POBOLJŠANJE SISTEMA ZA KGH RADI POVEĆANJA KVALITETA UNUTRAŠNJE SREDINE I ENERGETSKE EFIKASNOSTI “Tropsko voće nadohvat ruke”

HVAC SYSTEM ENHANCEMENTS FOR IMPROVED IEQ AND ENERGY EFFICIENCY “Tropical Low Hanging Fruits”

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Sistem za KGH treba da obavlja primarnu ulogu klimatizovanja vazduha pre nego što takav vazduh bude doveden u zone zgrade u kojima se boravi. Sve veća pažnja koja se posvećuje ljudima u zgradama i neosporna potreba da se smanji zavisnost od fosilnih goriva zbog zabrinutosti oko klimatskih promena iziskuje od stručnjaka za projektovanje sistema KGH da istraže inovativna sredstva i strategije kojima će povećati učinak sistema za KGH kako bi obezbedili bolji kvalitet unutrašnje sredine i veću energetska efikasnost. Rad se bavi jednostavnim ispitivim intervencijama koje obuhvataju nove strategije ili tehnologije u tropskim krajevima, koje su nazvane “topskih voće nadohvat ruke” i koje bi mogle značajno da poboljšaju energetske karakteristike zgrada, a i istovremeno da povećaju kvalitet unutrašnje sredine. Nove tehnologije ili strategije se očigledno lakše mogu primeniti u novim zgradama. Međutim, takve tehnologije se mogu smatrati i održivim rešenjima tokom faze obnove postojeće zgrade. Pored toga, nekoliko intervencija se lako može izvesti u fazi uobičajene eksploatacije tj. rada zgrade. Različite tehnologije/strategije koje su prikazane u ovom radu razmatraju se u kontekstu kako novih, tako i postojećih zgrada.

Ključne reči: sistem za KGH, poboljšanje karakteristika, kvalitet unutrašnje sredine, energetska efikasnost, zgrade u tropskim krajevima, jeftine intervencije

The HVAC system needs to serve the primary role of conditioning the air before it is delivered to the occupied zones of a building. The increasing focus on human centricity in buildings and the unquestionable need to curb the dependency on fossil fuels due to climate change considerations has necessitated the HVAC design professionals to explore innovative means and strategies to enhance HVAC system performance for improved Indoor Environmental Quality (IEQ) and energy efficiency. This paper deals with simple cost effective interventions, comprising new strategies or technologies in the tropics, dubbed Tropical Low Hanging Fruits that could significantly improve the energy performance of the buildings whilst simultaneously enhancing IEQ. It is obvious that new technologies or strategies are easier to be implemented in new buildings. However, such technologies could be easily seen as viable options during the refurbishment phase of an existing building. In addition, several interventions become easily possible in the normal operation stage of a building. The various technologies/strategies presented in this paper are discussed in the context of both new and existing buildings.

Key words: HVAC System; Performance Enhancements; Indoor Environmental Quality; Energy Efficiency; Tropical Buildings; Low Cost Interventions

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1. Role of the HVAC system

The HVAC system needs to serve the primary role of conditioning the air before it is delivered to the occupied zones of a building. Besides cleaning the air, it could further be seen as the need to provide for ventilation and cooling/heating requirements. In the tropics, this is essentially the process of cooling and dehumidification of both the outdoor and the recirculated air. It is apparent that heating would not be needed in the tropics, especially in comfort air-conditioning. In view of the high energy penalty that is inherent in conditioning outdoor air, tropical building designs employ a significantly high percentage of recirculation, almost as high as 90%. The increasing focus on human centricity in buildings and the unquestionable need to curb the dependency on fossil fuels due to climate change considerations has necessitated the HVAC design professionals to explore innovative means and strategies to enhance HVAC system performance for improved Indoor Environmental Quality (IEQ) and energy efficiency.

2. Tropical Low Hanging Fruits

This paper deals with simple cost effective interventions, comprising new strategies or technologies in the tropics, dubbed Tropical Low Hanging Fruits, presented in Figure 1, that could significantly improve the energy performance of the buildings whilst simultaneously enhancing IEQ.

Figure 1: Cost effective HVAC interventions – Tropical Low Hanging Fruits

It is obvious that new technologies or strategies are easier to be implemented in new buildings. However, such technologies could be easily seen as viable options during the refurbishment phase of an existing building. In addition, several interventions become easily possible in the normal operation

stage of a building. The various technologies/strategies presented in this paper are discussed in the context of both new and existing buildings.

2.1. High temperature cooling and dehumidification

In conventional HVAC designs, the cooling coil is typically designed with the Chilled Water Supply Temperature (CHWST) around 6-7°C and a ΔT of around 7°C. This would have a certain energy footprint for the chiller plant, which can be significantly reduced if the CHWST can be raised. Such a strategy is called the high temperature cooling and dehumidification. Caution needs to be exercised in exploring such options as there would be a limit at which dehumidifying performance of a coil would be severely compromised. A study revealed that CHWST up to 10°C may be viable for a given ΔT of 6°C, which leads to improved chiller performance [1]. Another recent study involving 11 office buildings in China employing split-system air-conditioning units found that occupants had adapted to the prevailing thermal environment and accepted a warmer temperature of 26°C, with a potential to save 8.6% energy during summer in buildings employing split-system air-conditioning units [2]. Whilst such strategies for chilled water or DX coils can be easily incorporated in new building designs, it is also a no-cost intervention during the operational stages in existing buildings.

2.2. Adaptable coils

HVAC systems are typically oversized in order to ensure that adequate cooling capacity is catered for. In the tropics, it is again quite common practice to resort to overcooling in order to achieve better dehumidifying performance from the cooling coil. Since active reheat is generally prohibited from being used to correct the temperature of the air leaving the coil, indoor spaces are often supplied air at quite low temperatures, resulting in them being colder than necessary. A strategy to overcome overcooled buildings is the adaptable coil, as shown in Figure 2, which offers flexibility in the operation of the coil in dynamically adapting its effective surface area to match the prevailing cooling loads for the right proportion of heat and mass transfer.

The fundamental theory is that the combination of low face velocity on the air side and high coolant velocity on the water side results in the coldest interface temperature that would achieve the maximum dehumidification per unit of sensible cooling [3, 4]. This is an important criterion to avoid overcooling. In conventional cooling coil operation, chilled water is modulated to reduce cooling capacity when loads drop. However, at part loads in tropical buildings, a higher

proportion of latent cooling would be needed per unit of sensible cooling, and the modulation of chilled water inhibits this process. At this time, a reduction of the coil size would enable the chilled water to be increased and this would help in better dehumidification per unit of sensible cooling. This is the primary feature of an adaptable coil and it can be applied for both new and existing buildings [5].

Figure 2: Adaptable coil

2.3. Heat Pipes

Heat pipe technology has been around for some time, both as a fundamental technology as well as its applications in air-conditioning, particularly from the perspective of humidity control [6, 7]. This is a passive system where no active energy is used to accomplish its primary goal of shifting the heat extracted from the incoming hot and humid air to the air leaving the cooling coil, thus providing free reheat. Overcooling is intentionally carried out as a process that assists in better dehumidification and the passive reheat helps in correcting the sensible temperature. Studies have shown potential energy benefits between 18 and 35% [8, 9, 10, 11]. Heat pipes are increasingly being adopted as an integrated HVAC design strategy for new buildings. But the major attraction for the heat pipe technology is that it can be readily applied in existing buildings as a wrap-around coil around an existing cooling coil in an Air Handling Unit (AHU).

2.4. Elevated space temperatures and elevated air speeds

Although until recently, comfort air-conditioning in tropical buildings was considered feasible only with cool temperatures accompanied by low air speeds, the idea of raising

indoor temperatures has been regularly explored since the 90s [12, 13, 14, 15, 16]. The strategy of achieving thermal comfort in air-conditioned buildings in the tropics from the perspectives of elevated air temperatures accompanied with elevated air speeds has been more systematically investigated within the past couple of years and the findings are very encouraging [17, 18]. Standards also advocate the use of elevated air speeds at warmer temperatures to achieve thermal comfort in both temperate and tropical climates [19].

Whilst this strategy is relatively easy to be implemented in any existing building, care must be taken to ensure that the elevated indoor humidity levels and potential surface emissions at elevated temperatures do not adversely affect the Indoor Air Quality (IAQ). The impact on IAQ is attributed to the fact that high recirculation rates are typically employed in tropical HVAC system designs and there is a potential concern of odour and stuffiness perception due to inadequate ventilation at elevated temperatures.

2.5. Move less air through the HVAC system

All air system designs, such as Constant Air Volume (CAV) and Variable Air Volume (VAV) systems, have traditionally been adopted in tropical buildings, albeit only a minimum ventilation air quantity of 10-20% of the total supply air is used. In a simulation study, it has been observed that the total power requirement for a HVAC system design with a space ΔT of 5°C can be as high as a factor of 2.2 when compared with a design having a ΔT of 8°C [20]. Significant energy savings can be realised when less air is moved through the HVAC system. It is also to be noted from psychrometric performance considerations that it is easier to design for a larger space ΔT , where the off-coil temperature gets closer to the saturation temperature.

It is quite straightforward to use this as a design criterion for new buildings. However, it should not be too difficult to implement this strategy as an intervention in an existing building by modifying the fan speed, and thereby the volume of supply air delivered by the fan. All else being equal, an intervention involving a larger ΔT would imply a reduction in the amount of supply air delivered by the fan, and consequently, leading to fan energy savings.

2.6. Decoupled ventilation and cooling systems

Based on the first principles of thermodynamics and heat and mass transfer, the advantages of retaining the appropriate enthalpy potential as a driving force for heat and/or mass transfer are well understood. It is quite apparent in hot and hu-

mid climates that it is beneficial to consider treating the outdoor air separately as the psychrometric process would reveal that the maximum enthalpy potential is available as a driving force for cooling and dehumidification. This would occur when the demand for latent cooling predominates as the outdoor air is very humid. By the same token, the recirculated air would have a high sensible cooling demand and it would be logical to treat this air stream separately. The concept of Dedicated Outdoor Air Systems (DOAS) arose out of this primary goal of being able to supply the ventilation air directly to the indoor spaces [21]. Whilst certain building applications may continue to prefer an all-air system, it must be borne in mind that sensible cooling can be achieved in a more energy efficient manner if a fluid (such as refrigerant or chilled water) is used as the medium rather than air. In such cases, radiant cooling panels (chilled ceiling) or localised active/passive forced convection strategies (localised fan coil units and active/passive chilled beams) become very attractive options for providing localised sensible cooling on a demand basis. A DOAS integrated with chilled beams for a high rise building in the tropics is shown in Figure 3. In the event an all-air system is preferred, the decoupled ventilation and cooling concept in the individual occupied zones can still be considered and the Single Coil Twin fan (SCTF) system is a technology that serves this purpose [22, 23].

The strategy of decoupling ventilation from cooling has dual benefits in comfort air-conditioning applications. Whilst it enhances cooling and dehumidification in an energy efficient manner, it also enables demand ventilation and demand cooling in the individual occupied zones for enhanced IEQ and further energy conservation. In the HVAC industry, DOAS is increasingly becoming popular and there is an increasing prevalence of such systems being considered as the main HVAC design concept for new buildings in the tropics. ASHRAE has developed a DOAS design guide to aid HVAC professionals involved in the design, installation, operation and maintenance of such systems [24].

It is apparent that the biggest “pull factor” towards the DOAS strategy is the fact that the overall HVAC system design can be conceptualised in such a way that only the minimum amount of air needed for ventilation be moved through the forced convection system [25]. In other words, the size of the AHU and the ducted air distribution system can be considerably reduced since the amount of outdoor air that needs to be conditioned and delivered to the various zones is usually very small in tropical building designs due to the high amount of recirculation employed. When combined with the strategy of elevated space temperatures and elevated air speeds, DOAS

becomes even more attractive as the secondary system need not employ any cooling process and simple air movement strategies, such as ceiling or desk fans, may be adequate [17, 18].

Figure 3: DOAS integrated with chilled beams

2.7. Condensate energy recovery

In DOAS AHUs in the tropics, it is quite apparent that considerable amount of condensate would be collected through the process of cooling and dehumidification of large quantities of hot and humid outdoor air. The condensate is typically at reasonably low temperatures of around 12.5°C, which can be seen as tremendous potential for pre-cooling applications. A simulation study involving 6 DOAS units found adequate condensate production that could make pre-cooling viable with approximately 10% energy savings [26]. Further, the study showed that cooling tower water demand could be offset in excess of 50%. This is an attractive low hanging fruit strategy that can be considered at any stage of the HVAC system design or operation, especially in building applications, such as hospitals and laboratories, that require 100% outdoor air provisions.

2.8. UVGI systems for AHUs

Ultraviolet Germicidal Irradiation (UVGI) systems, when installed in AHUs, can significantly improve the cooling coil performance by keeping the finned surfaces of the coil clean and, thereby, enhancing the heat and mass transfer characteristics of the coil. Findings from a recent tropical study, presented in Figure 4, shows an overall thermal conductance

increase of around 10%, air-side heat transfer coefficient increase in the range of 11.8 - 20.1% and a pressure drop reduction of 13% [27, 28].

The study also observed that the first month after UVGI intervention yielded the most benefit. A 9% reduction in fan energy over ten months of UVGI operation was observed and so was the fact that the fan energy savings were 39% greater than the UV lamps' energy consumption. UVGI systems also have a simultaneous IAQ benefit as they provide a disinfection function when installed in AHUs, and thus leading to a positive impact on occupant health and well-being [29].

Figure 4: UVGI Intervention Study - Overall thermal conductance and air side heat transfer coefficient characteristics

3. Conclusions

In the operational stages of HVAC systems in buildings, which is usually the longest in the life cycle, there is always a tendency to accept whatever performance is being delivered. Often, any possible options in improving the HVAC system performance both in terms of energy efficiency and IEQ, are not explored in adequate detail and not considered favourably, primarily due to operational pressures and constraints. This paper has discussed some of the “low hanging fruits” in terms

of operational strategies and simple no/low cost technological interventions that can significantly enhance IEQ and save energy. It is further discussed that these strategies and technologies can be easily considered as cost-effective HVAC design concepts for new buildings.

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