MODELING, CONTROL AND FAULT DIAGNOSIS OF AIR-CONDITIONING SYSTEMS

by

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Certificate

This is to certify that the thesis entitled **"Modeling, Control and Fault Diagnosis of Air-Conditioning Systems",** being submitted by **Mr. Mahendra Kumar** to the Department of Electrical Engineering, Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** is a record of bona-fide research work carried out by him under my supervision. In my opinion, the thesis has reached the standard fulfilling the requirement of the regulations relating to the degree.

The results contained in this thesis have not been submitted either in part or in full to any other University or Institute for the award of any degree or diploma.

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Abstract

The control of an air-conditioning system plays important role in its energy consumption, and thermal comfort of occupants. At present, small and medium capacity air-conditioning systems are equipped with the temperature based control. The temperature based control is not fully energy efficient and it may not always provide the desired level of thermal comfort. Also, the fault-free operation of an air-conditioning system is very important. This thesis contains both the aspects, i.e., control & fault-free operation of air-conditioning systems.

The thesis commences with thermal sensation index based ON-OFF control in which predicted mean vote (PMV) is used as a thermal sensation index. PMV based ON-OFF control is validated experimentally and is found better than the temperature based ON-OFF control scheme in terms of energy consumption and thermal comfort. The possibility of replacing the temperature based ON-OFF control with the PMV based ON-OFF control is also examined.

In the thesis, state space based multi-input multi-output lumped parameter model for direct expansion AC system is presented. The dynamic behavior of refrigeration circuit and air circuit is taken into account simultaneously in the proposed model. The model can serve as a platform for designing and implementing different modern control strategies. Experimental validation of the model has been done on an AC system equipped with the temperature based ON-OFF control.

The application of least square support vector machine is demonstrated to approximate PMV, and psychrometric functions. The result shows very good agreement between function values computed using conventional models and LS-SVM based

predictive models. The LS-SVM based predictive models are also found robust against the noises.

Two layers of model based feedback control scheme is presented with the objective of minimizing the energy consumption at desired level of thermal comfort. These two layers are: set point optimizing and dynamical optimizing control. In the set point optimizing control, optimal set points are computed for dry bulb temperature, relative humidity and relative velocity of air, evaporator pressure and condenser pressure. These setpoints correspond to the minimum energy consumption at desired level of thermal comfort. The dynamical optimizing control deals with the design of centralized control based on output feedback and state feedback to track the optimum set-points. The constraints on the control inputs are also considered in design of the control law. The proposed control scheme is simulated using non-linear model of an air-conditioning system. The result shows that the proposed control scheme saves substantial energy as compared to the constant set-points based control scheme to maintain same level of thermal comfort.

Further, model based fault diagnosis scheme using lumped parameter MIMO model is presented in the thesis. The characteristics of single as well as multiple faults are investigated in an air-conditioning system. The residuals of the fault are generated by using the real simulator and the fault-free model. The faults are diagnosed by classifying the residual patterns. The classifications of residual patterns are done by using three approaches: hexadecimal decision table, LS-SVM and a novel approach named as hybrid classification approach.

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