European Network of
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Small Grid Test Configuration

Version: 3.0.0

CGMES v2.4.15

31 May 2015

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1. Introduction

The document is providing an overview of the Small Grid Test Configuration applicable for the ENTSO-E Common Grid Model Exchange Standard (CGMES) Conformity Assessment Framework hereafter referred as “the Framework”.

Versioning of the document is following the rules specified in the Chapter 5.1 of the CGMES.

Disclaimer

The Test Configurations (test models) are owned by ENTSO-E and are provided by ENTSO-E “as it is”. To the fullest extent permitted by law, ENTSO-E shall not be liable for any damages of any kind arising out of the use of the models (including any of their subsequent modifications). ENTSO-E neither warrants, nor represents that the use of the models will not infringe the rights of third parties. Any use of the models shall include a reference to ENTSO-E. ENTSO-E web site is the only official source of information related to these models.

2. Usage and content of the test configuration

The Small Grid test configuration is packaged in the following structure:

- Documentation which contains configuration descriptions and results
  - CGMES_v2.4.15_SmallGridTestConfiguration_v3.0.0.docx - file explaining Small Grid test configurations (Base Case, HVDC and Reduced Network)
  - CGMES_v2.4.15_SmallGridTestConfiguration_v3.0.0.xls - Small Grid test configurations (Base Case, HVDC and Reduced Network), file containing in different sheets model descriptions and load flow results
- BusBranch which contains the data for the bus-branch configuration
  - CGMES_v2.4.15_SmallGridTestConfiguration_BaseCase_Complete_v3.0.0.zip
  - CGMES_v2.4.15_SmallGridTestConfiguration_HVDC_Complete_v3.0.0.zip
  - CGMES_v2.4.15_SmallGridTestConfiguration_ReducedNetwork_Complete_v3.0.0.zip
  - CGMES_v2.4.15_SmallGridTestConfiguration_Boundary_v3.0.0.zip
  - HVDC_Difference which contains
    - SmallGridTestConfiguration_HVDC_TP_diff_v3.0.0.xml
    - SmallGridTestConfiguration_HVDC_EQ_diff_v3.0.0.xml
    - SmallGridTestConfiguration_HVDC_GL_diff_v3.0.0.xml
  - ReducedNetwork_Difference which contains
    - SmallGridTestConfiguration_RN_TP_diff_v3.0.0.xml
    - SmallGridTestConfiguration_RN_EQ_diff_v3.0.0.xml
    - SmallGridTestConfiguration_RN_GL_diff_v3.0.0.xml
- NodeBreaker which contains the data for the node-breaker configuration
  - CGMES_v2.4.15_SmallGridTestConfiguration_BaseCase_Complete_v3.0.0.zip
  - CGMES_v2.4.15_SmallGridTestConfiguration_HVDC_Complete_v3.0.0.zip
  - CGMES_v2.4.15_SmallGridTestConfiguration_ReducedNetwork_Complete_v3.0.0.zip
  - CGMES_v2.4.15_SmallGridTestConfiguration_Boundary_v3.0.0.zip
  - BaseCase_Difference which contains
    - SmallGridTestConfiguration_BC_EQ_diff_v3.0.0.xml

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- SmallGridTestConfiguration_BC_TP_diff_v3.0.0.xml
- HVDC_Difference which contains
  - SmallGridTestConfiguration_HVDC_EQ_diff_v3.0.0.xml
  - SmallGridTestConfiguration_HVDC_TP_diff_v3.0.0.xml
- ReducedNetwork_Difference which contains
  - SmallGridTestConfiguration_RN_EQ_diff_v3.0.0.xml
  - SmallGridTestConfiguration_RN_TP_diff_v3.0.0.xml

Small Grid test configurations models are planned to be used for testing of both interoperability of HVDC and interoperability of equivalent elements. Also they are used to test the support to a load flow analyses. Short-circuit calculations and dynamics simulations cannot be performed using this test configuration.

For both variants (node-breaker and bus-branch) available for this test configuration there are Base Case, HVDC and Reduced Network model versions. All the models are created from the Small Grid Base Case (bus-branch) applying the appropriate difference files like on the Figure 1Error: Reference source not found The complete HVDC and Reduced Network models are also given in the zip package.

For the bus-branch configuration EQ, TP and SSH can be used without SV file, the same results are achieved like with the SV file, while for the node-breaker only EQ and SSH are enough for the load flow calculations.

All test models created from the Small Grid Base Case are shown in the following chart.

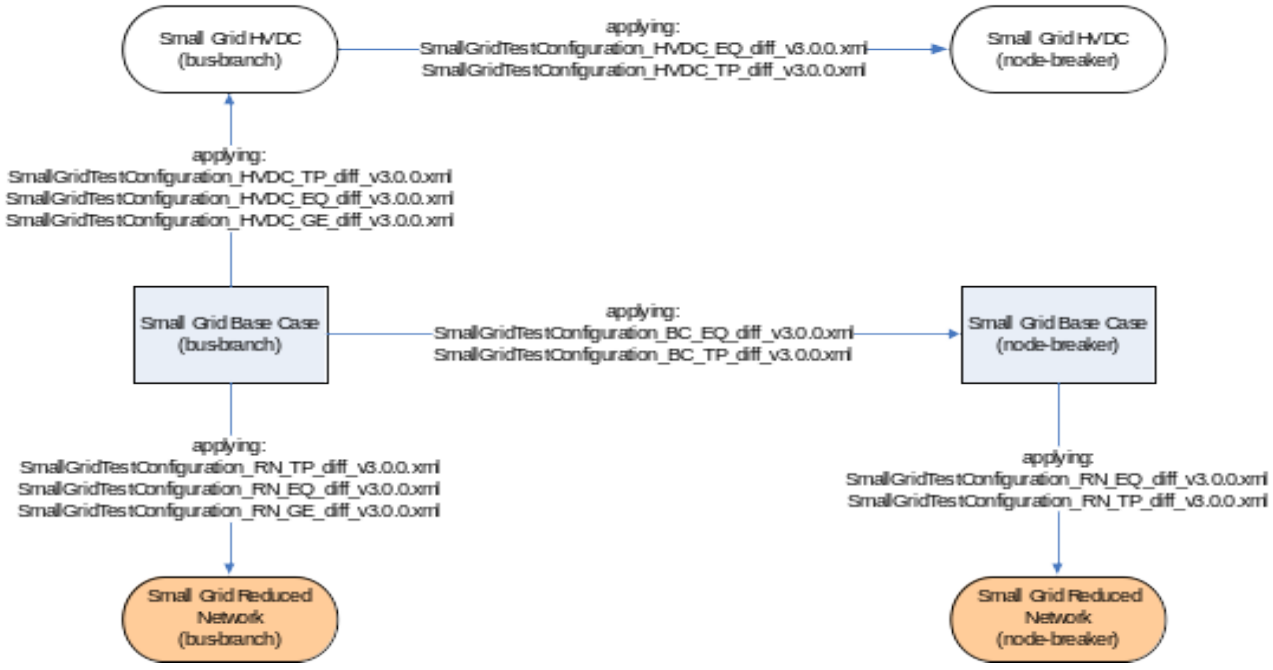

Figure 1 – Dependencies between Small Grid Base Case and HVDC and Reduced Network for bus-branch and node-breaker configurations

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3. Small Grid Base Case

3.1. General information

The Small Grid Base Case (SGBC) model is based on the IEEE 118 nodes (Figure 10). Originally the IEEE 118 Bus Test Case represents a portion of the American Electric Power System (in the Midwestern US) as of December, 1962.

This model is used to test interoperability of substation diagrams and wide area diagrams in addition to geographical representation and also as a support for the load flow analyses. The SGBC includes geographical location and wide area diagram instance files.

Boundary instance files are the same for the Base Case, HVDC and Reduced Network. They are located in the zip file “CGMES_v2.4.15_SmallGridTestConfiguration_Boundary_v3.0.0”.

Difference files are used for creating HVDC and reduced network from the base case and for creating node-breaker from bus-branch configurations, like it is shown before on the Figure 1. Beside the difference files, there are also complete HVDC and Reduced Network models.

Difference files for geographical location are also shown on the Figure 1.

3.2. Network topology and data

The summary of the Small Grid Base Case model is shown in the figure below.

Type Of	N
Nod	11
Lin	17
Transformers (ratio tap changer)	6
	0
Generat	1
Synchronous Compensators	9
Loa ds	10 6

Figure 2 – Small Grid Base Case Model Summary

Detail information about the each grid element is given in the external excel document CGMES_v2.4.15_SmallGridTestConfiguration_v3.0.0.xls in different sheets (md_Nodes, md_Lines, md_Transformers, md_CSConverter…).

There are two different configuration of the Small Grid Base Case model:

a) Bus-Branch Configuration

b) Node-Breaker Configuration

Node-breaker configuration is created by applying difference files (SmallGridTestConfiguration_BC_EQ_diff_v3.0.0.xml,SmallGridTestConfiguration_BC_TP_diff_v3.0.0.xml) on the standard SGBC bus-branch related model.

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3.3. Load flow calculation information

Load flow system summary, where results were obtained by setting all voltage angles to zero and all voltage magnitudes to 1.0 p.u (“flat” start):

AC Load Flow Type	Full Newton-Raphson
Active Power Mismatch Limit	P=0.02
Relative Error Tolerance of Q	Q=0.05
Number of Iterations	3
Slack Bus "Sporn1"	P = 515.1 MW Q = -62.3 MVAr V = 136 kV angle = 0

The load flow results are the same for the both SGBC configurations and they are available in the excel document CGMES_v2.4.15_SmallGridTestConfiguration_v3.0.0.xls, in the sheet “SGBC_AC_Results”.

3.4. CIMdesk validation report for bus-branch version

CIMdesk validation report (validation against Base profiles) on the assembled model which includes boundary and the base case bus-branch version is the following:

Type	Class	Recurrence	Description
Warning	SubGeographicalRegion	1/2	No Substations are associated with SubGeographicalRegion via Association Substation.Region, expecting at least 1.
Warning	Location	3/284	Fewer than 2 PositionPoints are associated with Location of the Junction that span two Substations.
Warning	ACLineSegment	1/176	ACLineSegment.x/ACLineSegment.r ratio is too large.

The above warnings should be ignored as:

- SubGeographicalRegion in the boundary can not contain any Substations, but they are referenced from Line containers in boundary.
- The rest are considered data issues.

3.5. CIMdesk validation report for node-breaker version

CIMdesk validation report (validation against Operation) on the assembled model which includes boundary and the base case node-breaker version is the following:

Type	Class	Recurrence	Description
Warning	SubGeographicalRegion	1/2	No Substations are associated with SubGeographicalRegion via Association Substation.Region, expecting at least 1.
Warning	ACLineSegment	1/176	ACLineSegment.x/ACLineSegment.r ratio is too large.

The above warnings should be ignored as:

- SubGeographicalRegion in the boundary can not contain any Substations, but they are referenced from Line containers in boundary.
- Data issue which is considered normal for the provided model.

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4. Small Grid HVDC

4.1. General information

The Small Grid HVDC model is based on the Small Grid Base Case model (Figure 1). This model is used to test interoperability of HVDC and also as a support for load flow analyses.

The bus-branch Small Grid HVDC model is created by upgrading the standard SGBC model by applying three difference files:

- SmallGridTestConfiguration_HVDC_TP_diff_v3.0.0.xml
- SmallGridTestConfiguration_HVDC_EQ_diff_v3.0.0.xml
- SmallGridTestConfiguration_HVDC_GL_diff_v3.0.0.xml

The node-breaker Small Grid HVDC model is created by upgrading the Small Grid HVDC bus-branch related model, applying two difference files:

- SmallGridTestConfiguration_HVDC_EQ_diff_v3.0.0.xml
- SmallGridTestConfiguration_HVDC_TP_diff_v3.0.0.xml

The following modifications were made (Figure 4):

a) internal AC line with the ID "_0473e004-c766-11e1-8775-005056c00008" (name "30-38") was replaced with the HVDC line (CSC) consisting of the following elements:

TYPE	CIM ID	NAME
RatioTapChanger	_5dbb1c11_5e13_4629_88a2_a4b4bd9e8022	rtc1
CsConverter	_5ede3438_e591_4816_bbc4_6e97c5e18ecb	Conv1
DCGround	_197ecdfb_1c8f_4a1f_bfd1_9a3725621adb	DCGnd1
DCLineSegment	_80b1e96c_befd_41d7_8b3e_4039f66aa74f	dcLine
DCGround	_0da46fb4_7c06_4923_9324_d4550e6c8e62	DCGnd2
CsConverter	_0df30da2_66ad_44d9_ba01_5c121c0a6ab7	Conv2
RatioTapChanger	_5dbb1c11_5e13_4629_88a2_a4b4bd9e802w	rtc2

b) replacing the tie-line with the HVDC line (VSC) wasn't possible because there were no two MAS, and due to internal AC line with the ID "_0475dbd8-c766-11e1-8775-005056c00008" (name "63-64") was replaced with the HVDC line (VSC) consisting of the following elements:

TYPE	CIM ID	NAME
VsConverter	_d22aec18_082e_41a8_ae50_35ed0c886d8e	VSC1
DCGround	_4b0e1c8b_b8d9_46e0_9531_d1a31bdaa64d	DCGnd3
DCLineSegment	_354bf631_051f_41b4_bde7_ed399ffb696d	dcLine2
DCGround	_6786173f_0a9c_46e7_8245_96204f73d844	DCGnd4
VsConverter	_8375e53f_9c4b_41b9_99fb_330ea4a6f2fc	VSC2
SeriesCompensator	_951a1096_7388_4ef3_b309_94b8479f8abb	reactor1
SeriesCompensator	_5cd34b0f_ee15_4b71_b69e_8f8eb72253c1	reactor2

4.2. Network topology and data

The summary of the Small Grid HVDC model is shown in the figure below.

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Type Of	N
Nodes(including 8 DC nodes)	12
Lines	17
Transformers (ratio tap changer)	4
Generators	1
Synchronous Compensators	1
Loads	10
DC Lines	2
VS Converter	2
CS Converter	2

Figure 3 – Small Grid HVDC Model Summary

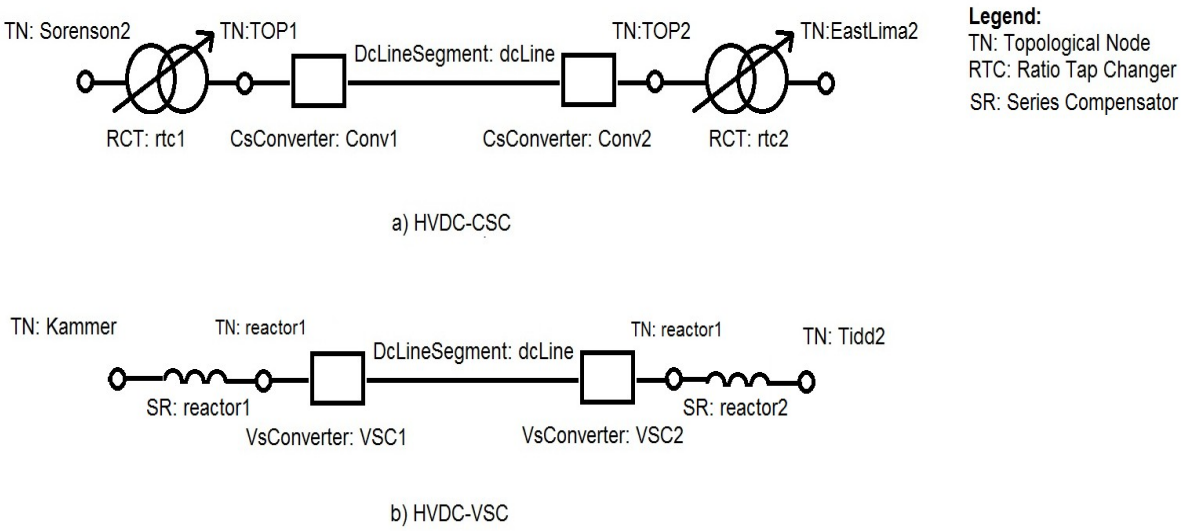

Figure 4 – HVDC (CSC) and HVDC (VSC)

There are two different configuration of the Small Grid HVDC (SG_HVDC) model:

a) Bus-Branch Configuration

b) Node-Breaker Configuration

Node-breaker configuration is created by applying the difference files (SmallGridTestConfiguration_BC_EQ_diff_v3.0.0.xml,SmallGridTestConfiguration_BC_TP_diff_v3.0.0.xml) on the SGBC node-breaker related model.

4.3. Load flow calculation information

Load flow calculation is based on sequential method for AC-DC networks [1, 2, 3, 4]. The sequential method solves AC and DC systems separately. Converters are treated as loads or power sources on an AC

system and iterations between AC and DC power flow algorithms are made to match boundary conditions between AC and DC systems.

Load flow system summary, with calculation achieved from flat start

AC Load Flow Type	Full Newton-Raphson
Reactive Limits	Off
Relative Error Tolerance	P=0.0002 Q=0.0005
Number of Iterations	3
Slack Bus "Sporn1"	P = 519.2 MW Q = -62.1 MVAr V = 13.16 kV angle = 0

The load flow results are the same for the both Small Grid HVDC configurations and they are available in the excel document CGMES_v2.4.15_SmallGridTestConfiguration_v3.0.0.xls, for the AC load flow in sheet “SG_HVDC_AC_Results” and for DC load flow in sheet “SG_HVDC_DC_Results”.

4.4. CIMdesk validation report for bus-branch version

CIMdesk validation report (validation against Base profiles) on the assembled model which includes boundary and the HVDC bus-branch version is the following:

Type	Class	Recurrence	Description
Error	CsConverter	1/2	Target DC voltage is less than minimum DC voltage.
Error	VsConverter	1/2	Target DC voltage is less than minimum DC voltage.
Warning	SubGeographicalRegion	1/2	No Substations are associated with SubGeographicalRegion via Association Substation.Region, expecting at least 1.
Warning	Location	3/284	Fewer than 2 PositionPoints are associated with Location of the Junction that span two Substations.
Warning	ACLineSegment	1/174	ACLineSegment.x/ACLineSegment.r ratio is too large.

The above warnings should be ignored as:

- The 2 errors should be investigated and potentially ignored or fixed in the next version of the test configuration.
- SubGeographicalRegion in the boundary can not contain any Substations, but they are referenced from Line containers in boundary.
- The other 2 warnings are considered data issues.

4.5. CIMdesk validation report for node-breaker version

CIMdesk validation report (validation against Operation) on the assembled model which includes boundary and the HVDC node-breaker version is the following:

Type	Class	Recurrence	Description
Error	CsConverter	1/2	Target DC voltage is less than minimum DC voltage.
Error	VsConverter	1/2	Target DC voltage is less than minimum DC voltage.
Warning	SubGeographicalRegion	1/2	No Substations are associated with SubGeographicalRegion via Association Substation.Region, expecting at least 1.
Warning	ACLineSegment	1/174	ACLineSegment.x/ACLineSegment.r ratio is too large.

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The above warnings should be ignored as:

- The 2 errors should be investigated and potentially ignored or fixed in the next version of the test configuration.
- SubGeographicalRegion in the boundary can not contain any Substations, but they are referenced from Line containers in boundary.
- ACLineSegment warning is a data issue which is considered normal for the provided model.

5. Small Grid Reduced Network

5.1. General information

The Small Grid Reduced Network (SGRN) model is based on the SGBC model (Figure 16). This model is used to test interoperability of equivalent elements and also as a support for load flow analyses on a reduced network.

The bus-branch SGRN model is created by performing the following modifications on the standard Small Grid Base Case (SGBC) model by applying three difference files:

- SmallGridTestConfiguration_RN_TP_diff_v3.0.0.xml
- SmallGridTestConfiguration_RN_EQ_diff_v3.0.0.xml
- SmallGridTestConfiguration_RN_GL_diff_v3.0.0.xml

The node-breaker SGRN model is created by performing the same modifications but on the node-breaker Small Grid Base Case (SGBC) model, by applying the two difference files:

- SmallGridTestConfiguration_RN_EQ_diff_v3.0.0.xml
- SmallGridTestConfiguration_RN_TP_diff_v3.0.0.xml

Reverse Differences

Difference files replaces elements from the model with equivalent elements, which are represented by the following classes defined in the CGMES. The following elements were removed from the model.

External nodes (11)

CIM ID	Name	Area	Voltage [kV]
_047ba832-c766-11e1-8775-005056c00008	Breed	GB	220
_044e7db1-c766-11e1-8775-005056c00008	X9	GB	220
_045163e5-c766-11e1-8775-005056c00008	Olive	GB	220
_047147f0-c766-11e1-8775-005056c00008	Olive	GB	132
_04555b87-c766-11e1-8775-005056c00008	NwCarlsl	GB	132
_0471bd2a-c766-11e1-8775-005056c00008	HickryCk	GB	132
_0458b6e4-c766-11e1-8775-005056c00008	SouthBnd	GB	132
_046b066a-c766-11e1-8775-005056c00008	Kankakee	GB	132
_044a8618-c766-11e1-8775-005056c00008	Riversde	GB	132
_045fe2d7-c766-11e1-8775-005056c00008	Pokagon	GB	132
_04684743-c766-11e1-8775-005056c00008	JacksnRd	GB	132

Figure 5 – Reduced Nodes

List of the removed terminals is located in the “SmallGridTestConfiguration_RN_EQ_diff_v3.0.0.xml” file.

- ACLineSegment:
    - _045a3d89-c766-11e1-8775-005056c00008

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- _04535fb7-c766-11e1-8775-005056c00008
- _045c8776-c766-11e1-8775-005056c00008
- _047f78c2-c766-11e1-8775-005056c00008
- _0483be84-c766-11e1-8775-005056c00008
- _044b9789-c766-11e1-8775-005056c00008
- _048963d9-c766-11e1-8775-005056c00008
- _0484f709-c766-11e1-8775-005056c00008
- _044bbe91-c766-11e1-8775-005056c00008
- _044a5f09-c766-11e1-8775-005056c00008
- _04553477-c766-11e1-8775-005056c00008
- _0474a358-c766-11e1-8775-005056c00008
- _0468e382-c766-11e1-8775-005056c00008
- _045ed162-c766-11e1-8775-005056c00008
- _04614263-c766-11e1-8775-005056c00008
- _04642896-c766-11e1-8775-005056c00008

- EnergyConsumer:
  - _044a5f08-c766-11e1-8775-005056c00008
  - _0447ee05-c766-11e1-8775-005056c00008
  - _044ea4c0-c766-11e1-8775-005056c00008
  - _048b5fa5-c766-11e1-8775-005056c00008
  - _04867dab-c766-11e1-8775-005056c00008
  - _0485e168-c766-11e1-8775-005056c00008
  - _045645e2-c766-11e1-8775-005056c00008
  - _046a4319-c766-11e1-8775-005056c00008
  - _047a48a8-c766-11e1-8775-005056c00008
- ThermalGeneratingUnit
  - _045868c0-c766-11e1-8775-005056c00008:
- PowerTransformer:
  - _04575750-c766-11e1-8775-005056c00008
- LinearShuntCompensator:
  - _0447c6f6-c766-11e1-8775-005056c00008

Forward Differences

Difference file introduces new elements to the model: EquivalentBranch, EquivalentInjection and EquivalentShunt. The following elements were changed:

- node “Concord“ with the ID “_045b4ef9-c766-11e1-8775-005056c00008” had obtained the following:
  c) new EquivalentBranch i.e. AC line segment towards the node “TwinBrch” with the ID “_047566a8-c766-11e1-8775-005056c00008”
  d) new EquivalentBranch i.e. transformer towards the node “Sorenson2” with the ID “_046c3ee8-c766-11e1-8775-005056c00008“
  e) new EquivalentShunt
  f) new EquivalentInjection

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- node “TwinBrch“ with the ID “_047566a8-c766-11e1-8775-005056c00008” had obtained the following:
  g) new EquivalentBranch i.e. AC line segment towards the node “Concord” with the ID “_045b4ef9-c766-11e1-8775-005056c00008”
  h) new EquivalentBranch i.e. transformer towards the node “Sorenson2” with the ID “_046c3ee8-c766-11e1-8775-005056c00008“
  i) new EquivalentShunt
  j) new EquivalentInjection
- node “Sorenson2“ with the ID “_046c3ee8-c766-11e1-8775-005056c00008“ had obtained the following:
  k) new EquivalentBranch i.e. transformer towards the node “Concord” with the ID “_045b4ef9-c766-11e1-8775-005056c00008”
  l) new EquivalentBranch i.e. i.e. transformer towards the node “TwinBrch” with the ID “_047566a8-c766-11e1-8775-005056c00008”
  m) new EquivalentShunt
  n) new EquivalentInjection

5.2. Network topology and data

The summary of the Small Grid Reduced Network model is shown in the figure below.

Type Of	N
Nod	10
Lin	16
Transformers (ratio tap changer)	9
Generat	1
Synchronous Compensators	6
Loads	10
Transformers (non-regulated)	0

Figure 6 – Small Grid Reduced Network Model Summary

There are two different configuration of the Small Grid Reduced Network (SGRN) model:

a) Bus-Branch Configuration
b) Node-Breaker Configuration

Node-breaker configuration is created by applying the difference files (SmallGridTestConfiguration_BC_EQ_diff_v3.0.0.xml, SmallGridTestConfiguration_BC_TP_diff_v3.0.0.) on the SGBC node-breaker related model.

5.3. Load flow calculation information

Load flow system summary, where results were obtained by setting all voltage angles to zero and all voltage magnitudes to 1.0 p.u (“flat” start):

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AC Load Flow Type	Full Newton-Raphson
Reactive Power Limits	Yes
Relative Error Tolerance	P=0.002 Q=0.005
Number of Iterations	3
Slack Bus "Sporn1"	P = 515.2 MW Q = -62.3 MVAr V = 1.016 kV angle = 0

The load flow results are the same for the both Small Grid Reduced Network configurations and they are available in the excel document CGMES_v2.4.15_SmallGridTestConfiguration_v3.0.0.xls, in the sheet "SGRN_AC_Results".

5.4. CIMdesk validation report for bus-branch version

CIMdesk validation report (validation against Base profiles) on the assembled model which includes boundary and the Reduced network bus-branch version is the following:

Type	Class	Recurrence	Description
Warning	SubGeographicalRegion	1/2	No Substations are associated with SubGeographicalRegion via Association Substation.Region, expecting at least 1.
Warning	EquivalentShunt	2/3	The value of Attribute EquivalentShunt.g is less than lower limit: 0.
Warning	Location	3/258	Fewer than 2 PositionPoints are associated with Location of the Junction that span two Substations.
Warning	ACLineSegment	1/160	ACLineSegment.x/ACLineSegment.r ratio is too large.

The above warnings should be ignored as:

- SubGeographicalRegion in the boundary can not contain any Substations, but they are referenced from Line containers in boundary.
- The model is result from a network reduction function and the EquivalentShunt.g can have negative value.
- The other 2 warnings are considered data issues.

5.5. CIMdesk validation report for node-breaker version

CIMdesk validation report (validation against Operation) on the assembled model which includes boundary and the Reduced node-breaker version is the following:

Type	Class	Recurrence	Description
Warning	SubGeographicalRegion	1/2	No Substations are associated with SubGeographicalRegion via Association Substation.Region, expecting at least 1.
Warning	EquivalentShunt	2/3	The value of Attribute EquivalentShunt.g is less than lower limit: 0.
Warning	ACLineSegment	1/160	ACLineSegment.x/ACLineSegment.r ratio is too large.

The above warnings should be ignored as:

- SubGeographicalRegion in the boundary can not contain any Substations, but they are referenced from Line containers in boundary.
- The model is result from a network reduction function and the EquivalentShunt.g can have negative value.
- Data issue which is considered normal for the provided model.

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6. Geographic information Small Grid

The geographic view of the Small Grid Base Case network is illustrated in the Figure 7.

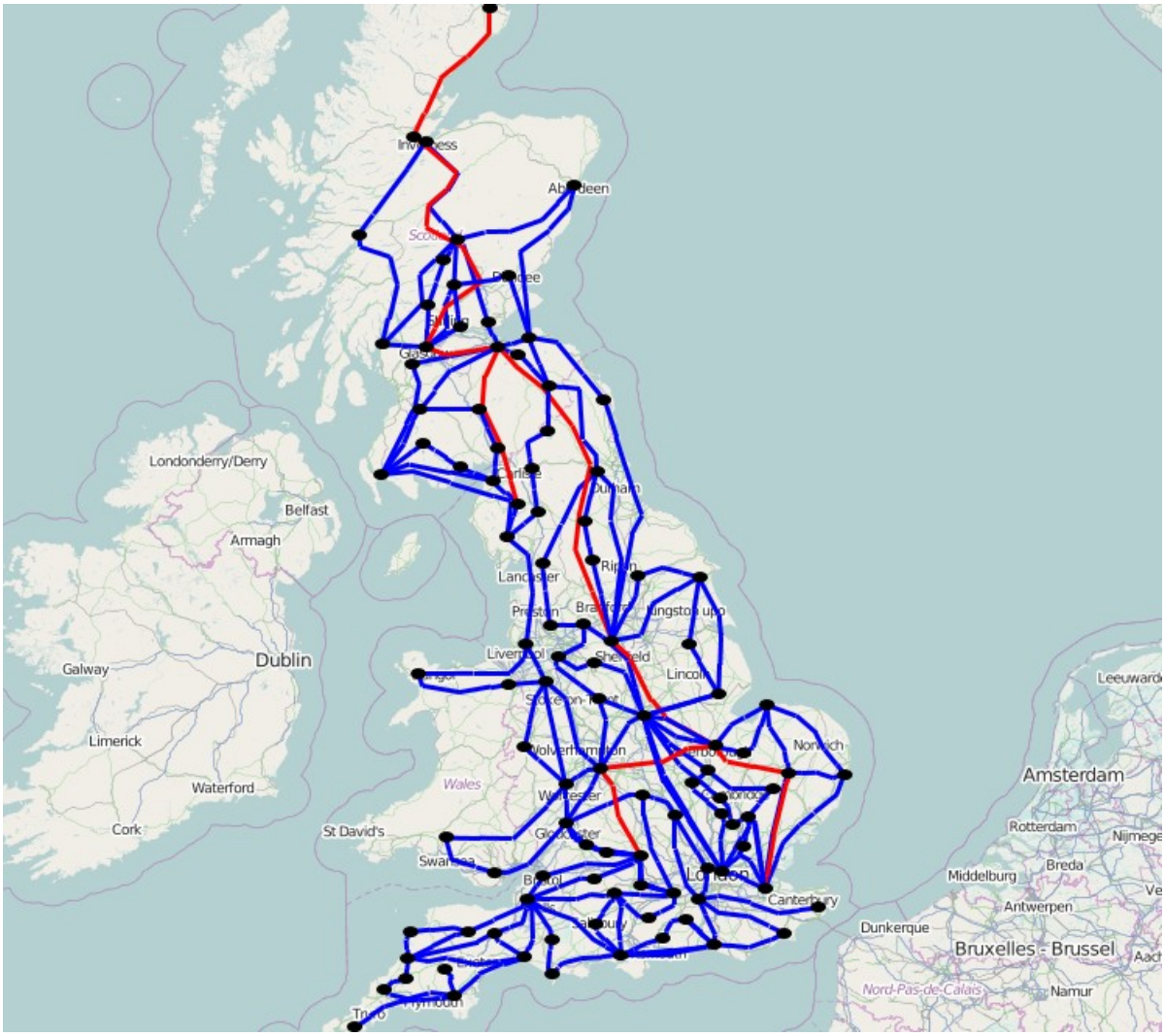

Figure 7 – Small Grid Base Case geographic view

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The geographic view of the Small Grid HVDC network is illustrated in the Figure 8.

DC lines are shown in green colour.

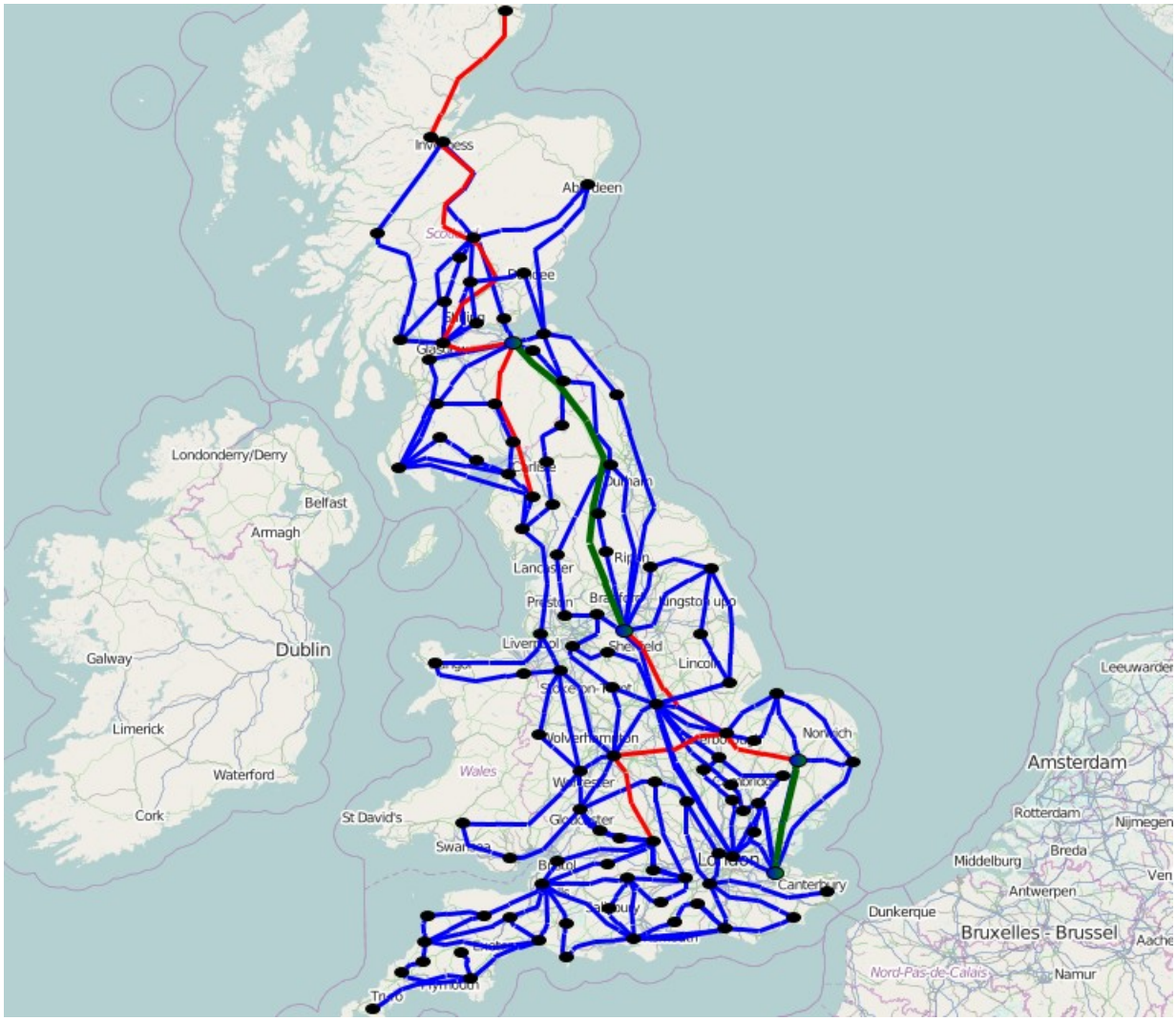

Figure 8 - Small Grid HVDC geographic view

The geographic view of the Small Grid Reduced Network is illustrated in the Figure 9.

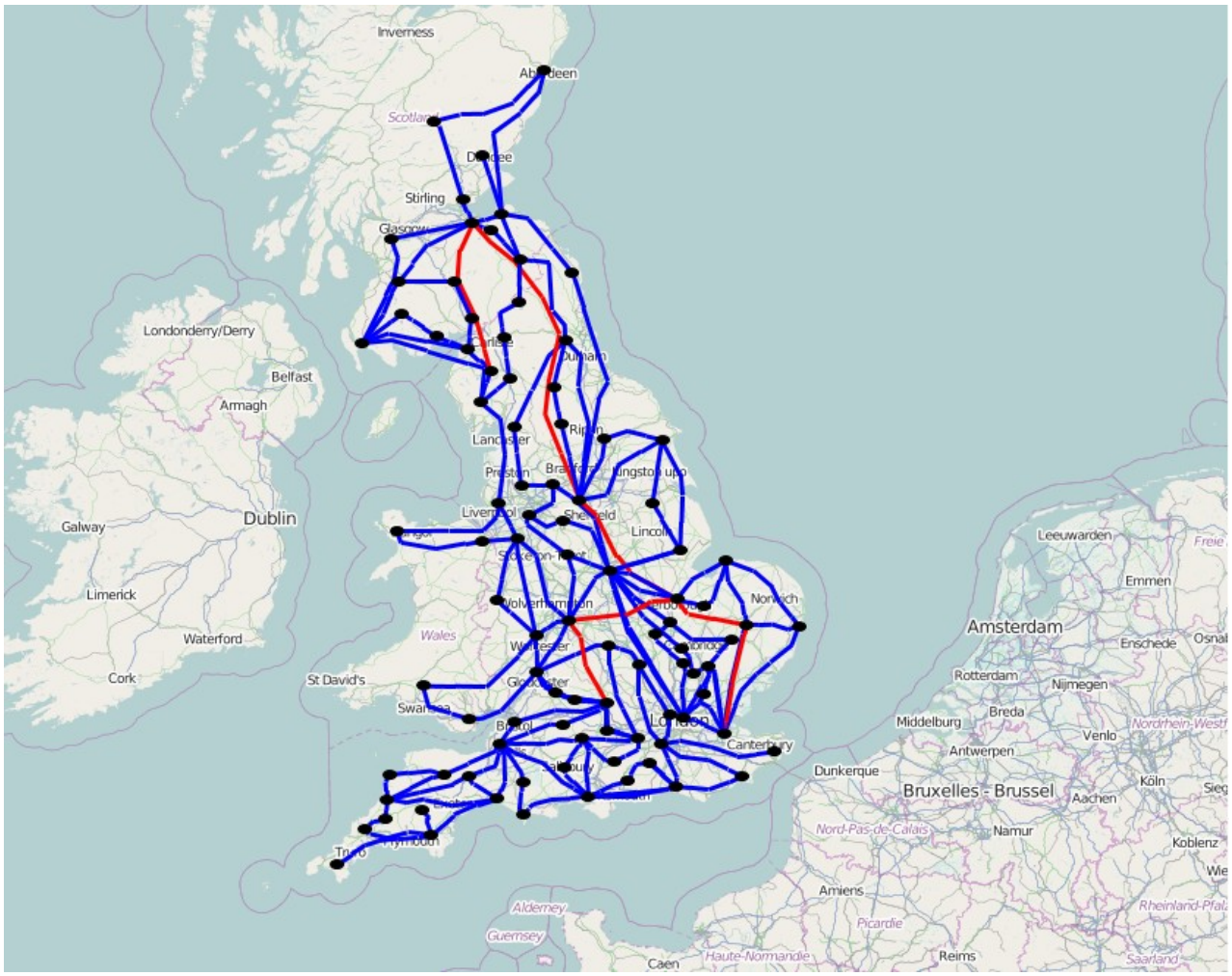

Figure 9 - Small Grid Reduced Network geographic view

7. Single line diagrams

The single line diagram of the Small Grid Base Case network is illustrated in the Figure 10, while in the Figure 15 is shown Small Grid Reduced Network. On the diagrams blue colour represents 220 kV voltage level while the red represents 133 kV.
Substation diagrams for bus-branch and node breaker configurations of SGBC model are shown in the figures between Figure 11and Figure 14.

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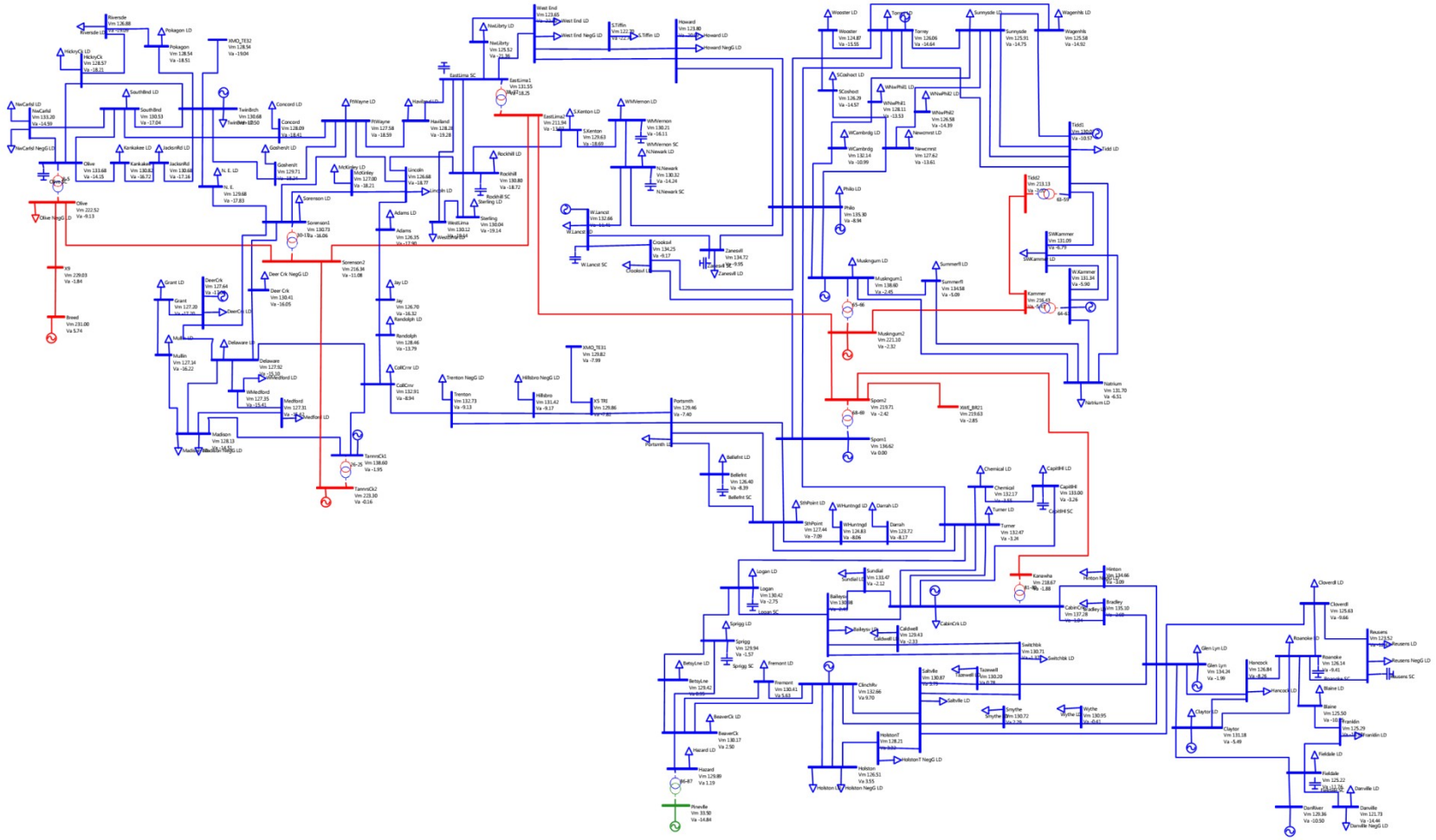

Figure 10 - SGBC single line diagram

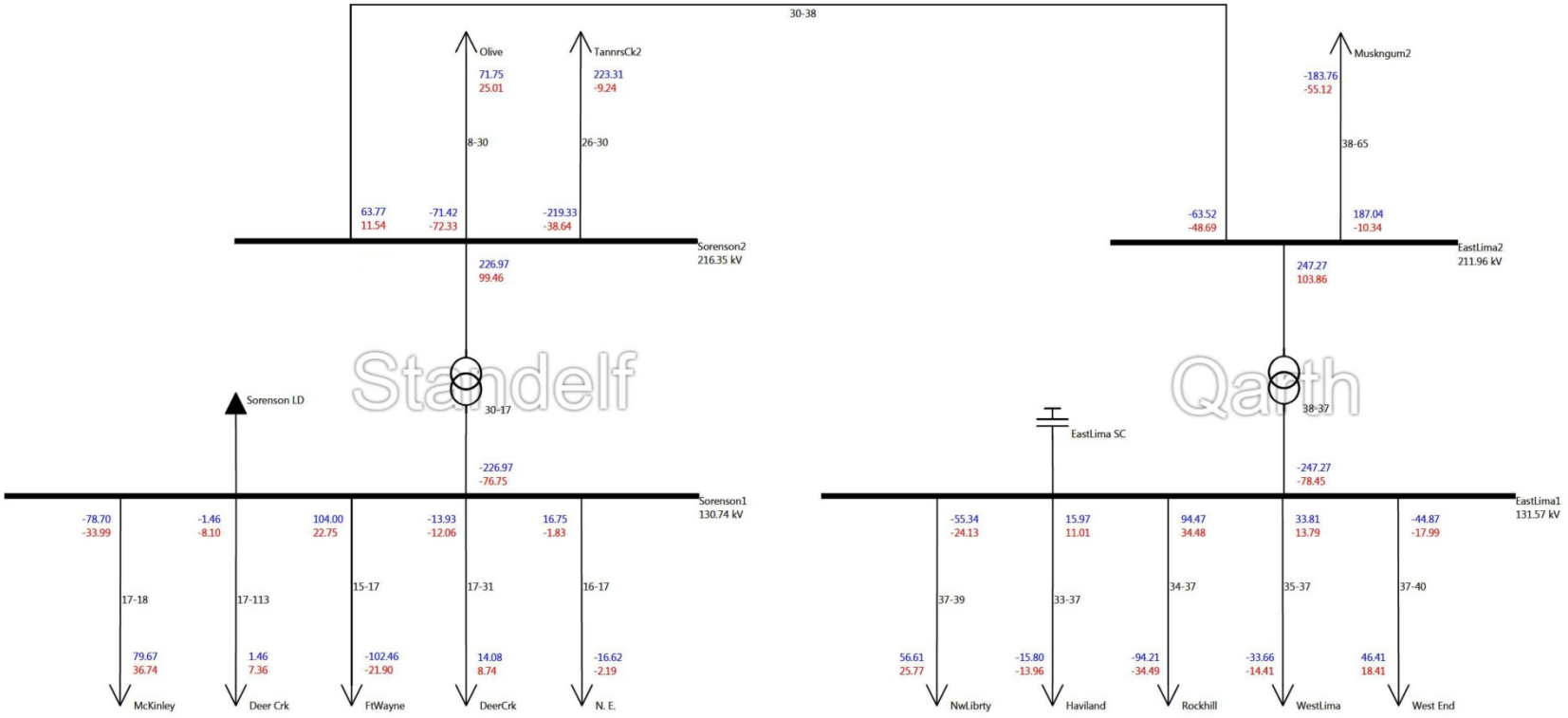

Figure 11- SGBC bus-branch, diagram for substations Standelf-Qarth

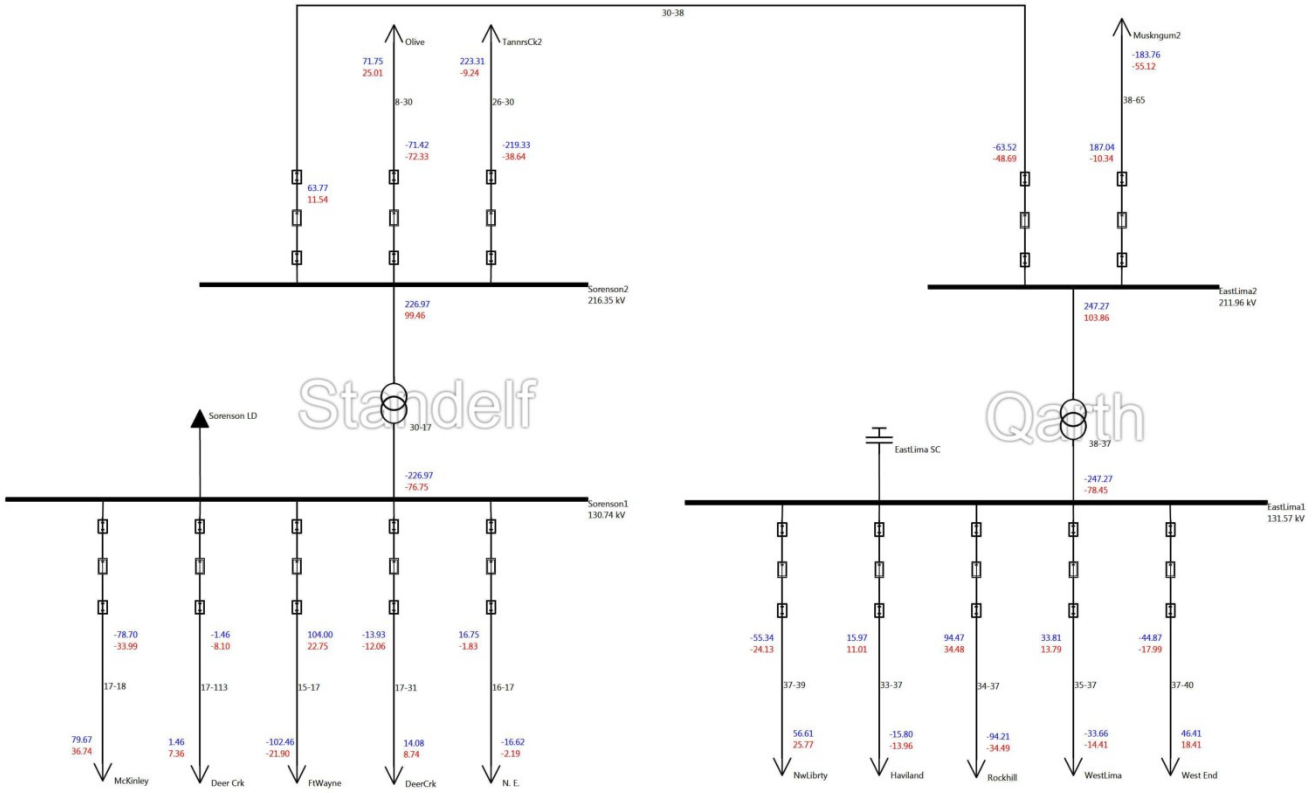

Figure 12 - SGBC node-breaker, diagram for substations Standelf-Qarth

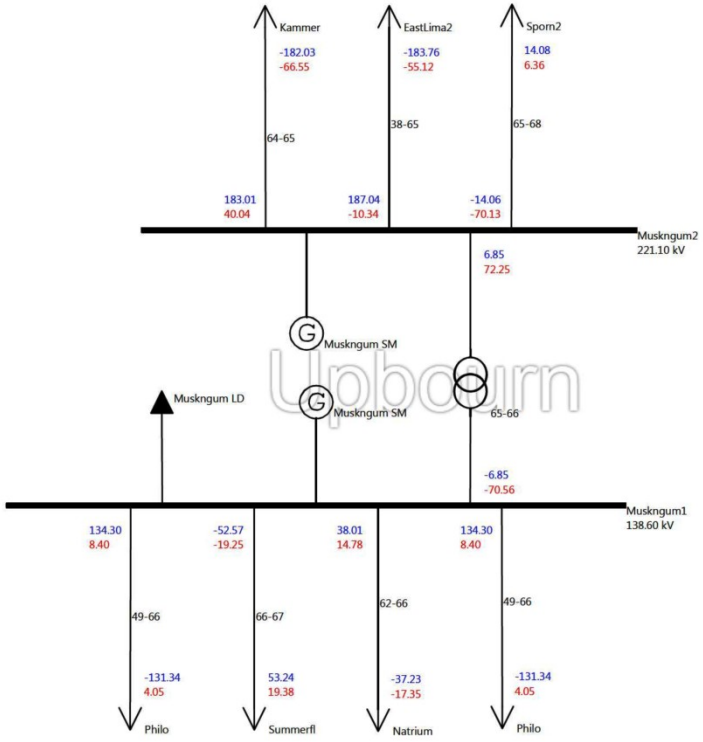

Figure 13 - SGBC bus-branch, diagram for substation Upbourn

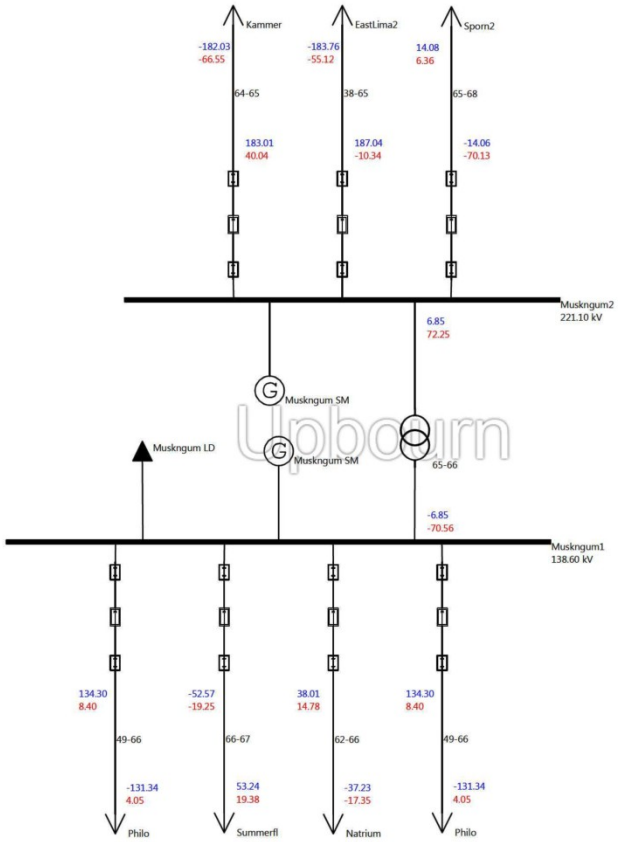

Figure 14 - SGBC node-breaker, diagram for substation Upbourn

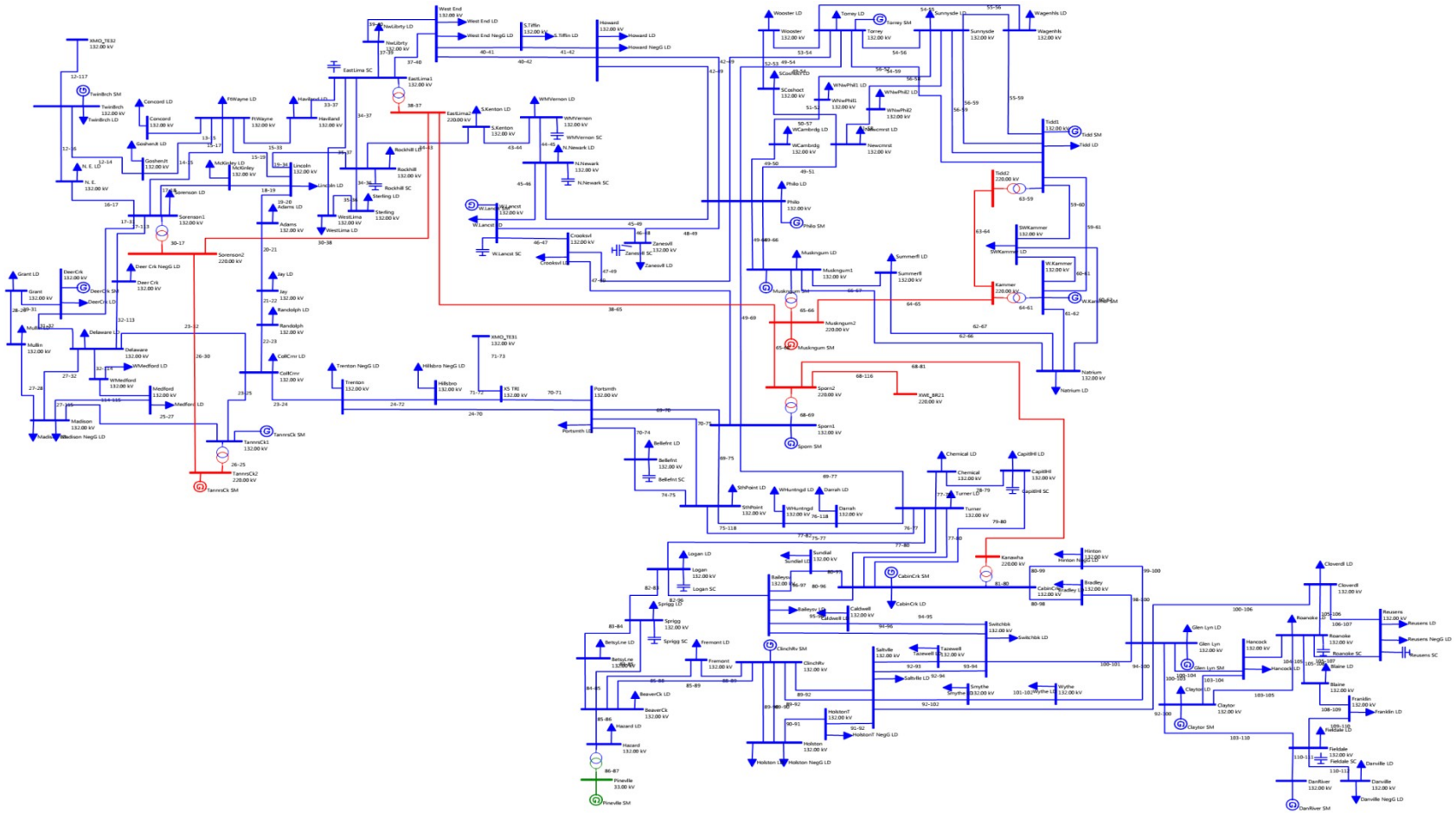

Figure 15- Small Grid Reduced Network(SGRN) single line diagram

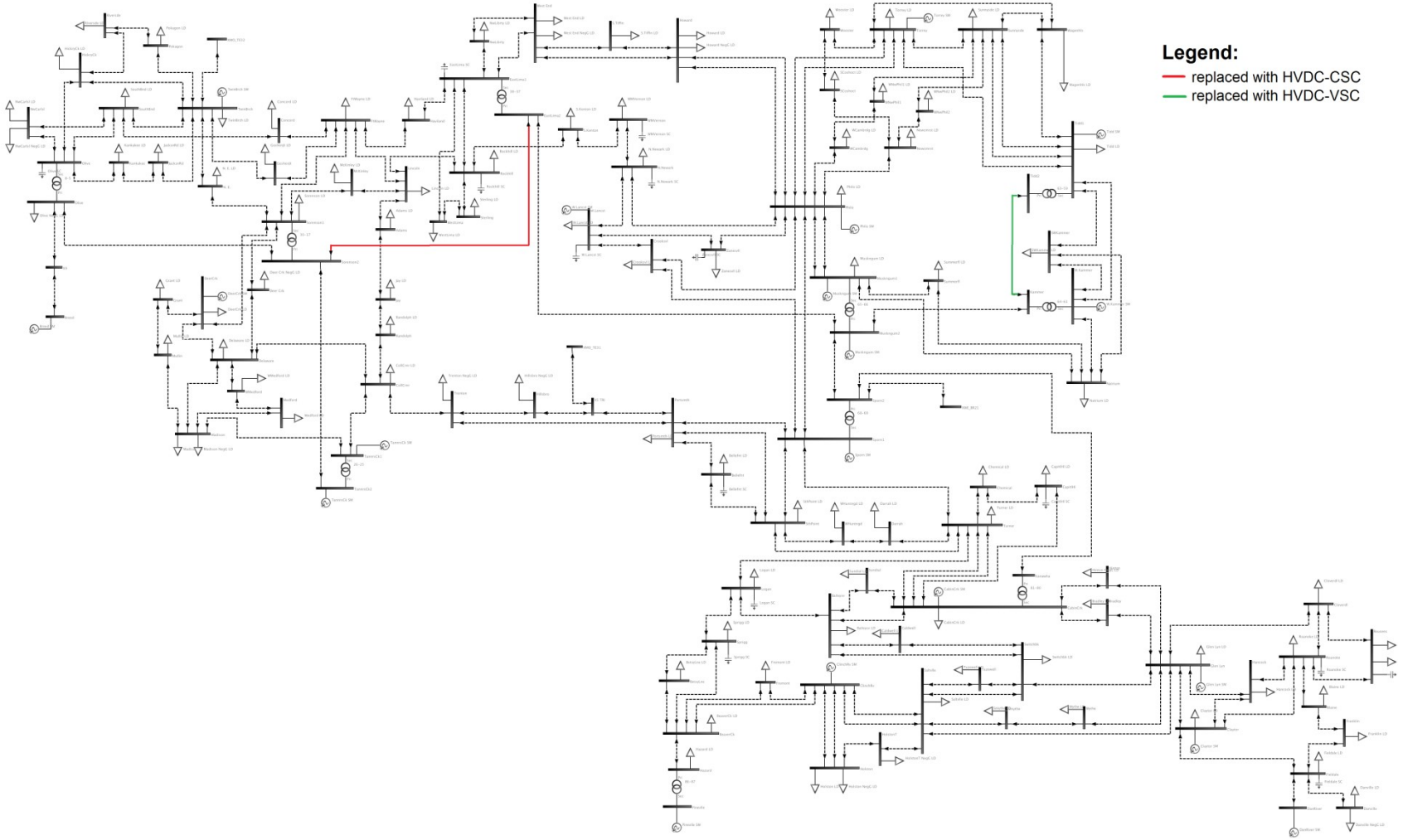

Figure 1 - SGBC network with the marked(red colour) replacements for HVDC configuration

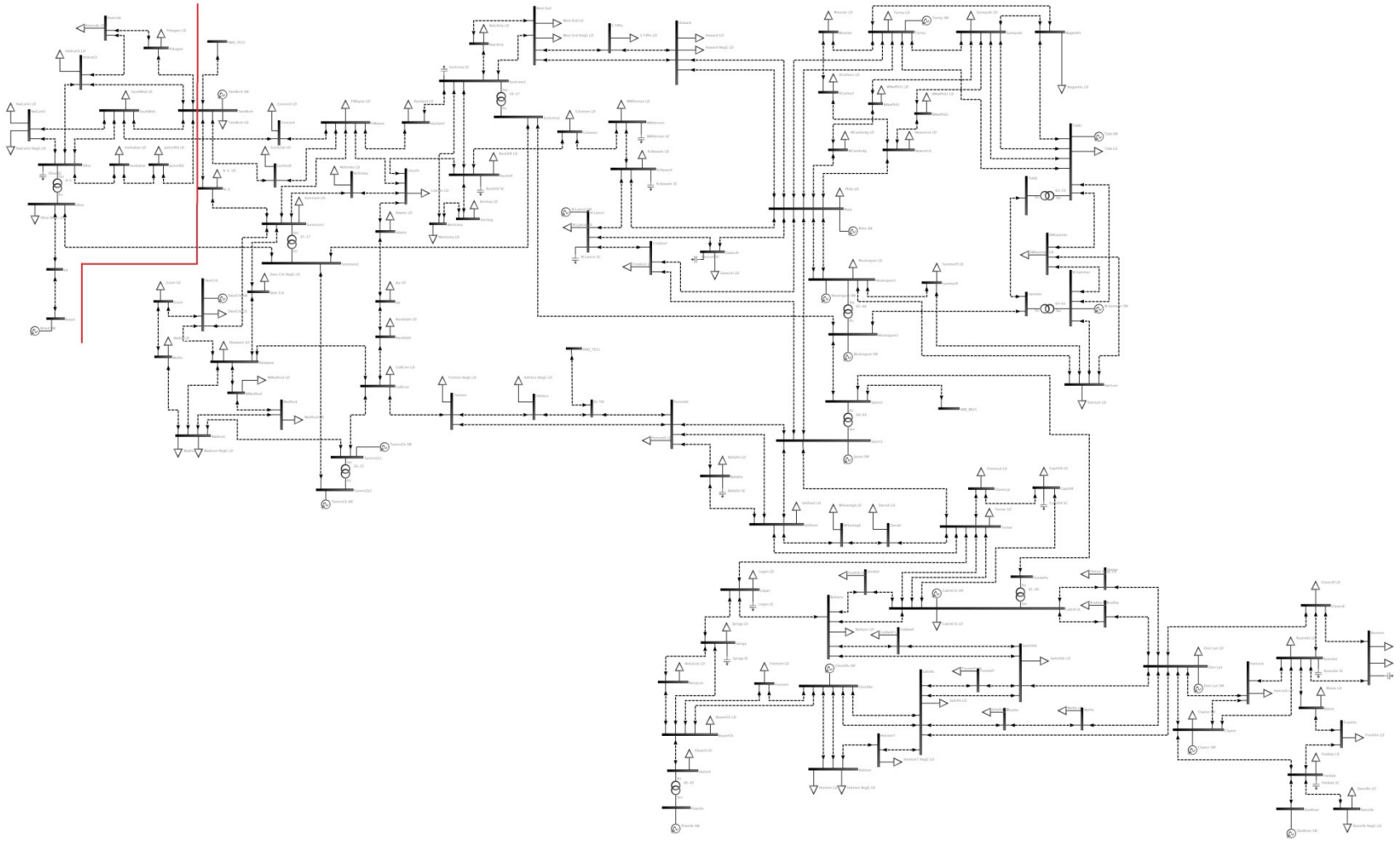

Figure 16 - SGBC network with the marked replacements for Reduced Network

8. References

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