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Non-linear modeling of micro-turbines using NARX structures on the distribution feeder

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Abstract

There is an increasing demand for an accurate model of a micro-turbine to study the transient and long term stability of the overall distribution system, the interconnected network formed by generators, loads and distribution lines.

The computational burden required for simulation is highly dependent on the complexity and accuracy of each generator model. The manufacturer often needs to provide the user a reliable low complexity prototype model of the micro-turbine generator set, that is sufficiently accurate for the above application.

In this paper, the non-linear autoregressive exogenous (NARX) approach is used to analyze the dynamics of this micro-turbine.

Keywords: Distributed generation; Gas turbines; Modeling; Non-linear systems

1. Introduction

While designs based on linear models are adequate in certain circumstances, new techniques for the analysis and design of gas turbine engines have been employed [1] to accommodate non-linear effects. As a consequence, gas turbine engine modeling has received special attention in the last few years in the literature devoted to non-linear system identification and analysis.

The first non-linear models to be proposed were based on physical principles applied in the time domain. These models are also known as thermodynamic models. The continuous time models,

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Nomenclature

Micro-turbine

A_{cc}	acceleration signal
a, b, c	valve parameters
c_{pa}	specific heat of air at constant pressure
c_{pg}	specific heat of combustion gases
c_{ps}	specific heat of steam
D	load damping constant
e_1	valve position
F_d	fuel demand signal
H	inertia constant
LHV	lower heating value
K	parameter of radiation shield
k_f	fuel system gain constant
k_{LHV}	factor which depends on LHV
M	mechanical starting time $= 2H$
N	rotation speed of gas turbine
N_{ref}	reference speed
P_c	compressor power consumption
p_{cin}	air pressure at compressor inlet
p_{cout}	air pressure at compressor outlet
P_m	mechanical power
P_T	total mechanical power delivered by turbine
p_{Tin}	pressure of combustion gases at turbine inlet
p_{Tout}	pressure of combustion gases at turbine outlet
R	speed regulation or droop
s	Laplace transform variable
T	temperature signal
t	time
T_m	mechanical torque delivered by turbine
T_{cout}	outlet air temperature
T_{is}	temperature of injected steam
T_{ref}	gas turbine rated exhaust temperature
T_{Tin}	turbine inlet gas temperature
w_a	air mass flow into compressor
w_f	fuel mass flow
w_g	turbine gas mass flow
w_{is}	injection steam mass flow
Δh_{25}	specific enthalpy of reaction at reference temperature of 25 °C
Δh_{IC}	isentropic enthalpy change for a compression from p_{cin} to p_{cout}
Δh_{IT}	isentropic enthalpy change for a gas expansion from p_{Tin} to p_{Tout}