Public

GB Reduced Model

Release Note

NESO
National Energy
System Operator

Contents

Introduction

The GB Reduced Model is a simplified representation of the National Electricity Transmission System of Great Britain, developed using DIgSILENT PowerFactory. Based on the 2024 Electricity Ten Year Statement (ETYS), the system is divided into 28 zones, each evaluated for generation and demand. Generators are categorised by fuel type, and demand is split into active and reactive components. Line impedances are calculated to reflect electrical distances between zones.

The GB reduced model is a flexible network model where changes can be easily implemented and thus enabling a wider variety of static and dynamic studies scenarios to be carried out.

Methodology and Assumptions

This section outlines the methodology and assumptions applied in developing a reduced representation of the GB transmission network for system studies. The objective of this approach is to simplify the full transmission model while preserving its essential electrical characteristics, enabling efficient analysis of the GB transmission network. The process involves systematic aggregation of network zones, representation of key components, and application of standard modelling. The principal methodology and assumptions adopted are as follows:

- DIgSILENT PowerFactory 2025 SP4 was utilised, with the 2024 ETYS serving as the reference base case.
- Winter peak is the adopted scenario, as this period typically represents the highest transmission system loading.
- The ETYS zones were aggregated into larger zones to form the GB reduced model zones. Each zone is represented by a substation, which serves as the connection point for the associated generators and loads.
- Equivalent impedances between the GB reduced model zones calculated using only transmission lines.
- Generators grouped by fuel type; parameters derived from typical PowerFactory data.
- Generation and demand backgrounds are based on Future Energy Scenarios (FES) used in ETYS 2024.
- Reactive compensation devices such as Mechanical Switched Capacitor (MSC), shunt reactors, Static Var Systems (SVSs) are represented as Static Var Compensators (SVCs) per zone.

- All generators operate in voltage control mode; transformer tap changers are enabled for HV voltage regulation.
- Synchronous generators include generic dynamic models (Governors, AVRs, PSSs as applicable).
- Static generators, except Hydrogen and Marine, are equipped with suitable generic dynamic models.
- HVDC links are represented as static generators, with Voltage Source Converter (VSC) types incorporating a simple dynamic controller.

Modelling Approach

The following sections provide further details on the methodology adopted to create the reduced version of the full GB model in DIgSILENT Power Factory.

1. Reduced Model Zones

To simplify the analysis, GB transmission network is mapped to a set of ETYS zones. These zones contain nodes and circuits describing a small area of the GB transmission network. Further details on ETYS zones can be found in the ETYS documentation and associated appendices ETYS documents and appendices.

For the reduced network model, these ETYS zones were aggregated into larger zones, which form the basis of the GB reduced model. This aggregation significantly decreases the number of buses within the model, thereby reducing its complexity while maintaining essential network characteristics. For example, the zone 1 in the GB reduce model consists of the following ETYS zones F6, E1, E7 and E8 as sown in Figure. 1.

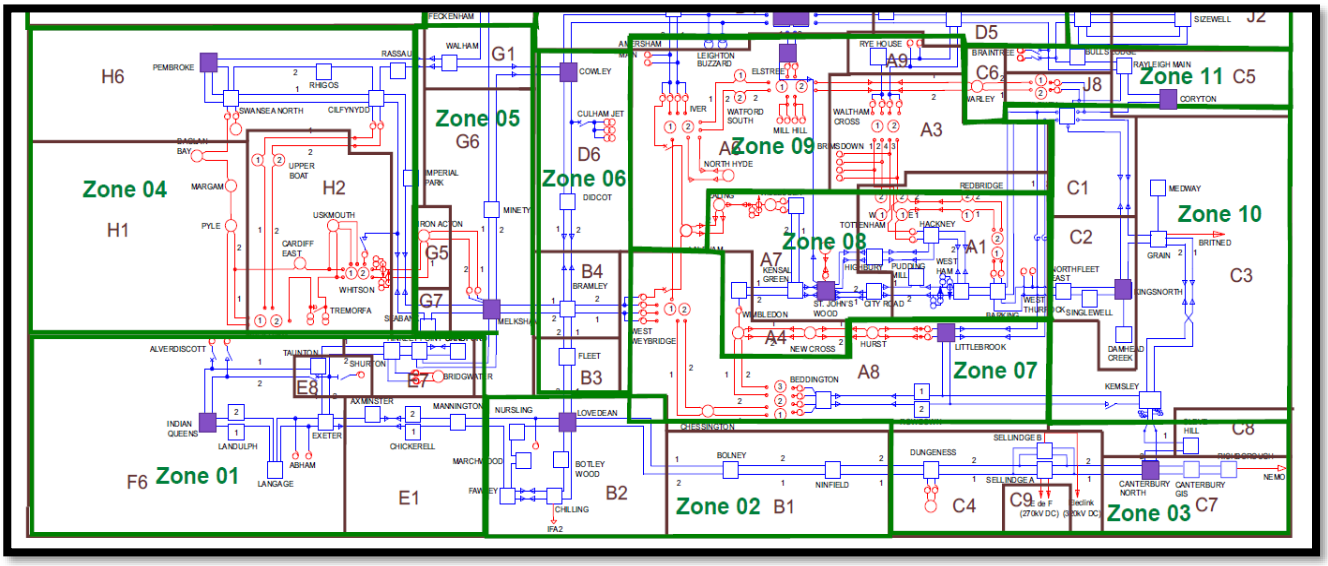


Figure 1. ETYS and GB reduced model zones.

The full diagram showing the GB Transmission System ETYS zones and the corresponding GB reduced model zones is provided in Appendix A. Additionally, Table 1 lists the 28 GB reduced model zones along with their constituent ETYS zones.

Table 1: Reduced model and ETYS zones.

No	GB reduced model	ETYS zones
1	Zone 01	F6, E8, E7, E1
2	Zone 02	B2, B1
3	Zone 03	C4, C7, C8, C9
4	Zone 04	H1, H2, H6
5	Zone 05	G1, G5, G6, G7
6	Zone 06	B3, B4, D6
7	Zone 07	A8
8	Zone 08	A1, A4, A7
9	Zone 09	A3, A6, A9
10	Zone 10	C1, C2, C3
11	Zone 11	C5, C6, J8
12	Zone 12	J1, J2, J3, J5
13	Zone 13	D4, D5, J4, J6, J7, L8
14	Zone 14	L3, L7
15	Zone 15	L1, L2, L5
16	Zone 16	K1, K2, K4, K5, K6

17	Zone 17	P3
18	Zone 18	M4, M5, M6, M7, M8
19	Zone 19	N2, N4, N5, N6, N7, N8
20	Zone 20	N1, N3
21	Zone 21	R4, R5, R6
22	Zone 22	P1, P2, P4, P5, P6
23	Zone 23	P7, P8
24	Zone 24	Q2, Q4, Q5, Q6, Q7, Q8
25	Zone 25	S6
26	Zone 26	S5
27	Zone 27	T3, T4
28	Zone 28	T1, T5, T2, T6

2. Substation layout

Each of the 28 zones within the GB reduced model was defined using a substation template. Generators were modelled for each fuel type, demand, and reactive power compensation devices are included as shown in Figure 2.

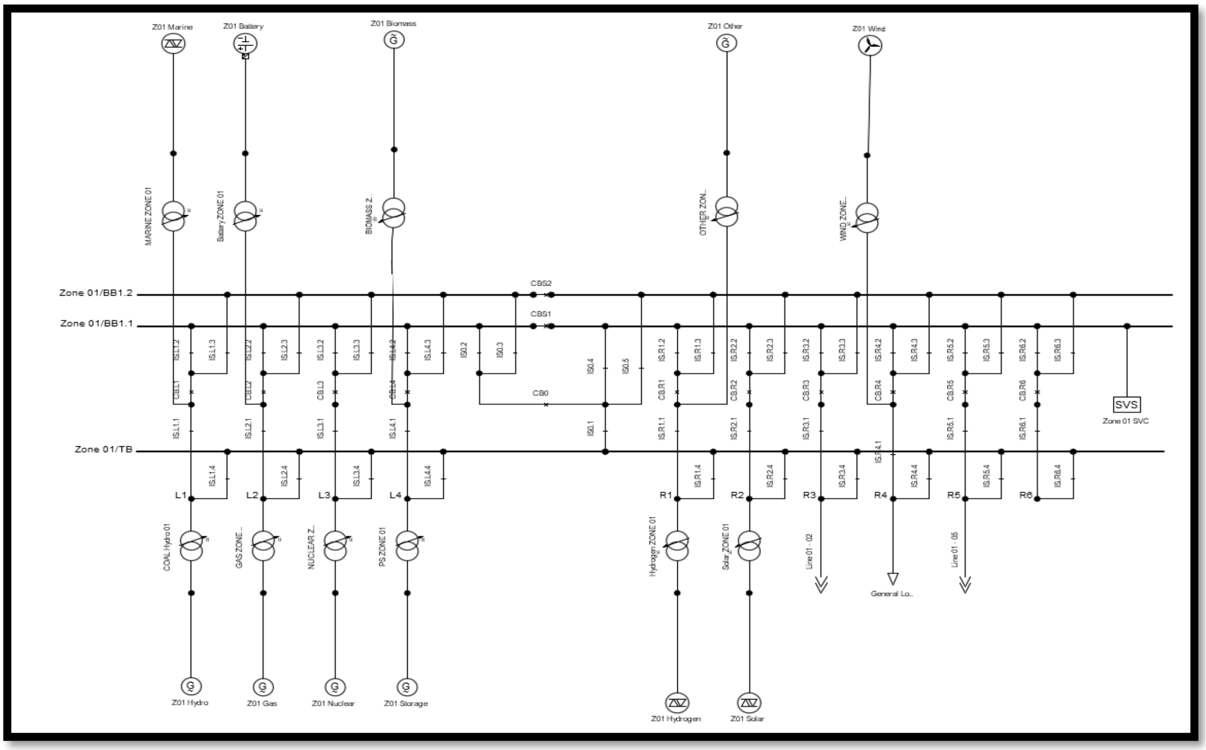


Figure 2. GB reduced model substation layout

3. Generation modelling

Each fuel type was represented within every reduced model zone using either synchronous or static generation models corresponding to its technology. The MVA rating and active power output for each generator type were derived from the ETYS model for the relevant zones after mapping them to the GB reduced model zones. Machine parameters, including synchronous reactance, transient reactance, and sub-transient reactance, were obtained from typical generator data. Generation transformer ratings were selected to align with the ratings of the associated generators.

Operational reactive power limits for each generator were defined using Mvar limit curves based on the respective technology and fuel type.

4. Demand

The total active and reactive power demand for each zone in ETYS model is aggregated and mapped to relevant GB reduced model zones (substation).

5. Line

In ETYS model, transmission lines are made up of different segments known as branches. The electrical parameters for each branch—resistance (R), reactance (X), and susceptance (B) were extracted for each branch and the overall impedance of the equivalent transmission line was computed as per Appendix B data depending on whether the branches were connected in series or in parallel.

For each zone in the GB reduced model a substation (highlighted in purple in Appendix B) was selected to act as the central connection node for all generators within that zone. The impedance between substations was then calculated. Figure 3 illustrates the process for determining the impedance between Zones 1 and 2, and Zones 1 and 5 specifically between (Indian Queens 400 kV substation in Zone 1 and Lovedean 400kV substation in Zone 2) and (Indian Queens 400 kV substation in Zone 1 and Melksham 400 kV substation in Zone 5). The same process was followed to calculate all the impedances between the relevant zones. All calculated lines used to connect the GB reduced model zones are shown in Appendix B.

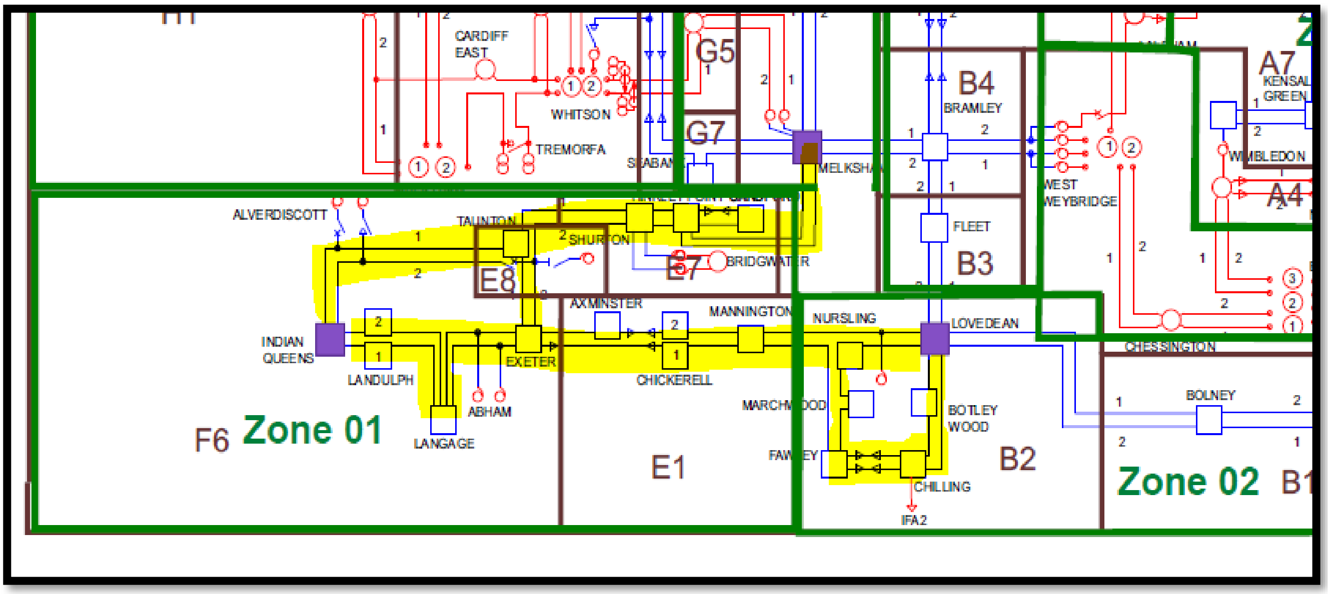


Figure 3. Line routes between reduced model zones.

6. Voltage profile

An appropriate voltage profile was established for the GB reduced network in compliance with the voltage limits specified in the Security and Quality of Supply Standard (SQSS). The reactive power requirements of the network were met through contributions from generators, transformer tap changers, and Static Var Systems (SVSs), which were employed to emulate the reactive compensation equipment present in the original network. The 2024 ETYS base model was used to identify the locations (zones) and capacities of reactive compensation devices such as Mechanical Switched Capacitors (MSCs), shunt reactors, and SVS compensators.

All generators were configured to operate in voltage control mode to provide reactive support to the system. Additionally, the automatic tap-changing functionality of transformers was enabled to assist with voltage regulation at high-voltage terminals. Given the presence of multiple machines regulating voltage at the same busbar, a station controller was implemented for each zone in the reduced model to coordinate reactive power contributions between generators and SVCs.

7. Dynamic models

Synchronous Machines

All synchronous generators in the reduced model are equipped with dynamic controller such as Automatic Voltage Regulators (AVRs) and Governors. Generic dynamic models were developed using DIgSILENT Simulation Language (DSL) to emulate the dynamic response of each synchronous generator. The standard governor model of type gov_GOV was applied to all synchronous generators connected to the network.

It is important to note that the parameter PN, which specifies the rated turbine power in megawatts (MW), must correspond to the generator's rated active power. This parameter should therefore be updated whenever the generator rating is modified to ensure model accuracy.

Static Generators

Static generators were equipped with dynamic elements appropriate to their respective technologies. The dynamic controller for wind turbines was based on the generic Western Electricity Coordinating Council (WECC) model, tuned to represent full-scale converter wind turbines connected to the GB network. Suitable dynamic controllers for solar generation and battery storage systems were sourced from the DIgSILENT library.

Given the current minimal contribution from hydrogen and marine generation, their dynamic impact on system behaviour is considered negligible; therefore, no dynamic controllers were assigned to these generation types.

HVDC links

In the reduced model, HVDC links are represented as static generators to avoid the complexity associated with full HVDC modelling. Since the objective is to assess the dynamic behaviour of the GB network without simulating events on the non-GB side of the DC links, a simplified dynamic controller may be employed to emulate converter dynamics at the GB terminals. For VSC based HVDC links, the generic battery dynamic controller is utilised which support exporting and importing power transfer scenarios.

If a more detailed representation of HVDC systems is required, suitable models for both Line Commutated Converter (LCC) and VSC HVDC links can be obtained from the DIgSILENT library.

Model Validation

This process was undertaken to assess the accuracy of the reduced model in comparison with the original full ETYS model. A series of tests were performed on the reduced network, and the results were benchmarked against those obtained from the 2024 ETYS winter peak scenario.

It should be noted that no dynamic validation was carried out, as the original ETYS model is not suitable for dynamic analysis and all dynamic controllers within the GB reduced model are generic.

The load flow analysis achieved successful convergence within a few iterations. Occasionally, warning messages may appear indicating that some generators have reached their maximum reactive power limits; however, these do not affect the validity of the results. RMS simulations were successfully initialised without errors or significant warnings. While the DSL dynamic models for generation and SVCs were developed some time ago and may produce warnings related to the stability of the integration algorithm, these warnings have no impact on the accuracy or performance of the model.

Load flow results

Load flow results were compared to identify any differences between the GB reduced model and the original full GB model. The same reference machine zone used in the original ETYS model was selected in the reduced model, located in Zone 21.

The zonal active power values in the reduced model were benchmarked against those from the full ETYS model, and the results indicate a high degree of similarity. This confirms that the locations of generation and demand are well aligned in both models. Furthermore, active power transfers between zones in the reduced model closely match the power flows observed in the original ETYS model. System losses were calculated to be approximately 3% of the winter peak demand, which is consistent with the original 2024 ETYS model.

Fault Levels

The fault levels in the GB reduced model were, on average, higher than those in the full ETYS model. This discrepancy arises primarily because certain substations in the reduced model have higher fault levels compared to their corresponding zones in the ETYS model.

Given the assumptions applied during the development of the reduced model, it is expected that fault levels will not exactly match those of the ETYS model. The key reasons for this variation are as follows:

- To simplify the reduced model, all generators and loads within certain ETYS zones were aggregated at one substation. Consequently, all generators are connected at the same node, whereas in the ETYS model, some generators are connected to neighbouring substations, introducing additional impedances that are not captured in the reduced model. This omission tends to increase fault levels.
- In the reduced model, all substations are assumed to have a solid busbar arrangement, whereas the ETYS model includes split busbar configurations in certain substations.

- The reduced model does not include distribution networks, thereby eliminating any fault contribution from these networks.
- Generator parameters in the reduced model are generic, which may result in fault contributions differing from those in the original ETYS model.

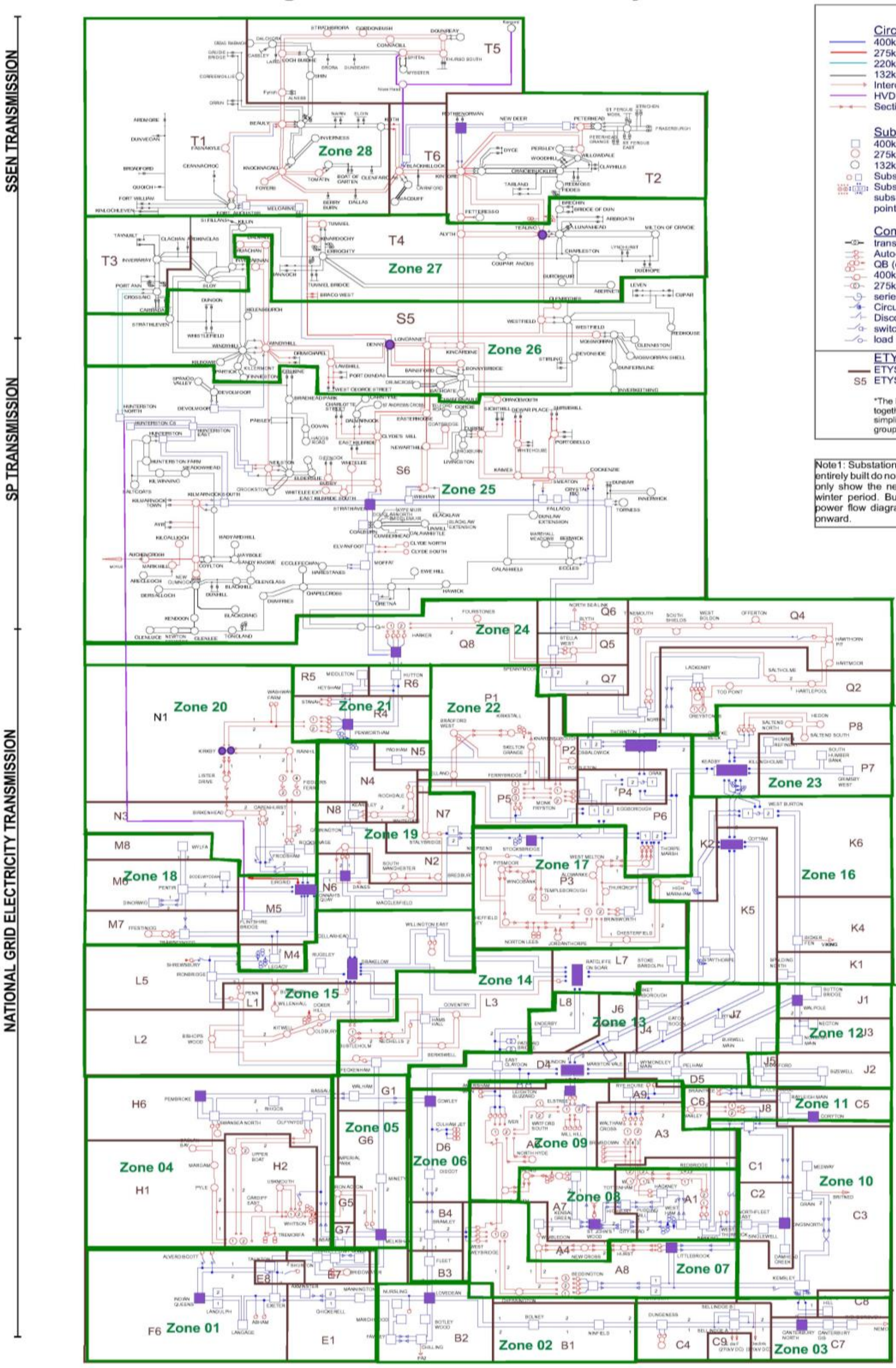
Model limitations

Several assumptions were made during the development of the GB reduced model, which inevitably introduce certain limitations in terms of accuracy. For each zone, a single central substation was selected to represent the connection point for all generators, loads, transmission lines, and reactive compensation devices within that zone. In reality, these assets are connected across multiple substations, creating electrical distances between the actual substations and the chosen reference substation. These impedances are not captured in the reduced model.

Furthermore, generic data was used to represent the parameters of network assets, including dynamic elements, which may not fully reflect their original performance characteristics.

Appendices:

A. GB Transmission System ETYS and GB reduced model zones



Legend

Circuits
- 400kV circuit
- 275kV circuit
- 220kV circuit
- 132kV circuit
- Interconnector link
- HVDC circuit
- Section change to underground cable

Substations
- 400kV substation
- 275kV substation
- 132kV substation
- Substation run solid
- Substation run split
- substation with no busbar connection (Tee point)

Components
- transformer - same voltage on both sides
- Auto-transformer
- QB (quadrature booster)
- 400kV/275kV transformer
- 275kV/132kV transformer
- series reactor
- Circuit breaker
- Disconnector/isolator
- switch disconnector
- load switch/breaker

ETYS zones components
- ETYS zones lines
- S5 ETYS zones names

*The ETYS zones are a useful tool to group together the parts of the network for simplification. The boundaries are defined by grouping the ETYS zones.

Note1: Substations and transmission circuits that are not entirely built do not appear in the Appendix A maps as they only show the network in operation for the 2024/2025 winter period. But they appear on the future network power flow diagrams in Appendix C from 2025/26(C2) onward.

B. GB reduced model connected substations in PowerFactory