Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 103 (2016) 322 – 327

Energy Procedia

Applied Energy Symposium and Forum, REM2016: Renewable Energy Integration with Mini/Microgrid, 19-21 April 2016, Maldives

Unified Power Flow Analysis in Natural Gas and Electricity Coupled Networks Considering the Uncertainty of Wind Power

Zheng Qiao[1]*, Shangyuan Huang[2], Rui Li[3], Qinglai Guo[1], Hongbin Sun[1], Zhaoguang Pan[1]

[1]*The Department of Electrical Engineering, State Key Laboratory of Power System, Tsinghua University, Beijing, 100084,China*
[2]*State Gird Shanghai municipal electric power company, Shanghai, 200122, China*
[3]*State Gird Shanghai electric power research institute, Shanghai, 200437, China*

Abstract

The widely application of renewable energy in power system makes a big influence on the system security and stability. The main work of this paper was building a comprehensive system model of a natural gas and electricity coupled network and analyzing the steady-state power flow of the coupled network. On this basis, this paper further studied the impact of uncertainty of wind power, and analyzed the interval range of the variables of natural gas system using interval algorithm. The analysis and case studies led to the conclusion that the uncertainty of wind power has a significant impact on the security of natural gas system.

Peer-review under responsibility of the scientific committee of the Applied Energy Symposium and Forum, REM2016: Renewable Energy Integration with Mini/Microgrid.

Keywords: Power flow analysis; natural gas and electricity coupled system; uncertainty analysis; wind power; interval power flow algorithm

1. Introduction

Natural gas has become an important choice as fuel for power system because of its less pollutant emissions, higher energy conversion efficiency, shorter construction period and better load characteristics. Natural gas accounts for a greater proportion of the total generating capacity, such as 40% in Britain, 39.4% in America, more than 30% in Europe and 29% in Japan [1]. Thus, natural gas plays an increasingly influential role in the electricity market, which gained more and more applications in the power generation

* Zheng Qiao. Tel.: +86 185-0070-5458.
E-mail address: qiaomuzi@163.com.

Peer-review under responsibility of the scientific committee of the Applied Energy Symposium and Forum, REM2016: Renewable Energy Integration with Mini/Microgrid.
doi:10.1016/j.egypro.2016.11.293

of the power system. The coupling between natural gas system and the power system gets stronger, which will result in unified management of the coupled system in the future. Therefore, issues related to the natural gas and electricity coupled networks require more attention and become practical and significant subject.

On the other hand, due to the fact that the energy shortage and environmental pollution become prominent problems, wind power becomes competitive because of its advantages like environmentally friendly, mature technologies and sustainable. A survey by the Global Wind Energy Council (GWEC) showed that the total installed capacity of global wind power is 318,596MW in 2013 and rose 15.99% within two years to 369,553MW in 2014. However, the wind turbine is unable to provide continuous and stable active power because it is limited by real-time changing wind resources. Obviously the wind power is unreliable power supply with characteristics of volatility, randomness and intermittency. Thus, the uncertainty of wind power brought a great influence on the steady-state operation of coupled networks. In today's trend of unified operation mode of coupled networks, interactions become more tightly between different energy systems, leading to urgent need to study how the uncertainty of wind power affects steady-state operation of other energy systems.

Uncertainty analysis has always been an important and difficult tool in power flow analysis. There are three methods mostly used for uncertainty analysis as following: (1) Probabilistic algorithm. Take random perturbation of wind speed and active power output uncertainty of wind turbine into account to obtain the probability density function or distribution function of system state variables [2,3,4]. (2) Fuzzy algorithm. Build a fuzzy model under subjective assumptions of uncertain variable. This method avoids a lot of data statistics and complex calculations but the model is too complex and strong subjective assumptions may ignore much original information [5,6,7]. (3) Interval algorithm. Analyze the problem with only range information using interval mathematics and interval analysis methods. Optimization method can employed in calculation. This paper chooses the third method and will introduce in detail later.

This paper is divided into 5 sections. Section 1 presents the main content of the paper. Section 2 details the coupling system of natural gas and electricity. Section 3 details the methods of interval algorithm used in the uncertainty analysis of the coupled system. Section 4 gives a numerical example. Section 5 concludes.

2. Coupled natural gas and electricity power flow formulation

The coupled natural gas and electricity networks consist of natural gas system and power system. The two coupling parts operate unified by gas turbines.

2.1. Natural gas system formulation

Natural gas pipeline system mainly consists of gas supply, pipelines, pressure regulators and compressor stations. The natural gas flow is in steady state when the flow parameters are independent of time. Strictly speaking, the steady-state is a special state which never exists because the temperatures cannot remain the same [8]. But the steady-state analysis of the coupled networks is of great importance since the results under the constant system are closed to the theoretical data.

A. Pipeline equation

Many equations have been proposed to calculate the gas flow through pipelines. The main difference between them is how to define the friction coefficient. Reference [9] gives a common formula as *Panbandle 'A'* equation, which is also employed in this paper.

To simplify the calculation, some assumption has been proposed ignoring some secondary factors:

1) No significant difference in temperature of gas pipeline, the gas flow is assumed to be constant.
2) Ignoring changes in height of pipeline, assume the pipeline between two nodes is horizontal.
3) The pipe sectional can meet Darcy friction relationship, so assuming no change in the compressibility factor.

Then simplify the formula as: