC do not exceed the limits set by the EREC P28 standard. Therefore, it can be inferred that the site conditions, from the perspective of transformer energisation, local generation trip and motor starting, all comply with the grid code requirements.

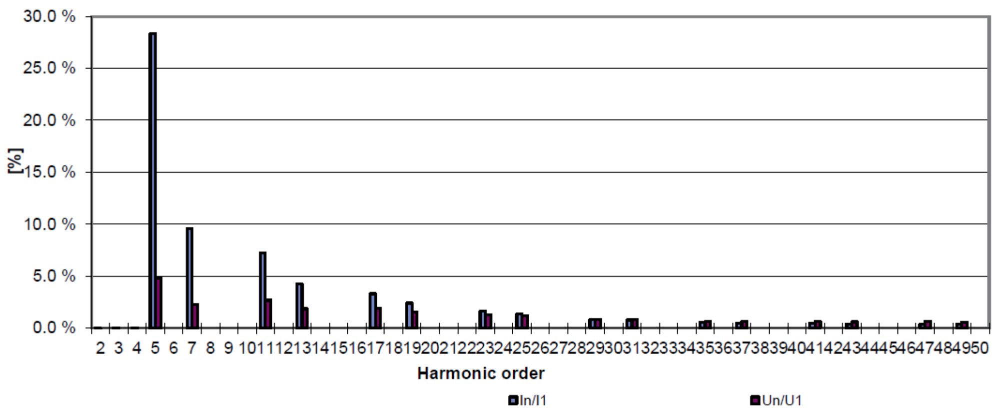
Grid Code Compliance Studies

G5/5 Harmonic Compliance Assessment

Aims & Objectives

National Grid requested that our client undertake a G5/5 assessment demonstrating compliance with EREC G5/5. To help accomplish this, EPS were engaged to perform a harmonic evaluation of the electrical infrastructure at their waste-to-energy facility, reviewing the Total Harmonic Distortion (THD), Incremental Harmonic Voltage (IHV), and Total Harmonic Voltage (THV).

Methodology



As per G5/5 recommendations, National Grid had recorded the background harmonic levels at the Point of Common Coupling (PoCC) for a period of seven days. The maximum and 95th percentile harmonics were recorded up to the 50th harmonic order.

With the integration of there new synchronous generator, it was necessary to examine the potential voltage distortion introduced by this parallel source. This is a critical aspect of determining levels of harmonic distortion at the PoCC. All site-connected power electronic loads, including ID fans, oil pumps, and water pumps were taken into account for this assessment. We used ETAP to run these simulations as it is one of the most advanced software tools available for grid code harmonic studies.

Grid Code Compliance Studies

G5/5 Harmonic Compliance Assessment

G5/5 | Stage 2C Assessment

To demonstrate adherence with the specified planning levels in G5/5, EPS engineers conducted a Stage 2C assessment. We used the current emissions and the worst-case harmonic impedance curve to help determine compliance.

This assessment included:

- Measuring the background harmonic level at the PoCC (Vhm) for each harmonic order (h).
- Establishing the harmonic current emission (Ih) of the proposed plant or equipment (in Ampere or %h = 1) at each harmonic order (h).
- Determining the three-phase short-circuit power at the PoCC
- Calculating the harmonic impedance (Zh) at the PoCC for each harmonic order (h).
- Calculating the incremental increase in harmonic voltage distortion (Vh c) at the PoCC for each harmonic order (h) due to the proposed harmonic current emission.
- Predicting the future harmonic voltage distortion (Vh p) at the PoCC for each harmonic order by summation of Vh m and Vh c.
- Predicting the future total harmonic voltage distortion (THDVp).
- Comparing the predicted THDVp and Vh p with the planning limits THDV PL and Vh PL stated in G5/5 recommendation.

Outcomes

The waste-to-energy facility was assessed for all voltage planning levels, including THDVp and all individual harmonic orders. The new connection has been assessed as compliant as all the predicted THDVp and all Vh p remained below the planning levels of THDVPL and VPL, respectively.

Conclusion

Overall, the comprehensive suite of grid code compliance studies delivered by EPS **(G99 / P28 / G5/5)** confirmed that our client's new 2.9 MVA ORC synchronous generator meets all applicable UK grid code requirements. The detailed modelling and analysis conducted by our power system experts validated the generator's ability to operate under various fault, frequency, and harmonic conditions. The client's waste-to-energy facility was shown to operate well within the allowable thresholds for voltage dips, flicker, and harmonic distortion.

As a result, the generator is now fully configured for long-term, standards-compliant operation within the UK transmission and distribution (T&D) network.

Partner with EPS for Seamless Grid Connections

Whether you're integrating new generation assets or navigating evolving grid code requirements, our team of specialist electrical engineers is here to help. We deliver tailored studies, expert power system modelling, and end-to-end consultancy to ensure full grid code compliance.

Our capabilities include, but are not limited to:

- Full Grid Connection Impact Studies
- Grid Code Compliance Studies
- Availability & Curtailment Studies
- ENA G5 Issue 5 Harmonic Voltage Distortion Studies
- ENA G99 Issue 1 Connection of Generation Equipment Studies
- Fault-Level Studies
- Contingency Studies
- Transient Stability Analysis
- Voltage Fluctuation Analysis

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