Title: Fast, Robust and Accurate Power-Flow Solvers

Relevant Workstreams: Workstreams 1, the development of fast and accurate numerical analysis tools to simulate large-scale hybrid AC/DC grids, such as for Power-Flow Analysis, Fault Analysis, Harmonic Analysis, Transient Stability, and Electromagnetic Transients.

Project Description:

Power-flow analysis is a critical tool in the planning, design, and operation of complex power system networks. Given the generation, load, and network topology parameters, it computes the bus voltage profiles and branch flows of a power system network. The outputs from Power-flow analysis provide the initial conditions for transient/dynamic analysis of the power system network, and it has a wide range of applications in power system analysis. In the future, the complexity of electricity networks will increase with integrated DC networks, it is crucial to have faster, robust and accurate power flow solvers to view operation.

The power flow equations are non-linear and require numerical solution methods. All of these methods, in some form or another, perform repeated iterations (steps) to refine the power-flow solution until the error is reduced below a desired tolerance. Two well-known methods are Newton-Raphson (NR) and Gauss-Seidel (GS). Beneficially, NR requires few steps; however, each step requires a significant amount of computational time, as it formulates and factorises the Jacobian matrix in each step. In contrast, GS requires many steps, but the computational time cost of each step is very low, as only matrix multiplication is required. In practice sparsity matrix techniques are employed to reduce the solution time.

The goal of this project is to create a new and improved power-flow solver in MATLAB or Python to analyse Hybrid AC-DC power systems. There are four possible developmental directions in order of preference:

Student 1: Developing a NR method while using an indirect method to solve $A\mathbf{x} = \mathbf{b}$, such as conjugate gradient and Newton-Krylov (e.g. Newton-GMRES) methods.

Student 2: Developing a NR method where the Power-flow equations are formulated as an optimisation problem. Determine the best formulation of the objective function and equality and inequality constraints to quickly solve the Power-flow equations.

Student 3: Develop a GS method with an acceleration technique. This could include Anderson-Acceleration, Algebraic Multigrid, Preconditioners, etc.

Student 4: The purpose of this task is to verify the expected advantages and disadvantages of different power-flow algorithms. This will involve coding each algorithm in the same programming environment (e.g. MATLAB) and applying them to standard test systems (yet to be identified). The main two techniques to be considered are; the standard NR and Z-matrix (current injection) methods. Some of the factors to consider are; 1. Simulation time; 2. Robustness (radius of convergence); 3. Easy of modelling components, and particularly converters.

The electrical network to be analysed could be a proportion of the NZ grid, or one of the IEEE test systems networks. Keep the number of nodes around 20. However, bear in mind that the advantages of these new methods are appreciated for networks that are much larger. Also for simplicity, a balanced power-flow should be assumed for initial development. Lastly, verify results with a power-flow simulation in DIgSILENT Power Factory.

Specific Requirements: A good background knowledge in Power Systems Analysis, and strong mathematical analysis ability.

Resources:

https://www.cambridge.org/core/journals/acta-numerica/article/numerical-methods-for-nonlinear-equations/B9E91D8ABB02ECC16B8715CAD263EA06