AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Mechanical Power Engineering

An Analytical Approach to Optimize the Performance of the Bypass for Two-Way Control Valves in Chilled Water Central Air-Conditioning Systems

A Thesis submitted in partial fulfillment of the requirements of the degree of

Master of Science in Mechanical Engineering

(Mechanical Power Engineering)

by

Hashim Ibrahim Mohamed Elzaabalawy

Bachelor of Science in Mechanical Engineering

(Mechanical Power Engineering)

Faculty of Engineering, Ain Shams University, 2014

Supervised By

Dr. Ahmed Youssef El-Assy

Dr. Mohamed Ahmed Abdelaziz

Cairo - (2016)

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Date:14 December 2016

Statement

This thesis is submitted as a partial fulfillment of Master of Science in Mechanical Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Thesis Summary

Primary-secondary pumping system is widely utilized in Heating, Ventilating, and Air Conditioning industry. This type of system has an energy saving potential over the constant speed primary pumping system. However, the system uses a surplus amount of energy that can be saved, the low delta T syndrome and low pumping efficiency are the main energy wasting reasons. The implementation of a proper design and novel control strategy can eliminate these two problems, knowing that the design of the bypass (Decoupler Bridge) is still a topic of debate. Thus, the focus in this thesis will be enhancing the design and control of the bypass and developing an energy efficient control for the secondary loop including the pumps and the two way control valves. Calculating the bypass pipe diameter and its control strategy are often estimated according to the designer experience, rather than a code of practice, the goal for this thesis is setting a guide for the bypass design. An analytical model is used to find the most efficient design, where the model simulates the water distribution loop, pumps, chillers and control valves.

Pressure drop in the system is categorized into three types; speed dependent, pipes, and controlling pressure drops. Pumps are modelled by curve fitting to real pump performance curves. Control valves are modelled with their non-linear flow characteristics. While the control scheme is applied as the signal given to the variable frequency drive on the secondary pump. The model is built to simulate chilled water system.

Results are acquired from several schemes, having different number of load terminals, each having its separate control valve, each system has its constant speed primary pumps, where one pump is installed for each chiller, and a variable speed secondary pumps set are chosen according to each system. Also the results are validated with an experimental model. The various configurations for both bypass and secondary pump control are implemented on this model, in order to demonstrate the energy savings, and also testing the performance of each system showing its effect on the heat loads. The results show that some modifications to the design can save a considerable amount of energy compared to the conventional design. As a conclusion a design guideline is suggested in this thesis for an energy efficient bypass pipe.

Key words: Primary-Secondary; Bypass; Two way control valve; Decoupler-bridge; Air Conditioning

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Nomenclature

h	Pressure head	m
f	Friction factor	-
Q	Volume flow rate	m3/s
v	Average flow velocity	m/s
l	Pipe length	m
D	Pipe diameter	m
K	Resistance coefficient	-
V	Volume	m3
g	Gravitational acceleration	m/s2
N	Rotational speed	RPM
P	Pressure	Pa
Re	Reynold's number	-
RR	Relative Roughness	-
r	Speed ratio	-
t	Time	s
T	Temperature	K

Greek letters

β	Valve opening	-
ε	Roughness	m
ϑ	Kinematic viscosity	m2/s
ρ	Density	kg/m3
Δ	Difference	-

Subscripts and Superscripts

pc	Primary circuit
sc	Secondary circuit
pp	Primary pump
sp	Secondary pump
bp	Bypass
Sec	Secondary
Prim	Primary
Load	Load terminal

Chapter 1
Introduction

1.1 Systems Overview:

Chilled water system is one of the most used types in central air conditioning. Often used in Egypt and Arabian Gulf countries, typically the system circulates water through a pipe network, where the water chills down at the chiller, usually to around 6 degrees Celsius. The chilled water is pumped to the load terminals, whether the load terminal is a fan coil unit, an air handling unit, or a heat exchanger. At the load terminal the flow is throttled to sustain the required water volume flow rate, conventionally by using a thermostat and a control valve in order to maintain water ΔT at the terminal within design limits. Due to this cooling operation heat is exchanged from the load to the water increasing the water temperature. Water is circulated back to the chiller in order to chill down again and the loop goes on. Many system configurations had been developed recently to achieve this operation of this system with the least energy consumption. Where there are no changes in the chiller or load terminals, variations are limited to the pumping system, pipping network, valves and sensors locations. Originally, pumps are the heart of any chilled water system as their role in the system is mandatory. There are several ways of pumping the water across the piping network; the three most common used configurations are:

1) The constant flow pumping system shown in figure 1-1, this system is simply a set of constant speed pumps circulating a constant flow across the network. This pumping system has proven its durability, reliability and performance over the years. However, this compromises its simplicity with the high energy consumption at the part load conditions.