Systems and methods for fault detection and diagnosis (FDD) in a heating, ventilation and air conditioning (HVAC) system include a server identifying a fault and one or more predicted causes of the fault based on measurements of operational parameters from the HVAC system. The server also receives and utilizes information associated with the reported fault from service technicians who service the HVAC to correct the reported fault condition. The information includes details of the corrective measures successfully implemented by the technicians to correct the fault, and a determination of whether the server correctly identified the actual fault. The information is implemented by the server to improve the accuracy of the FDD algorithms based on measured parameters of the HVAC system.
Fig. 2
Fig. 3A

1. Identifying a fault in an HVAC system
2. Predicting causes based on measured operational parameters of the HVAC system
3. Transmitting a fault notification and instructions for correcting the fault to a service technician’s mobile device
4. Receiving information associated with the fault based on observations from service technicians after servicing the HVAC
5. Determining an accuracy of identifying the actual fault and cause based on the information received
6. Storing a record of the accuracy of detecting and diagnosing the actual fault, the measured operational parameters, and the information received
7. Tracking a number of instances each service technician provides information after a service call
Receiving information associated with a fault based on observations from service technicians after servicing the HVAC

Applying a logic condition to identify the fault

Analyzing the measured operational parameters, the threshold levels, the logic condition, and the information associated with the fault

Determining adjustments to the logic condition and/or the operational parameters, and/or threshold levels to improve the accuracy

Applying the adjustments

Performing the applying step periodically based on a time interval or a number of times information is received
Fig. 4
FAULT DETECTION AND DIAGNOSTICS SYSTEM UTILIZING SERVICE PERSONNEL FEEDBACK FOR IMPROVED ACCURACY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Provisional Application Ser. No. 62/182,106 entitled “FAULT DETECTION AND DIAGNOSTICS SYSTEM UTILIZING SERVICE PERSONNEL FEEDBACK FOR IMPROVED ACCURACY” and filed Jun. 19, 2015, and U.S. Provisional Application Ser. No. 62/182,119 entitled “SELF-LEARNING FAULT DETECTION FOR HVAC SYSTEMS” and filed Jun. 19, 2015, the entirety of which is hereby incorporated by reference herein for all purposes.

BACKGROUND

[0002] 1. Technical Field

[0003] The present disclosure relates generally to fault detection and diagnostics (FDD) for heating, ventilation and air conditioning (HVAC) systems. More specifically, this disclosure relates to incorporating actual fault determination and their diagnosis into an FDD system to improve predictions.

[0004] 2. Background

[0005] Various methods and systems for detecting and diagnosing faults that occur in HVAC systems are known in the prior art. These systems often rely on manufacturer’s data for fault detection and diagnosis (FDD), but may also implement various algorithms for predicting a fault in a particular system based on measured readings of operating parameters associated with the equipment, for example. In some cases, diagnostic capabilities may be embedded in the equipment itself.

[0006] However, there is no known system or method for capturing and analyzing the success rate of an FDD system in predicting faults and diagnoses. There is also no known system for incorporating details of a serviced fault into the FDD system, after repairs have been made to resolve the reported fault.

SUMMARY

[0007] In one aspect, the present disclosure provides a method for fault detection and diagnosis of an HVAC system. A server associated with the HVAC system identifies a fault in the system and determines one or more predicted causes of the fault based on measurements of operational parameters associated with the HVAC system. The server also receives information associated with the fault that is based on observations from one or more service technicians upon servicing the fault. The information includes a corrective measure that was implemented to correct the fault, an indication of success or failure of the corrective measure, and an identification of an actual fault and a cause of the actual fault. The server then determines an accuracy of identifying the actual fault and the cause of the actual fault based on the information received from the one or more service technicians.

[0008] In embodiments, the cause of the actual fault is determined based on the corrective measure that successfully corrected the fault, as provided in the information received from the service technician(s). Corrective measures reportedly implemented by the service technician may include, for example, adding a charge, removing a charge, replacing a component, correcting an airflow, or modifying a thermostat configuration in the heating, ventilation and air conditioning system.

[0009] In embodiments, the server transmits a notification of the fault identified and instructions for correcting the fault, based on the one or more predicted causes, to a mobile device accessible by one of the one or more service technicians. The server receives the information via an app installed on the mobile device.

[0010] In embodiments, the fault and the one or more predicted causes may be identified by applying a logic condition for determining whether the fault exists, wherein the logic condition associated with the fault is based on the operational parameters applied by the logic condition and a threshold level for each of the operational parameters.

[0011] Embodiments of the method may further include analyzing the measurements of the operational parameters, the threshold levels, the logic condition, and the information associated with the fault, in response to a determination that the actual fault is different than the fault identified by the server, or that the cause found by the service technician is different than the server’s predicted cause(s). From the analysis, the server can then determine adjustments for improving the accuracy of the fault detection and diagnosis, including adjustments to any combination of the logic condition, the operational parameters, and one or more threshold levels of the operational parameters to identifying the fault and the one or more predicted causes.

[0012] In further embodiments, the server may then apply the adjustments to the at least one of the logic condition, the operational parameters, and the one or more threshold levels. Such adjustments may be applied periodically, for example, based on one of a predetermined time interval and a predetermined number of instances of receiving the information. In other embodiments, the adjustments may be automatically applied upon determining what adjustments to the fault detection and diagnosis method will improve the accuracy.

[0013] In embodiments, the method may include storing a record of the fault identified by the server, the one or more predicted causes, the measurements of the operational parameters, and the information associated with the fault.

[0014] In further embodiments of the method, the server identifies the service technician associated with each instance of the information received and stores a record of a number of instances associated with each of the service technicians who provide the information.

[0015] In another aspect, the present disclosure provides a system for fault detection and diagnosis in an HVAC system. The system includes a server communicably connected to a plurality of HVAC systems. The server is configured to identify a fault in one of the plurality of HVAC systems and one or more predicted causes of the fault based on measurements of operational parameters associated with the HVAC system. The server is further configured to receive information associated with the fault based on observations from one or more service technicians. The information includes a corrective measure implemented to correct the fault, an indication of success or failure of the corrective measure, and an identification of an actual fault and a cause of the actual fault. An accuracy of identifying the actual fault and
the cause of the actual fault is then determined by the server based on the information received from the one or more service technicians.

In embodiments, the server is further configured to apply a logic condition for determining whether the fault exists. The logic condition associated with the fault is based on the operational parameters and a threshold level for each of the operational parameters.

In further embodiments, the server is configured to analyze the measurements of the operational parameters, the threshold levels, the logic condition, and the information associated with the fault, in response to determining that the actual fault is different than the fault identified by the server and/or the cause reported by the service technician is different than the predicted cause(s). The server is also configured to determine adjustments to one or more of the logic condition, the operational parameters applied by the logic condition, and one or more threshold levels of the operational parameters to improve the accuracy of the fault detection and diagnosis analysis.

In embodiments, the server may be further configured to apply the adjustments to the at least one of the logic condition, the operational parameters, and the one or more threshold levels in response to determining the adjustments for improving the accuracy.

In additional embodiments, the server is further configured to transmit a notification of the fault identified by the server and instructions for correcting the fault based on the one or more predicted causes to a mobile device accessible by the one or more service technicians; and to receive the information via an app installed on the mobile device.

The server may be further configured, in embodiments, to store a record of the fault, the one or more predicted causes, the measurements of the operational parameters, and the information associated with the fault.

In additional embodiments, the server is further configured to store a record of a number of instances information is received from each of the one or more service technicians.

In another aspect, the present disclosure provides a computer-readable device to store instructions that, when executed by a processing device, cause the processing device to perform operations. The operations include identifying a fault in a heating, ventilation and air conditioning system and determining one or more predicted causes of the fault based on measurements of operational parameters associated with the heating, ventilation and air conditioning system. The operations also include receiving information associated with the fault. The information is based on observations from one or more service technicians, and includes details of a corrective measure implemented to correct the fault, an indication of success or failure of the corrective measure, and an identification of an actual fault and a cause of the actual fault associated with the measurements of the operational parameters. The operations further include determining an accuracy of identifying the actual fault and the cause of the actual fault based on the information received from the one or more service technicians.

In embodiments, the operation of identifying the fault and the one or more predicted causes includes applying a logic condition for determining whether the fault exists. The logic condition associated with the fault is based on the operational parameters applied by the logic condition and a threshold level for each of the operational parameters. The operations may further include analyzing the measurements of the operational parameters, the threshold levels, the logic condition, and the information associated with the fault, in response to determining that the actual fault reported is different than the fault identified by the server, or that the cause reported is different than the one or more predicted causes. Based on the results of the analysis, the operations then further include determining the appropriate adjustments to at least one of the logic condition, the operational parameters, and one or more threshold levels of the operational parameters to improve the accuracy of identifying the fault and the one or more predicted causes.

In further embodiments, the operations include applying the adjustments to the at least one of the logic condition, the operational parameters, and the one or more threshold levels.

Other features and advantages will become apparent from the following description of the preferred embodiments, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the disclosed system and method are described herein with reference to the drawings wherein:

FIG. 1A is a schematic block diagram representation of an embodiment of a system of the present disclosure;

FIG. 1B is a schematic block diagram representation of an embodiment of a heating, ventilation and air conditioning system that is communicably coupled to the embodiment of the system of FIG. 1;

FIG. 2 is a block diagram representation of data flow in an embodiment of a system of the present disclosure;

FIG. 3A is a block diagram representation of an embodiment of a method of the present disclosure;

FIG. 3B is a block diagram representation of another embodiment of a method of the present disclosure; and

FIG. 4 is a schematic block diagram representation of another embodiment of a system of the present disclosure.

The various aspects of the present disclosure mentioned above are described in further detail with reference to the aforementioned figures and the following detailed description of exemplary embodiments.

DETAILED DESCRIPTION

The present disclosure is directed to a method and system for fault detection and diagnosis in heating, ventilation and air conditioning systems. Embodiments of the method and system incorporate feedback from field service technicians to improve the accuracy of algorithms used for detecting and diagnosing faults in the HVAC systems. The cooperation of the various field service technicians in providing such feedback data is also preferably tracked so that rewards may be granted as an incentive for increased participation by the field service technicians.

Particular illustrative embodiments of the present disclosure are described hereinbelow with reference to the accompanying drawings; however, the disclosed embodiments are merely examples of the disclosure, which may be embodied in various forms. Well-known functions or constructions and repetitive matter are not described in detail to avoid obscuring the present disclosure in unnecessary or
redundant detail. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosure in virtually any appropriately detailed structure. In this description, as well as in the drawings, like-referenced numbers represent elements which may perform the same, similar, or equivalent functions. The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any embodiment described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments. The word “example” may be used interchangeably with the term “exemplary.”

[0036] The present disclosure may be described herein in terms of functional block components, code listings, optional selections, page displays, and various processing steps. It should be appreciated that such functional blocks may be realized by any number of hardware and/or software components configured to perform the specified functions. For example, the present disclosure may employ various integrated circuit components, e.g., memory elements, processing elements, logic elements, look-up tables, and the like, which may carry out a variety of functions under the control of one or more microprocessors or other control devices.

[0037] Referring to an embodiment of a system 10 of the present disclosure as shown in FIG. 1A, for example, in various embodiments, the hardware and/or software components for implementing one or more of the functional blocks or method steps may be implemented on one or more server(s) 12 accessing data from a plurality of HVAC systems 16, or distributed between any combination of one or more server(s) 12 and a user device 14 operably connected to the one or more server(s) 12.

[0038] The user devices of the present disclosure may be mobile devices, such as a smart phone or tablet, including an app installed for enabling service technicians to communicate information obtained from servicing a reported fault in an HVAC system. In embodiments, user devices may also include any other suitable device, including a computer, laptop, and so on, for entry and transmission of the information via a web-based interface, for example.

[0039] Similarly, the software elements of the present disclosure may be implemented with any programming or scripting language such as C, C++, C#, Java, COBOL, assembler, PERL, Python, PHP, or the like, with various algorithms being implemented with any combination of data structures, objects, processes, routines or other programming elements. The object code created may be executed by any device, on a variety of operating systems, including without limitation Apple OSX®, Apple iOS®, Google Android®, HP WebOS®, Linux, UNIX®, Microsoft Windows®, and/or Microsoft Windows Mobile®.

[0040] It should be appreciated that the particular implementations described herein are illustrative of the disclosure and its best mode and are not intended to otherwise limit the scope of the present disclosure in any way. Examples are presented herein which may include sample data items which are intended as examples and are not to be construed as limiting. Indeed, for the sake of brevity, conventional data networking, application development and other functional aspects of the systems (and components of the individual operating components of the systems) may not be described in detail herein. It should be noted that many alternative or additional functional relationships or physical or virtual connections may be present in a practical electronic system or apparatus.

[0041] As will be appreciated by one of ordinary skill in the art, the present disclosure may be embodied as a method, a device, e.g., a server device, configured to implement the methods disclosed herein, and/or a computer program product. Accordingly, the present disclosure may take the form of an entirely software embodiment, an entirely hardware embodiment, or an embodiment combining aspects of both software and hardware. Furthermore, the present disclosure may take the form of a computer program product on a computer-readable storage medium having computer-readable program code means embodied in the storage medium. Any suitable computer-readable storage medium may be utilized, including hard disks, CD-ROM, DVD-ROM, optical storage devices, magnetic storage devices, semiconductor storage devices (e.g., flash memory, USB thumb drives) and/or the like.

[0042] Computer program instructions embodying the present disclosure may also be stored in a computer-readable memory that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture, including instruction means, that implement the function specified in the description or flowchart block(s). The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer-implemented process such that the instructions that execute on the computer or other programmable apparatus provide steps for implementing the functions specified in the present disclosure.

[0043] Referring again to FIG. 1A, for example, in one embodiment, the server 12 includes at least a processing device or devices 22, memory including computer readable memory or storage 24 for storing software, instructions, or executable code, which when executed by the processing device(s) 22 causes the processing device(s) 22 to perform methods or method steps of the present disclosure, which may be embodied at least in part in programming instructions 26 stored on or retrievable by the server 12. It will be appreciated by those of ordinary skill in the art that such components 22, 24 and programming instructions 26 for performing the methods or method steps of the present disclosure may be also be distributed among various devices, which may include user devices 14, such as computers, laptops, mobile devices, phones, tablets, and so on, and may also, in embodiments, include programmable logic installed in components of the HVAC system(s) 16.

[0044] One skilled in the art will also appreciate that, for security reasons, any databases, systems, or components of the present disclosure may consist of any combination of databases or components at a single location or at multiple locations, wherein each database or system includes any of various suitable security features, such as firewalls, access codes, encryption, de-encryption, compression, decompression, and/or the like.

[0045] The disclosed systems and/or methods may be embodied, at least in part, in application software that may be downloadable, in whole or in part, from either a public or
private website or an application store ("app store") to a mobile device. In another embodiment, the disclosed system and method may be included in the mobile device firmware, hardware, and/or software. In another embodiment, the disclosed systems and/or methods may be embodied, at least in part, in application software executing within a webserver to provide a web-based interface to the described functionality.

[0046] In yet other embodiments, all or part of the disclosed systems and/or methods may be provided as one or more callable modules, an application programming interface (e.g., an API), a source library, an object library, a plug-in or snap-in, a dynamic link library (e.g., DLL), or any software architecture capable of providing the functionality disclosed herein.

[0047] The term “sensors” as used herein refers collectively to both sensors and transducers as commonly used in the art, and includes sensors associated with a particular piece of equipment and/or control unit or thermostat in the HVAC system, such as a temperature sensor in a thermostat. Sensors may be located on or operably connected to certain HVAC equipment. Other sensors co-located with an HVAC system may, or may not be operably connected to HVAC equipment, but may still be used in accordance with methods of the present disclosure to analyze the data collected for detecting and diagnosing a fault in the HVAC system. Examples of sensors from which data may be collected for analysis in accordance with the present disclosure include, but are not limited to, temperature, humidity, pressure, occupancy, smoke, light, motion, security, humidity, pressure sensors, and so on. Data that may be acquired from sensors and/or equipment (which may include sensors or embedded controllers) includes, but is not limited to, measured data readings (e.g., temperature, pressure, humidity, and so on), set point (e.g., a user-defined temperature setting), current state (e.g., an “occupied” or “unoccupied” reading from an occupancy sensor), and modes of operation (e.g., heat or cool mode of a thermostat).

[0048] Referring to FIG. 1A, an embodiment of a system 10 of the present disclosure for detecting and diagnosing faults in a heating, ventilation and air conditioning (HVAC) system is shown. The system 10 includes a server 12 communicably coupled to a plurality of HVAC systems 16, via the Internet 28, for example, and specially configured to implement and execute the methods of the present disclosure. The server 12 may also be configured to establish communications with a plurality of user devices 14 utilized by field service technicians and to send various notifications and instructions to the user devices 14 regarding any faults detected in the HVAC systems 16 in accordance with the present disclosure. In embodiments described further hereinafter, the user devices 14 are enabled to receive such notifications from the server 12 and to respond by sending information regarding the fault reported by the server 12. In embodiments, a database 30 is communicatively coupled to the server 12 for storing such information and fault data. The database 30, in embodiments, may also be accessible to the service technicians’ devices 14, via the Internet 28, for example, for storing the feedback information from the service technicians.

[0049] Referring to FIG. 1B, by way of example, an HVAC system 16a typically includes a thermostat 18 and may include various additional control units 20, each of which may be operable via a touch-screen panel as well as via a separate user device operated by a homeowner or system operator. Additional equipment in the HVAC system 16a may include, but is not limited to, furnaces and heating equipment, air conditioners, filters, air purifiers, ventilation equipment, chillers, pumps, and air handlers.

[0050] Equipment in the HVAC system 16a may include both indoor 40 and outdoor equipment 42, each of which may include sensors 32 operably connected to and/or embedded in the equipment. Some equipment may include embedded logic controllers 34 for monitoring and controlling operation.

[0051] Additional sensors 36 may be co-located with the system 16a and may or may not be operably connected to equipment within the HVAC system 16a. Such sensors 36 may include, but are not limited to, occupancy, smoke, light, motion, security, humidity, pressure sensors, and so on. In accordance with the present disclosure, data from these sensors 32, 36 and logic controllers 34 may be collected, stored, and analyzed by the server 12 to assess current operational parameters and trends in the equipment and HVAC system 16a, for detection and diagnosis of faults in accordance with predetermined logic conditions.

[0052] As will be described further below, various types of data are generated by the sensors associated with the plurality of HVAC systems 16. Referring still to FIG. 1B, embodiments of the HVAC system 16a may include an electronic gathering device 44 configured to acquire data from any components associated with the system 16, including the control unit(s) 20, thermostat 18, both indoor 40 and outdoor equipment 42, and associated sensors 32, 36, and forward the data via the Internet 28, for example, to the server 12 for processing.

[0053] The electronic gathering device 44 is operably connected to the server 12 for transmission of the acquired data thereto and configured for transmitting the data by any suitable connection, either wired or wireless 46, of any appropriate type, including but not limited to Wi-Fi, cellular, Ethernet, POTS via modem, and so on.

[0054] In some embodiments, the thermostat 18 of the HVAC system is operably connected to the data gathering device 44, has Internet connectivity 48, e.g., Wi-Fi, Ethernet, and so on, and can provide the data pathway from the electronic data gathering device 44 to the central remote server 22 via the Internet 28. Any combination of the thermostat 18 and the optional electronic data gathering device 44, or any other method known in the art, may be used to transmit the data, including measurements of various operating parameters, from the HVAC systems 16 to the server 12 for fault detection and diagnosis.

[0055] FIG. 2 illustrates a flow of data between an HVAC system 16a, a service technician’s device 14, which may be a mobile device, and an embodiment of a server 12 in accordance with the present disclosure. The measured data 50 from the sensors 32, 36, and the like associated with the HVAC system 16a may include continuous data 52 and event data 54. The measured data is collected and transmitted to the server 12 for monitoring and analysis and may also be stored in the database 30. The data 50 may include continuous measurements 52 of various operational parameters, such as, but not limited to, indoor temperature, outdoor temperature, pressure, system modes, setpoints, indoor humidity, compressor power, and so on. The data 50 may also include discrete system operation events 54, such as, but not limited to, calls for cooling operation, recorded
events of a compressor turned on or off, changes in setpoints and/or system modes, and any other event that is triggered, for example, by a change in a system operating condition. The measurements of the operational parameters that are stored in the database 30, therefore, can be any combination of continuously acquired data 52 and discrete, event data 54.

[0056] The server 12 detects and diagnoses faults based on the measurements 50 of the operational parameters acquired from the HVAC system 16a as described further hereinafter. If a fault is detected, a notification of the fault with instructions 56 may be sent by the server 12 to a user device 14 accessible by a service technician. Upon correction of the fault, the service technician provides information 58 associated with the correction via the user device 14 to the server 12, which may also be stored in the database 30 by the server 12, or directly to the database 30. In embodiments, the database 30 may include records 60 that include all faults detected by the server 12, along with the FDD-generated fault diagnoses, the measured dataset 50 to which each FDD diagnosis was applied, and the feedback information provided via the user device 14, including whether or not the FDD fault diagnosis provided by the server 12 was correct. These records 60 are used by the server 12, or in other embodiments of the present disclosure, by a third-party server, to optimize the fault detection and diagnosis logistics as described further herein.

[0057] FIG. 3A illustrates embodiments of a method 70 in accordance with the present disclosure to detect and diagnose faults in an HVAC system that is operably connected to a server 12 as described above. Referring also to FIG. 2, in accordance with the method 70, the server identifies, at 72, a fault in an HVAC system 16 and determines, at 74, one or more predicted causes of the fault based on the measurements of operational parameters 50 that are passed to the server 12 from the HVAC system 16. In embodiments, the server transmits, at 75, a fault notification and instructions for correcting the fault to a service technician’s mobile device. The server 12 receives information associated with the fault at 76 from the service technician to which the fault notification was issued and also accumulates information from other service technicians based on their observations in servicing the same reported fault in past service calls. The information reported by the service technicians includes the corrective measure(s) that were implemented to successfully correct the fault. The information may also include a listing of corrective measure(s) that were implemented without success, including any measures that the service technician was originally instructed to implement to correct a suspected cause of the fault, as diagnosed by the server 12.

[0058] For example, the service technician may determine the actual cause of the fault by making suggested changes to correct the operational error. The service technician may have attempted certain corrections that were provided in the instructions along with the fault notification, or may try other changes based on his or her prior experience. Such corrective measures may include, for example, adding a charge, replacing a component, correcting an airflow, or modifying a thermostat configuration in the heating, ventilation and air conditioning system. In embodiments, the information provided at 76 by the service technicians preferably includes this level of detail for implementation by the FDD server 12.

[0059] By comparing the information from the service technicians with the fault and predicted cause that the server determined from the measured parameters, the server, at 78, determines an accuracy of the algorithm and parameters used to identify and diagnose the fault.

[0060] In additional embodiments, the server, at 80, stores a record of the fault identified by the server and the one or more predicted causes, the accuracy of detecting and diagnosing the actual fault, the measured operational parameters used to detect and diagnose, and the information about the actual fault and causes received from the service technicians.

[0061] In embodiments, at 82, the server 12 also identifies the service technician associated with each instance of information received and tracks the number of instances associated with each service technician. In this way, a reward system may be implemented to incentivize the service technicians to provide helpful information after each service call.

[0062] Referring now to FIG. 3B, in embodiments, the information associated with a fault is collected from service technicians, at 88, via the service technicians’ user devices. The information may be collected by a third-party server 112, as shown in FIG. 4, or by an FDD server 12, as shown in FIG. 1A. The method includes the server 112, or server 12, applying a logic condition, at 90, to determine whether or not a fault exists and to identify the fault. The logic condition associated with the fault is based on measurements of particular operational parameters, and a predetermined threshold level for each of the operational parameters.

[0063] Referring to FIG. 4, in embodiments of a system of the present disclosure utilizing third-party server 112, server 112 includes at least a processing device or devices 122, memory including computer readable memory or storage 124 for storage of software, instructions, or executable codes, which when executed by the processing device(s) 122 causes the processing device(s) 122 to perform methods or method steps of the present disclosure, including analysis of the information about the actual faults reported, and the predictions provided by the server 112. The method steps may be embodied at least in part in programming instructions 126 stored on or retrievable by the server 112. In embodiments, a database 130 is also communicatively coupled to the server 112 for storing such information and fault data for analysis. In the system of FIG. 4, the analysis of the accuracy of the FDD based on the technicians’ feedback, as described further below, is performed by third-party server 112, and the recommended adjustments to the FDD analysis are stored for either manual, or automatic, integration into an FDD server in accordance with the present disclosure.

[0064] Various methods of fault detection and diagnosis are known in the art and can be applied to the methods of the present disclosure. In embodiments of the present disclosure, logic conditions are established and applied by the server 12 for identifying faults based on measurements of the operational parameters. For example, a threshold value may be predetermined for a particular operational parameter, and a logic condition established that determines a particular fault exists, under certain system operating conditions, when a particular operational parameter either exceeds, or drops below, the predetermined threshold value. In other embodiments, the logic condition determines the existence of a fault based on an analysis of measurements of a predetermined set of operational parameters and their predetermined threshold values. An accuracy of an FDD will depend on the logic condition applied, the set of operational parameters selected
by the logic condition to identify a fault, and the predetermined threshold values for those operational parameters.

The information provided by the service technicians can help optimize the logic condition for defining a fault, for example, by determining whether the optimal combination of operational parameters are being applied to predict that a fault exists, as well as to optimize the threshold values and algorithms used to determine which fault out of all possible faults for a particular HVAC system exists. In particular, if the information provided by the service technicians indicates that there is an error in the logic used to predict a fault in a particular instance, for example, because the actual fault and/or cause were found to differ from that predicted by the server, further analysis is warranted. Accordingly, embodiments of the method further include analyzing, at 92, the measurements of the operational parameters, the threshold levels, the logic condition, and the information, and determining, at 94, adjustments to the logic condition and/or the operational parameters, and/or one or more threshold levels of the operational parameters to improve the accuracy of the FDD by the server 12. These adjustments may be determined and stored by the third-party server 112 for manual, or automated, importation to an FDD server 12, as shown in FIG. 4, for example, or the analysis, determination of adjustments, as well as the application, at 96, of the adjustments may be performed in whole, or in part, by the FDD server 12, as shown in FIG. 1A, for example.

In embodiments, the adjustments determined at 94 are applied to the server 12 at 96 for improving the accuracy of the fault detection and diagnosis. Accordingly, as more information is received from the service technicians, the accuracy of the FDD by the server 12 is further improved. In additional embodiments, the server 12 performs the applying step periodically, at 98, based on a predetermined time interval or on a predetermined number of instances of receiving the information.

Aspects

It is noted that any of aspects 1-9 below can be combined with each other in any combination and combined with any of aspects 10-17, or any of aspects 18-20. Any of aspects 10-20 can be combined with each other in any combination.

Aspect 1. A method of detecting and diagnosing faults detection in a heating, ventilation and air conditioning system, the method comprising: identifying, by a server, a fault in a heating, ventilation and air conditioning system; receiving, by the server, information associated with the fault, the information being based on observations from one or more service technicians, the information including a corrective measure implemented to correct the fault, an indication of success or failure of the corrective measure, and an identification of an actual fault and a cause of the actual fault; and determining, by the server, an accuracy of identifying the actual fault and the cause of the actual fault based on the information received from the one or more service technicians.

Aspect 2. The method according to Aspect 1, further comprising transmitting, by the server, a notification of the fault identified by the server and instructions for correcting the fault based on the one or more predicted causes to a mobile device accessible by one of the one or more service technicians, the server receiving the information via an app installed on the mobile device.

Aspect 3. The method according to any of Aspects 1-2, further comprising: storing, by the server, a record of the fault identified by the server, the one or more predicted causes, the measurements of the operational parameters, and the information associated with the fault.

Aspect 4. The method according to any of Aspects 1-3, wherein identifying the fault and the one or more predicted causes includes applying a logic condition for determining whether the fault exists, wherein the logic condition associated with the fault is based on the operational parameters applied by the logic condition and a threshold level for each of the operational parameters.

Aspect 5. The method according to any of Aspects 1-4, further comprising analyzing, by the server, the measurements of the operational parameters, threshold levels for each of the operational parameters, a logic condition for determining whether the fault exists, and the information associated with the fault, in response to one of the actual fault being different than the fault and the cause being different than the one or more predicted causes; and determining, by the server, adjustments to at least one of the logic condition, the operational parameters, and one or more threshold levels of the operational parameters to improve the accuracy of identifying the fault and the one or more predicted causes based on results of the analyzing step.

Aspect 6. The method according to any of Aspects 1-5, further comprising: applying, by the server, adjustments to the at least one of the logic condition, the operational parameters, and the one or more threshold levels based on results of the analyzing step of Aspect 5.

Aspect 7. The method according to any of Aspects 1-6, further comprising applying adjustments to the at least one of the logic condition, the operational parameters, and the one or more threshold levels based on results of the analyzing step of Aspect 5 periodically based on one of a predetermined time interval and a predetermined number of instances of receiving the information.

Aspect 8. The method according to any of Aspects 1-7, wherein the cause of the actual fault is determined based on the information including the corrective measure that successfully corrected the fault.

Aspect 9. The method according to any of Aspects 1-8, wherein the corrective measure includes one of adding a charge, removing a charge, replacing a component, correcting an airflow, and modifying a thermostat configuration in the heating, ventilation and air conditioning system.

Aspect 10. The method according to any of Aspects 1-9, further comprising: identifying, by the server, the one of the service technicians associated with each instance of the information received; and storing, by the server, a record of a number of instances associated with each of the one or more service technicians.

Aspect 11. A system for fault detection and diagnosis in a heating, ventilation and air conditioning system, the system comprising: a server communicably connected to a plurality of heating, ventilation and air conditioning systems, wherein the server is configured to: identify a fault in one of the plurality of heating, ventilation and air conditioning systems and one or more predicted causes of the fault based on measurements of operational parameters associated with the one of the plurality of heating, ventilation and
air conditioning systems; receive information associated with the fault based on observations from one or more service technicians, the information including a corrective measure implemented to correct the fault, an indication of success or failure of the corrective measure, and an identification of an actual fault and a cause of the actual fault; and determine an accuracy of identifying the actual fault and the cause of the actual fault based on the information received from the one or more service technicians.

[0079] Aspect 12. The system according to Aspect 11, wherein the server is further configured to: transmit a notification of the fault identified by the server and instructions for correcting the fault based on the one or more predicted causes to a mobile device accessible by the one or more service technicians; and receive the information via an app installed on the mobile device.

[0080] Aspect 13. The system according to any of Aspects 11-12, wherein the server is further configured to: store a record of the fault, the one or more predicted causes, the measurements of the operational parameters, and the information associated with the fault.

[0081] Aspect 14. The system according to any of Aspects 11-13, wherein the server is further configured to apply a logic condition for determining whether the fault exists, wherein the logic condition associated with the fault is based on the operational parameters and a threshold level for each of the operational parameters.

[0082] Aspect 15. The system according to any of Aspects 11-14, the server being further configured to: analyze the measurements of the operational parameters, the threshold levels for each of the operational parameters, the logic condition for determining whether the fault exists, and the information associated with the fault, in response to one of the actual fault being different than the fault and the cause being different than the one or more predicted causes; and determine adjustments to at least one of the logic condition, the operational parameters applied by the logic condition, and one or more threshold levels of the operational parameters to improve the accuracy of identifying the fault and the one or more predicted causes based on results of the analysis.

[0083] Aspect 16. The system according to any of Aspects 11-15, wherein the server is further configured to: apply adjustments to at least one of the logic condition, the operational parameters, and the one or more threshold levels of the operational parameters in response to determining the adjustments.

[0084] Aspect 17. The system according to any of Aspects 11-16, wherein the server is further configured to identify the one of the service technicians associated with each instance of the information received; and store a record of a number of instances associated with each of the one or more service technicians.

[0085] Aspect 18. A computer-readable device to store instructions that, when executed by a processing device, cause the processing device to perform operations comprising: identifying, by a server, a fault in a heating, ventilation and air conditioning system and determining one or more predicted causes of the fault based on measurements of operational parameters associated with the heating, ventilation and air conditioning system; receiving information associated with the fault, the information being based on observations from one or more service technicians, the information including a corrective measure implemented to correct the fault, an indication of success or failure of the corrective measure, and an identification of an actual fault and a cause of the actual fault; and determining an accuracy of identifying the actual fault and the cause of the actual fault based on the information received from the one or more service technicians.

[0086] Aspect 19. The computer-readable device according to Aspect 18, wherein identifying the fault and the one or more predicted causes includes applying a logic condition for determining whether the fault exists, wherein the logic condition associated with the fault is based on the operational parameters applied by the logic condition and a threshold level for each of the operational parameters, the operations further comprising: analyzing the measurements of the operational parameters, the threshold levels, the logic condition, and the information associated with the fault, in response to one of the actual fault being different than the fault and the cause being different than the one or more predicted causes; and determining adjustments to at least one of the logic condition, the operational parameters, and one or more threshold levels of the operational parameters to improve the accuracy of identifying the fault and the one or more predicted causes based on results of the analyzing step.

[0087] Aspect 20. The computer-readable device according to any of Aspects 18-19, the operations further comprising: applying adjustments to at least one of the operational parameters, and the one or more threshold levels in response to analyzing and determining the adjustments according to Aspect 19.

[0088] Particular embodiments of the present disclosure have been described herein, however, it is to be understood that the disclosed embodiments are merely examples of the disclosure, which may be embodied in various forms. Well-known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosure in any appropriately detailed structure.

What is claimed is:

1. A method of detecting and diagnosing faults in a heating, ventilation and air conditioning system, the method comprising:
   identifying, by a server, a fault in a heating, ventilation and air conditioning system and determining one or more predicted causes of the fault based on measurements of operational parameters associated with the heating, ventilation and air conditioning system;
   receiving, by the server, information associated with the fault, the information being based on observations from one or more service technicians, the information including a corrective measure implemented to correct the fault, an indication of success or failure of the corrective measure, and an identification of an actual fault and a cause of the actual fault; and
   determining, by the server, an accuracy of identifying the actual fault and the cause of the actual fault based on the information received from the one or more service technicians.

2. The method of claim 1, further comprising:
   transmitting, by the server, a notification of the fault identified by the server and instructions for correcting
the fault based on one or more predicted causes to a mobile device accessible by one of the one or more service technicians, the server receiving the information via an app installed on the mobile device.

3. The method of claim 1, further comprising:
   storing, by the server, a record of the fault identified by the server, one or more predicted causes, the measurements of the operational parameters, and the information associated with the fault.

4. The method of claim 1, wherein identifying the fault and one or more predicted causes includes applying a logic condition for determining whether the fault exists, wherein the logic condition associated with the fault is based on the operational parameters applied by the logic condition and a threshold level for each of the operational parameters.

5. The method of claim 4, further comprising:
   analyzing, by the server, the measurements of the operational parameters, the threshold levels, the logic condition, and the information associated with the fault, in response to one of the actual fault being different than the fault and the cause being different than the one or more predicted causes; and
   determining, by the server, adjustments to at least one of the logic condition, the operational parameters, and one or more threshold levels of the operational parameters to improve the accuracy of identifying the fault and the one or more predicted causes based on results of the analyzing step.

6. The method of claim 5, further comprising applying, by the server, the adjustments to the at least one of the logic condition, the operational parameters, and the one or more threshold levels in response to determining the adjustments.

7. The method of claim 6, further comprising performing the applying step periodically based on one of a predetermined time interval and a predetermined number of instances of receiving the information.

8. The method of claim 1, wherein the cause of the actual fault is determined based on the information including the corrective measure that successfully corrected the fault.

9. The method of claim 8, wherein the corrective measure includes one of adding a charge, removing a charge, replacing a component, correcting an airflow, and modifying a thermostat configuration in the heating, ventilation and air conditioning system.

10. The method of claim 1, further comprising:
   identifying, by the server, one of the service technicians associated with each instance of the information received; and
   storing, by the server, a record of a number of instances associated with each of the one or more service technicians.

11. A system for fault detection and diagnosis in a heating, ventilation and air conditioning system, the system comprising a server communicably connected to a plurality of heating, ventilation and air conditioning systems, wherein the server is configured to:
   identify a fault in one of the plurality of heating, ventilation and air conditioning systems and one or more predicted causes of the fault based on measurements of operational parameters associated with one of the plurality of heating, ventilation and air conditioning systems;
   receive information associated with the fault based on observations from one or more service technicians, the information including a corrective measure implemented to correct the fault, an indication of success or failure of the corrective measure, and an identification of an actual fault and a cause of the actual fault; and
   determine an accuracy of identifying the actual fault and the cause of the actual fault based on the information received from the one or more service technicians.

12. The system of claim 11, wherein the server is further configured to:
   transmit a notification of the fault identified by the server and instructions for correcting the fault based on the one or more predicted causes to a mobile device accessible by the one or more service technicians; and
   receive the information via an app installed on the mobile device.

13. The system of claim 11, wherein the server is further configured to:
   store a record of the fault, the one or more predicted causes, the measurements of the operational parameters, and the information associated with the fault.

14. The system of claim 11, wherein the server is further configured to:
   apply a logic condition for determining whether the fault exists, wherein the logic condition associated with the fault is based on the operational parameters and a threshold level for each of the operational parameters.

15. The system of claim 14, the server being further configured to:
   analyze the measurements of the operational parameters, the threshold levels, the logic condition, and the information associated with the fault, in response to one of the actual fault being different than the fault and the cause being different than the one or more predicted causes; and
   determine adjustments to at least one of the logic condition, the operational parameters applied by the logic condition, and one or more threshold levels of the operational parameters to improve the accuracy of identifying the fault and the one or more predicted causes based on results of the analysis.

16. The system of claim 15, wherein the server is further configured to apply the adjustments to at least one of the logic condition, the operational parameters, and the one or more threshold levels in response to determining the adjustments.

17. The system of claim 11, wherein the server is further configured to:
   identify the one of the service technicians associated with each instance of the information received; and
   store a record of a number of instances associated with each of the one or more service technicians.

18. Non-transitory computer-readable media storing instructions that, when executed by a processing device, cause the processing device to perform operations comprising:
   identifying a fault in a heating, ventilation and air conditioning system and determining one or more predicted causes of the fault based on measurements of operational parameters associated with the heating, ventilation and air conditioning system;
   receiving information associated with the fault, the information being based on observations from one or more service technicians, the information including a corrective measure implemented to correct the fault, an
indication of success or failure of the corrective measure, and an identification of an actual fault and a cause of the actual fault; and
determining an accuracy of identifying the actual fault and the cause of the actual fault based on the information received from the one or more service technicians.

19. The non-transitory computer-readable media of claim 18, wherein identifying the fault and the one or more predicted causes includes applying a logic condition for determining whether the fault exists, wherein the logic condition associated with the fault is based on the operational parameters applied by the logic condition and a threshold level for each of the operational parameters, the operations further comprising:
analyzing the measurements of the operational parameters, the threshold levels, the logic condition, and the information associated with the fault, in response to one of the actual fault being different than the fault and the cause being different than the one or more predicted causes; and
determining adjustments to at least one of the logic condition, the operational parameters, and one or more threshold levels of the operational parameters to improve the accuracy of identifying the fault and the one or more predicted causes based on results of the analyzing step.

20. The non-transitory computer-readable media of claim 19, the operations further comprising applying the adjustments to the at least one of the logic condition, the operational parameters, and the one or more threshold levels in response to determining the adjustments.

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