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SYSTEM AND METHOD FOR REMOTE MONITORING AND DIAGNOSTICS OF HVAC EQUIPMENT

Abstract

Described is a system and method for remote monitoring and diagnostics of heating, ventilation, and air conditioning (HVAC) equipment utilizing components to remotely monitor performance metrics for HVAC systems, report data to a centralized database for analysis and formulate a remediation plan. The system and method use monitoring devices which monitor air quality data and other data from the HVAC system. IoT and cloud-based solutions transmit data from monitoring devices to a centralized database for analysis/storage. An application program uses algorithms to analyze data to provide actionable alerts to the user if maintenance is needed. The algorithm is a control sequence for use in HVAC settings and uses logic based on the operating conditions reported by monitoring devices. If a need for system investigation or equipment maintenance is identified, the system generates an alert to the HVAC maintenance team for validation before sending the alert to the customer.

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Background/Summary

RELATED APPLICATION [0001] This Application claims priority to U.S. Provisional Application 63/555,862 filed Feb. 20, 2024, which is incorporated herein by reference in its entirety.

STATEMENT REGARDING FEDERALLY FUNDED RESEARCH
[0002] None.
FIELD
[0003] Embodiments are directed generally to the field of mechanical systems and more particularly new and retrofit Heating, Ventilation, and Air Conditioning (HVAC) systems.
BACKGROUND
[0004] Heating, Ventilation, and Air Conditioning (HVAC) systems are integral to maintaining comfort and health within residential buildings. They regulate indoor climate by managing temperature, humidity, and air quality. Traditional systems rely on manual checks, periodic maintenance, and reactive repairs, which can lead to inefficiencies, higher energy consumption, unexpected breakdowns, and poor indoor air quality.
[0005] Commercial HVAC systems require sophisticated monitoring to maintain efficiency, comfort, and air quality across large spaces. System monitoring in these settings involves a range of expenses, including: (1) installation of numerous sensors (at multiple locations), wiring, conduit, controllers, gateways, computers, and software for real-time data analysis can be significantly high due to the complexity and scale of commercial buildings. Costs can range from two to five thousand dollars for each monitored control point; (2) Continuous maintenance, calibration of sensors, and integration with building management systems (BMS) contribute to ongoing expenses. This includes costs for fault detection, targeted maintenance, and ensuring optimal energy use through smart controls; (3) monitoring systems allow for better energy consumption tracking and management, which can lead to savings but requires investment in technologies like Direct Digital Controls (DDC) and various sensors for different metrics (temperature, humidity, airspeed, etc.); (4) regular assessments by HVAC technicians to interpret data, perform maintenance, and address issues before they escalate into more costly repairs or replacements.
[0006] Residential systems are typically smaller and less complex, making the cost-benefit analysis of installing comprehensive monitoring systems less favorable. Residential setups might only include a smart thermostat, which is much less expensive but also less comprehensive. The expense of installing a full commercial type monitoring system in a residence does not justify the potential energy savings or maintenance benefits, especially considering the lower usage intensity compared to commercial spaces. The initial cost for such systems in residences is cost prohibitive for many homeowners, particularly when simpler, less costly solutions like smart thermostats exist.
[0007] Residential HVAC systems do not undergo the same level of wear and tear as commercial systems due to differences in scale and hours of use. Hence, the need for expensive monitoring and predictive maintenance does not align with the typical residential scenario. The savings from energy efficiency or reduced maintenance would take years to offset the initial investment in a current monitoring system in a residential context, where energy consumption and system load are

generally lower. In fact, the amount of time it would take to pay back the initial investment with energy and maintenance savings would exceed the life of the HVAC equipment itself.

[0008] While commercial HVAC systems benefit from extensive monitoring to manage efficiency and maintenance across large areas, the same level of investment in residential settings is generally not cost-effective due to the smaller scale, lower operational demands, and higher relative cost per unit of benefit.

[0009] There remains a need for cost effective residential HVAC monitoring devices and systems.

SUMMARY

[0010] Challenges related to remote HVAC management in residential systems include (i) generation of false alarms and errors; (ii) cost of initial investment to setup IoT-enabled HVAC systems can be costly; (iii) privacy and security concerns with internet connectivity increases the risk of data breaches; (iv) complexity for users, not all homeowners will be comfortable with the technology or understand how to maximize its benefits; and compatibility with older systems can result in problems retrofitting with monitoring solutions, potentially requiring complete HVAC system upgrades.

[0011] Embodiments of the present invention provide monitoring and maintenance systems for an HVAC system that address at least one of the abovementioned problems or deficiencies and provides a consumer with a useful non-commercial choice. Some of the unique aspects of the unit include: (1) The configuration for and the receiving of input from both external sensors (temp, pressure, IAQ) and the HVAC system (cooling, heating, fan) to determine if the HVAC system is functioning appropriately, e.g., calling for cooling and the supply temp has expectedly reduced, or calling for fan operation and the differential air pressure has expectedly increased across the filter. (2) In addition, the HVAC monitoring device is powered directly from the HVAC system not requiring any additional power sources such as a wall plug or battery.

[0012] Certain embodiments are directed to an HVAC monitoring system comprising: a monitoring device configured to connect directly to and receive power from an existing residential HVAC unit, the device having one or more HVAC sensors and/or environmental sensors, the HVAC sensors configured to monitor the operation of heating, ventilation, and air conditioning components of a new or existing residential HVAC unit (internal conditions) and the sensors configured to measure air quality conditions of air supplied by the residential HVAC; and a communication module for transmitting data to and receiving data from a remote monitoring system; wherein the device can be further configured to execute a training phase during an initial period of operation, wherein the training phase includes collecting data from at least one sensor regarding internal and environmental conditions; establishing baseline operational parameters and alert thresholds for the residential HVAC unit based on the collected data; transition from the training phase to a remote monitoring regime upon completion of the training phase, wherein the remote monitoring regime includes: continuously monitoring the operational data of the residential HVAC unit through the communication module; transmitting the operational data to a remote server for analysis; and displaying data, alerts, and operational recommendations via an online portal. The environmental conditions can include, but are not limited to temperature, humidity, carbon dioxide, total volatile organic compounds, and an air quality index. The online portal can be a graphical user interface, including but not limited to a mobile application or webpage. The operation of HVAC components of a residential HVAC unit can include, but is not limited to measuring or determining filter differential pressure (inches water column), input power voltage (Volts), leaving air carbon dioxide (PPM), leaving air total volatile organic compounds (VOCs PPB), leaving air quality index, leaving air particulate count, leaving air humidity (% RH), leaving air drybulb temperature (° F.), system cooling mode (on/off), system heating mode (on/off), system fan only mode (on/off), outdoor air temperature Max (° F.), outdoor air temperature Min (° F.), outdoor air temperature average (° F.), outdoor air quality, cooling degree days (CDD), heating degree days (HDD), input power voltage max (V), input power voltage min (V), input power voltage average (V), cooling or heating or fan only runtime duration (minutes), total cooling or heating or fan only runtime (Minutes), consecutive maximum cooling or heating or fan only runtime (Minutes), consecutive minimum cooling or heating or fan only runtime (Minutes), consecutive average cooling or heating or fan only runtime (Minutes), consecutive maximum temperature (° F.) during cooling or heating or fan only runtime, consecutive minimum temperature (° F.) during cooling or heating or fan only runtime, consecutive average maximum temperature (° F.) during cooling or heating or fan only runtime, consecutive average minimum temperature (° F.) during cooling or heating or fan only runtime, consecutive filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive maximum filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive minimum filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive average filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive average maximum filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive average minimum filter differential pressure (inches water column) during cooling or heating or fan only runtime, or any combination or all of the above.

[0013] Certain embodiments are directed to a self-contained HVAC monitoring device comprising a plurality of sensors and communication module, the self-contained HVAC monitoring device configured to be position within an HVAC system and wire directly into an HVAC power source. The plurality of sensors can include but is not limited to an air quality sensor, a temperature sensor, a pressure sensor, and a humidity sensor. In certain aspects the communication module is Bluetooth, cellular data, and WiFi enabled or otherwise in communication with the internet.

[0014] Other embodiments are directed to methods for monitoring a residential HVAC system comprising: (i) monitoring HVAC parameters using a self-contained HVAC monitoring device configured to measure various conditions and gather data; (ii) transmitting the data to a central database; (iii) processing the data using programming at the central database; (iv) performance and status is assessed and determinations are made regarding information transmission to users and technicians; and (v) transmitting a status notification, maintenance recommendation, or an alert if such transmission is determined to be necessary.

[0015] Other embodiments of the invention are discussed throughout this application. Any embodiment discussed with respect to one aspect of the invention applies to other aspects of the invention as well and vice versa. Each embodiment described herein is understood to be embodiments of the invention that are applicable to all aspects of the invention. It is contemplated that any embodiment discussed herein can be implemented with respect to any method or composition of the invention, and vice versa. Furthermore, compositions and kits of the invention can be used to achieve methods of the invention.

[0016] The use of the word “a” or “an” when used in conjunction with the term “comprising” in the claims and/or the specification may mean “one,” but it is also consistent with the meaning of “one or more,” “at least one,” and “one or more than one.”

[0017] Throughout this application, the term “about” is used to indicate that a value includes the standard deviation of error for the device or method being employed to determine the value.

[0018] The use of the term “or” in the claims is used to mean “and/or” unless explicitly indicated to refer to alternatives only or the alternatives are mutually exclusive, although the disclosure supports a definition that refers to only alternatives and “and/or.”

[0019] As used in this specification and claim(s), the words “comprising” (and any form of comprising, such as “comprise” and “comprises”), “having” (and any form of having, such as “have” and “has”), “including” (and any form of including, such as “includes” and “include”) or “containing” (and any form of containing, such as “contains” and “contain”) are inclusive or open-ended and do not exclude additional, unrecited elements or method steps.

[0020] As used herein, the transitional phrases “consists of” and “consisting of” exclude any element, step, or component not specified. When the phrase “consists of” or “consisting of”

appears in a clause of the body of a claim, rather than immediately following the preamble, the phrase “consists of” or “consisting of” limits only the elements (or components or steps) set forth in that clause; other elements (or components) are not excluded from the claim as a whole.
[0021] As used herein, the transitional phrases “consists essentially of” and “consisting essentially of” are used to define a composition and/or method that includes materials, steps, features, components, or elements, in addition to those literally disclosed, provided that these additional materials, steps, features, components, or elements do not materially affect the basic and novel characteristic(s) of the claimed invention. The term “consisting essentially of” occupies a middle ground between “comprising” and “consisting of”.
[0022] Other objects, features and advantages of the present invention will become apparent from the following detailed description. It should be understood, however, that the detailed description and the specific examples, while indicating specific embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

Description

DESCRIPTION OF THE DRAWINGS
[0023] The following drawings form part of the present specification and are included to further demonstrate certain aspects of the present invention. The invention may be better understood by reference to one or more of these drawings in combination with the detailed description of the specification embodiments presented herein.
[0024] FIG. **1**. Diagram of a system.
[0025] FIG. **2**. Illustration of a general flow of system operation.
DESCRIPTION
[0026] The following discussion is directed to various embodiments of the invention. The term “invention” is not intended to refer to any particular embodiment or otherwise limit the scope of the disclosure. Although one or more of these embodiments may be preferred, the embodiments disclosed should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. In addition, one skilled in the art will understand that the following description has broad application, and the discussion of any embodiment is meant only to be an example of that embodiment, and not intended to imply that the scope of the disclosure, including the claims, is limited to that embodiment.
[0027] The advent of IoT (Internet of Things) technologies has revolutionized how HVAC systems operate, particularly in residences. Remote monitoring of HVAC systems involves connecting various components of the HVAC setup to the internet, allowing for real-time data collection, analysis, and control from a distance. This technology leverages sensors, and connectivity solutions to monitor performance by connecting to an indoor air-handler's control board and using sensors to gather data on aspects like temperature, pressure, airflow, and indoor air quality, providing insights into the system's operation and efficiency; suggest predictive maintenance by analyzing data trends, systems can predict potential failures or maintenance needs before they become critical, thus preventing system breakdowns and extending the life of equipment; can make recommendations for system adjustments to improve comfort and energy efficiency.
[0028] There is a growing trend towards integrating HVAC controls with broader smart home ecosystems for a seamless user experience. Advanced algorithms and machine learning are being used to make more precise predictions and optimizations. Efforts are underway to standardize IoT protocols in HVAC, ensuring interoperability and security. While adoption is increasing, particularly in new constructions, there is still a significant push needed in the retrofit market. Commercial systems generate an enormous amount of data related to vast areas of space and

multiple environmental systems integrated into a commercial monitoring system. Much of this is not utilized because the amount of data cannot be processed to a functional end, it is the proverbial paralysis by analysis problem. Aspects of the algorithms implemented in conjunction with the devices and systems described herein provide a solution to the paralysis by analysis problem by providing an efficient and cost-effect residential HVAC monitoring solution, which can be used in either new or retrofit situations.

[0029] FIG. **1** provides a diagram of a residential HVAC system comprising an air handler **102** coupled to a thermostat **101** and self-contained monitor **103**. Self contained monitor **103** is connected to a remote database **104** and is located in the connection between air handler **102** and supply ducts **105**, evaporator coils **106**, and return ducts **107**. Supply ducts **104** feed into air distribution **108**. Return ducts **107** are connected to air return **109**. Evaporator coils **106** are connected to compressor **110** with air return **109** and compressor **110** connecting down stream of air distribution **108** and into air filter **111** which is in turn connected to blower fan **112**.

[0030] Disclosed herein is a system and method for remote monitoring and diagnostics of heating, ventilation, and air conditioning (HVAC) equipment utilizing hardware and software components to remotely monitor performance metrics for HVAC systems and report data to a centralized database for analysis and formulation of a monitoring, maintenance, and/or remediation plan. The system and method use hardware monitoring devices which monitor key performance variables from the HVAC system. IoT and cloud-based solutions transmit data from monitoring devices in the HVAC system (e.g., self-contained monitoring device) to a centralized database for analysis and storage. An application program uses specialized algorithms to analyze data received from the HVAC monitoring device and can then provide actionable alerts to the HVAC system owner or technician if repair or maintenance is needed. The implementation process and program allow for the minimization of false alarms and errors by providing a calibration or integration period onsite in its installed environment while providing a cost-effective monitoring option, in both new and retrofit residential applications.

[0031] The specialized algorithm is a control sequence for use in an HVAC setting for monitoring and assessing the operating conditions reported by a monitoring device(s). When the specialized algorithm identifies an actionable issue, an alert is generated by the system and sent to the HVAC maintenance team to validate the alert before sending the alert to the customer.

[0032] The disclosed system uses a hardware monitoring device (e.g., self-contained monitor) having sensors for measuring numerous metrics related to air quality and equipment performance, such as air temperature, leaving air relative humidity, indoor air quality, and filter pressure drop. This monitoring device can be wired directly to the HVAC system thus need not require a battery or other power source. The monitoring device can also take key reading indicative of cooling, heating, and fan only modes of operation. The monitoring device can be installed in equipment associated with one HVAC system. The monitoring device is able to monitor performance of the HVAC system and report data associated with the readings for analysis and evaluation. The monitoring device can be connected to a centralized database, e.g., via WIFI or other communication mode, to enable application and transmit the data to a centralized database. A general flow of the initiation and operation of a system is diagramed in FIG. **2**. Once the HVAC unit is started with the appropriate monitoring device(s) in place initial data is collected and stored. The initial data collection and storage is used in a calibration period or integration mode to establish parameters and conditions as a base line for system evaluation going forward. A calibration period or integration mode can be initiated periodically during the life of the system, e.g., every 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12 weeks, months, quarter, or year. Once the calibration period or integration mode is complete the system enters an active or condition assessment mode that includes receiving data over time, processing the data, evaluating and comparing recent data with historical data, determining threshold points, aggregating data over time, and generating a system response based on continuous and/or intermittent data collection/analysis. When the data is received at the centralized database, the data is analyzed for indications of immediate failure or performance deterioration of the HVAC equipment. The application programing has data for the optimal ranges of key metrics and the analysis of the data in conjunction with the programmed criteria for the key metrics can determine what is occurring in the system and identify the most likely cause of a problem when one or more metric is out of range or trending towards a threshold. If failure or deterioration or trend to problematic state is identified from the data analysis, actionable alerts may be provided to the HVAC system owners or technicians, which allow users to instigate mitigation or remediation measures prior to entering a problematic state or system malfunction.

[0033] Certain embodiments are directed to methods of monitoring/assessing or remote monitoring/assessing of a HVAC system performance using a specialized application program or control unit via local one or more local onsite hardware monitoring device(s). Data received from or generated by the monitoring device(s) sensor(s) is transmitted from the onsite HVAC equipment to a remote centralized database, e.g., via WIFI or other communication devices/methods. The data received is analyzed using a specialized application program. In certain aspects the specialized application program analyzes continuous or intermittent measures to identify trends indicative of failure, immediate failure, and/or performance deterioration for HVAC equipment. If imminent failure or performance deterioration is identified in the analysis, specialized application programming provides communications to HVAC users or monitors with actionable alerts identifying problems and providing solutions to the identified problems.

[0034] The application program uses specialized algorithms to process data received from monitoring devices and provide actionable alerts. The application algorithm is a control sequence used in an HVAC setting and uses various logic-based processing on the operating conditions reported by the monitoring device(s). When the control unit running one or more algorithms identifies an actionable issue an alert is generated by the system and sent to selected persons or entities to validate the alert, once validated the alert is sent to a customer and/or HVAC technician.

[0035] The control unit is configured to support monitoring device setup, credential entry and verification to databases, monitoring device operation and maintenance. In some embodiments, the control unit connects to shortrange wireless signals sent by the hardware device, presents a form to the HVAC user to input identifying data as a part of setup, presents a Wi-Fi form to connect to users Wi-Fi, then confirms connection to the database once complete.

[0036] Monitoring device(s) in the HVAC system is programmed to record data points on a set schedule, e.g., every two minutes. Readings for the specified types of data are recorded at the monitoring device(s) and transmitted to the centralized database on a scheduled basis, or the data may be sent as a push notification depending on the type of reading received, for example, if a critical threshold is approaching or has been passed. Monitoring device(s) data points may include, but are not limited to, date and time, filter differential pressure (DP-measured in inches water column), input voltage, leaving coil equivalent CO.sub.2 (eCO2), leaving coil total volatile organic compounds (TVOC), air quality index (AQI), leaving coil relative humidity (RH), leaving coil temperature, and thermostat call (on or off) for heating, cooling, or fan only operation. Data points may also include outdoor air temperature, outdoor air humidity, and outdoor air quality index. Outdoor air data is especially useful in the analysis of the monitoring device(s) data when outdoor conditions are significantly above or below normal or calibrated parameters.

[0037] The monitoring device(s) data points are used to generate calculated data points for the HVAC system. Calculated data points include daily readings for system cooling, such as daily cooling total run time, daily cooling maximum and minimum consecutive run times, and cooling occurrences less than 10 minutes. Calculated data points include daily readings for system heating, such as daily heating total run time, daily heating maximum and minimum consecutive run times, and heating occurrences less than 10 minutes. Calculated data points also include overall system readings, such as daily time off, daily maximum and minimum consecutive off times, and daily occurrences of less than 5 minutes off time for the system.

[0038] When these measured and calculated data points are analyzed by the control unit running the application program, immediate or imminent system failures can be detected as can performance deterioration for the HVAC equipment. The logic of the algorithm identifies the most likely cause of the failure based on the measured and calculated data.

[0039] Herein provided are some examples of possible system failures identified by analysis of key metrics. These are examples only and are not inclusive of all possible system failures that may occur or potential issues that may be identified by the algorithm.

[0040] Refrigerant Leak. A refrigerant leak may be identified by analysis of the following data—leaving air temperature (LAT), system in cooling mode, and positive filter pressure drop (indicating fan operation). The criteria for diagnosis of this problem would be: if the LAT is greater than the average LAT for the system, cooling is active, and the fan is operating, with an increased cooling run time, then the cause is likely due to an inadequate amount of refrigerant indicating that a leak has occurred. The criteria can be set to specify how much of a rise in leaving air temperature and how much longer the cooling run time must be in order to trigger an alert. System criteria can also take into consideration outdoor environmental factors such as outdoor air temperature and humidity that may affect runtimes and LAT.

[0041] Compressor Short Cycle. A compressor short cycle may be identified by analysis of the following data—System cooling mode is active with a positive filter pressure drop (indicating fan operation). The criteria for diagnosis of this problem would be: if the last **3** calls for cooling exceed the established acceptable time and last for less than the established acceptable time, then the cause may be the compressor is running short cycles. This may trigger an alert that the compressor is not keeping up with the demand and may be subject to failure.

[0042] Provided herein are some examples of possible alerts that might be issued to users for mitigation or remediation of an HVAC problem identified by data analysis by the control unit. These are examples only and are not inclusive of all possible alerts that may be issued, or potential issues that may be identified by the algorithm.

[0043] Reduced Airflow. If the readings for the filter differential pressure fall significantly out of range and other systems are operating properly, an alert may be issued regarding the filter. After evaluation by a team member, an alert may be sent to the system owner or technician recommending that the air filter be replaced, along with advising that dirty air filters can lead to higher energy bills and equipment malfunction.

[0044] Cooling Energy Use is Elevated. If the cumulative monthly cooling runtime and cooling degree days show runtime is consistently exceeding the expected runtime for the environmental conditions, an alert may be issued to the team regarding the out-of-range runtime. An alert may then be sent to the system owner or technician with possible causes of the extended runtime and recommending that the equipment be evaluated to determine the cause of the runtime issue and provide repair or maintenance options to prevent system failure.

[0045] High Humidity/Mold Risk. If air conditions delivered to the space exceed certain thresholds for an extended period of time, the risk of mold growth is present. An alert may then be sent to the user recommending additional relative humidity or moisture content testing in the occupied spaces of the home and potentially intervention from a qualified service provider, licensed to test for mold and interpret the results.

[0046] These are just a few examples of where the disclosed system would be able to identify a problem with the HVAC system and provide alerts and/or remediation advice to a user. These examples are not intended to show the entire scope of the system and method of the invention.

[0047] A monitoring system can include a thermostat, one or more monitoring devices, a computing cloud, and a control unit running a software application. The computing cloud may communicate with the monitoring device(s) and the control unit. An intermediate user and/or end user may interact with control unit to communicate to the computing cloud.

[0048] The system for monitoring and controlling the environment comprises an HVAC system, a monitoring device(s), and control unit. The monitoring device(s) are in communication with the control unit. The system can include a computing cloud which is accessible through the Internet or other communication system. Communication links may not be direct connections between components and may rely on other intermediate devices to facilitate the communication links.
[0049] Unless specifically stated otherwise, it shall be understood that disclosure employing the terms "coupling," "receiving," "communicating," "computing," "determining," "calculating," and others refer to a data processing system or other electronic device manipulating or transforming data within the device memories or controllers into other data within the system memories or registers. When applicable, the ordering of the various steps described herein may be changed, combined into composite steps, or separated into sub-steps to provide the features described herein.
[0050] Computer programs such as a program, software, software application, code, or script may be written in any computer programming language including conventional technologies, object-oriented technologies, interpreted or compiled languages, and can be a module, component, or function. Computer programs may be executed in one or more processors or computer systems.
[0051] In certain aspects a monitoring and maintenance system for a HVAC system includes at least one remotely accessible server; at least one monitoring device operatively connected to at least one communication system and configured to acquire data (operational and environmental) and transmit along the at least one communication line or system; and a control unit operatively connected to a monitoring device(s) and configured to provide for system initiation including calibration or integration, and assessment and analysis processes including receiving and storing data acquired by monitoring device(s); identifying any operational anomalies by analyzing the data; generating response to conditions or status identified by the software program of the control unit; and transmitting messages to interested parties such as a technician, home owner, or monitor of a HVAC system.
[0052] Advantageously, the systems and method of the present invention enable a plurality of HVAC systems to be remotely monitored so that any operational conditions or anomalies may be readily identified and addressed. The result of processing the data can include transmitting a maintenance request, or transmitting a warning or alert to a homeowner, a technician, or a third party. Furthermore, the tiered maintenance required status and requests enable a suitably qualified technician to be dispatched for the anomaly meaning qualified HVAC technicians will be freed up to attend to more severe anomalies than minor or false anomalies.
[0053] An HVAC system may include any suitable type of air conditioning system. For example, in some embodiments, the HVAC system may include a packaged direct-expansion (DX) air conditioner system. In other embodiments, the HVAC system may include a split DX system with at least one indoor unit, at least one outdoor unit and at least one communication line extending therebetween. The HVAC system can be capable of modifying the condition of air to provide outdoor air, filtration, cooling, heating, and humidification. The HVAC system may be a ducted or ductless system. The HVAC system may also include a DX refrigeration cycle, typically extending between at least one indoor unit and at least one outdoor unit or a packaged unit. The HVAC system may be a ductless split-type air conditioner with an indoor unit and at least one outdoor unit located external to a structure. The outdoor unit may include an outdoor heat exchanger, a compressor, a fan and an outdoor controller for controlling the compressor and the fan. The outdoor controller may typically include a microcomputer.
[0054] An indoor unit may generally be located within a structure. The indoor unit may include an indoor heat exchanger for cooling and heating, a fan for blowing air to the indoor heat exchanger, air filtration, an outdoor air damper, a humidifier, and an indoor controller for controlling operation of the system. The indoor controller may typically include a microcomputer like with the outdoor controller.
[0055] A monitoring device can include a plurality of sensors each configured to acquire

operational or environmental data for the HVAC system. Examples of operational data may include but are not limited to: intake pressure, discharge pressure, compressor temperature, outdoor unit expansion valve opening, indoor unit expansion valve opening, compressor current, compressor frequency, atmospheric temperature, evaporation temperature, suction temperature, suction temperature, blowout temperature, gas pipe temperature, liquid pipe temperature and set temperature. Examples of the sensors include but are not limited to temperature sensors, humidity sensors, motion sensors, infra-red sensors, current sensors, voltage sensors, air (atmospheric) pressure sensors, flow pressure sensors, and overflow safety switch sensors.

[0056] A communication system can include a network. The network may be a computer network or data network and may be a wired or wireless network.

[0057] A remotely accessible server may be any appropriate server computer, distributed server computer, cloud-based server computer, sever computer cluster or the like. The server may typically include one or more processors and one or more memory units containing executable instructions/software to be executed by the one or more processors. Generally, the server may be in communication with at least one database.

[0058] The remotely accessible server is configured to receive/transmit communications from/to monitoring device(s) operatively connected to a HVAC system. The communications may be received and transmitted over any suitable communications network or networks. For example, the communications may be received and transmitted over a communications network, which may include, among others, the Internet, LANs, WANs, GPRS network, a mobile-communications network, etc., and may include wired and/or wireless communications. The communications network may be a secure communications network, such as, e.g., an encrypted communication channel such as Hypertext Transfer Protocol Secure (HTTPS), Transport Layer Security/Secure Sockets Layer (TLS/SSL) or other secure channel.

[0059] Communication between the electronic device and the remotely accessible server may be effected by way of Short Message Service (SMS) protocol, Unstructured Supplementary Service Data (USSD) protocol, over a secure Internet connection, or by way of data communication enabled by a software application installed on the electronic device.

[0060] Control unit can include at least one processor, at least one memory unit and at least one display. The control unit may be in the form of a desktop computer, a laptop computer, a tablet device, a smart phone, a smart watch or a PDA, for example.

[0061] The monitoring device(s) are hardware configured to be coupled to a communication network in a wired or wireless arrangement.

[0062] The operational data received may typically include an identifier, e.g., a record/account number or username, to assist in identification of a HVAC system.

[0063] Normal operational data may be provided in the form of calibration or integration data ranges and the anomaly identifying component may compare the operational data received and stored against the calibration or integration data ranges to assist in analyzing operation or identifying any anomaly.

[0064] The analysis or processing include algorithms for comparing the operational data received and stored for the HVAC system against calibration or integration data for the HVAC system and for recognizing differences in operating trends to identify anomalies.

[0065] Analysis or processing can include algorithms for comparing operational data received and stored for the HVAC system against local environmental data for HVAC systems. In certain aspects the algorithm may take into account seasonal fluctuations.

[0066] In certain aspects a monitoring device described herein can be added to new equipment or retrofitted to an installed HVAC system and the monitoring system used to provide analysis of data received. A device is powered by the HVAC unit and can integrate unit information (thermostat etc.) with information provided by the installed monitoring device to provide analysis of equipment performance etc.

[0067] Information provided by a monitoring device and/or sensors can include: local date and time, filter differential pressure (inches water column), input power voltage (Volts), leaving air carbon dioxide (PPM), leaving air total volatile organic compounds (VOCs PPB), leaving air quality index, leaving air particulate count, leaving air humidity (% RH), leaving air drybulb Temperature (° F.), system cooling mode (on/off), system heating mode (on/off), system fan only mode (on/off), outdoor air temperature Max (° F.), outdoor air temperature Min (° F.), outdoor air temperature average (° F.), outdoor air quality, cooling degree days (CDD), heating degree days (HDD), input power voltage max (V), input power voltage min (V), input power voltage average (V), cooling or heating or fan only runtime duration (minutes), total cooling or heating or fan only runtime (Minutes), consecutive maximum cooling or heating or fan only runtime (Minutes), consecutive minimum cooling or heating or fan only runtime (Minutes), consecutive average cooling or heating or fan only runtime (Minutes), consecutive maximum temperature (° F.) during cooling or heating or fan only runtime, consecutive minimum temperature (° F.) during cooling or heating or fan only runtime, consecutive average maximum temperature (° F.) during cooling or heating or fan only runtime, consecutive average minimum temperature (° F.) during cooling or heating or fan only runtime, consecutive filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive maximum filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive minimum filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive average filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive average maximum filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive average minimum filter differential pressure (inches water column) during cooling or heating or fan only runtime, or any combination or all of the above.

[0068] Various errors can be logged as data points including data points for cooling on fan off error, cooling short cycle error, heating on fan off error, fan off error, fan on error, or a combination or all of the above errors.

[0069] In certain aspects the algorithm will enable alarms, warnings, suggestions, recommendations, etc. related to intervention, preventative/predictive maintenance, or repairs including but not limited to notifications to evaluate cooling system on-site, likely compressor failure based on thermostat call for cooling and/or filter pressure drop similar to previous daily average cooling filter pressure drop and/or leaving air temperature higher than previous daily average cooling leaving; evaluate heating system on-site—for gas furnaces, likely malfunctioning starting mechanism, flame sensor, or the pilot light is out—for heat pump systems, likely debris is clogging or blocking the outdoor condenser coils based on thermostat call for heating and/or filter pressure drop similar to previous daily average heating filter pressure drop and/or leaving air temperature less than previous daily average heating leaving air temperature; evaluate thermostat and control board on-site, likely incorrect thermostat wiring based on thermostat call for cooling and/or confirmation of airflow via differential pressure (DP) and/or excessively high leaving air temperatures; evaluate thermostat and control board on-site, likely incorrect thermostat wiring based on thermostat call for heating and/or confirmation of airflow via DP and/or excessively low leaving air temperatures; evaluate thermostat and control board on-site, likely incorrect thermostat wiring based on thermostat call for fan only and/or confirmation of airflow via DP and/or excessively high leaving air temperatures; evaluate thermostat and control board on-site, likely incorrect thermostat wiring based on thermostat call for fan only and/or confirmation of airflow via DP and/or excessively low leaving air temperatures; evaluate thermostat and control board on-site. Likely malfunctioning control board or thermostat based on no daily total cooling cycle run time with elevated daily average outdoor temp; evaluate thermostat and control board on-site, likely malfunctioning control board or thermostat based on no daily total heating cycle run time with reduced daily average outdoor temp; time to replace the air filter(s) if filter differential pressure

(DP) at a predetermined level.

[0070] The algorithm can include the identification and transmission of preventative/predictive trends to home owner, technician, or other entities including but not limited to evaluate cooling system on-site, likely refrigerant leak or malfunctioning reversing valve for heat pumps based on increase in daily total cooling cycle run times normalized with daily average outdoor temps and/or normal increase or no change in daily average cooling filter pressure drops and/or increase in daily average cooling leaving air temps; evaluate cooling system on-site, likely compressor malfunction based on increase in daily total cooling cycle run times normalized with daily average outdoor temps and/or normal increase or no change in daily average cooling filter pressure drops and/or increase in daily average cooling leaving air temps; evaluate cooling system on-site, likely frozen coil based on increase in daily total cooling cycle run times normalized with daily average outdoor temps and/or decrease in daily average cooling filter pressure drops and/or increase in daily average cooling leaving air temps; evaluate cooling system on-site, compressor is short cycling-coils could be dirty, the condenser might be clogged with debris, the thermostat might be malfunctioning, the low pressure control switch might be faulty, or the compressor motor may be wearing out based on numerous occurrences of cooling short cycles; evaluate air handler fan system on-site, likely malfunctioning fan component (e.g. bearings, belts, capacitor) based on increase in daily total cooling cycle run times normalized with daily average outdoor temps and/or decrease in daily average cooling filter pressure drop and/or decrease in daily average cooling leaving air temps; evaluate air handler fan system on-site. likely malfunctioning fan component (e.g. bearings, belts, capacitor) based on increase in daily total heating cycle run times normalized with daily average outdoor temps and/or decrease in daily average heating filter pressure drop and/or increase in daily average heating leaving air temps; evaluate heating system on-site, likely cracked heat exchanger for gas furnaces or malfunctioning reversing valve for heat pump systems based on increase in daily total heating cycle run times normalized with daily average outdoor temps and/or normal increase or no change in daily average heating filter pressure drops and/or decrease in daily average heating leaving air temps; evaluate heating system on-site, likely malfunctioning high limit switch for gas furnaces based on decrease in daily total heating cycle run times normalized with daily average outdoor temps and/or normal increase or no change in daily average heating filter pressure drops and/or increase in daily average heating leaving air temps; Filter(s) are approaching the end of their useful life, filter replacement is recommended within the next month.

Claims

1. An HVAC monitoring system comprising: a monitoring device configured to connect directly to and receive power from a new or existing residential HVAC system, the device having one or more HVAC sensors and or environmental sensors, the HVAC sensors configured to monitor the operation of heating, ventilation, and air conditioning components of a new or existing residential HVAC system (internal conditions) and the environmental sensors configured to measure environmental conditions external to a new or existing residential HVAC system; a communication module for transmitting data to and receiving data from a remote monitoring system; wherein the device is further configured to: execute a training phase during an initial period of operation, wherein the training phase includes: collecting data from at least one sensor regarding internal and environmental conditions; establishing baseline operational parameters and alert thresholds for the new or existing residential HVAC system based on the collected data; transition from the training phase to a remote monitoring regime upon completion of the training phase, wherein the remote monitoring regime includes: continuously monitoring the operational data of the new or existing residential HVAC system through the communication module; transmitting the operational data to a remote server for analysis; displaying data, alerts, and operational recommendations on a portal.

2. The HVAC monitoring system of claim 1, wherein the environmental conditions include temperature, humidity, carbon dioxide, total volatile organic compounds, and air quality index.
3. The HVAC monitoring system of claim 1, wherein the portal is a graphical user interface.
4. The HVAC monitoring system of claim 1, wherein the graphical user interface is a mobile application or webpage.
5. The HVAC monitoring system of claim 1, wherein the operation of heating, ventilation, and air conditioning components of a new or existing residential HVAC system include filter differential pressure (inches water column), input power voltage (Volts), leaving air carbon dioxide (PPM), leaving air total volatile organic compounds (VOCs PPB), leaving air quality index, leaving air humidity (% RH), leaving air drybulb Temperature (° F.), system cooling mode (on/off), system heating mode (on/off), system fan only mode (on/off), outdoor air temperature Max (° F.), outdoor air temperature Min (° F.), outdoor air temperature average (° F.), outdoor air quality, cooling degree days (CDD), heating degree days (HDD), input power voltage max (V), input power voltage min (V), input power voltage average (V), cooling or heating or fan only runtime duration (minutes), total cooling or heating or fan only runtime (Minutes), consecutive maximum cooling or heating or fan only runtime (Minutes), consecutive minimum cooling or heating or fan only runtime (Minutes), consecutive average cooling or heating or fan only runtime (Minutes), consecutive maximum temperature (° F.) during cooling or heating or fan only runtime, consecutive minimum temperature (° F.) during cooling or heating or fan only runtime, consecutive average maximum temperature (° F.) during cooling or heating or fan only runtime, consecutive average minimum temperature (° F.) during cooling or heating or fan only runtime, consecutive filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive maximum filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive minimum filter differential pressure (inches water column) during cooling or heating or fan time only runtime, consecutive average filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive average maximum filter differential pressure (inches water column) during cooling or heating or fan only runtime, consecutive average minimum filter differential pressure (inches water column) during cooling or heating or fan only runtime, or any combination or all of the above.
6. A self-contained HVAC monitoring device comprising a plurality of sensors and communication module, the self-contained HVAC monitoring device configured to be positioned within an HVAC system and wire directly into a HVAC system power source.
7. The self-contained HVAC monitoring device of claim 6, wherein the plurality of sensors includes an air quality sensor, a temperature sensor, a pressure sensor, and a humidity sensor.
8. The self-contained HVAC monitoring device of claim 6, wherein the communication module is WiFi and Bluetooth enabled.
9. Methods for monitoring a residential HVAC system comprising: (i) monitoring HVAC parameters using a self-contained HAVC monitoring device configured to measure various conditions and gather data; (ii) transmitting the data to a central database; (iii) processing the data using programming at the central database; (iv) performance and status is assessed and determinations are made regarding information transmission to users and technicians; and (v) transmitting a status notification, maintenance recommendation, or an alert if such transmission is determined to be necessary.