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On the Numerical Solution of Power Flow Problems[1]

Manolis Vavalis and Dimitris Zimeris
Department of Electrical and Computer Engineering, University of Thessaly, Volos, Greece
{mav,dzimeris}@uth.gr

Abstract

The power generation, transmission and distribution system has been widely recognized as one of the most complex man-made systems and the related power flow analysis as the main ingredient of many related studies.

The power flow problem is modeled through a system of non-linear equations that relate the bus voltages to the power generation and consumption. Its solution is used to access the stability of the power system and perform contingency analysis. It is also required by other related and relatively new problems, for example the optimal power flow problem, the financial transmission rights mechanisms and many others.

Several recent advances (the liberalization of the energy markets, the emerging of smart grid technologies, the stochasticity in the power production due to utilization of renewable energy sources, the decentralization of the energy production) have recently increased the complexity of the power flow problems significantly.

The envisioned interconnection of national power systems with global energy markets will be based on truly large scale, continent-wide power flow simulations where the efficiency of the numerical solution of the power flow equations is expected to be a vital component.

This paper consists an up-to-day review of the various numerical methods that have been very recently proposed for the solution of power flow equations and several other related problems. These methods are examined from both the theoretical (convergence analysis) and the practical (efficiency, robustness, numerical stability, implementation) viewpoint.

We also propose several new research directions which, we believe, have the potential to lead us to next generation power grid simulation engines. Engines that are capable to support operational large scale modern power grid systems associated with open energy markets, paying special attention to the information flow in addition to the power flow.

Key words: Numerical linear algebra, Newton's method, power flow equations, GMRES, preconditioning, basic iterative methods.

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