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Energy Optimization of Condenser water loop in HVAC System using Artificial Co-operative Search (ACS) algorithm

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Abstract:

This paper presents optimization of condenser water loop in Heating, Ventilation and Air Conditioning (HVAC) systems using Artificial Co-operative Search (ACS) algorithm. Condenser water loop has various components like cooling tower, chiller, fans and pumps. Set points for this optimization are air and water flow rates, supply water temperature, wet and ambient bulb temperature. Energy cost obtained by multi objective optimization developed in this paper. ACS based approach is based methodology is equipped for taking care of the improvement issue In Comparison with the routine strategies, this technique can possibility of considerable decrease in the operating cost.

***Keywords* — HVAC system optimization, ACS, optimization, condenser water loop**

I. INTRODUCTION

A typical centralized Heating, Ventilation and Air- conditioning (HVAC) system comprises of condenser water loop, together with chillers, indoor air loops and chilled water loop to provide comfort environment for the conditioned space. The process of a condenser water loop consists of condensers, condenser water piping and pumps, and cooling towers. Condensers transfer indoor cooling load and heat generated by compressors into condenser water pipe where condenser water pumps provide the energy to overcome the friction loss and deliver condenser water to cooling towers. Cooling towers reject heat to the environment through heat transfer and evaporation to the ambient air.

The control and improvement has been considered as a standout amongst the most troublesome issues for practice control engineers. Condenser water loop is one of the five principle capacity loops and its operation has noteworthy impact to the general system execution. The principle issues for effective operation of condenser water loop are the execution of cooling towers and the collaborations between cooling towers, condenser water pumps and chillers. For cooling towers, Cassidy and Stack's Work [1] demonstrated that changing the rate of cooling tower fans is a decent approach to decrease energy utilization. Braun and Doderrich [2] proposed Near-ideal control of cooling towers taking into account parameter assessed from configuration information. This strategy was further received by Cascia [3] to improve the segment demonstrate and give conditions to deciding the set purposes of close ideal control. For connections amongst chillers and cooling towers, Shelton and Joyce's work [4] suggested 1.5 gpm/Ton condenser water stream rate as an ideal arrangement. Later, Kirsner [5] called attention to that high condenser water stream rate (3 gpm/Ton) has great execution at full load condition, while low condenser water stream rate (1.5 gpm/Ton) has points of interest at part stack conditions. Michael and Emery [6] broke down the cost-ideal determination of the cooling tower range and approach and gave the outline data to hermetic divergent and responding chillers. Schwedler [7] contemplated the variety of condenser water supply temperature and utilized a few case to show his primary thought that the most reduced conceivable leaving tower water temperature does not generally ration framework utilization. Be that as it may, his examination just considered the fans with half-speed and full-speed conditions, which was not indisputable. Regardless of the advancement made as of late on individual part demonstrating, control, enhancement and operation rules, there is still absence of a methodical methodology which considers the condenser water loop in general to advance its operation. Jayakumar [10] et al, used TLBO algorithm and demonstrated that the potential energy saving in condenser water loop system in HVAC system.

The operation of HVAC system is critical activity in terms of optimizing the control settings to reduce the energy consumption and maintaining the thermal comfort for occupants. The performance and operating efficiency of the HVAC systems can be improved by adjusting the set points.

II. PROBLEM FORMULATION

The schematic block diagram of a condenser water loop is shown in Fig.1

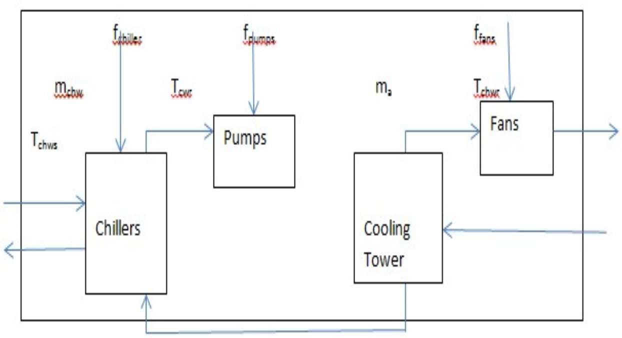

Fig .1 Schematic diagram of condenser water loop

Without loss of sweeping statement, it is expected that both chilled water supply temperature, Temp-CHWS, and chilled water flow rate inside chiller, m-CHW, are kept as constants, while the chilled water return temperature, Temp-CHWR, shifts with the cooling load in the conditioned space. The controlled variables of the system for control and optimization are as

The quantities of working chillers r, condenser water pumps s, and cooling tower fans t.

- ✓ The condenser water flow rate Mw, s, controlled by the sth Variable-Speed Drive (VSD) condenser water pump.
- ✓ The wind current rate in cooling towers Ma,t, controlled by the tth VSD cooling tower fan.

The condenser water supply temperature, T_{CWS}, controlled by the blend of aggregate condenser water flow rate mw and air flow rate principle cooling towers.

Objective Function

The objective is to minimize total power consumption of the whole condenser water loop, and is given as defined by Lu[9],

$$\min P_{total} = \bar{P}_{chiller} + \bar{P}_{pump} + P_{fan} \quad (3)$$

In Eq. (3), the expression for power consumption of chillers $P_{chiller}$, is given as Stoecker [13]:

$$P_{chiller} = \sum_{i} Q_{cap,i} \cdot COP_{nom,i} \cdot (PLR_{adj,i}) \cdot (Temp_{adj,i}) \quad (4a)$$

$$PLR_{adj,i} = b_0 + b_1\left(\frac{Q_i}{Q_{cap,i}}\right) + b_2\left(\frac{Q_i}{Q_{cap,i}}\right)^2 \quad (4b)$$

$$Temp_{adj,i} = c_0 + c_1 T_{CHWS} + c_2 T_{CHWS}^{\ 2} + c_3 T_{CWS} + c_4 T_{CWS}^{\ 2} + c_5 T_{CHWS} T_{CWS} \quad (4c)$$

Constraints:

Considered single-chiller systems as a of multi-chiller installations and it employs only one chiller, one condenser water pump and one cooling tower fan. The combination of multiple chillers, pumps, and fans is no longer required in the problem solving process

III. ARTIFICIAL COOPERATIVE SEARCH ALGORITHM

Artificial Cooperative Search (ACS) calculation (ACS) [8] is a swarm insight calculation produced for understanding genuine esteemed numerical streamlining issues. A mutualism based organic association exists between various living species in nature. The living species required in a mutualism based natural communication attempt to determine shared advantages from the specified cooperation.

Participation is the association of homogenous living species that embrace mutualism. Mutualism and participation based natural cooperation of two eusocial superorganisms living in the same environment motivated the ACS calculation. The territory idea in ACS calculation coordinates the look space idea that has a place with the related issue.

ACS depends on the movement of two fake super creatures as they naturally connect to accomplish the worldwide least esteem to the issue. The amount of sustenance that can be gotten from an encompassing environment is by and large subject to occasional atmosphere, a change which shifts quickly. This climatic change has created regular movement conduct for various encouraging situations. Preceding relocation, greater part of the individuals bunch together to frame a superorganism. The superorganisms that display regular relocation conduct can move and discover more rich nourishment natural surroundings. Before the movement, numerous superorganisms likewise sort out into subgroups known as sub-superorganisms. Amid such conditions, the character of a superorganism is resolved with the coordination of sub-superorganisms. Wayfarers are utilized to seek in point of interest another spot before endeavoring to move to another territory. The adventurers then hand-off the information relating to the new relocation zone to the superorganism. On the off chance that the superorganism considers the territory proposed appropriate for movement, at that point the pertinent superorganism moves to this newfound zone, stops and nourishes there for a period, in the interim, it rehashes its conduct to discover more productive regions and moves once more. In this way, the living species naturally cooperate with each other to discover their encouraging and propagation needs.

In ACS calculation, a superorganism comprising of irregular arrangements of the related issue compares to an manufactured superorganism relocating to more profitable bolstering ranges. ACS calculation contains two superorganisms; α and β that have manufactured sub-superorganisms equivalent to the measurement of the populace (N). The measurement of the issue (D) is equivalent to the quantity of people inside the related sub-superorganisms. In ACS calculation, α and β superorganisms are utilized for the discovery of simulated Predator and Prey subsuperorganisms.

The Predator sub-superorganisms in ACS calculation can seek after the Prey sub-superorganisms for a timeframe while they relocate towards worldwide least of the issue. At the point when the iterative estimation procedure of ACS calculation that is named as co development procedure is thought of it as, can be seen that the two superorganisms searching for the worldwide least of the related issue, set up participation based natural association between each other. In ACS calculation the underlying estimations of the people of ith sub-superorganism of α (i.e., α_(i,j)) and β (i.e., β_(i,j)) are characterized by utilizing (1) and (2) ;

$$\alpha_{i,j,g} = rand.(up_j - low_j) + low_j \quad (1)$$

$$\beta_{i,j,g} = rand.(up_j - low_j) + low_j \quad (2)$$

where i = 1, 2, 3, ... , N, j = 1, 2, 3, ... , D and g = 0, 1, 2, 3, ... , max cycle. The "g" esteem here means the era number communicating the co advancement level containing the related superorganisms. The rand demonstrates an irregular number browsed the uniform circulation with U~[0 1]. The upj and lowj are the upper furthermore, bring down breaking points of quest space for jth measurement of the related issue. The efficiency values (i.e., wellness values) got by the related sub-superorganisms are figured by utilizing (3) and (4);

$$y_{i,\alpha} = f(\alpha i) \quad (3)$$

$$y_{i,\beta} = f(i) \quad (4)$$

The organic cooperation area, X, amongst Predator and Prey sub-superorganisms is demonstrated utilizing the condition;

$$X = Predator + R(Prey - Predator) \quad (5)$$

where, R is the Scale figure that controls the pace of organic collaboration. The probabilistic way of ACS calculation causes the superorganism that is resolved as the predator to be changed in every era. Along these lines, ACS calculation gives a helpful/coevolution process for both of the superorganisms.

The pseudo code of ACS calculation is given in [3]. The proposed calculation can be actualized with meeting, cycle or resilience as the halting criteria. In this proposed study, emphasis tally has been taken as the halting criteria.

IV. RESULT AND DISCUSSION

The average energy consumption by using optimization method is nearly 8.1% less than that of commonly used control strategy. In practice, the energy savings resulted from operating points optimization may be different from system to system. In general, however, it can be expected that the proposed optimization method can substantially reduce the energy consumption of condenser water loops.

To delineate the benefits of the optimization strategies for seeking the optimal operating points, an application case is given beneath:

A central air-conditioning has four chillers, four condenser water pumps, and four cooling towers.

- ✓ Three chillers have the same ostensible cooling load limit, 500 Ton.
- ✓ The chilled water supply temperature is 45 °F (7.2 °C)
- ✓ The nominal condenser water supply temperature is 85°F (29.4 °C).
- ✓ The energy utilization of every chiller is 0.6 kW/Ton at the full load condition.
- ✓ Each chiller has one condenser water pump and its ostensible water stream rate is 100 kg/s.
- ✓ Each cooling tower is furnished with an enthusiast of 30 kW at full load and can give 30 kg/s wind current rate
- ✓ All pumps and fans are outfitted with VSDs and their velocity extending from half to 150% of full load.
- ✓ To contrast and the optimal working point control technique, a generally utilized augmentation/decrement chiller organizing technique with altered condenser water stream rate and air flow rate control procedure is utilized with taking after working conditions.
- ✓ The condenser water flow rate is settled at 100 kg/s per condenser water pump and the pump is arranging on with the comparing chiller.

The wind current rate in cooling tower is altered at 30 kg/s when the cooling tower fan working under the evaluated speed.

V. CONCLUSIONS

The normal energy utilization by utilizing optimization technique is almost 10% not as much as that of ordinarily utilized control system. By and by, the energy saving came about because of working focuses advancement might be unique in relation to system. By and large, in any case, it can be normal that the proposed optimization technique considerably diminish the energy utilization of condenser water loop.

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