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Should the Configuration of a Chiller Plant be Established According to Standards or Recommendations?

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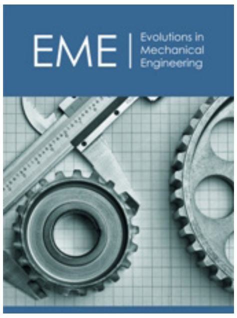

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Opinion

A chiller plant is a complex HVAC system. Its main feature is that it uses water as a heat transfer fluid, extracts heat from the medium, and thus lowers the air temperature through a heat transfer process. These systems offer many advantages over direct expansion systems in terms of operation, reliability and efficiency. The initial investment is approximately 2.2 times greater than individual air conditioning systems, but the comfort achieved is superior and also provides quieter operation and enhances the internal and external aesthetics of the building. Thermal distribution requires less space compared to All-Air systems, making it very suitable for buildings with limited space. They allow simultaneous control of different thermal zones as well as air conditioning and heating circuits. They are usually used in facilities that have significant air conditioning needs, such as large hotels, restaurants, cinemas, theatres, shopping centres, hospitals and other public buildings. They are usually installed when the building is constructed, although in some cases they are installed when existing buildings are remodelled. Chillers or "chillers" (technical terminology) are the central axis of a system, which in turn consists of several machines and is responsible for 60% of energy consumption [1].

Efficient design of a chiller system, based on proper selection of its components, can reduce energy consumption. According to Fang et al. [2], when a system is improperly designed, the efficiency of each element in the system deviates from its optimal operation. They also affirm that poor design of a chiller system is a common problem in engineering. For example, in a study by Gang et al. [3], changing the total number of chillers as well as the distribution of cooling capacity between chillers allows up to 69% variability in consumption. The asymmetric configuration of chillers of different capacities allows a saving of 10.1% according to the study presented by Yu & Chan [4]. Kapoor & Edgar [5] found that chillers configured in series consume 9.62% more energy than those configured in parallel. Lee & Lee [6] showed that the increase of chillers of the same capacity in a plant favors the increase of efficiency and decrease of energy consumption. The redundancy of chillers ensures additional load on the cooling load in case of failure in the system, which largely provides robustness. For example, Wang et al. [7] determined a significant increase in the failure rate of a non-redundant system over a redundant one, from 1.3 *10-6 to 2.4 * 10-2. As can be seen, different decisions applied to the design of the chiller units made a difference in the energy efficiency of the system.

The design of chillers refers to the determination of the cooling capacity of the systems and their configuration. The configuration must consider the total capacity of the system, the number of chillers to be installed, the arrangement of cooling capacity between chillers, and the hydraulic arrangement. But is it enough to achieve an efficient design using only the standards or recommendations established in the field, or does it only help us to establish basic design of a chiller plant?

For example, a conventional plant design suggested by ASRHAE Fundamentals [8] indicates that the total capacity of the plant is approximately 15% higher than the peak demand resulting from the thermal load calculation. This safety factor is used to avoid the risk of undersizing. On the other hand, there is another criterion used by ASHRAE Standard 90.1-2010 [9] that affects the total capacity of the installation, which specifies that the unmet hours cannot exceed 300 hours. Regarding the number of chillers to be installed, it is generally stated that a system must consist of N + 1 chillers to ensure system reliability. Taylor [10] points out that there are installations that are critical is required to install usually N + 1 or N + 2 redundant chillers, taking into account the possibility that the chiller with the larger capacity fails. Only one chiller is unacceptable for most facilities, especially where the use of these systems is vital (laboratories, data centres, hospitals, hotels, etc.). On the other hand, Yu & Ho [11] report that a large capacity facility must contain at least three chillers. However, space constraints may influence the decision.

Cooling capacity between chillers is another of the decisions that are predetermined. ASHRAE 90.1-2013 [12] (Table G3.1.3.7) recommends the use of a symmetrical arrangement according to the cooling needs of the building. On the other hand, Yu & Chan [13] state as a rule that four to eight chillers should be used in buildings with cooling demand between 1050-7032kW. A similar statement is made by Chan et al. [1]. Stanford [14], recommends the use of asymmetric configurations composed of 80% -20% of the total capacity and the other is 60% -40%. This last split was first advocated by Haviland & CEM [15] under the criterion that in applications such as hotels and offices, chillers can operate more than 50% at part load. Another suggestion was made by Matheu & Greenberg [16] who propose a ratio of 30% -70% in the case of laboratories. Finally, in the case of hydraulic arrangement Kapoor & Edgar [5], the parallel configuration is recommended because it allows the operation of the number of chillers that is really needed, depending on the heat demand of the building. Moreover, it allows the continuous operation of one of the chillers in case of maintenance or unexpected failure of the other, ensuring uninterrupted operation.

These aforementioned rules allow us to have a starting point to create an initial design of the chiller, which can serve as a basic structure for comparing multiple combinations that come from different methods or studies conducted by the researcher. It is important to realize that it is not the plant that defines the building, but rather the opposite. It is the building that defines the operation of the air conditioning system. Therefore, the decision on the arrangement to be set up must be based on a thorough study of the thermal dynamics of the facility. Some studies based on the analysis of the thermal requirements of a facility in operation allow us to identify interesting modes of investigation that should be applied in the early stages of the design. For example, Deng [17], Cheng et al. [18] and Wang et al. [19], in their studies proposed a modification of the existing configuration. However, these decisions have an economic cost due to the initial inefficiency.

Therefore, estimating the variation of the thermal demand that the installation will have should be the main task of the engineer. In the new design procedure for chiller installations, it is necessary to consider not only the construction of a demand profile that reflects the worst operating conditions, but also to elaborate several profiles that incorporate the uncertainties of the demand. For this, the stochastic method can be used or otherwise, knowing the variables of utilisation of similar plants, assuming work schedules, percentage of occupancy, variations of the degree's days of the place and simulating, through the different thermodynamic programmes using deterministic methods, profiles of thermal demands and at the wide working regime to which the chiller can be subjected. Finally, to conclude this extensive search and creation of data, a deep statistical analysis that helps to determine the prevailing cooling capacities and thus create different chiller configurations. Then, using creative mathematical algorithms, different configurations are created from the result by changing the total cooling capacity of the plant and the number of chillers [20,21].

The design phase of a chiller system should be the maximum saving point for the system. It is time for engineers to waste creativity. In this sense, it is also suggested that the energy analysis should not be done by traditional methods but use mathematical optimization to take into account the use of automatic control systems and operational measures that affect energy efficiency. It is a challenge, but from an economic and energy point of view, it is worthwhile not to limit oneself to the rules dictated by technology, but also to expand engineering knowledge.

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