Energy Conversion and Management 92 (2015) 366–384

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Preliminary design and validation of a Real Time model for hardware in the loop testing of bypass valve actuation system

Luca Pugi [a,*], Emanuele Galardi [a], Carlo Carcasci [a], Andrea Rindi [a], Nicola Lucchesi [b]

[a] DIEF: Department of Industrial Engineering, University of Florence, Via Santa Marta, 3, 50139 Florence, Italy
[b] VELAN ABV SPA, Lucca, Italy

ARTICLE INFO

Article history:
Received 1 September 2014
Accepted 21 December 2014
Available online 13 January 2015

Keywords:
Real time simulation
Steam plants
Hardware in the loop
Turbine bypass controller

ABSTRACT

During the start-up and shut-down phases of steam power plants many components are subjected to pressure and temperature transients that have to be carefully regulated both for safety and reliability reasons. For this reason, there is a growing interest in the optimization of turbine bypass controllers and actuators which are mainly used to regulate the plant during this kind of operations. In this work, a numerically efficient model for Real Time (RT) simulation of a steam plant is presented. In particular, a modular Simulink™ library of components such as valves, turbines and heaters has been developed. In this way it is possible to easily assemble and customize models able to simulate different plants and operating scenarios. The code, which is implemented for a fixed, discrete step solver, can be easily compiled for a RT target (such as a Texas Instrument DSP) in order to be executed in Real Time on a low cost industrial hardware. The proposed model has been used for quite innovative applications such as the development of a Hardware In the Loop (HIL) test rig of turbine bypass controllers and valve positioners. Preliminary experimental activities and results of the proposed test rig developed for Velan ABV are introduced and discussed.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Efficiency and more generally cost optimization of energy production are important specifications for the development of power generation units [1]. However, there is growing interests in the improvement of the performance in transients and off-design operating conditions [3] (e.g., the cyclic operation). This interest is mainly justified by industrial and economic reasons such as the delocalization of energy production and the increasing global liberalization of the energy market. One of the most important causes of the delocalization of the energy production (especially in western Europe) is the growing use of renewable energy sources. Also, integration and management of renewables into Total Sites, as proposed for example by Varbanov [4] should offer a way to mitigate this kind of troubles, but not to change the trend towards a more flexible exercise of both power plants and grids. Another important aspect is the globalization and liberalization of the energy market [5]. Liberalization involves the availability of different power sources, countries and producers. With a free energy market even an intermittent use of the plant should become remunerative, considering fluctuations of the energy price. This is one of the most cited reasons to optimize, as much as possible, the control and behaviour of power plants during the start-up phase [6].

For large steam or combined cycle power plants, a flexible use of the plant involves higher reliability, availability, and duration of components which are more subjected to potentially dangerous thermo-mechanical stresses.

Turbine Bypass Valves (TBVs) are typically used to smoothly control temperature and pressure gradients which can negatively affect safety and reliability of potentially critical components such as heat exchangers or turbines [7]. In particular, in this work are simulated and investigated the transients associated to plant start-up and shut-down.

The system architecture is heavily influenced by features and performances of the valves used to control pressure and temperature: useful technical information concerning valve structure and performances are available from the sites of some of the most important industrial suppliers [8–10].

Typical applications of bypass systems are in large fossil fired steam plants [11], in combined gas-steam turbine power plants [1] or even in nuclear plants [12]. Main components of a TBS are described in Fig. 1[8]: the steam flows through a lamination valve, represented in Fig. 2[13], whose internal pressure losses are controlled to produce a desired pressure drop. In this paper, the lamination valve is described with the acronym DTP (Discrete

* Corresponding author.
E-mail address: luca.pugi@unifi.it (L. Pugi).

http://dx.doi.org/10.1016/j.enconman.2014.12.061
0196-8904/© 2014 Elsevier Ltd. All rights reserved.

Nomenclature

c_p	specific heat at constant pressure (kJ/kg K)
c_v	specific heat at constant volume (kJ/kg K)
C_v	flow coefficient (–)
CvA	numerical constant (–)
C_v^g	single group flow coefficient (–)
dh	hole diameter of the spray water valve (m)
$F_k(\gamma)$	specific heats ratio factor (–)
F_p	piping geometry factor (–)
Hrg	holes number per ring of the spray water valve (–)
h	specific enthalpy (kJ/kg)
L	specific work (kJ/kg)
MM	molar mass (kg/kmol)
N_6	numerical constant (–)
N_g	groups number (–)
Nrg	rings number of the spray water valve (–)
P	pressure (Pa)
Q	heat (kW)
R	specific gas constant (kJ/(kg K))
Re	Reynolds number
R_u	universal gas constant (kJ/(kg K))
$\dot{m}$	mass flow rate (kg/s)
s	specific entropy (kJ/kg K)
T	temperature (K)
$\dot{T}$	temperature variations (K/s)
u	specific internal energy (kJ/kg)
V	volume (m^3)
$\dot{v}$	volume variations (m^3/s)
v	specific volume (m^3/kg)
$\dot{v}_s$	specific volume variations ($m^3/kg\ s$)
v_x	longitudinal speed of the flow (m/s)
W	power (kW)
W_{sp}	specific power (kJ/kg)
X	ratio of pressure drop to upstream absolute static pressure
x_c	control signal
x_t	pressure drop ratio factor
Y	expansion factor

Greek symbols

γ	specific heats ratio
γ_{SW}	specific weight (kg/m^3)
δ_{rg}	pressure drop of the spray water valve rings (Pa)
η	efficiency
λ_p	thermal conductibility (W/mK)
μ	dynamic viscosity (kg/ms)
ρ	density (kg/m^3)
ψ	dynamic viscosity exponential coefficient

Subscripts

0	reference
BVHP	high pressure bypass valve
BVLP	low pressure bypass valve
CND	condenser
ECO	economizer
EV	evaporator
FW	feed water
GAS	gas from the gas turbine
Is	isentropic
MXHP	high pressure mixer
MXLP	low pressure mixer
RH	reheater
SH	superheater
THP	High Pressure Turbine
TLP	Low Pressure Turbine
WVHP	High Pressure Spray Water Valve
WVLP	Low Pressure Spray Water Valve
w_EV	evaporator water

Acronyms

BVHP	High Pressure Bypass Valve
BVLP	Low Pressure Bypass Valve
CND	Condenser
DSP	Digital Signal Processor/Digital Signal Processing Unit
ECO	Economizer
ECU	Electronic Control Unit
EV	evaporator
HIL	Hardware In the Loop
HP	High Pressure
Kd	Derivative Gain
Ki	Integral Gain
Kp	Proportional Gain
LP	Low Pressure
MCR	Maximum Continuous Rating
MXHP	High Pressure Mixer
MXLP	Low Pressure Mixer
PID	Proportional Integral Derivative Controller
RH	reheater
RT	Real Time
SH	superheater
TBV	Turbine Bypass Valve
TBVHP	High Pressure Turbine Bypass Valve
TBVLP	Low Pressure Turbine Bypass Valve
THP	High Pressure Turbine
TLP	Low Pressure Turbine
TVHP	High Pressure Turbine Valve
TVLP	Low Pressure Turbine Valve
WVHP	High Pressure Spray Water Valve
WVLP	Low Pressure Spray Water Valve
TBS	Turbine Bypass System
Inlet	Generic inlet section
Outlet	Generic outlet section

Tortuous Path), which is referred to a high performance proprietary technology, specifically developed by Velan ABV S.P.A. The main features of a DTP valve are visible in the scheme of Fig. 3 [8]. Since this is a control related application, a smooth linear response of the valve and a noiseless vibration free behaviour are recommendable specifications. In Fig. 2 a scheme of a lamination valve taken from the work of Kwon [13] is shown: the valve is composed by a set of stacked discs on which is produced a tortuous path in radial directions; by controlling the axial position of a piston/plug is possible to change linearly the numbers of discs through which the steam flows. The axial position of the plug inside the valve is controlled by a fluid operated (hydraulic or pneumatic) actuator regulated by an electronic control board which is usually called "Positioner". In this way, it is possible to control the equivalent passage area of the valve in a proportional manner. For this reason, the valve is used also to proportionally control the steam mass-flow rate in the plant. As stated by different works in literature [14–18], this kind of construction is robust, reliable and considerably reduces the noise and vibrations associated to the fluid lamination. The lamination process inside this valve can be approximated as an adiabatic, isenthalpic transformation; thus, in order to control the outlet steam temperature, the specific enthalpy of the flow is reduced by mixing the main steam flow with atomized cold water.

Download English Version:

https://daneshyari.com/en/article/7163126

Download Persian Version:

https://daneshyari.com/article/7163126

Daneshyari.com