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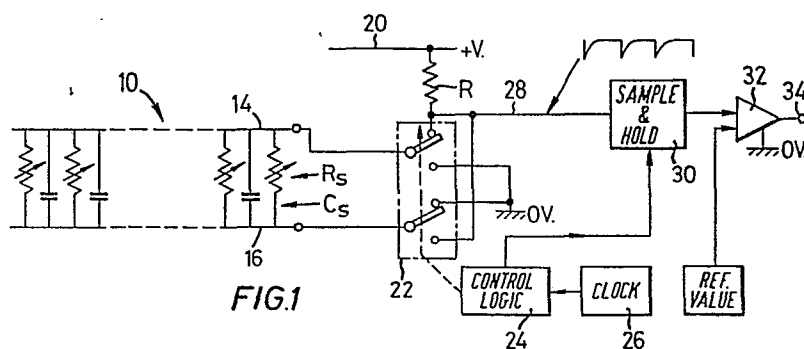
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54 Temperature monitoring systems.

57 A temperature monitoring system, useful for example for detecting fires, comprises a cable (10) having at least two conductors (14, 16) separated by elongate temperature-sensitive means having reactance (C_s) and resistance (R_s), at least the resistance (R_s) varying with temperature. A voltage source (+V) sends a d.c. current through a resistor (R) and said resistance (R_s), thereby to generate on a line (28) a d.c. signal that is representative of the value of the resistance (R_s). Switch means (22) is operative periodically to reverse

the direction of current flow through the resistance (R_s), the frequency of operation being sufficiently low that, after the change in the signal that will take place upon each reversal due to the cable reactance (C_s), the signal will revert to a steady value before the next reversal. The steady state of the signal is sampled and held (30) and compared (32) with a reference value (fixed or variable). If the steady state value exceeds the reference value, an alarm or the like can be generated.



TEMPERATURE MONITORING SYSTEMS

This invention relates to temperature monitoring systems and is particularly concerned with the way in which cables of such systems are energised.

A known type of temperature monitoring system, particularly (but
5 not exclusively) used for detecting fires, includes a cable comprising two or
more conductors separated by elongate temperature-sensitive means whose
impedance varies with temperature and detection means operative to
provide an output signal if such impedance achieves a predetermined or
threshold value indicative of the cable being at a predetermined
10 temperature. The elongate temperature sensitive means may for example
comprise polyvinyl chloride (PVC) which has a negative temperature
coefficient such that at room temperature it acts as an insulator and such
that its impedance drops with increasing temperature in a known manner.
The impedance (or a component thereof) of the temperature sensitive means
15 is measured by sending a current through the temperature sensitive means
and generating a signal related to the impedance (or a component thereof)
of the temperature sensitive means. It is particularly convenient to employ
d.c. current for this purpose, since one can make use of a simple circuit
network in the form of a resistive divider to develop a voltage proportional
20 to the resistance of the temperature-sensitive means. One can, for
example, use the resistance of the temperature-sensitive means as at least
part of one arm of a Wheatstone bridge. Although the use of d.c. therefore
means that one can simply and accurately monitor the resistance of the
temperature-sensitive means, the use of d.c. gives rise to a phenomenon in
25 the cable itself which undermines the inherent accuracy and simplicity of
using d.c. The phenomenon in question is that the resistance of the
temperature-sensitive means, in particular when such means is PVC,
increases with time when a d.c. voltage is applied across it, i.e. when a d.c.
current flows through it. This phenomenon, which is believed at least partly
30 due to a polarisation effect, is very pronounced in the case of PVC. For a
given length of cable at a given temperature, the initial resistance of the

PVC may for example increase by a factor of about 10 once the system has been in use for some while. Thus, if the temperature indicated by the system is calibrated in terms of the initial resistance of the cable, the results obtained in the steady state, once the cable has 'aged', will be inaccurate. It might at first be assumed that the ageing of the cable could be allowed for by 'pre-ageing' it by connecting it for a sufficiently long time to a d.c. supply before it is used. However, this technique would not overcome the problem because the 'ageing' is not wholly permanent. That is to say, when the d.c. supply is removed from the cable its resistance tends slowly to revert towards its initial value. Thus, if d.c. is to be used, there is no alternative but to design the system to cater for the whole range of resistance values that can be expected for a particular temperature due to the ageing phenomenon.

One can of course avoid the above-described problem by using a.c. instead of d.c. energisation, since it has been found that the ageing phenomenon does not occur in the case of a.c. energisation, probably because it does not of course involve polarisation in that the polarity of the applied voltage is periodically reversed. However, it has been found in practice that a.c. energisation is very much inferior to d.c. energisation in that the monitoring of the resistance tends to be much more difficult and complex to effect reliably and tends to be inherently less accurate than monitoring of a d.c. voltage. For example, it is necessary to use a very low frequency of around 2 Hz to avoid the effects of 50 Hz a.c. mains hum, and considerable problems are experienced in processing a signal of this frequency.

According to the present invention there is provided a temperature monitoring system comprising:

a cable having at least two conductors separated by elongate temperature-sensitive means having reactance and resistance, at least the resistance varying with temperature; and

energisation means operative to send d.c. current through a circuit network including said temperature-sensitive means, thereby to generate a d.c. signal representative of the resistance of the temperature-sensitive means;

the system being characterised by:

switch means operative periodically to reverse the connection of the temperature-sensitive means into the circuit network and therefore to reverse the direction of current flow through the temperature-sensitive means, the frequency of operation of the switch means being sufficiently
5 low that, after the change in said signal that will take place upon each said reversal due to said reactance, the signal will revert substantially to a steady value before the next reversal; and

means responsive to a predetermined relationship between said steady value and a reference value to indicate that the temperature of at
10 least part of the cable has exceeded a predetermined value.

With a system in accordance with the present invention, the periodic reversal of the direction of current flow through the temperature-sensitive means at least alleviates the problem of ageing and may in some instances be able to reduce it to substantially the same extent as if the energisation
15 were a.c. However, the use of what is essentially switched d.c. at a frequency low enough to avoid transient phenomena due to cable reactance (e.g. capacitance) means that one can avoid the use of difficult, cumbersome and not altogether accurate low frequency a.c. measurement techniques.

20 The above-mentioned reference value may be a fixed value determined for a particular cable and a particular operating temperature. However, it is within the scope of the invention for the reference value to be variable in a sense to compensate at least partly for changes in the ambient temperature of the cable.

25 The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawings, in which:

Figure 1 is a circuit diagram - partially in block diagram form - of a first temperature monitoring system embodying the invention;

30 Figure 2 is a cross-section through wires of a cable forming part of the system of Figure 1;

Figure 3 is a circuit diagram - partially in block diagram form - of a second temperature monitoring system embodying the invention;

35 Figure 4 is a cross-section through wires of a cable forming part of the system of Figure 3; and

Figure 5 is a graph showing the approximate relationship of the resistance (R_s) with temperature (T) of an insulating material of the wires of Figures 2 and 4.

The temperature monitoring system shown in Figure 1 includes a cable 10 comprising two wires 12 that are twisted together and, preferably, enclosed within a sheath (not shown). (The cable 10 could however be of coaxial construction). The cable 10 is disposed in proximity to an object or an area whose temperature is to be monitored, e.g. above a conveyor belt or on a ceiling, in particular to detect a fire.

The wires 12 comprise respective conductors 14 and 16 having sheaths 18. The sheaths 18 are of a material of which the resistance has a temperature coefficient, for example a negative temperature coefficient.

The material can be silicone rubber or a form of rubber known in the art as "EP rubber". Preferably, however, the material is polyvinyl chloride (PVC), which may or may not be doped with a material that enhances its conductivity. As is known to those skilled in the art, the resistance of PVC, whether doped or undoped, drops from a very high value at room temperature, in a substantially logarithmic value, as its temperature increases. As will be appreciated, the material of the sheaths 18 presents a distributed shunt resistance between the conductors 14 and 16. For convenience of representation, the resistance is shown as comprising a plurality of discrete resistors connected in parallel, the total resistance thereof as viewed at an end of the cable being R_s . The sheaths 18 naturally also constitute a distributed capacitance between the conductors 14 and 16. Again, for convenience of representation, such capacitance is shown in Figure 1 as comprising a plurality of discrete capacitors connected in parallel, the total capacitance thereof as viewed at an end of the cable being C_s .

As shown in Figure 1, a resistor R is connected in series with the parallel combination of the resistance R_s and the capacitance C_s between a +V rail 20 and an OV rail. Such connection is effected via a switch arrangement 22 which is preferably an electronic switch arrangement and, for simplicity of comprehension, is represented as a pair of changeover switches. As will be appreciated, when the switch arrangement 22 is reversed the direction of flow of d.c. current from the source through the material of the sheaths 18 (i.e. through the resistance R_s and the capacitance C_s) is reversed. In other words, the switch arrangement 22 is operative periodically to reverse the way in which the temperature sensitive material of the sheaths 18 is connected into the resistive divider circuit

network constituted by such material and the resistor R. The speed of operation of the switch arrangement 22 is controlled by control logic 24 which is driven by a clock 26.

5 The periodic reversal of the direction of current flow through the material of the sheaths 18 reduces the net d.c. current flow through them and therefore reduces the above-described ageing effect. The reduction of the effect can be maximised if the net d.c. current is reduced to zero, e.g. if the applied d.c. voltage and its duration are identical in the two positions of the switch arrangement 22. The voltages are kept identical by using the
10 common voltage source +V and ensuring that the switches making up the arrangement 22 have negligible "on" resistance. The durations are kept identical by suitable design of the control logic 24. To this end, the control logic 24 may comprise an edge-triggered counter/divider driven by the clock 26 to produce an output switching waveform whose two halves are of
15 exactly equal time span.

The way in which the resistance R_s is measured will now be described. Assume for the sake of argument that the switch arrangement 22 is not being operated but remains in the illustrated state. The resistor R and the resistance R_s are connected in series across the d.c. supply +V.
20 Consequently, the voltage (with respect to the OV rail) on a line 28 is directly proportional to the resistance R_s . If the switch arrangement 22 is then changed over, and if transient phenomena could be ignored, the level of the signal on the line 28 would not change because all that will have happened is that the direction of current flow through the resistance R_s will
25 have changed. However, transient effects cannot be ignored. In particular, there will be a change in the signal on the line 28 due to the reactance of the cable 10. More specifically, since the voltage across the capacitance C_s is reversed every time the switch arrangement 22 operates, and since it will take a finite time for the capacitance to charge up to the new value,
30 there will be a spike on the signal on the line 28 each time that the current is reversed. The resultant waveform on the line 28 is shown in Figure 1. To ensure that the signal on the line 28 reliably represents the value of the resistance R_s , the switching frequency provided by the control logic 24 is chosen to be sufficiently low that the capacitance C_s charges in good time
35 for the signal on the line 28 to be considered to have changed to a substantially steady value before the next current reversal. The frequency

chosen will of course vary with different materials and different applications, though a typical value might be about 1/6th or 1/7th Hz, that is to say the period of the waveform will in this case be about 6 or 7 seconds. A sample and hold unit 30, the operation of which is synchronised
5 by the control logic 24, is provided in the line 28 to sample the waveform during each 'plateau' portion, i.e. after the end of each spike, whereby the output voltage of the sample and hold unit is periodically updated so that its magnitude represents the latest sampled value of the signal representing the resistance R_s . This signal is applied to one input of a comparator 32. A
10 reference value or signal appropriate to a particular application is applied to another input of the comparator 32. The magnitude of the reference signal is such as to be equal to that provided by the sample and hold unit 30 when the cable 10 has been heated to a temperature which is sufficiently high that an alarm is required. The comparator 32 is responsive to the signal
15 from the sample and hold unit 30 achieving this reference value to provide an alarm output signal on a terminal 34.

Since the sampled values of the signal on the line 28 and thus the actual value input to the comparator 32 are obtained when the circuit has reached a steady state, the selection of the comparator reference voltage is
20 simple because only an application of Ohm's Law is required.

The reference value applied to the comparator 32 may be a value which is fixed for a particular application. Preferably, however, the reference value is varied to at least a certain extent to compensate for changes in the ambient temperature of the cable. A modified system, in
25 which the reference value is in fact varied to compensate for ambient temperature changes of the cable thereby enabling an increase in the maximum length of cable that can be used for a particular differential between the maximum ambient temperature and required operating temperature, will now be described with reference to Figure 3.

30 The system of Figure 3, which is described also in our co-pending UK Patent Application No. 8205339 and in our corresponding co-pending European patent application of even date herewith, largely resembles that of Figure 1 and will only be described in so far as it differs therefrom.

The system of Figure 3 includes a modified cable 10'. The cable 10'
35 is similar to the cable 10 of Figure 1, except that it comprises two further wires 12 having conductors 14', 16' and sheaths 18 the same as for the two wires 12 of the system of Figure 1. All four wires 12 are twisted together

and are preferably enclosed in a sheath (not shown). The wires 12 having the conductors 14, 14' are joined at one end of the cable 10' (the left-hand end as shown in Figure 3) - or comprise a single wire folded back on itself - thereby to form a single looped conductor 36 whose ends are accessible at the other end of the cable 10'. Similarly, the wires 12 having the conductors 16 16' are joined - or integral - at the left-hand end of the cable 10' as shown in Figure 3 to form another looped conductor 38. The looped conductors 36, 38 are useful for a number of reasons, especially in that they enable the continuity of the wiring to be checked by checking that the loops are not broken. However, at least one of the loops is used for a further purpose, the nature of which is explained below.

The wires 12 are shown in Figure 4 as being so arranged that the conductors forming each of the looped conductors 36, 38 are diagonally opposite each other. They could instead be arranged with such conductors adjacent each other.

As will be appreciated from an inspection of Figures 3 and 4, due to the sheaths 18 there will be distributed resistance and capacitance between the conductors 14' and 16 and between the conductors 14 and 16' as well as between the conductors 14 and 16. However, for convenience, the further distributed resistance and capacitance is omitted from the drawing.

A current source 40 is connected via a gate 42 controlled by the clock 26 to the looped conductor 38 such that, when the gate 42 is opened, a predetermined d.c. current is sent through the looped conductor 38. (The current source 40 could be a constant current source, but preferably comprises simply a resistor where resistance is high with respect to that of the looped conductor 38 whereby the predetermined d.c. current is substantially unaffected by changes in the resistance of the conductor 38). The looped conductor 38 is of a material whose resistance changes in known manner with temperature. The material may for example be copper, whose resistance changes by approximately 0.4 per cent per deg C and in fact increases by a factor of only about two between normal ambient temperature and its melting temperature. Consequently, it will be appreciated that when such current is flowing through the looped conductor 38 the voltage (with respect to the OV rail) on a line 44 will be representative of the resistance of the looped conductor 38. That is to say, such voltage will vary with changes in the ambient temperature of the cable

10'. Note, however, that since the resistance of the loop 38 can be considered to be the series combination of a multiplicity of incremental resistance elements, the overall resistance of the looped conductor 38 will be subjected only to a small change if the cable 10' is subject to intense local heating as a result of localised fire. (This contrasts with the way in which the voltage on the line 28 changes with temperature because, since the resistance R_s can be considered as being constituted by a multiplicity of incremental resistance elements connected in parallel, the resistance R_s can drop to a low value either by general heating of the whole cable or by more intense localised heating of a part of the cable.)

The resistance/temperature characteristic of a typical sheath material 18, that is to say the value of the resistance R_s , is represented in Figure 5. As will be seen, below a value typically equal to about 60°C, on a logarithmic scale, the relationship between R_s and temperature is approximately linear, there being typically a 17 deg C change in temperature per decade of resistance or in other words a doubling or halving of resistance for a change in temperature typically of about 5 deg C. It will be appreciated that the magnitude of the signal on the line 28 representing the parameter R_s will vary in similar manner, though not in exactly the same manner because R_s forms a potential divider chain with the resistor R. The signal on the line 44, which represents the series resistance of the looped conductor 38, is processed by a converter or amplifier 46 which has a logarithmic characteristic or transfer function such as to produce from the signal on the line 44 a modified (reference) signal which is applied to the comparator 32 and which varies with temperature in similar manner to that on the line 28. Thus, the reference signal from the converter 46 provides a degree of ambient temperature compensation for the signal on the line 28 in that both signals vary in a similar manner with changes in the ambient temperature of the cable 10', but does not preclude the generation of an output alarm signal on the terminal 34 in the event of a fire situation in that the reference signal, unlike the signal on the line 28, does not respond substantially to localised heating, for the reasons explained above.

In the arrangement described above, in order to prevent interference between the signals on the lines 28 and 44, the gate 42 is operated by the control logic 24 such that the current from the source 40 is sent through the

looped conductor 38 in the form of a pulse for a short interval at the end of each 'plateau' of the signal on the line 28, i.e. just before the next spike. The converter 46 incorporates a sample and hold unit (not shown) to sample each pulse on the line 44 whereby the reference value supplied by the
5 converter 46 represents the latest updated value of the series resistance of the looped conductor 38.

With the circuit as described above with reference to Figure 3, a fixed differential (e.g. say 5 deg C) is maintained, as the ambient temperature varies, between the ambient temperature and the temperature
10 level at which an alarm will be generated. There is therefore some risk that a gradual rise in temperature of the cable 10' to a dangerous value, e.g. in the event of an adjacent but not contiguous fire, could be ignored if it is sufficiently gradual. This can be avoided by limiting the extent to which the reference value (representing ambient temperature) applied to the
15 comparator 32 can be altered. In other words, the converter 46 can be arranged so that it does not continue to alter the reference value if the signal on the line 44 goes beyond a value equivalent to a limit temperature value of, say, 32 deg C greater than a predetermined temperature value equal, for example, to a normal ambient temperature value. Looking at the
20 matter another way, the converter 46 causes the system to cease to preserve the fixed differential between the ambient temperature and alarm temperature - i.e. to stop the alarm temperature tracking the ambient temperature - once the ambient temperature exceeds said limit temperature value.

25 The converter 46 may in fact be designed so that it does not provide a continuously varying output but instead provides an output which can adopt only one of (say) eight discrete values each corresponding to the signal on the line 44 indicating a respective step in temperature of (say) 4 deg C above said predetermined temperature value (e.g. normal ambient
30 temperature value). Such a feature can readily be accomplished, essentially by sensing the magnitude of the input signal on the line 44 and allocating one of eight particular values to the reference signal applied to the comparator 32, the reference values being related in logarithmic manner to the input threshold value on the line 44 whereby the desired logarithmic
35 transfer function of the converter 46 is obtained.

The invention can of course be embodied in various different ways than those described above by way of example. For example, other forms of cable than the cables 10 and 10' could be used. For instance, though the cable 10' happens to have two looped conductors 36, 38, it should readily be apparent that for present purposes only one looped conductor is needed. Furthermore, the looped conductor 38 does not have to be common with one of those conductors between which the resistance R_s is measured. The looped conductor could in fact be wholly separate and need not even be sheathed by temperature-sensitive material. It is in fact possible for the conductors associated with the resistance R_s and those forming the loop to be separate cables laid together or at least reasonably close to one another to form a common cable arrangement. Further, it is not even essential in the embodiment of Figure 3 to use a looped conductor. It is instead feasible to feed the current from the source 40 into a single, non-looped conductor having a good earth connection at its end remote from the source 40 whereby the voltage of the conductor with respect to earth could be measured to determine its resistance. (If the remote earth potential were different to that at the monitoring system, the difference could be trimmed out). In this case, it is the resistance between two ends of a non-looped conductor (rather than between the two ends of a looped conductor formed by a series circuit of two conductors) that is monitored. In general, one can monitor the impedance (or a component thereof) between the ends of a series circuit comprising at least one of the conductors. The invention can in fact be carried into effect with a cable having only two conductors.

It is further contemplated that the parameter of the loop 38 that is measured may not be its resistance. It is contemplated that a cable might be provided in which the inductance of the loop 38 might vary with temperature, in which case the inductance could be measured and used to provide the ambient temperature compensation reference signal.

It is within the scope of the invention to connect a device having a different characteristic for positive and negative polarities (e.g. a diode) between that end of the conductors separated by the temperature-sensitive means that is remote from the detecting means. This can enable different properties of the cable arrangement to be measured by reversing the polarity of energisation. For example, if the device is a diode then the shunt-impedance detection means in effect monitors the shunt impedance

(or a component thereof) between the two conductors when the polarity is such that the diode does not conduct. With the opposite polarity, the diode is forward-biased whereby the diode effectively short-circuits the remote ends of the conductors together and enables their continuity to be checked by measuring the resistance presented to the detection means. If the conductors monitored by the shunt-impedance detection means and the series-circuit impedance monitoring means are common, e.g. if there are only two conductors, the continuity check can be carried out by the monitoring means monitoring the impedance (e.g. resistance) of the two conductors. That is to say, the impedance of the temperature-sensitive means is monitored when the energisation is of one polarity (e.g. during half-cycles of an alternating supply of one polarity) and the conductor continuity and the series circuit impedance representing ambient temperature are monitored when the energisation is of the other polarity (e.g. during half-cycles of the opposite polarity).

CLAIMS

1. A temperature monitoring system comprising:
a cable (10; 10') having at least two conductors (14, 16) separated by elongate temperature-sensitive means having reactance (C_s) and resistance (R_s), at least the resistance (R_s) varying with temperature; and
5 energisation means operative to send d.c. current through a circuit network including said temperature-sensitive means, thereby to generate a d.c. signal representative of the resistance (R_s) of the temperature-sensitive means;
the system being characterised by:
10 switch means (22) operative periodically to reverse the connection of the temperature-sensitive means into the circuit network and therefore to reverse the direction of current flow through the temperature-sensitive means, the frequency of operation of the switch means being sufficiently low that, after the change in said signal that will take place upon each said
15 reversal due to said reactance (C_s), the signal will revert substantially to a steady value before the next reversal; and
means (32) responsive to a predetermined relationship between said steady value and a reference value to indicate that the temperature of at least part of the cable has exceeded a predetermined value.
- 20 2. A system according to claim 1, wherein the net d.c. current flow in use through the temperature-sensitive means is substantially equal to zero.
3. A system according to claim 2, wherein both the magnitude and the duration of the d.c. current flow in use through the temperature-sensitive means is the same in each direction.
- 25 4. A system according to claim 1, claim 2 or claim 3, including means for providing a fixed said reference value.
5. A system according to claim 1, claim 2 or claim 3, including compensation means for varying said reference value to compensate for the ambient temperature of the cable (10').

6. A system according to claim 5, including means for generating a signal representing the impedance (or a component thereof) measured between the ends of a series circuit comprising at least one conductor (16, 16') of the cable, the compensation means (46) being responsive to the value
5 of said signal to alter said reference value in a sense at least partially to compensate for changes in the ambient temperature of the cable.

7. A system according to claim 6, wherein the signal to which the compensation means (46) is responsive is wholly or predominantly representative of the resistance of the series circuit.

10 8. A system according to claim 6 or claim 7, wherein said series circuit comprises a pair of conductors (16, 16') connected together or integral with one another at one end of the cable (10') and connected to the compensation means (46) at the other end of the cable.

15 9. A system according to claim 6, claim 7 or claim 8, wherein the compensation means (46) is operative to vary the relationship between the signal to which it is responsive and the reference value in a sense complementary to that in which the signal representative of the resistance (R_s) of the temperature-sensitive means varies with temperature.

20 10. A system according to claim 9, wherein the signal representative of the resistance (R_s) of the temperature-sensitive means varies substantially antilogarithmically with temperature and the compensation means (46) provides a generally logarithmic transfer function between the other signal and the reference value.

25 11. A system according to any one of claims 6 to 10, wherein the compensation means (46) is operative not to alter said reference value if the signal to which it is responsive exceeds a predetermined limit value.

30 12. A system according to any one of claims 5 to 11, wherein the compensation means (46) is operative to vary the reference value between a plurality of predetermined desired values in response to variation in the ambient temperature of the cable.

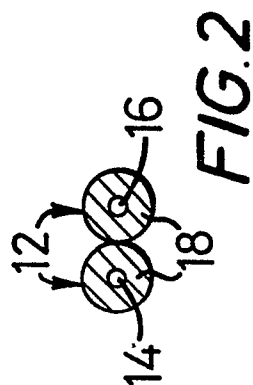


FIG. 2

