SURGE PROTECTION DEVICE MONITORING

Priority Documents

[0001] The present application claims priority from Australian Provisional Patent Application No. 2016901375 titled "SURGE PROTECTION DEVICE MONITORING" and filed on 13 April 2016, the contents of which are hereby incorporated by reference in their entirety.

Background of the Invention

[0002] The present invention relates to a method and system for monitoring one or more operating parameters of a surge protection device and in one example, to a method and system enabling remote monitoring of the one or more parameters.

Description of the Prior Art

[0003] The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that the prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

[0004] Surge protection devices (SPDs) are used to protect electrical equipment from the effects of surges, impulses and other temporary over-voltage events.

[0005] The lifespan of an SPD is not infinite, and an SPD will be degraded over time due to exposure to repeated impulses, exposure to over-voltages and from exposure to excessive temperatures. Eventually, this degradation leads to the SPD failing completely, at which point the equipment is no longer adequately protected.

[0006] Typically, SPDs are visually inspected at work sites periodically to determine if they are OK or whether they have failed and need to be replaced. Visual status indication methods require physical access to the SPD to check them. Often, an SPD will be installed in a restricted area, such as an electrical switchboard, which can only be accessed by persons with particular qualifications (e.g. an electrician) due to the potentially unsafe nature of the work site. Visual

status monitoring of an SPD is therefore not able to be readily performed by unqualified or low-skilled staff which adds expense to the process of SPD monitoring.

[0007] A further issue with visual status monitoring in the form of an "OK/Not OK" indicator using a fault detector (such as a fuse in series with the SPD) is that there is no advance warning of when the SPD will fail or is approaching end of life. Additionally, even when the SPD has failed, this will not be detected until the next scheduled visual inspection. Accordingly, there may be a period of time between when the SPD fails and when it is replaced during which the electrical equipment is not protected from surges, impulses and other temporary over-voltage events.

[0008] In the past, SPD status has been indicated visually on the SPD itself, using either mechanical or electrical indicators, and sometimes also remotely using voltage free contacts. The problem with remote status indication is that it requires a galvanic connection to the SPD. This adds installation costs, as well as increases the risk of impulses and surges on the remote status indication connections.

[0009] It is against this background, and the problems and difficulties associated therewith, that the present invention has been developed.

Summary of the Present Invention

[0010] In one broad form, the present invention seeks to provide a system for monitoring one or more operating parameters of a surge protection device, the system including:

a) a surge protection device for electrical interconnection between a power supply and electrical equipment to be protected;
b) one or more sensors for monitoring the one or more operating parameters of the surge protection device;
c) at least one electronic processing device coupled to the one or more sensors, wherein the at least one electronic processing device:
    i) determines sensor data indicative of signals from each of the one or more sensors, the sensor data at least partially indicative of the one or more operating parameters; and,
    ii) causes sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to a remote monitoring device; and,

d) a remote monitoring device for wirelessly receiving the sensor information from the at least one electronic processing device;

wherein the at least one electronic processing device:

i) processes the sensor data to determine sensor information at least partially indicative of:

(1) whether the surge protection device is working or has failed; and,

(2) a level of degradation based on one or more of the operating parameters including an operating temperature; and,

ii) sends the sensor information to the remote monitoring device; and,

the remote monitoring device:

iii) receives the sensor information; and,

iv) if the sensor information is indicative that the surge protection device has failed or is approaching end of life in accordance with the level of degradation, then at least one of:

(1) generates an alert; and,

(2) schedules maintenance action.

[0011] Disclosed herein is a method for monitoring one or more operating parameters of a surge protection device, the surge protection device for electrical interconnection between a power supply and electrical equipment to be protected, the method including in at least one electronic processing device:

a) determining sensor data indicative of signals from one or more sensors, the sensor data at least partially indicative of the one or more operating parameters of the surge protection device;

b) causing sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to a remote monitoring device;

c) in the at least one electronic processing device:

i) processing the sensor data to determine sensor information at least partially indicative of:

(1) whether the surge protection device is working or has failed; and,

(2) a level of degradation based on one or more of the operating parameters including an operating temperature; and,

ii) sending the sensor information to the remote monitoring device; and,

d) in the remote monitoring device:

i) receiving the sensor information; and,

ii) if the sensor information is indicative that the surge protection device has failed or is approaching end of life in accordance with the level of degradation, then at least one of:

(1) generating an alert; and,

(2) scheduling maintenance action.

[0012] Disclosed herein is a surge protection device for electrical interconnection between a power supply and electrical equipment to be protected, the surge protection device including:

a) a base for connection to electrical wiring; and,

b) a plug releasably secured to the base, the plug including a body for housing:

i) one or more sensors for monitoring one or more operating parameters of the surge protection device; and,

ii) at least one electronic processing device coupled to the one or more sensors, wherein the at least one electronic processing device:

(1) determines sensor data indicative of signals from each of the one or more sensors, the sensor data at least partially indicative of the one or more operating parameters; and,

(2) causes sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to a remote monitoring device.

[0013] Typically, the one or more operating parameters include a surge protection device status indicative of whether the device is working or has failed.

[0014] Typically, the one or more operating parameters include one or more of:

a) an operating voltage;

b) an operating temperature;

c) a number of surges;

d) an amplitude of surges; and,

e) leakage current.

[0015] Typically, the one or more operating parameters are indicative of a level of degradation of the surge protection device.

[0016] Typically, an indication of end of life of the surge protection device is determined based on the level of degradation by one of:

a) the at least one electronic processing device; and,

b) the remote monitoring device.

[0017] Typically, the at least one electronic processing device determines sensor data at least one of:

a) continuously; and,

b) periodically.

[0018] Typically, the at least one electronic processing device determines sensor data for a first sensor at a different frequency to a second sensor.

[0019] Typically, the at least one electronic processing device is coupled to data storage for storing sensor data.

[0020] Typically, the determined sensor data is at least one of:

a) an instantaneous value; and,

b) based on statistical data.

[0021] Typically, the sensor information includes at least one of:

a) raw sensor data; and,

b) processed sensor data.

[0022] Typically, the system further includes a remote monitoring device for wirelessly receiving the sensor information from the at least one electronic processing device.

[0023] Typically,

a) the at least one electronic processing device:

i) processes the sensor data to determine sensor information at least partially indicative of at least one of:

(1) whether the surge protection device is working or has failed; and,

(2) a level of degradation; and,

ii) sends the sensor information to the remote monitoring device; and,

b) the remote monitoring device:

i) receives the sensor information; and,

ii) if the sensor information is indicative that the surge protection device has failed or is approaching end of life in accordance with the level of degradation, then at least one of:

(1) generates an alert; and,

(2) schedules maintenance action.

[0024] Typically, the remote monitoring device:

a) processes the received sensor information;

b) uses the processed sensor information to determine whether the surge protection device is working or has failed; and,

c) in response to determining that the surge protection device has failed, schedules maintenance action.

[0025] Typically, the remote monitoring device:

a) processes the received sensor information;

b) uses the processed sensor information to determine a level of degradation of the surge protection device;

c) determines an indication of end of life of the surge protection device based on the level of degradation;

d) compares the indication of end of life to a threshold; and,

e) optionally schedules maintenance action in accordance with a result of the comparison.

[0026] Typically, the remote monitoring device selectively generates an alert that the surge protection device has failed or otherwise requires maintenance action to be performed.

[0027] Typically, the surge protection device includes one or more of the following types:

a) spark gap;

b) gas discharge tube;

c) metal oxide varistor;

d) silicon avalanche diode;

e) silicon carbide (SiC); and,

f) tranzorb diode.

[0028] Typically, the sensor information is wirelessly transmitted to the remote monitoring device via a wireless communication protocol including one of:

a) Bluetooth;
b) Wi-Fi;
c) Zigbee; and,
d) 6LowPAN.

[0029] Typically, the surge protection device is modular and includes:

a) a base for connection to electrical wiring; and,
b) a plug releasably secured to the base, the plug including a body for housing the one or more sensors and at least one electronic processing device.

[0030] Typically, the plug includes a retaining clip for releasably securing the plug body to the base.

[0031] Typically, the base is generally U-shaped defining an open channel disposed between opposing terminal blocks for at least partially receiving the plug body.

[0032] Typically, the retaining clip forms part of a sidewall of the plug body and is a resiliently deformable element which terminates in a tab member that is retained, in use, in a groove located in one of the terminal blocks.

[0033] Typically, the system includes a plurality of surge protection devices.

[0034] In another broad form, the present invention seeks to provide a method for monitoring one or more operating parameters of a surge protection device, the surge protection device for electrical interconnection between a power supply and electrical equipment to be protected, the method including in one or more electronic processing devices:

a) determining sensor data indicative of signals from one or more sensors, the sensor data at least partially indicative of the one or more operating parameters of the surge protection device; and,
b) causing sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to a remote monitoring device.

[0035] Typically, the method further includes:

a) in the at least one electronic processing device:
    i) processing the sensor data to determine sensor information at least partially indicative of at least one of:

(1) whether the surge protection device is working or has failed; and,

(2) a level of degradation; and,

ii) sending the sensor information to the remote monitoring device; and,

b) in the remote monitoring device:

i) receiving the sensor information; and,

ii) if the sensor information is indicative that the surge protection device has failed or is approaching end of life in accordance with the level of degradation, then at least one of:

(1) generating an alert; and,

(2) scheduling maintenance action.

[0036] Typically, the surge protection device includes a plug releasably securable to a base, and wherein the method further includes:

a) terminating electrical wiring to the base, the electrical wiring for electrically interconnecting the surge protection device between a power supply and electrical equipment to be protected; and,

b) releasably securing the plug to the base.

[0037] In another broad form, the present invention seeks to provide a surge protection device for electrical interconnection between a power supply and electrical equipment to be protected, the surge protection device including:

a) a base for connection to electrical wiring; and,

b) a plug releasably secured to the base, the plug including a body for housing:

i) one or more sensors for monitoring one or more operating parameters of the surge protection device; and,

ii) at least one electronic processing device coupled to the one or more sensors, wherein the at least one electronic processing device:

(1) determines sensor data indicative of signals from each of the one or more sensors, the sensor data at least partially indicative of the one or more operating parameters; and,

(2) causing sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to a remote monitoring device.

[0038] Typically, the plug includes a retaining clip for releasably securing the plug body to the base.

[0039] Typically, the base is generally U-shaped defining an open channel disposed between opposing terminal blocks for at least partially receiving the plug body.

[0040] Typically, the retaining clip forms part of a sidewall of the plug body and is a resiliently deformable element which terminates in a tab member that is retained, in use, in a groove located in one of the terminal blocks.

[0041] Typically, the base is configured for mounting onto a rail.

[0042] It will be appreciated that the broad forms of the invention and their respective features can be used in conjunction, interchangeably and/or independently, and reference to separate broad forms is not intended to be limiting.

Brief Description of the Drawings

[0043] An example of the present invention will now be described with reference to the accompanying drawings, in which: -

[0044] Figure 1A is a schematic diagram of an example of a system for monitoring one or more operating parameters of a surge protection device;

[0045] Figure 1B is a schematic diagram of an example of a system for monitoring one or more operating parameters of a plurality of surge protection devices;

[0046] Figure 2 is a schematic diagram showing further details of a system for monitoring one or more operating parameters of a surge protection device;

[0047] Figure 3 is a schematic diagram of an example of a remote monitoring device of Figure 2;

[0048] Figure 4 is a schematic diagram of an example of a user client device of Figure 2;

[0049] Figure 5 is a flow chart of an example of a process for monitoring one or more operating parameters of a surge protection device;

[0050] Figure 6A is a flow chart of an example of a process for monitoring the status of a surge protection device in order to determine if maintenance action needs to be performed;

[0051] Figure 6B is a flow chart of another example of a process for monitoring the status of a surge protection device in order to determine if maintenance action needs to be performed;

[0052] Figure 6C is a flow chart of another example of a process for monitoring the status of a surge protection device in order to determine if maintenance action needs to be performed;

[0053] Figure 7A is an exploded side view of an example of an SPD "plug and base" arrangement;

[0054] Figure 7B is an exploded front view of the SPD "plug and base" arrangement of Figure 7A;

[0055] Figure 7C is a perspective view of the SPD "plug and base" arrangement of Figure 7A when assembled;

[0056] Figure 7D is a front view of the SPD "plug and base" arrangement of Figure 7C showing the plug releasably secured to the base by a retaining clip;

[0057] Figure 8 is a schematic diagram of an example of a system of an SPD with monitoring capabilities;

[0058] Figure 9 is a schematic diagram of an example of an SPD monitoring system showing communication and reporting options;

[0059] Figure 10 is a schematic circuit diagram showing an example implementation of an SPD monitoring system; and,

[0060] Figures 11A to 11B provide a schematic circuit diagram showing a further example implementation of an SPD monitoring system.

Detailed Description of the Preferred Embodiments

[0061] An example of a system for monitoring one or more operating parameters of a surge protection device will now be described with reference to Figure 1A.

[0062] In this example, the system 100 includes a surge protection device 110 for electrical interconnection between a power supply 102 and electrical equipment 104 to be protected. It will be appreciated that the surge protection device 110 will include surge protection electronics designed to protect the electrical equipment 104 from the effects of surges, impulses and other transient over-voltage events. In use, the surge protection device 110 protects the electrical equipment 104 from voltage spikes by limiting the voltage supplied to the electrical equipment 104 either by blocking or shorting to ground any unwanted voltages above a safe threshold as will be well understood by persons skilled in the art.

[0063] The system 100 further includes one or more sensors 112 for monitoring the one or more operating parameters of the surge protection device 110. Typically, the one or more sensors 112 are housed within a housing of the surge protection device 110. The term "sensor" as used herein may refer to any suitable form of sensing arrangement capable of measuring the one or more operating parameters. As such, the sensors may include dedicated sensing circuitry or off-the-shelf sensor components that are able to be integrated into the surge protection

device. An example implementation of a sensing arrangement will be described in further detail below.

[0064] At least one electronic processing device 114 is coupled to the one or more sensors 112 and is also typically housed within the housing of the surge protection device 110, although this is not essential and both the processing device and sensors may be arranged outside the housing in other examples. The electronic processing device 114 determines sensor data indicative of signals from each of the one or more sensors 112, the sensor data at least partially indicative of the one or more operating parameters. The electronic processing device 114 then causes sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to a remote monitoring device such as a smartphone, network connected device, or cloud based processing system. As will be described in further detail below, the sensor information may represent raw or processed sensor data and in at least one example, the sensor data is processed by the electronic processing device 114 prior to being sent to the remote monitoring device.

[0065] The above described arrangement provides a number of advantages. Firstly, it enables one or more operating parameters or conditions of a surge protection device to be monitored remotely without having to visually inspect the device or gain access to restricted areas that can only be accessed by suitably qualified personnel. Accordingly, non-qualified or low-skilled workers are able to monitor the status of the surge protection device(s) which is cost effective and additionally minimises the need for persons to access potentially unsafe work sites.

[0066] The above described monitoring system enables a user to ascertain when an SPD has failed in an expedient manner enabling the SPD to be replaced in order to minimise any period where protection to the electrical equipment is not provided. Furthermore, remote monitoring of the operating parameters may enable an advance warning to be provided when an SPD is approaching its end of life so that suitable preventative maintenance action can be scheduled.

[0067] In Figure 1A, a single surge protection device 110 is illustrated, however it is to be appreciated that the system may include a plurality of surge protection devices as shown for example in Figure 1B. In this example, the system 100 includes a plurality of surge protection devices 110.1, 110.2…110.n in wireless communication with a remote monitoring device 120, such as a user client device (e.g. smartphone), computer system, remote server, or the like. Each of the plurality of surge protection devices 110.1, 110.2…110.n will include one or more

sensors as described with respect to Figure 1A for monitoring one or more operating parameters as well as an electronic processing device for determining sensor data and causing the sensor data to be wirelessly transferred to the remote monitoring device 120.

[0068] A number of further features will now be described.

[0069] Typically, a number of different operating parameters or conditions may be monitored including, but not limited to, operating voltage, operating temperature, number and amplitude of surges, leakage current and a surge protection device status indicative of whether the device is working or has failed (e.g. "OK"/"Not OK"). In regard to operating voltage, this may include just the RMS value or it may detail the harmonic content, power quality, number of maximum/minimum values associated with over-voltage events or brownout. Typically, at least the SPD status will be monitored so that a user is able to ascertain immediately if the device has failed enabling it to be replaced as soon as possible.

[0070] The operating parameters are generally indicative of a level of degradation of the surge protection device and in one example, an indication of end of life of the surge protection device is determined based on the level of degradation by one of the at least one electronic processing device and the remote monitoring device, as will be discussed in further detail below.

[0071] The at least one electronic processing device may determine sensor data continuously or periodically depending on how the processing device has been programmed. For example, it is not necessary for each operating parameter to be monitored continuously, nor at the same frequency. Temperature for example may be monitored once a minute whilst operating voltage may be monitored once a second. Accordingly, in at least one example the processing device determines sensor data for a first sensor at a different frequency to a second sensor.

[0072] The determined sensor data may be instantaneous values indicative of the operating parameters or alternatively may be based on statistical data such as maximums, minimums or averages over a period of time.

[0073] In one example, the electronic processing device is coupled to data storage for storing sensor data. For example, sensor data may be stored and used to calculate a maximum, minimum or average over a period of time which is then sent to the remote monitoring device.

[0074] The sensor data may be processed by the electronic processing device on-board the SPD or alternatively the sensor data may be processed by the remote monitoring device depending on the implementation. It is therefore to be appreciated that the sensor information sent to the remote monitoring device could include either raw sensor data or processed sensor data.

[0075] The surge protection device used herein may be based on any suitable technology including, but not limited to spark gap, gas discharge tube, metal oxide varistor (MOV), silicon avalanche diode, silicon carbide (SiC) and tranzorb diode.

[0076] In one example, the surge protection device is modular and includes a base for connection to electrical wiring and a plug releasably secured to the base, the plug including a body for housing the one or more sensors and electronic processing device. The "plug and base" arrangement is advantageous as in the event of a failure of the device, the plug can be easily removed and replaced without having to disconnect the wiring, or de-energise the circuit.

[0077] Typically, the plug includes a retaining clip for releasably securing the plug body to the base. The retaining clip prevents the plug from becoming separated from the base, particularly when subjected to high levels of vibration.

[0078] In one example, the base is generally U-shaped defining an open channel disposed between opposing terminal blocks for at least partially receiving the plug body. Typically, the retaining clip forms part of the sidewall of the plug body and is a resiliently deformable element which terminates in a tab member that is retained, in use, in a groove located in one of the terminal blocks.

[0079] The remote monitoring device may be configured to perform any required function. In one example, the remote monitoring device processes the received sensor information from the surge protection device and uses the processed sensor information to determine whether the surge protection device has failed. In response to determining that the surge protection device has failed, the remote monitoring device may schedule maintenance action and optionally generate an alert to notify a user that the device has failed and requires replacing.

[0080] In another example, the remote monitoring device processes the received sensor information and uses the processed sensor information to determine a level of degradation of the surge protection device. An indication of end of life (i.e. time remaining until failure) may

then be determined based on the level of degradation. Any suitable predictive algorithm may be used for example based on empirical data of one or more of the operating parameters of the device measured over its lifetime combined with known performance data/limits of the device. In one example, end of life calculations may be based at least in part upon operating temperature and leakage current. For example, end of life may be determined if the operating temperature exceeds a maximum temperature of 80°C or if the leakage current exceeds 1mA.

[0081] The remote monitoring device then compares the predicted end of life to a threshold and optionally schedules maintenance action in accordance with a result of the comparison. The threshold may be a pre-determined amount of time before end of life or failure, which when exceeded by the predicted end of life based on determined level of degradation causes maintenance action to be scheduled. In this instance, the maintenance action may be preventative in order to replace and/or repair a surge protection device before it actually fails. Again optionally, an alert may be generated to notify a user that the device needs maintenance action to be performed.

[0082] In a further example, the at least one electronic processing device processes the sensor data to determine sensor information at least partially indicative of at least one of: whether the surge protection device is working or has failed; and, a level of degradation. The electronic processing device then sends the sensor information to the remote monitoring device. The remote monitoring device receives the sensor information and if the sensor information is indicative that the surge protection device has failed or is approaching end of life in accordance with the level of degradation, then at least one of generates an alert; and, schedules maintenance action. In this example, most data processing occurs in the SPD processing device and the remote monitoring device is simply responsive to generate alerts or any suitable form of representation of the sensor information for a user and/or schedule maintenance action if required.

[0083] Further details of an example of a system for monitoring one or more operating parameters of a surge protection device will now be described with reference to Figure 2.

[0084] In this example, the system includes at least one surge protection device 110, in communication with one or more of a remote monitoring system 220 and client devices 230, via a communications network 250.

[0085] The surge protection device 110 includes a housing 111 containing surge protection electronics 210 coupled to one or more sensors for monitoring the one or more operating parameters of the surge protection device 110. In the example shown, sensors 211, 212, 213, 214 are provided which for example monitor SPD status ("OK/Not OK"), operating temperature, operating voltage and number and intensity of surges. It is to be understood that these represent examples only of the possible parameters which could be measured and are not intended to be limiting in any way. For example, other parameters such as leakage current could also be measured. In practice, any suitable number of sensors may be used, including a single sensor. In a further example, a single sensor to monitor SPD status (i.e. whether or not the SPD has failed or is still working) may be used.

[0086] The housing 111 further contains at least one electronic processing device including a processor 201 (for example a microprocessor) coupled to the one or more sensors 211, 212, 213, 214, a memory 202, an optional display 203 such as an LCD display, LED indicator or the like and a communications interface 207 for allowing wireless communication with the communications network 250. The housing 111 may also contain a power supply 204, such as a battery, for powering the electrical components within the housing 111.

[0087] In use, the microprocessor 201 operates to execute instructions stored in the memory 202, allowing signals from the sensors 211, 212, 213, 214 to be interpreted, allowing information to be optionally presented via the display 203 and for communicating with the remote monitoring device 220 and/or client devices 230. Accordingly, the microprocessor 201 determines sensor data indicative of signals from each of the one or more sensors, and causes sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to the remote monitoring device 220. It is further to be appreciated that in some implementations, the microprocessor 201 may perform some or all of the data processing of the sensor data prior to it being sent to the remote monitoring device 220. The "sensor information" transmitted to the remote monitoring device 220 may therefore be raw data from the sensors or alternatively it may be processed data.

[0088] In use, the remote monitoring device 220 operates to receive sensor information from the surge protection device 110,. The remote monitoring device 220 can also be adapted to provide information to the surge protection device 110, for example allowing aspects of the monitoring to be controlled remotely by the remote monitoring device 220. In one example, the remote monitoring device 220 may be used to set sample rates at which the microprocessor

201 samples the sensor output in order to vary the periodicity of the measurements of various operating parameters.

[0089] As well as being able to communicate with the surge protection device 110, the remote monitoring device 220 is also able to communicate with one or more client devices 230, via the communications network 250, allowing alerts, status information or other notifications to be provided thereto. The remote monitoring device 220 may also be configured to receive commands from the client devices, allowing these to be routed to the surge protection device 110, allowing this to be controlled remotely by the client devices 230. The remote monitoring device 220 can also be coupled to one or more databases 221, allowing data to be stored therein and retrieved as required.

[0090] Whilst the remote monitoring device 220 is shown as a single entity, it will be appreciated that the remote monitoring device 220 can be distributed over a number of geographically separate locations, for example by using multiple processing systems 220 and/or databases 221 that are provided as part of a cloud based environment. However, the above described arrangement is not essential and other suitable configurations could be used.

[0091] It will be appreciated that any client devices 230 used in the system must be capable of communicating via the communications network(s) 250 with the remote monitoring device 220 or directly with the surge protection device 110, displaying content to users and receiving user input commands. Whilst the client devices 230 may be of any suitable form, these are typically a computer system, or a mobile communications device such as a smart phone, tablet, phablet, or the like.

[0092] The communications network 250 can include one or more communications networks, such as the Internet, local area networks (LANs), cellular networks, phone networks or the like, and the use of the communications network is for the purpose of example only. In practice the remote monitoring device 220 and client devices 230 can communicate via any appropriate mechanism, such as via wired or wireless connections, including, but not limited to mobile networks, private networks, such as an 802.11 networks, the Internet, LANs, WANs, or the like, as well as via direct or point-to-point connections, such as Bluetooth, or the like.

[0093] An example of a remote monitoring device 220 is shown in Figure 3. In this example, the remote monitoring device 220 includes at least one microprocessor 300, a memory 301, an optional input/output device 302, such as a keyboard and/or display, and an external interface

303, interconnected via a bus 304 as shown. In this example the external interface 303 can be utilised for connecting the remote monitoring device 220 to peripheral devices, such as the communications network 250, database 221, other storage devices, or the like. Although a single external interface 303 is shown, this is for the purpose of example only, and in practice multiple interfaces using various methods (e.g. Ethernet, serial, USB, wireless or the like) may be provided.

[0094] In use, the microprocessor 300 executes instructions in the form of applications software stored in the memory 301 to allow the required processes to be performed, including communicating with the client devices 230, receiving sensor information from the surge protection device 110 that is at least partially indicative of the sensor data and optionally processing the sensor information to determine if maintenance action needs to be performed as will be described in further detail below. The applications software may include one or more software modules, and may be executed in a suitable execution environment, such as an operating system environment, or the like.

[0095] Accordingly, it will be appreciated that the remote monitoring device 220 may be formed from any suitable processing system, such as a suitably programmed computer system, PC, web server, network server, Internet terminal, lap-top, or hand-held PC such as a smartphone, tablet or the like. In one particular example, the remote monitoring device 220 is a standard processing system such as an Intel Architecture based processing system, which executes software applications stored on non-volatile (e.g., hard disk) storage, although this is not essential. However, it will also be understood that the processing system could be any electronic processing device such as a microprocessor, microchip processor, logic gate configuration, firmware optionally associated with implementing logic such as an FPGA (Field Programmable Gate Array), or any other electronic device, system or arrangement.

[0096] As shown in Figure 4, in one example, the client device 230 includes at least one microprocessor 400, a memory 401, an input/output device 402, such as a keyboard and/or display, and an external interface 403, interconnected via a bus 404 as shown. In this example the external interface 403 can be utilised for connecting the client device 230 to peripheral devices, such as the communication networks 250, databases, other storage devices, or the like. Although a single external interface 403 is shown, this is for the purpose of example only, and in practice multiple interfaces using various methods (e.g. Ethernet, serial, USB, wireless or the like) may be provided.

[0097] In use, the microprocessor 400 executes instructions in the form of applications software stored in the memory 401 to allow communication with the remote monitoring device 220 or surge protection device 110, for example to receive sensor information and alerts or notifications.

[0098] Accordingly, it will be appreciated that the client devices 230 may be formed from any suitable processing system, such as a suitably programmed PC, Internet terminal, lap-top, or hand-held PC, and in one preferred example is either a tablet, or smart phone, or the like. Thus, in one example, the client device 230 is a standard processing system such as an Intel Architecture based processing system, which executes software applications stored on non-volatile (e.g., hard disk) storage, although this is not essential. However, it will also be understood that the client devices 230 can be any electronic processing device such as a microprocessor, microchip processor, logic gate configuration, firmware optionally associated with implementing logic such as an FPGA (Field Programmable Gate Array), or any other electronic device, system or arrangement.

[0099] A general process for monitoring one or more operating parameters of a surge protection device will now be described with reference to Figure 5.

[00100] In this example, at step 500 sensor data is determined. In particular, the electronic processing device 201 coupled to the sensors determines the sensor data indicative of the one or more operating parameters in accordance with signals or outputs from one or more of the sensors 211, 212, 213, 214. Typically, the signals from the one or more sensors are received via an Analog to Digital (A/D) port of the microprocessor 201.

[00101] At step 510, the sensor data is optionally processed by the processor 201 in order to determine sensor information which may include for example a level of degradation of the surge protection device based on the sensor data.

[00102] At step 520, the processor 201 causes the sensor information to be wirelessly transmitted to the remote monitoring device 220. Any suitable wireless communication protocol may be used including for example Bluetooth, Zigbee, Wi-Fi, 6LowPAN and the like. If the sensor data has been processed at step 510 prior to sending to the remote monitoring device 220, then the sensor information will be indicative of the processed data, otherwise the sensor information may simply be indicative of raw sensor data. As previously described, the remote monitoring device 220 may be formed from any suitable processing system including

for example a smartphone, central monitoring device or the cloud. The remote monitoring device 220 may have a display for displaying representations of the sensor information to a user. In other examples, the remote monitoring device 220 may communicate with one or more client devices 230, which may instead be configured to display information and alerts to a user through a monitoring application or the like.

[00103] An example of a process for monitoring one or more operating parameters of a surge protection device in order to determine if maintenance action needs to be performed will now be described with reference to Figure 6A.

[00104] In this example, at step 600, the remote monitoring device 220 receives sensor information that has been wirelessly transmitted from the processing device 201 of the surge protection device 110. At step 602, the sensor information is optionally stored in a data store for further processing as needed.

[00105] At step 604, the sensor information is processed which may include for example generating a representation of the information for display to a user. Alternatively, the information may be processed to determine particular attributes of the data such as maximums, minimums or averages of the measured data.

[00106] At step 606, the SPD status is determined as a result of processing data from the SPD status sensing arrangement, an example of which is described below with reference to Figure 10. At step 608, the remote monitoring device 220 determines whether the SPD is still working or whether it has failed. If the SPD has failed then at step 610, an alert may optionally be generated for display to a user (or sent to a client device 230) warning that the device has failed and needs to be replaced. Finally at step 612, the remote monitoring device 220 may schedule maintenance action, which in the case of a failed SPD, is a replacement of the device.

[00107] Alternatively, if the SPD is determined to be still working at step 608, then the process returns to step 600.

[00108] An example of a further process for monitoring one or more operating parameters of a surge protection device in order to determine if maintenance action needs to be performed will now be described with reference to Figure 6B. This method may be implemented for example when an SPD is still working.

[00109] In this example, at step 620, the remote monitoring device 220 receives sensor information that has been wirelessly transmitted from the processing device 201 of the surge protection device 110. At step 622, the sensor information is optionally stored in a data store for further processing as needed.

[00110] At step 624, the sensor information is processed which may include for example generating a representation of the information for display to a user. Alternatively, the information may be processed to determine particular attributes of the data such as maximums, minimums or averages of the measured data.

[00111] At step 626, the processed sensor information is used to determine a level of degradation of the surge protection device. The level of degradation may be determined based on one or more of the operating parameters for example operating temperature and leakage current. The level of degradation may then be used at step 628 to determine end of life (i.e. time remaining until failure) of the SPD.

[00112] As previously mentioned, any suitable predictive algorithm may be used to determine end of life, for example based on empirical data of one or more of the operating parameters of the device measured over its lifetime combined with known performance data/limits of the device. In one example, end of life calculations may be based at least in part upon operating temperature and leakage current. For example, end of life may be determined if the operating temperature exceeds a maximum temperature of 80°C or if the leakage current exceeds 1mA.

[00113] At step 630, the predicted end of life (i.e. time remaining until failure) is compared to a threshold that may be a pre-determined amount of time before end of life is reached. If the threshold is exceeded at step 632 (for example threshold is set at 2 weeks and end of life is determined to be 1 week away) then at step 634 an alert is optionally generated by the remote monitoring device 220 to notify a user that the device needs maintenance action to be performed. At step 636, if the threshold has been exceeded, preventative maintenance action is scheduled to ensure that the electrical equipment being protected by the SPD remains protected at all times.

[00114] If at step 632, the remote monitoring device 220 determines that the threshold has not been exceeded, then end of life is not imminent and the process returns to step 620 where monitoring is continued.

[00115] An example of a further process for monitoring one or more operating parameters of a surge protection device in order to determine if maintenance action needs to be performed will now be described with reference to Figure 6C. In this example, the electronic processing device on-board the SPD performs most of the data processing.

[00116] In this example, at step 640 sensor data is determined. In particular, the electronic processing device 201 coupled to the sensors determines the sensor data indicative of the one or more operating parameters in accordance with signals or outputs from one or more of the sensors 211, 212, 213, 214. Typically, the signals from the one or more sensors are received via an Analog to Digital (A/D) port of the microprocessor 201.

[00117] At step 642, the sensor data is processed by the processor 201 in order to determine sensor information indicative of the operating condition of the SPD. The sensor information may include for example an SPD status indication and an indication of a level of degradation of the surge protection device which may in turn be used to determine whether end of life is approaching.

[00118] At step 644, the processor 201 causes the sensor information to be wirelessly transmitted to the remote monitoring device 220. Any suitable wireless communication protocol may be used including for example Bluetooth, Zigbee, Wi-Fi, 6LowPAN and the like. The sensor information is received by the remote monitoring device 220 at step 646. If the sensor information is indicative that the surge protection device has failed or is approaching end of life based on the level of degradation then the remote monitoring device at least one of generates an alert at step 648 or schedules maintenance action at step 650.

[00119] Referring now to Figures 7A to 7D, there is shown an example of a surge protection device. In this example, the surge protection device 700 is of modular construction, incorporating a plug 710 and a base 720 into which the plug 710 is received in use. The plug body 711 houses all of the surge protection and monitoring electronics including the one or more sensors and electronic processing device whilst the base 720 provides a method of connection to electrical wiring. In the event of a device failure, the plug 710 can be easily removed from the base 720 without having to disconnect the wiring or de-energise the circuit.

[00120] The base 720 is of a generally U-shaped construction including an open channel 725 formed between opposing upright termination blocks 723, 724. Whilst the base in this example is generally U-shaped, this is an example only and any suitable shape or configuration may be

used. In use, the plug 710 slots into the open channel 725 thereby sandwiching it between the termination blocks 723, 724. The termination blocks 723, 724 are each for termination electrical wiring associated with the electrical system. The plug body 711 includes a plurality of downwardly extending connectors 715 which plug into mating receptacles formed in a base region 721 of the channel 725 to thereby electrically interconnect the plug 710 with the electrical wiring terminated in the base. In this manner, the plug is electrically interconnected between the power source and electrical equipment to be protected.

[00121] As shown most clearly in the assembled view of Figure 7D, the plug 710 includes a retaining clip 712 for releasably securing the plug body 711 to the base 720 and which in use, prevents the plug body 711 from inadvertently becoming disconnected from the base 720. In the example shown, the retaining clip 712 forms part of the sidewall of the plug body 711 and is a resiliently deformable element which terminates in a tab member that is retained, in use in a groove 724.1 located in terminal block 724. To remove the plug 710 from the base 720, a user grips the retaining clip 712 and squeezes until the tab member is urged out of the groove thereby enabling the plug and base to be separated.

[00122] As further shown in Figure 7D, the base 720 may be configured for mounting onto a rail 740 that would typically be installed in an electrical switchboard or the like. In this example, the base 720 includes a recessed portion on the bottom thereof with slotted regions for receiving flanges of the base rail 740.

[00123] Referring now to Figures 8 and 9, there are shown schematic diagrams of example implementations of the system. In Figure 8 for example, there is shown a surge protection device in series with a fuse used as a means of monitoring the status ("OK/Not OK") of the SPD. The operational parameters of the SPD being monitored by appropriate sensing circuitry in this example are SPD status, voltage, temperature and surges. Measurements of these parameters are input to the control and communication module which in one example is a suitably programmed microprocessor or microcontroller having on-board memory, and other peripherals such as a transmitter, transceiver (e.g. antenna) for broadcasting wireless signals such as Wi-Fi or Bluetooth to the remote monitoring device. Optionally, the controller may also provide a visual status indication.

[00124] In Figure 9, a plurality of SPDs denoted SPD1, SPD2…SPDn are shown which wirelessly communicate with a remote monitoring device which could take the form of a

central monitoring device, smart phone or a cloud based system. Typically, communication is permitted both ways so that the controller of the surge protection device is able to be controlled or programmed by user input to the remote monitoring device.

[00125] Referring now to Figure 10, there is shown a schematic circuit diagram of an example implementation of a monitoring system for a metal oxide varistor (MOV) based surge protection device able to monitor SPD status, operating temperature, operating voltage and surges. The functionality of each aspect of the circuit will now be briefly described, although the working will be apparent to a person skilled in the art.

SPD Status

[00126] The SPD status in the form a simple "OK/Not OK" indication is achieved using thermal fuses that link thermally to the MOVs, F1 & F2, but are not electrically connected to them. The thermal fuses are combined with pull up resistors R11 and R12 to provide a DC voltage to the inputs STATUS1 and STATUS2 on the microprocessor, which monitors these inputs. If the MOV is OK, these inputs are normally LOW (i.e. 0V) If one of the MOVs were to fail, this would trigger the associated thermal fuse, which would then see the corresponding status input go HIGH which would be detected by the microprocessor and interpreted as being a failure of the SPD.

Surge Detection

[00127] When a surge is clamped by MOVs F1 & F2, this causes a momentary rise in the voltage at the output of diode bridge V1. Zener diode D2 conducts, which causes a surge of current through R28. This is captured using a peak and hold circuit made up of D5 and capacitor C4 and is then detected by the microprocessor via one of its A2D input ports. R31, R32, R33 and transistor Q6 allow the microprocessor to reset the voltage across C4 to zero, ready for the next surge impulse.

Voltage Measurement

[00128] When the microprocessor activates Q2, this connects resistor R19 in series with resistors R18, R20 and R21. This forms a resistor divider network, enabling the microprocessor to measure the voltage across R19 via one of its A2D ports, which is proportional to the voltage at the output of diode bridge V1. R26/R27/C2/Q4 and R25/R25/Q3

are used to enable and disable the bootstrap power supply formed by resistors R15, R16 and R17 on and off using a pulse width modulation (PWM) signal from the microprocessor applied to C2. This enables the loading on the input resistor chain formed by R1-R10, R14 to be reduced to very low levels so that an accurate measurement of the input voltage level can be made.

Temperature Monitoring

[00129] In this example, the temperature measurement function of the microprocessor is used to infer an external ambient temperature based on a measured internal temperature of the integrated circuit (IC) of the microprocessor.

[00130] Figures 11A to 11B provide a schematic circuit diagram showing a further example implementation of an SPD monitoring system. This circuit is provided for completeness and to provide a person skilled in the art with a useful alternative for implementing SPD monitoring functionality as described herein.

[00131] Accordingly, it will be appreciated that in at least one example the above described system and method enables one or more operating parameters or conditions of at least one surge protection device to be monitored remotely. The ability to remotely monitor operating parameters may for example provide indication that a surge protection device has failed or is approaching its end of life so that suitable maintenance actions can be performed by a user. Implementation of such a system will ensure that equipment is protected for longer and that suitable maintenance can be scheduled as soon as a fault or potential fault is identified. Accordingly, the likelihood of any electrical and electronic equipment being damaged from surges, impulses and other transient over-voltage events is minimised. In addition, as on-site visual inspection of surge protection devices is avoided, non-qualified or low skilled staff can be used to monitor the operating parameters, thereby making the monitoring process more cost effective and reducing the frequency at which workers are required to access potentially hazardous sites where the devices may be installed.

[00132] Throughout this specification and claims which follow, unless the context requires otherwise, the word “comprise”, and variations such as “comprises” or “comprising”, will be understood to imply the inclusion of a stated integer or group of integers or steps but not the exclusion of any other integer or group of integers.

[00133] Persons skilled in the art will appreciate that numerous variations and modifications will become apparent. All such variations and modifications which become apparent to persons skilled in the art, should be considered to fall within the spirit and scope that the invention broadly appearing before described.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1) A system for monitoring one or more operating parameters of a surge protection device, the system including:
   a) a surge protection device for electrical interconnection between a power supply and electrical equipment to be protected;
   b) one or more sensors for monitoring the one or more operating parameters of the surge protection device;
   c) at least one electronic processing device coupled to the one or more sensors, wherein the at least one electronic processing device:
      i) determines sensor data indicative of signals from each of the one or more sensors, the sensor data at least partially indicative of the one or more operating parameters; and,
      ii) causes sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to a remote monitoring device; and,
   d) a remote monitoring device for wirelessly receiving the sensor information from the at least one electronic processing device;

      wherein the at least one electronic processing device:
      i) processes the sensor data to determine sensor information at least partially indicative of:
         (1) whether the surge protection device is working or has failed; and,
         (2) a level of degradation based on one or more of the operating parameters including an operating temperature; and,
      ii) sends the sensor information to the remote monitoring device; and,

      the remote monitoring device:
      iii) receives the sensor information; and,
      iv) if the sensor information is indicative that the surge protection device has failed or is approaching end of life in accordance with the level of degradation, then at least one of:
         (1) generates an alert; and,
         (2) schedules maintenance action.

2) The system according to claim 1, wherein the one or more operating parameters include a surge protection device status indicative of whether the device is working or has failed.

3) The system according to claim 1, wherein the one or more operating parameters include one or more of:
    a) an operating voltage;
    b) an operating temperature;
    c) a number of surges;
    d) an amplitude of surges; and,
    e) leakage current.
4) The system according to claim 3, wherein the one or more operating parameters are indicative of a level of degradation of the surge protection device.
5) The system according to claim 4, wherein an indication of end of life of the surge protection device is determined based on the level of degradation by one of:
    a) the at least one electronic processing device; and,
    b) the remote monitoring device.
6) The system according to claim 1, wherein the at least one electronic processing device determines sensor data at least one of:
    a) continuously; and,
    b) periodically.
7) The system according to claim 6, wherein the at least one electronic processing device determines sensor data for a first sensor at a different frequency to a second sensor.
8) The system according to any one of the preceding claims, wherein the at least one electronic processing device is coupled to data storage for storing sensor data.
9) The system according to any one of the preceding claims, wherein the determined sensor data is at least one of:
    a) an instantaneous value; and,
    b) based on statistical data.
10) The system according to any one of the preceding claims, wherein the sensor information includes at least one of:
    a) raw sensor data; and,
    b) processed sensor data.
11) The system according to claim 1, wherein the remote monitoring device:
    a) processes the received sensor information;
    b) uses the processed sensor information to determine whether the surge protection device is working or has failed; and,

c) in response to determining that the surge protection device has failed, schedules maintenance action.

12) The system according to claim 1, wherein the remote monitoring device:
   a) processes the received sensor information;
   b) uses the processed sensor information to determine a level of degradation of the surge protection device;
   c) determines an indication of end of life of the surge protection device based on the level of degradation;
   d) compares the indication of end of life to a threshold; and,
   e) optionally schedules maintenance action in accordance with a result of the comparison.

13) The system according to claim 11 or claim 12, wherein the remote monitoring device selectively generates an alert that the surge protection device has failed or otherwise requires maintenance action to be performed.

14) The system according to any one of the preceding claims, wherein the surge protection device includes one or more of the following types:
   a) spark gap;
   b) gas discharge tube;
   c) metal oxide varistor;
   d) silicon avalanche diode;
   e) silicon carbide (SiC); and,
   f) tranzorb diode.

15) The system according to any one of the preceding claims, wherein the sensor information is wirelessly transmitted to the remote monitoring device via a wireless communication protocol including one of:
   a) Bluetooth;
   b) Wi-Fi;
   c) Zigbee; and,
   d) 6LowPAN.

16) The system according to any one of the preceding claims, wherein the surge protection device is modular and includes:
   a) a base for connection to electrical wiring; and,
   b) a plug releasably secured to the base, the plug including a body for housing the one or more sensors and the at least one electronic processing device.

17) The system according to claim 15, wherein the plug includes a retaining clip for releasably securing the plug body to the base.

18) The system according to claim 16, wherein the base is generally U-shaped defining an open channel disposed between opposing terminal blocks for at least partially receiving the plug body.

19) The system according to claim 17, wherein the retaining clip forms part of a sidewall of the plug body and is a resiliently deformable element which terminates in a tab member that is retained, in use, in a groove located in one of the terminal blocks.

20) The system according to any one of the preceding claims, wherein the system includes a plurality of surge protection devices.

21) A method for monitoring one or more operating parameters of a surge protection device, the surge protection device for electrical interconnection between a power supply and electrical equipment to be protected, the method including in at least one electronic processing device:

a) determining sensor data indicative of signals from one or more sensors, the sensor data at least partially indicative of the one or more operating parameters of the surge protection device;

b) causing sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to a remote monitoring device;

c) in the at least one electronic processing device:

i) processing the sensor data to determine sensor information at least partially indicative of:

(1) whether the surge protection device is working or has failed; and,

(2) a level of degradation based on one or more of the operating parameters including an operating temperature; and,

ii) sending the sensor information to the remote monitoring device; and,

d) in the remote monitoring device:

i) receiving the sensor information; and,

ii) if the sensor information is indicative that the surge protection device has failed or is approaching end of life in accordance with the level of degradation, then at least one of:

(1) generating an alert; and,

(2) scheduling maintenance action.

22) The method according to claim 21, wherein the surge protection device includes a plug releasably securable to a base, and wherein the method further includes:
    a) terminating electrical wiring to the base, the electrical wiring for electrically interconnecting the surge protection device between a power supply and electrical equipment to be protected; and,
    b) releasably securing the plug to the base.

23) A surge protection device for electrical interconnection between a power supply and electrical equipment to be protected, the surge protection device including:
    a) a base for connection to electrical wiring; and,
    b) a plug releasably secured to the base, the plug including a body for housing:
        i) one or more sensors for monitoring one or more operating parameters of the surge protection device; and,
        ii) at least one electronic processing device coupled to the one or more sensors, wherein the at least one electronic processing device:
            (1) determines sensor data indicative of signals from each of the one or more sensors, the sensor data at least partially indicative of the one or more operating parameters; and,
            (2) causes sensor information that is at least partially indicative of the sensor data to be wirelessly transmitted to a remote monitoring device.

24) The surge protection device according to claim 23, wherein the plug includes a retaining clip for releasably securing the plug body to the base.

25) The surge protection device according to claim 23, wherein the base is generally U-shaped defining an open channel disposed between opposing terminal blocks for at least partially receiving the plug body.

26) The surge protection device according to claim 24, wherein the retaining clip forms part of a sidewall of the plug body and is a resiliently deformable element which terminates in a tab member that is retained, in use, in a groove located in one of the terminal blocks.

27) The surge protection device according to any one of claims 24 to 26, wherein the base is configured for mounting onto a rail.