Modeling the Power Flow in the Substation

The scope of this sub-group is to provide an accurate model of the power flow (PF) in a substation with a wind- and solar farm. To accurately satisfy TSO requirements, while having minimal power losses and maximum stability in the substation, a well-defined model is required that has been tested under normal and critical operating conditions.

Requirements

In order to achieve the goal stated above, several requirements are determined. To keep an overview of the requirements, they were divided into mandatory, trade-off and optional requirements. A short summary of each of the requirements is given below. Firstly, the mandatory requirements:

- Formulate a simplified system topology, implemented in MATPOWER, which connects each node of the single line diagram, including the components of the transmission system(see Appendix) . Subsequently, algorithms are designed to calculate a vector of the system's active- and reactive power, voltage profile, losses and topology connection. This vector is sent to the optimization unit, from which setpoints are received to update the vector. Furthermore, an equivalent ideal solar farm design is included.

Secondly, the trade-off requirements:

- Generate random loading demands and design daily dispatches for wind and solar profiles using probabilistic distributions to test the normal and critical operating conditions. Include the losses generated by changing the transformer's tap position. Additionally, the exact losses of the transformer have to be included.

Eventually, the optional requirements:

- Provide a more accurate model of the system topology, which takes the losses of the components in the wind turbine generators (WTGs) strings and PhotoVoltaic(PV) strings into account. In addition, this requires an accurate overview of the solar farm implemented consisting of the interconnection of the solar modules and the type of converters used.

Deliverables for the scope of this research

- A converged system topology, in which the voltage profiles, loading demands, reactive power injections and the losses are analysed using 2-D and 3-D relation plots.
- A solar farm design, in which the PV modules can operate at full capacity, including the case in which the WTGs are operating at rated wind speed.

Progress

To be able to present a defensible thesis at the end of the project, the group was required to work linearly towards the deliverables. Firstly, the behaviour and configuration of the components were determined. The data of the transmission cables, 3-winding transformers, WTGs and PV modules were implemented.

The PV modules were designed and connected as a parallel string to the WT generating strings to generate at full capacity when WTGs are connected (see Appendix).

Subsequently, the system configuration's nodes were connected and converged by running a Newton-Raphson PF method [1] on MATPOWER. The system parameters were determined accurately such that the initial tests yielded total losses that approach actual losses in transmission systems [2].

An algorithm that updates the transmission system's available power generation and voltage profiles after every wind/solar dispatch, was designed for each node and branch. The system's WTGs were tested for a nominal daily wind profile, neglecting the PV power generation and changing the transformer tap positions. The same was done for a nominal daily solar profile and the PV modules, for which the WTGs were disconnected. During the nominal output generation, the test model generated random Q-demands (load) for each connected generating string.

Course ahead

The main goal is to improve the system model in an iterative approach. Also, the PFs for wind/solar profiles and Q-demands can be explained by the 3-D relation plots. With four weeks remaining, each week a more difficult test model is used to analyse power flows. In week 6, PFs for a Weibull wind distribution will be run. PFs for cloudy days' solar profile will be run using a Beta-Cauchy distribution. Additionally, the PFs will be run with both WTGs and PVs connected under critical operating conditions. In week 8 work will be put in modelling the WTGs strings on string level and PFs can be run with the effects of tap positions taken into account. In week 9, a visualizable model of the PFs will be made. Hence, a diagram is provided with PFs in each branch for each dispatch and request. This will be the proof of concept for an accurate model.

Appendix

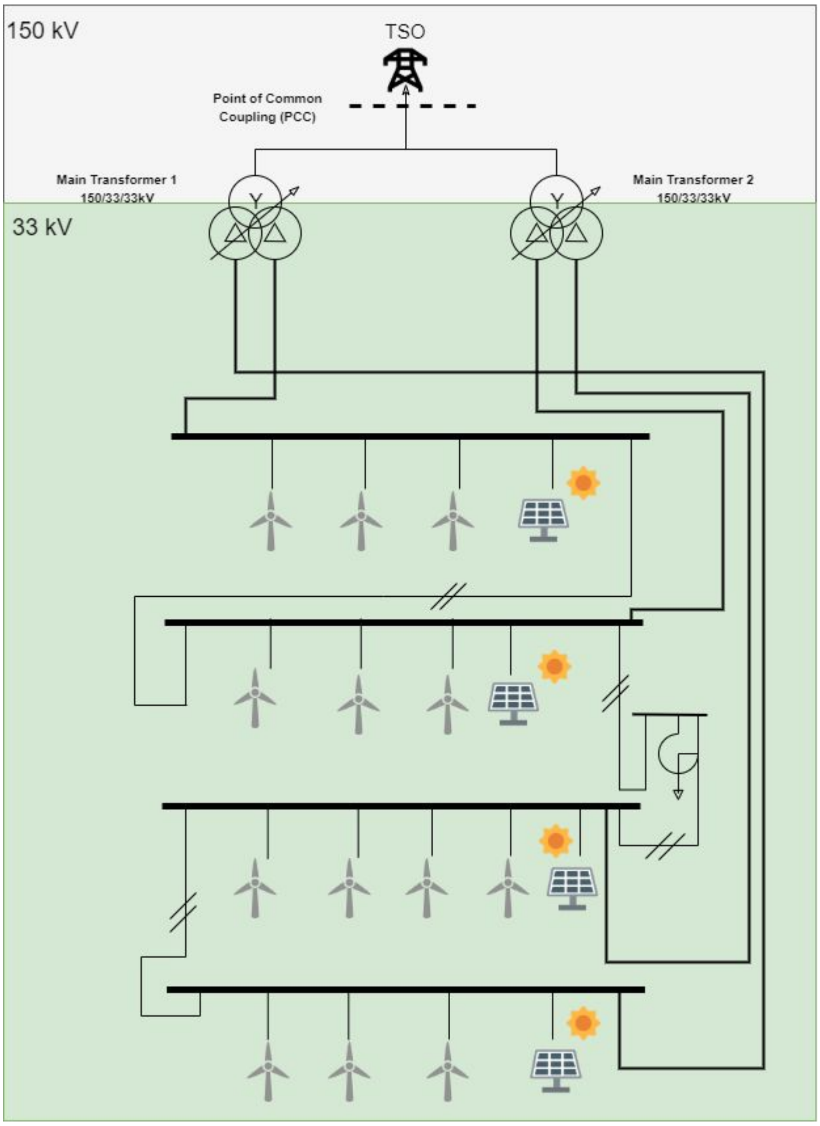

Fig. 1.1 Simplified schematic of the transmission system's configurations
// indicates that status is disconnected in most cases

References

1 W.F. Tinney and C.E. Hart. Power flow solution by newton's method. IEEE Transaction on Power Apparatus and Systems, PAS-86(11):1449–1460, November 1967

2 J. L. Rueda, S. Wildenhues, Optimization Algorithm for System 41, Working Group on Modern Heuristic Optimization, February 2014