
This version is available at https://strathprints.strath.ac.uk/56052/

Strathprints is designed to allow users to access the research output of the University of Strathclyde. Unless otherwise explicitly stated on the manuscript, Copyright © and Moral Rights for the papers on this site are retained by the individual authors and/or other copyright owners. Please check the manuscript for details of any other licences that may have been applied. You may not engage in further distribution of the material for any profitmaking activities or any commercial gain. You may freely distribute both the url (https://strathprints.strath.ac.uk/) and the content of this paper for research or private study, educational, or not-for-profit purposes without prior permission or charge.

Any correspondence concerning this service should be sent to the Strathprints administrator: strathprints@strath.ac.uk
Complexity of Future Power Grids: applications of HPC for OPF operational tools

Milana Plecas¹ and Ivana Kockar²

1- Department of Electronic and Electrical Engineering, University of Strathclyde, Glasgow, milana.plecas@strath.ac.uk
2- Department of Electronic and Electrical Engineering, University of Strathclyde, Glasgow

Problem description

One of the major challenges in the energy sector is to ensure secure and sustainable energy supply. Traditional power systems were organized around centralized power generation with the unique direction of electricity flow. However, the scale and complexity of power systems have been increased significantly in the last few decades, especially on the distribution side with the growing utilization of distributed energy resources that includes renewable generation as well as technology that allows active demand participation.

Optimal Power Flow

The optimal power flow is a non-convex, large scale, nonlinear optimization problem which minimizes the costs of meeting the load demand for a power system while maintaining the security of the system. Objective function - minimize the total generation cost, power losses

\[ \min f(P_g, Q_g, V, \delta) \]

Equality constraints - power flow equations

\[ P_k = V_k \sum_{i=1}^{N_{bus}} V_i (G_{ki} \cos \theta_{ki} + B_{ki} \sin \theta_{ki}) \]
\[ Q_k = V_k \sum_{i=1}^{N_{bus}} V_i (G_{ki} \sin \theta_{ki} - B_{ki} \cos \theta_{ki}) \]

Inequality constraints - physical limits of control variables, network operating limits

\[ P_{g_i}^{\max} \leq P_g \leq P_{g_i}^{\min} \]
\[ Q_{g_i}^{\max} \leq Q_g \leq Q_{g_i}^{\min} \]
\[ V_i^{\min} \leq V_i \leq V_i^{\max} \]

Interior Point Method

Optimization problem

Add slack variables

Make all inequality constraints into non-negativities

Replace non-negativity constraints with logarithmic barriers in the objective function

Form the Lagrange function associated with this problem

Set the first-order optimality conditions

Apply Newton’s method to the set of equations coming from the first-order optimality conditions

The major computational effort is solving the large, sparse linear equation system to compute Newton direction.

OPF parallelization

The OPF parallelization is very difficult task due to its nonlinearity and a large number of different types of constraints. In recent years, IPM has been recognized as the most efficient way to improve the performance of the OPF. Although, many different approaches have been proposed to improve efficiency and accuracy of the OPF problem based on IPM, only two of them investigated how HPC can be used to improve its performance.

Conclusions

The current process of optimal decision making in power systems is still challenging, especially in real time. Typical values of number of buses in transmission network are around 1500 nodes and if we want to consider distribution network, the size of a problem becomes much bigger and we have to deal with up to hundreds of thousands of variables and constraints.

The parallel efficiency of IPM depends on the efficient parallel implementation of several key sparse linear algebra kernels.

References


This work is part of the Novel Asynchronous Algorithms and Software for Large Sparse Systems project supported by EPSRC under grant number EP/I006729/1.

Matrix-matrix multiplication

Linear solver

Matrix-vector multiplication

Although this is relatively new area of research, it is shown that HPC can contribute to faster solving of the OPF problem and there is a great potential for further improvement.