International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Optimizing BAS Control Strategies for Mitigating Respiratory Infections: Insights from COVID-19

Pradip R. Thorat

[1]Next Level HVAC Energy Management Systems, 9834 Norwalk Blvd, Santa Fe Springs, CA 90670. USA
Email: *prthorat2021[at]gmail.com*

Abstract: ***This research explores the intricate relationship between indoor HVAC systems and respiratory infections like COVID-19, placing much emphasis on the fundamental role that is played by ventilation and filtration together with maintenance in mitigating various forms of transmission risks. Furthermore, it also examines some of the major challenges that are posed by recirculated air together with inadequate ventilation, proposes various solutions that entail advanced technologies like UV-C germicidal irradiation and HEPA filtration. Building automation systems (BAS) offer an adaptable approach to addressing respiratory infections transmission issues. The BAS includes various components like microprocessor based programmable controllers, field sensors and control devices. BAS facilitates real time monitoring and data oriented corrective actions in HVAC equipment to reduce the spread of virus transmission through air. The investigation confines a rigorous examination of sensor technologies, control logics, and some system alteration employed in building automation to ensure an exact understanding of their impact on air transmission. It scrutinizes how automated control logic, related with real-time data, contributed to the efficient operation of HVAC systems. The research observes the alliance between automation technologies and HVAC components, highlighting their role in not only ensuring comfort conditions but also in achieving energy-efficient operation.***

Keywords: Respiratory Infections, WHO, BMS, HVAC, Ultraviolet germicidal irradiation (UVGI)

1. Introduction

Respiratory infections, such as tuberculous (TB), influenza and severe acute respiratory syndrome (SARS), SARS-CoV-2, constitute a worldwide threat to humans. This paper focuses on covid-19 coronavirus. A coronavirus (COVID-19) emerged in China at the end of year 2019. It has been spread worldwide since 2020. This virus attacks the respiratory airway, causes breathing issues as well cough, body pain and fever. This virus disseminates via droplets contacts, sneezing, coughing and bloodborne. The coughing and sneezing droplets from an infected person spread to the environment causing infections in other individuals [1]. These droplets settle on the surface or are breathe in by others could transmit the coronavirus. Other ways of transmission are touching doorknobs, tables, computer displays, or other surfaces on which droplets have landed. The common guidelines are physical distancing, mask-wearing, and use of sanitizers. The five to ten micron-sized heavy droplets settled on the surface less than one meter distance while transmitting, the 0.1 microns size droplets may evaporate, leaving virus particles, in the suspended air. Latest research discovered that coronavirus molecules may be alive for up to three hours after their deliverance [2]. The World Health Organization (WHO) guidelines state that the coronavirus aerial infection may be possible within the doors, particularly for folks who spend prolonged timeframes in crowded, poorly ventilated rooms. Initially, the WHO stated that the coronavirus could not spread via aerosols but later the WHO reversed its stance. Because the 293 researchers wrote a letter to WHO asking to re-examine its position on respiratory droplet transmission [3]. The government imposed various non-pharmaceutical interventions (NPIs) worldwide to reduce coronavirus transmission. The NPIs involve travel bans, stay-at-home, education and other institutes closures. Infectious people are sent to quarantine facilities to take medical treatments and avoid transmission through the contacts. By June 2021, In Australia and New Zealand the quarantine security staffs, and hotel staffs were contaminated by the virus. Approximately 32 COVID-19 quarantine facilities were failed to stop the aerial transmission into the community. Melbourne government temporarily roll down the usage of quarantine hotels in the city because the four epidemics were detected back to the hotel quarantine facilities, which driven to one of the world's longest lockdowns [4]. This was due to a poor understanding of the coronavirus transmission mechanism and inappropriate facilities as a quarantine site. Appropriate infrastructure and building control systems effectively mitigate the virus transmission from one person to another. Nowadays people spend most of their time in constructed environments and the respiratory infections can disseminate from "human to human" and "building to human" in present construction. So indoor infection control is critical for preventing respiratory infection. The building managers, facility operators, and safety experts might take steps to optimize ventilation and indoor airflows and prevent the spread of viruses. The building managers, facility operators, and safety experts intervene into the buildings to enhance ventilation and indoor airflows to prevent the virus dissemination by making physical and control operation sequence changes in the Heating, ventilation, and air conditioning (HVAC) systems. Their aim to achieve improved indoor air quality in the building. Indoor air quality improvement strategies are depending on various parameters and the mechanical filtration and ventilation are leading among the others. The filters remove the dust particles, gases, vapours, aerosols and capture the gases, vapours, and air suspended molecules that contain the virus. Filters dilute the virus concentration in indoor air and help to reduce occupant exposure. Mechanical filters are made by a fiberglass mesh to trap particles passing through them. Air passes over the filters, the airborne particles attach to the fibrous media, and purified air is supplied to the occupant spaces [5]. Ventilation is the process by which outdoor clean air is provided to the space and distribute within the space or room and simultaneously removal of stale air from space by natural or mechanical methods. Proper and sufficient air ventilation keeps low contaminant levels, maintains the indoor air humidity, pressure and temperature. The mechanical ventilation process involves the use of electric powered equipment such as blowers, motor driven fans, heating, ventilation, and air-conditioning (HVAC) systems, and local exhaust fans. In this process the supply fans supply the outdoor clean air to the space and exhaust fans remove the stale air from the space to maintain the air quality, humidity and temperature [6]. Building Automation Systems (BAS) or Building Management Systems (BMS) was an important instrument for the facility managers/operators to diminish the COVID-19 infections transmission during the current pandemic. Because of the BAS system they were able to modify the air ventilation strategy quickly to reduce the virus spread. The BAS/BMS is a computer networking system which includes integrated devices like supervisory controllers, application specific controllers and filed devices. Those devices control the building air conditioning units, heating, cooling & ventilation units, lighting, security systems, scheduling and energy management. BMS help to maintain the temperature, humidity, pressure and air quality inside the space.

2. Literature Review

Mr. Yan Zhang and his team finalized from their investigation that HVAC, drainage interruption, cleaning, and antisepticise methods are insufficient for the existing building to stop the indoor infection spread. This paper shows that the transmission dynamics of the respiratory virus at the constructive scale are not fully developed. They are impacted by lot of considerations, including building structural design, mechanical HVAC design and maintenance, sewage plants, washing methods, internal room structures, partitions, furniture arrangement, level of occupancy, and tenant behaviors. Their investigation identifies that there is a research gap in facility management interventions to prevent the virus transmission [7].

Yaolin Lin and his team presented a review on the influence of the COVID-19 on the indoor environmental conditions and HVAC system based on the relevant research and the building energy consumption [8]. They examined the building design, air filtration system, HVAC equipment, and air diffuser arrangement to study indoor ventilation. They proposed that natural ventilation and mechanical ventilation with extra devices can help to maintain a ventilated indoor environment in the room and to maintain improved indoor air quality. However, their proposed solution of 100% fresh air supply increases the building energy cost. They summarize that their future research should concentrate on developing efficient air purification systems and designing natural ventilation methods to lower the chances of infections during the pandemic and reduce energy consumption.

Safaa N. Saud Al-Humairi & Ahmad Aiman A. Kamal states that, COVID-19 brings noticeable changes to the community, and to tackle this type of future pandemic situation, we must make plans early and choose the steps. People are forced to stay at home to avoid infection transmission and, in this situation, buildings play the most important role in people's welfare. The various field researchers addressed the possible epidemic resolutions through technological interventions. This paper proposed a face recognition method and thermal infrared scanning technologies to reduce transmission. Thermal infrared scanning investigates the skin temperature, and a face recognition device can match a human face from a digital image. Those devices can be used simultaneously to scan the people walking by or coming through the building. This is a very expensive and challenging concept to check virus transmission within a building. This technology is not yet fully developed and there is no software or coding available yet. [9]. Daniel de Robles and Scott W. Kramer proposed ultraviolet germicidal irradiation (UVGI) technology to intercept sickness due to indoor air pollution within buildings [10]. The CDC (Centre for Disease Control) recommends installing surface and air disinfection equipment like ultraviolet germicidal irradiation (UVGI) or germicidal ultraviolet (GUV) in the HVAC system of hospitals, commercial, educational, and residential infrastructure. Ultraviolet germicidal irradiation (UVGI) uses ultraviolet (UV) energy to kill bacterial, viral, and fungal organisms in the air. UV lights can kill up to 99.9% of pathogenic cells by damaging DNA [11]. The building owner will have to consider the initial investment to install ultraviolet germicidal irradiation (UVGI) and periodic maintenance. Some experts claim that the UVGI system is a low-maintenance system; however, periodic UV lamp and filter replacement is required. If this system is not maintained periodically, then its performance will decline significantly. Without a proper preventative maintenance plan, building owners and tenants will face indoor air quality issues. A lot of studies recommend major HVAC system improvements, but building owners will have to be willing to make the initial investment and cover the full life cycle costs.

3. Building Automation System (BAS)

The building automation system (BAS) is a centralized control system to maintain the indoor comfort conditions. The main objective of the BAS is to provide efficient building operation at a reduced energy cost and to provide a comfortable environment for the building's occupants. The main components of the building automation system are microprocessor based DDC controllers, field devices like sensors, actuators & control valves, communication protocols, and user interface. The DDC controllers are the brain of the BAS system that receives the data from the sensor and makes a conclusion to take action to maintain the comfort level. A sensor that measures the temperature, CO2 level, humidity, pressure, occupancy and oxygen levels. The devices which accept the controller commands and take action to control the variables are called output devices like valves, damper actuators and field, panel mounted relays. DDC controllers communicate with each other by language called communication protocol, like BACnet, LON, Modbus etc. The BACnet (building automation and control networks) is the most acceptable communication protocol globally. The user interface or dashboard is the human interaction device with the BAS [12].

The BAS automates the heating, ventilation, and air conditioning equipment of the building to maintain temperature, humidity, building pressure, and indoor air quality. Based on building occupancy, they can adjust the air flow to maintain the indoor temperature and pressure. In HVAC systems, the most controlled conditions are temperature, humidity, pressure, and air flow. The automatic control system requires a controllable variable. The second variable called manipulating variable makes the required changes to the controlled variable. In a hot water coil duct heater system, the air flow passes through the hot water coil to maintain the zone temperature. In this system, temperature is a controlled variable, hot water is a control agent, air is the controlled medium, and water flow is a manipulated variable. When the zone temperature drops and needs heating, the thermostat activates the control valve actuator to regulate the water flow through the coil. In this way, the coil transfers heat to warm the room air.

3.1 Respiratory Infection Mitigation BAS Control Methodology

100% fresh air ventilation will significantly reduce and anticipate the spread of COVID-19. Owing to increasing outside air flow, the aerosolized particles become airborne instead of dropping on the ground. Respiratory infections like COVID-19 transmission can be reduced by HVAC (heating, ventilation, and air conditioning) system alteration and advanced control strategies. ASHRAE "recommends building owners and operators to increase their HVAC system's outdoor air ventilation to reduce the recirculation air back to the building space as much as the system and space conditions will allow." When adhering to these standards, controls engineers should consider system capacity as well as zone temperature and humidity requirements. Supplying excess outside air (OA) into space will consume more energy. ASHRAE research concluded that, if outside air flow increases by 20% to 90% in space, then the chilled water requirement boosts two times, the coil pressure drops three times and requires a double cooling source from the chilled water plant [13]. It is important to supply the correct quantity of the outside air into space. The various control strategies include, demand control ventilation (DCV), air flushing, nighttime free cooling, humidity control, Zone pressurization controls are useful to prevent virus transmission.

Demand controlled ventilation (DCV) is an energy-saving control technique to regulate the air flow setting within a building. According to the varying occupancy in a building. The DCV system can increase the air flow intensity during peak hours and automatically reduce the ventilation during off-peak periods to save energy. The DCV system detects indoor climate changes like CO2 levels, humidity and temperature and takes the necessary action to maintain comfort conditions and be free from pollution. This control strategy can be added to a DDC controller by adding some space CO2 sensors and Variable Frequency Drives (VFD) to the fixed speed fan motor. The air flow rate is controlled through the VFD drives and will save electric energy.

Air flushing is called a 'Purge Control Mode' in which the polluted air within space is flushed out of the building every day. This mode is activated prior to or post occupancy schedule for one to three hours, to minimize airborne infectious particle concentration by 95%. This would be achieved by controlling the air changes per hour (ACH) and adding the purge mode logic to the BAS controller. ACH is the measurement of the number of times a volume of air within a space that will be added, removed, or exchanged with filtered air. Air changes per hour (ACH) are an important factor in determining space ventilation effectiveness. For that, additional instrumentation like air flow stations is required to measure and control ACH. Nighttime free cooling is like purge mode, but it is activated and controlled by logic when the outside weather conditions are suitable.

Indoor air humidity is also an important factor to reduce the infectious particles transmission. When humidity levels are high over long periods of time in the room, then microorganisms such as mold, fungi and bacteria can grow rapidly. Inhaling or touching these microorganisms may cause allergic reactions for people with asthma or allergies to mold. Low humidity can cause discomfort and respiratory irritation. In BAS humidification mode and de-humidification mode strategies are implemented to control the room humidity. For example, in dehumidification mode is enabled by the BAS controller when the space humidity rises above the high limit set point of 50% RH (adj.) when outdoor air temperature rises above 60°F (adj.). The chilled water valve is modulated based on greatest demand of the supply air temperature control and dehumidification control. The mode is disabled when the space humidity falls 5% (adj.) below the set point. In this mode to prevent subcooling the reheat coil valve is enabled and modulated to maintain the supply air temperature and space temperature at set point (adj.).

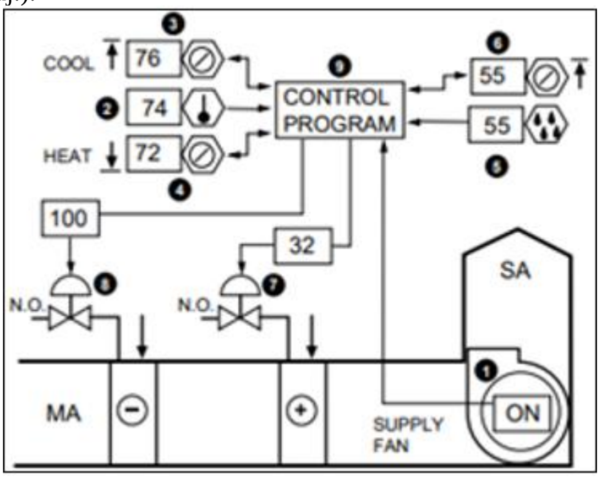

Figure 1: BAS Dehumidification Control Process

Room pressurization is the effective method to reduce virus transmission within a building. There are two types of room pressurization: positive pressurization and negative pressurization. Positive pressure rooms maintain a higher pressure inside the room than that of the adjacent room. It prevents contaminants from entering the positive pressure room. This means air cannot circulate back in the room. In this method, virus particles in the room will be filtered out. The clean linen laundry rooms are an example of the positive pressurization room in a hospital. Negative pressure rooms maintain a lower pressure inside the room than that of the

Paper ID: SR25401105639 DOI: https://dx.doi.org/10.21275/SR25401105639

surrounding zone. When the door is opened, potentially contaminated air or other dangerous particles from inside the room will not flow outside into non-contaminated zones. Soiled linens in the laundry room are the negative pressurization room in a hospital.

3.2 Air Filtration Methodology

The most common and effective HVAC system is air filtration. In an indoor environment, the lower average particulate matter (PPM) is considered to cause long-term occupants' health benefits. Other methods include irradiation and thermal sterilization [14]. The fibrous media make up the air filters, which help to remove particles from the airflow. Air filters are made of fibrous media to remove particles from the airflow. The polluted air passes through the filter, polluted particles attach to the fibrous media, and pure air is transmitted to the indoor space. Mechanical filters are categorized by their Minimum Efficiency Reporting Value (MERV), which reflects the percentage of particles they can remove. MERV 11-12 filters capture 65-80% of particles, 1-3 microns in size. MERV 13-15 filters capture 50-85% of particles, 0.3-1-micron size. 95% of particles are captured by the MERV 16 filters, 0.3-1.0 microns in size. 99.99% of particles, which are 0.3 microns in size, are captured by HEPA filters. MERV 16 and HEPA filters are the most effective method to reduce air-borne virus transmission. The higher the MERV ratings, the higher the energy costs because the resistance to airflow is increased through the filter. Traditional HVAC systems are unable to utilize the HEPA filters due to the high-pressure drop.

A common technique which is used in intensive care locations, such as hospitals to neutralize pathogens is called Ultraviolet Germicidal Irradiation (UVGI). Existing air-supply ducts can be installed with UVGI. This is the most effective method of destroying biological contaminants in the moving airstream. The intensity, along with the concentration of irradiation must be planned, considering factors such as lamp output under different temperatures and air speeds passing over the lamp. The strength and density of irradiation need to be engineered along with considerations of lamp output at various temperatures and air speeds across the lamp. The location is also an important factor when designing this air filtration system. Most often UVGI is placed immediately downstream of the HVAC coils to abstain from microbial growth on the coil, drain pan, and wet surfaces and treats the moving air.

4. Case Study

Upgrade HVAC in a District School through BAS control strategies-
The client, a school district, determined the significance of HVAC air transmission for student health, and overall well-being. They had concern about rising virus transmission issues and overall poor ventilation in the school. The school faced several challenges like inconsistent ventilation, difficulty in monitoring air quality, and higher energy bills. The existing traditional HVAC control system was inefficient in maintaining indoor air comfort conditions and ventilation.

A comprehensive Building Automation System (BAS) was proposed and executed to address the identified challenges. The system included programmable controllers, Temperature, humidity, building pressure Sensors, CO2 monitoring systems, and occupancy sensors. The controllers were installed for each HVAC system (rooftop units, VAVs, & Fan coil units), and temperature, humidity & CO2 sensors were installed in each zone. All field devices are placed to monitor the air parameters and communicate to the controller to take corrective actions to maintain the comfort conditions. All controllers are loaded with logic to operate all HVAC equipment to prevent the virus transmission into the air by maintaining proper ventilation.

The BAS enabled consistent and healthy air quality by adjusting ventilation rates and responding to occupancy changes. The optimum use of HVAC equipment operation with actual demands results in reduced energy bills. The improved ventilation and comfort conditions positively impacted on the well-being of students and staff, contributing to an overall healthy learning experience.

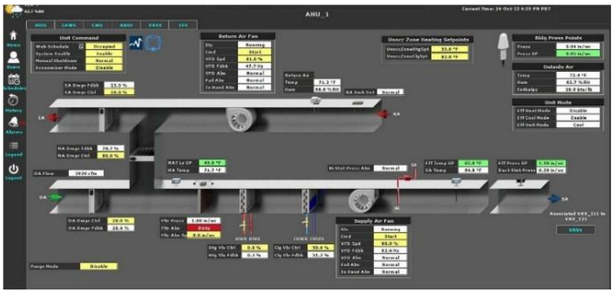

Figure 2: BAS HVAC system control dashboard

5. Challenges and Opportunities

Navigating the landscape of indoor HVAC systems amidst the threat of respiratory infections like COVID-19 comes on board with lots of opportunities and challenges. Moreover, opportunities exist in the adoption of various forms of advanced technologies like advanced building controls systems (BAS), UV-C germicidal irradiation and HEPA filtration, that can end up significantly enhancing the overall indoor air quality and at the same time scale down the spread of various pathogens. On the other hand, different challenges also emerge inform of financial constraints that are mainly associated with the implementation of all these solutions, retrofitting existing systems, and addressing the complexity of indoor environments. The art of balancing all these opportunities with various challenges always require a strategic planning, investments together with advanced levels of collaboration among different types of stakeholders to adequately mitigate the risks that are likely to be posed by respiratory infections in indoor settings. This research has many constraints and could be considered in future research work.

6. Recommendation

To adequately mitigate the risk of respiratory infections like COVID-19 in indoor environments, there is the need to take into consideration a diverse kind of an approach. This majorly entails investment in advanced HVAC technologies such as UV-C germicidal irradiation and HEPA filtration to improve indoor air quality. On the other hand, scaling up advanced forms of ventilation rates, introducing outdoor air and even going as far as implementing regular maintenance air protocols for HVAC systems are crucial. On the other hand, the promotion of advanced levels of awareness together with the adherence to CDC guidelines among different occupants, alongside encouraging behaviors like wearing masks indoors, can further help in the enhancement of different forms of proactive measures. Additionally, through an integration of all these recommendations into one of the most comprehensive risk mitigation strategies, it is much easier for the stakeholders to create safer indoor environments and even go as far as scaling down the spread of respiratory infections. Modifications to HVAC systems and controls logic help to reduce the spread of respiratory infections like COVID-19. It is recommended to add Variable Frequency Drives (VFD) to the fixed speed fan motor to maintain the building pressure by controlling air flow rate and result in electrical energy saving.

7. Conclusion

In this research, the intervention of building automation control strategies has been implemented in the HVAC systems to reduce respiratory infection transmission. The COVID-19 pandemic led to noticeable changes to society, and thus pandemic building owners should prepare a plan and take some appropriate steps for future disease pandemic. Scientists from various fields are dedicated to finding possible pandemic solutions through technological intervention and artificial intelligence. To solve virous transmission issues related to building facilities and learning from the COVID-19 pandemic are essential. Building automation systems play a crucial role in reducing infection transmission, especially in environments where people gather, such as offices, schools, hospitals, and public buildings. By implementing various controls strategies like demand control ventilation, Pre-occupancy, after-occupancy air flushing, Nighttime free cooling, Humidity control, and zone pressurization controls, the buildings can manage the indoor environment, including ventilation, air quality, and occupancy levels, to minimize the infectious diseases transmission like COVID-19. Building automation controls optimize indoor air ventilation, space temperature, humidity, CO_2 level, and occupancy management. BAS is a touchless solution and can provide real-time data monitoring and implement corrective actions to safeguard occupant health.

References

[1] Mazlan N, Tarofder APDAK, Al-Humairi SNS, Razalli H. COVID-19 PANDEMIC: Monitoring Technologies. Healthcare and Panic buying behavior: White Falcon Publishing; 2020. [Google Scholar]

[2] Neeltje van Doremalen et al, "Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1," New England Journal of Medicine, March 17, 2020, nejm.org.

[3] Apoorva Mandavilli, "293 experts with one big claim: The coronavirus is airborne," New York Times, July 4, 2020, nytimes.com.

[4] Taylor J. The Guardian; 2020. Victoria Hotel Quarantine Failures "Responsible" for Covid Second Wave and 768 Deaths, Inquiry Told. https://www.theguardian.com/australia-news/2020/sep/28/victoria-hotel quarantine-failures-responsiblefor-covid-second-wave-and-768-deaths-inquiry-told [Google Scholar]

[5] American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). ASHRAE position document on filtration and air cleaning [Internet]. Atlanta, GA: ASHRAE; 2015 [cited 2022 Aug 18].

[6] American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE). ASHRAE terminology: a comprehensive glossary of terms for the built environment [Internet]. Atlanta, GA: ASHRAE; 2021 [cited 2021 Jan 22]. Available from: https://xp20.ashrae.org/terminology.

[7] Yan Zhang, Felix Kin Peng Hui, Colin Duffield, and Ali Mohammed Saeed. A review of facilities management interventions to mitigate respiratory infections in existing buildings. Elsevier published on 2022 Jun 28.

[8] Yaolin Lina, Jiajun Wanga, Wei Yang b, Lin Tianc, Christhina Candido. A systematic review on COVID-19 related research in HVAC system and indoor environment. Science Direct-Energy and Built Environment.

[9] Safaa N. Saud Al-Humairi & Ahmad Aiman A. Kamal, Opportunities, and challenges for the building monitoring systems in the age-pandemic of COVID-19: Review and prospects. Springer Nature published on 2021 Jan 12.

[10] Daniel de Robles, Scott W. Kramer, 'Improving Indoor Air Quality Through The Use of Ultraviolet Technology In Commercial Buildings.' Science Direct Procedia Engineering, Creative Construction Conference 2017.

[11] Ventilation in building, COVID-19 Home by Centers for disease Control and Prevention (CDC) updates dated May 12, 2023.

[12] Vrushank Mistry, Impact of Building Automation on Indoor Air Quality and HVAC Performance. Journal of Artificial Intelligence & Cloud Computing. Published: November 16, 2023.

[13] "ASHRAE Epidemic Task Force," 17 & " Web October 27, 2020, 15.

[14] Al-Humairi, S.N.S. and Kamal, A.A.A., 2021. Opportunities and challenges for the building monitoring systems in the age-pandemic of COVID-19: Review and prospects. Innovative Infrastructure Solutions, 6, pp.1-10.

Author Profile

Pradip Thorat completed Master of Engineering (M.E.) degree in Mechanical engineering from Savitribai Phule Pune University in 2016. He has 14 years of experience in designing the Building Automation Controls systems. He is working with the Next Level HVAC Energy Management Systems, CA-USA. He worked with Honeywell automation, Johnson controls, Syserco Inc and various clients in multiple countries, including USA, Canada, KSA, & Qatar. He demonstrated expertise in project management, system design, commissioning, and customer support across various automation platforms, particularly in HVAC and refrigeration systems.