

SURGE VOLTAGE ABSORBING APPARATUS

BACKGROUND OF THE INVENTION

[0001]

The invention relates to a surge voltage absorbing apparatus.

[0002]

The following patent document describes a technique for protecting various electrical apparatuses from a surge voltage. This patent document's claim 1 recites that "a surge protective device comprising: a gas arrester to which an AC power supply voltage is applied; a varistor group connected in series to the gas arrester and including high-resistance varistors connected in parallel and each having a varistor voltage set to higher than a peak value of the AC power supply voltage; a resistor connected between both the electrodes of the varistor group for discharging a charge stored in the electrostatic capacitance of the varistor group".

[0003]

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[0004]

However, the parallel connection of the varistors causes a leak current to increase in a normal state. In addition, if the varistors connected in parallel are gradually exhausted, it is difficult to understand how degree they as a whole are exhausted, and they have a problem in maintainability.

SUMMARY OF THE INVENTION

[0005]

This invention is directed to a surge voltage absorbing apparatus which achieves a high maintainability.

The surge voltage absorbing apparatus includes a surge absorbing unit and a control unit.

The surge absorbing unit includes: a first surge voltage absorbing circuit inserted between two lines on which a surge voltage may occur and including a first surge voltage absorbing element having a couple of terminals and coming to a conductive state when a predetermined voltage or more is applied to the couple of terminals; a relay contact; and a second surge voltage absorbing circuit connected in parallel to the first surge

voltage absorbing circuit and including a second surge voltage absorbing element connected in series to the relay contact and coming to a conductive state when the predetermined voltage or more is applied to the second surge voltage absorbing element. The control circuit is configured to keep the relay contact turned off before detecting the first surge voltage absorbing circuit exhausted and configured to turn on the relay contact when detecting the first surge voltage absorbing circuit exhausted.

[0006]

According to the invention, the surge voltage absorbing apparatus achieves a high maintainability.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

[0007]

FIG. 1 is a block diagram of a surge protective apparatus according to an embodiment of the invention;

FIGS. 2A and 2B are circuit diagrams of surge absorbing units, respectively;

FIGS. 3A, 3B and 3C are waveform charts of units of the surge protective apparatus, respectively;

FIG. 4 is a time chart of the surge protective apparatus;

FIG. 5 is other time chart of the surge protective apparatus; and

FIG. 6 is a circuit diagram of a modification of an SPD (Surge Protective Device).

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0008]

<Whole Configuration of Embodiment>

When a lightning occurs close to a transmission line, a surge voltage caused by an induced lightning is applied to the transmission line. The surge voltage caused by the induced lightning has a voltage of several thousand volts and a current of several hundred to several thousand amperes and a time of several micro seconds to about 20 micro seconds. The surge voltage is larger in energy than a noise or a surge voltage caused by other factors. It is a surge protective apparatus that serves as a device for protecting various electric apparatuses from this surge voltage. Hereafter, the description will be given of a configuration of a surge

protective device according to an embodiment of the invention with reference to FIG.1.

[0009]

In FIG. 1, a three-phase four-wire external power supply line system 3 includes a voltage line 3R of R phase, a voltage line 3S of S phase, a voltage line 3T of T phase, and a neutral line 3N. It is noted that the external power supply line system 3 assumed in this embodiment has a nominal phase voltage of “200 V”. The surge protective apparatus 1 includes therein a voltage line 2R of R phase, a voltage line 2S of S phase, a voltage line 2T of T phase, and a neutral line 2N, which is connected to electric wires (the voltage lines and neutral line) 3R, 3S, 3T and 3N of the external power supply line 3, respectively. The surge protective apparatus 1 includes therein a ground line 2G grounded. An apparatus 4 to be protected is an objective to be protected from a surge voltage caused by the external power supply system 3. The apparatus 4 is connected to the electric wires 2R, 2S, 2T, 2N in the surge protective apparatus 1. The apparatus 4 to be protected includes a grounded casing.

[0010]

The surge protective apparatus 1 includes surge absorbing units 10RN, 10SN and 10TN inserted between respective voltage lines 2R, 2S and 2T and the neutral line 2N. The respective voltage lines 2R, 2S and 2T and the ground line 2G have corresponding surge absorbing units 10RG, 10SG, and 10TG inserted therebetween. These surge absorbing units 10RN, 10SN, 10TN, 10RG, 10SG and 10TG include the identical circuit configurations and each are generally called a “surge absorbing unit 10”. The neutral line 2N and the ground line 2G have a surge absorbing unit 30 inserted therebetween. The surge absorbing units 10 and 30 are provided for absorbing surge voltages generated on the respective electric wires 2R, 2S, 2T and 2N to protect the apparatus 4 to be protected.

[0011]

The mode of surge voltage is divided into a “common mode” and a “normal mode”. The “common mode” is a situation under which surge voltages with equivalent waveforms are generated on the voltage lines 3R, 3S and 3T and the neutral line 3N, respectively. The “normal mode” is a situation under which a particularly high surge voltage is generated on only a part of the electric wires 3R, 3S and 3T and the neutral line 3N.

The surge absorbing units 10RG, 10SG and 10TG and 30 primarily absorb surge voltages of the common mode. The surge absorbing units 10RN, 10SN and 10TN primarily absorb surge voltages of the normal mode.

[0012]

The surge protective apparatus 1 includes a control circuit 50. The control circuit 50 includes therein a power supply circuit 54 which supplies a power to each unit. The voltage detecting circuit 55 detects respective phase voltages between respective voltage lines 2R, 2S and 2T and the neutral line 2N. The logic circuit 56 drives relays (specifically described below) provided in the surge absorbing units 10 and 30 using a relay drive circuit 57 in response to states of the surge absorbing units 10 and 30, and switch between an On or Off state of each relay contact. The external interface 58 outputs a state of the surge protective apparatus 1 to an external monitor and the like.

[0013]

The logic circuit 56 may be configured with a micro computer including a CPU (Central Processing Unit), a memory and the like. On the other hand, from the perspective of preventing the runaway due to a lightning surge, the logic circuit 56 may be implemented with a logic IC such as a TTL (Transistor Transistor Logic) circuit or an integrated circuit such as an FPGA (Field Programmable Gate Array).

[0014]

<Configuration of Surge Absorbing Unit 10>

The subsequent description will be given of a configuration of the surge absorbing unit 10 with reference to FIG. 2A. The surge absorbing unit 10 includes a terminal 10a connected to any of the voltage lines 2R, 2S and 2T; and a terminal 10b connected to the neutral line 2N or the ground line 2G. The surge absorbing unit 10 includes six SPDs (Surge Protective Device). Herein, in particular the configuration of the SPD 11 is specifically described. The SPD 11 includes therein a temperature fuse 101 and an MOV (Metal Oxide Varistor) 102 connected in series.

[0015]

The micro switch 110 is switched with a state of the temperature fuse 101. The micro switch 110 includes a common terminal 110b; and a terminal 110a to be connected to the common terminal 110b while the temperature fuse 101 is not blown out; and a terminal 110c to be connected

to the common terminal 110c when the temperature fuse 101 is blown out. In the embodiment, a contact signal serving as a state between the terminal 110a and the common terminal 110b is outputted as a state signal S11. In an initial state, the state signal S11 is an On state as illustrated by the figure.

[0016]

Herein, when generation of a surge voltage and the like causes the terminal voltage of the MOV 102 to be a clamp voltage (maximum breakdown voltage) or more, a large current flows through the MOV 102. When this situation is repeated several times, the MOV 102 becomes deteriorated and the leak current gradually increases, so that a heat generation value of the MOV 102 becomes larger. When the surface temperature of the MOV 102 achieves the operation temperature of the temperature fuse 101, the temperature fuse 101 blows out. Thereby, a state signal S11 comes to an Off state, which makes it possible to detect from outside that “the SPD 11 is exhausted with the temperature fuse 101 blown out”.

[0017]

The mentioned above specifically describes the configuration of SPD 11, and the other SPDs 12 to 16 are identically configured. The contact signals between the terminals 110a and 110b of respective SPDs 12 to 16 are called “state signals S12 to S16”. Herein, the SPD 11 is connected in parallel to a relay contact 21. The SPD 12 is connected in series to a relay contact 22, and this series circuit is connected in parallel to the SPD 11. The SPDs 14, 15 and 16 are connected in series to relay contacts 24, 25 and 26, respectively. The respective series circuits are connected in parallel to the SPD 13.

[0018]

The relay contacts 21 to 26 as shown in FIG.2A have On/Off states in initial states, respectively. That is, the relay contact 21 is in an On state, and the other relay contacts 22 to 26 are in Off states. Therefore, in an initial state, a voltage between the terminals 10a and 10b is applied to only the couple of terminals of the SPD 13, and any voltage is not applied to the other SPDs 11, 12 and 14 to 16. As described above, the nominal phase voltage of the external power supply system 3 is “200 V”. If a voltage variation in a normal state is in a range of $\pm 10\%$, the maximum voltage in a

normal state is “220V”. This “220 V” is an effective value and the wave peak value of the voltage is “311 V” of $\sqrt{2}$ times the effective value.

[0019]

The MOV 102 housed in the SPD 13 has a clamp voltage V_{C1} (=340 V) to which the wave peak value “311 V” with some allowance is applied. The breakdown does not occur within a range of a normal voltage variation. The SPDs 14, 15, 16 are applied in place of the SPD 13 when the SPD 13 is exhausted (specifically described below). The clamp voltages of MOVs 102 housed in the SPDs 14 to 16 are V_{C1} (=340 V) as well.

[0020]

The SPDs 11 and 12 are connected in series to any of the SPDs 13 to 16 when an overvoltage over a range of a normal voltage variation ($\pm 10\%$) occurs (specifically described below). The MOVs 102 in the SPDs 11 and 12 have a clamp voltage V_{C2} (=150 V). The MOVs 102 are connected in series to any of the SPDs 13 to 16, and the total clamp voltage ($V_{C1} + V_{C2}$) is “490 V”.

[0021]

<Configuration of Surge absorbing unit 30>

The subsequent description will be given of the configuration of the surge absorbing unit 30 connected between the neutral line 2N and the ground line 2G with reference to FIG. 2B. The surge absorbing unit 30 includes a terminal 30a connected to the neutral line 2N and a terminal 30b connected to the ground line 2G. The terminals 30a and 30b have an SPD 33 connected therebetween. The SPDs 34, 35 and 36 are connected in series to relay contacts 44, 45 and 46, respectively. These series circuits are connected in parallel to the SPDs 33. The MOVs 102 in the SPDs 33 to 36 have clamp voltages V_{C1} (=340 V) as well as the above described SPDs 13 to 16.

[0022]

<Clamp Voltage Setting Operation>

The voltage detecting circuit 55 shown in FIG.1 includes resistor unit (not shown in FIGS.) which divides a voltage of each R, S and T phase to the neutral line 2N and a voltage of each R, S and T phase to the ground line 2G, which are full-wave rectified by a diode bridge. The rectified voltages are smoothed by a smoothing circuit (not shown in FIGS.) having a time constant of about several minutes. This time constant removes

influence of a ripple, a surge, an external noise and the like from a voltage and may be a value for preventing an excessive current from flowing through the SPDs 13 to 16 (see FIGS. 2A and 2B). Herein, the description will be given of an operation for setting a clamp voltage in the surge absorbing unit 10 by the control circuit 50.

[0023]

In the voltage detecting circuit 55, the above described voltage detected via the smoothing circuit is called "detection voltage V". This "detection voltage V" corresponds specifically to any of a voltage to the neutral line 2N for the voltage lines 2R, 2S and 2T or a voltage to the ground line 2G. An example of a waveform of the detection voltage V is shown in FIG. 3A. In FIG. 3A, the threshold voltage V_{TH} is an effective value of the maximum voltage within a range of a normal voltage variation, or a value corresponding to "220 V". FIG. 3B shows an On/Off state of the relay contact 21 (see FIGS. 2A and 2B). FIG. 3C shows a total clamp voltage V_C in the surge absorbing unit 10.

[0024]

In FIGS. 3A to 3C, the detection voltage V is less than the threshold voltage V_{TH} before time t_1 . The relay contact 21 is kept in an On state, and the total clamp voltage V_C of the surge absorbing unit 10 is equal to the clamp voltage V_{C1} (=340 V) of the SPDs 13 to 16. When the detection voltage V becomes the threshold voltage V_{TH} or more at the time t_1 , the logic circuit 56 shown in FIG. 1 immediately outputs to the relay drive circuit 57 a signal with which the relay contact 21 comes to an Off state.

[0025]

This, as shown in FIG. 3B, turns off the relay contact 21 at the time t_1 . When the relay contact 21 is set to an Off state, any of the SPDs 11 and 12 for overvoltage is connected in series to any of the SPDs 13 to 16 for normal voltage. This, as shown in FIG. 3C, raises the total clamp voltage V_C to $V_{C1} + V_{C2}$ (= 490 V). Next, at the time t_2 the detection voltage V again becomes less than the threshold voltage V_{TH} . However, the logic circuit 56 does not respond to it immediately, and outputs a signal for turning on the relay contact 21 to the relay drive circuit 57 at the time t_3 when a delay time T_d elapses from the time t_2 . This, at the time t_3 , turns on the relay contact 21 and the total clamp voltage V_C returns to V_{C1} .

[0026]

Thus, the reason for setting the delay time T_d is to prevent the relay contact 21 from being frequently switched between On and Off states when the detection voltage V frequently varies in the vicinity of the threshold voltage V_{TH} . It is noted that the delay time T_d may be about several hundred milliseconds to several seconds. The operation after the time t_3 is the same as the above described operation. That is, at the timing when the detection voltage V becomes the threshold voltage V_{TH} or more, the relay contact 21 is immediately set to an Off state and the total clamp voltage V_C is set to $V_{C1} + V_{C2}$. On the other hand, at the timing when the detection voltage V becomes less than the threshold voltage V_{TH} and the delay time T_d further elapses from the timing, the relay contact 21 is set to an On state and the total clamp voltage is set to V_{C1} .

[0027]

The above-described operation is executed independently for respective surge absorbing units 10RN, 10SN, 10TN, 10RG, 10SG and 10TG in response to respective detection voltages V . However, the surge absorbing unit 30 inserted between the neutral line 2N and the ground line 2G has a constant clamp voltage, and an operation for setting the clamp voltage is not executed.

[0028]

<Operation for Switching SPD in Surge Absorbing Unit 10>

In each surge absorbing unit 10, the relay contacts 22, 24, 25 and 26 are switched between On and Off states in response to exhaustion states of the SPDs 11 and 13 to 16 (state signals S_{11} and S_{13} to S_{16}). An “exhaustion state” means that applying a surge voltage to the varistor 102 causes the varistor 102 to be deteriorated or broken down and a leak current to flow through the varistor 102, and when the leak current is increased, the temperature fuse 101 is blown out so as to open each SPD 11 and 13 to 16. On the other hand, a current sensor such as a hall element may be used with or in place of the temperature fuse 101 to detect a leak current value. The current sensor may detect the leak current value increased to a threshold as an exhaustion state of the SPD.

The contents of the processing will be described with reference to FIG. 4.

[0029]

Before the time t_{21} all the state signals S_{13} to S_{16} of the SPDs 13 to 16 are in On states. On the other hand, at the time t_{21} the SPD 13 for

normal voltage is exhausted with the temperature fuse 101 blown out, and the state signal S13 comes to an Off state. When detecting this state, the logic circuit 56 sets the relay contact 24 to an On state with the relay drive circuit 57. This makes the SPD 14 connected between the terminals 10a and 10b while an overvoltage is not generated. The SPD 14 is applied as an SPD for normal voltage.

[0030]

At the time t22 the SPD 14 is exhausted and the state signal S14 comes to an Off state. The logic circuit 56 and the relay drive circuit 57 set the relay contact 24 to an Off state and the relay contact 25 to an On state. Thereby, the SPD 15 hereafter is used as an SPD for normal voltage. As described above, the SPD 11 for overvoltage is connected in series to the SPDs 13 to 16 for normal voltage. At the time t23, this SPD 11 is exhausted and the state signal S11 comes to an Off state. With this state, at the time t23 the logic circuit 56 and the relay drive circuit 57 set the relay contact 22 to an On state. Thereby, the SPD 11 is replaced with the SPD 12, which thereafter is used as an SPD for overvoltage.

[0031]

At the time t24 the SPD 15 for normal voltage is exhausted and the state signal S 15 comes to an Off state. Therefore, the logic circuit 56 and the relay drive circuit 57 set the relay contact 25 to an Off state and the relay contact 26 to an On state. At the time t25 the SPD 16 is exhausted and the temperature fuse 101 inside of it is blown out. This causes the state signal S16 to come to an Off state. Thereby, all the SPDs 13 to 16 for normal voltage are exhausted and the surge absorbing unit 10 does not function.

[0032]

In FIG. 4, the status signals ST11 to ST14 are outputted as a signal for a display lamp or an alarm signal from the logic circuit 56 (see FIG. 1) through an external interface 58 to an external monitor and the like based on the above described state signals S11 and S13 to S16. Firstly, the status signal ST11 comes to an On state, on condition that both the state signals S11 and S13 of the respective SPDs 11 and 13 applied in an initial stage are in On states. Therefore, the status signal ST 11 in an On state means that all the SPDs in the surge absorbing unit 10 are normal. In the example of FIG. 4, this corresponds to the state before the time t21.

[0033]

The status signal ST12 comes to an On state if both the following conditions are satisfied. One condition is that “any one of the state signal S11 and the state signal S13 is in an Off state”. The other condition is that “all of the state signals S12 (see FIGS. 2A and 2B), S15 and S16 are in On states”. Therefore, the status signal ST12 in an On state means that at least “two” normal SPDs for normal voltage and at least “one” normal SPD for overvoltage remain though some SPDs are exhausted.

[0034]

This means that the surge absorbing unit 10 has a sufficient remaining life. If a user of the surge protective apparatus 1 asks a supplier for taking care of the surge protective apparatus 1 at this time, he can carry out planned exchange or maintenance for the surge absorbing unit 10 with a time allowance. This corresponds to the states at the times t21 to t24 in the example of FIG. 4.

[0035]

The status signal ST13 comes to an On state if the following condition is satisfied. The condition is that “the status signal S15 is in an Off state and both the state signals S12 (see FIGS. 2A and 2B) and S16 all are in On states”. The status signal ST13 in an On state means that “three of four SPDs 11 to 16 have been exhausted”. The remaining life of the surge absorbing unit 10 decreases to “one fourth” or less from the initial. This shows that the surge absorbing unit 10 is desired to be exchanged or maintained as soon as possible. This corresponds to the states at times t24 to t25 in the example of FIG. 4.

[0036]

The status signal ST14 comes to an On state when any of the state signals S12 and S16 comes to an Off state. This state means that the last SPD 12 for over voltage or the last SPD 16 for normal voltage has been exhausted, and indicates that the function of the surge absorbing unit 10 remarkably lowers or does not work at all. This situation shows that the surge absorbing unit 10 is desired to be immediately executed for exchange or maintenance. This corresponds to the state after the time t25 in FIG. 4. It is noted that even if one surge absorbing unit 10 does not function at all, all the surge protective apparatus 1 “does not function”. That is, in FIG. 1

even if one surge absorbing unit 10 does not function at all, other surge absorbing unit 10 can compensate the function to some degree.

[0037]

Herein, the description will be given of the reason for providing two SPDs 11 and 12 for overvoltage in this embodiment. The period for operating the SPDs 11 and 12 (connecting them in series to the SPDs for normal voltage) is a period for which an overvoltage is occurring, and is slightly related to a period for which an induced lightning causes a surge voltage. That is, as described in FIGS. 3A to 3C, the detection voltage V is an output voltage of the smoothing circuit having a time constant of about several seconds. Therefore, after respective actual voltages of the voltage lines 2R, 2S and 2T comes to overvoltage states, the SPDs 11 and 12 operate with a delayed timing of about several seconds. On the other hand, a period for generating a surge voltage due to an induced lightning is several micro seconds to about 20 micro seconds, and a generation period for a surge voltage normally finishes before the SPDs 11 and 12 start to operate.

[0038]

Then, if they are used under the same environment, a ratio of an expected life of the SPD for overvoltage to an expected life for the SPD for normal voltage is inversely proportional to a ratio of an overvoltage generation time to a total operation time. For example, if an all operation time is "six months (4320 hours)" and a total overvoltage generation time is "20 hours", an expected life of the SPD for overvoltage is "216 (=4320/20) times" that of the SPD for normal voltage. Thus, the SPD for overvoltage is expected to have a considerable long life. Thereby, it is understood that the SPD for overvoltage does not need to complete the same number as the number of the SPD for normal voltage and is operated with the less number.

[0039]

This embodiment uses four SPDs 13 to 16 as SPDs for normal voltage. On the other hand, according to simple calculation from the ratio of the expected life, it is considered that a single SPD for overvoltage is sufficient in many cases. However, if the number of the SPD is set to one when said one SPD is exhausted, it comes into a situation under which exchange or maintenance of the surge absorbing unit 10 is desired to be urgently

carried out. This makes it difficult to carry out planned maintenance with a time allowance. In the embodiment, in order to receive an alarm signal on the stage where the surge absorbing unit 10 sufficiently functions, two SPDs 11 and 12 are applied for overvoltage.

[0040]

<Switching Operation of SPD in Surge Absorbing Unit 30>

The subsequent description will be given of a switching operation of the SPD in the surge absorbing unit 30. As described in FIGS. 2A and 2B, the configuration of the surge absorbing unit 30 is identical to a configuration in which the SPDs 11 and 12 for overvoltage, the relay contacts 21 and 22 are removed from the surge absorbing unit 10. In the surge absorbing unit 30, the relay contacts 44, 45 and 46 are switched between On and Off states under control of the relay drive circuit 57 in response to the state signals S33 to S36 outputted from the respective SPDs 33 to 36. The contents of the processing are described with reference to FIG. 5.

[0041]

The waveforms of the state signals S33 to S36 and the states of the relay contacts 44, 45 and 46 as shown in FIG. 5 are identical to the waveforms of the state signals S13 to S16 and the states of the relay contacts 24, 25 and 26, respectively. Then, if the state signal S33 of the SPD 33 applied in an initial state is in an On state, the status signal ST41 is kept in an On state. If the state signal S33 is in an Off state and any of the state signals S34 and S35 of the secondarily and thirdly applied SPDs 34 and 35 are in On states, the status signal ST42 is in an On state.

[0042]

If the state signals S33 to S35 are in Off states and the state signal S36 is in an On state, the status signal ST43 is in an On state. If all the state signals S33 to S36 are in Off states, the status signal ST44 is in an On state. Therefore, the status signal ST41 indicates that all the SPDs in the surge absorbing units 30 are normal. The status signal ST42 indicates that one or two SPDs are exhausted. The status signal 43 indicates that three SPDs are exhausted. The status signal ST44 indicates that all the SPDs are exhausted. The status signals ST41 to ST44 are also outputted from the logic circuit 56 through the external interface 58 to the external monitor and the like.

[0043]

<Benefits of Embodiment>

As described above, the surge protective apparatus (surge voltage absorbing apparatus) 1 includes a surge absorbing unit group and a control circuit.

(a) The surge absorbing unit group (10RN, 10SN, 10TN, 10RG, 10TG and 30) includes one or more surge absorbing units (10, 30). One of the surge absorbing units (10, 30) includes: a first surge voltage absorbing circuit (13) inserted between two lines on which a surge voltage may occur and including a first surge voltage absorbing element (102 in the SPD 13) having a couple of terminals and coming to a conductive state when a predetermined voltage or more is applied to the couple of terminals thereof; a relay contact (24); and a second surge voltage absorbing circuit (14, 24) connected in parallel to the first surge voltage absorbing circuit (13) and including a second surge voltage absorbing element (102 in the SPD 14) which is connected in series to the relay contact and comes to a conductive state when said predetermined voltage or more is applied to the second surge voltage absorbing element.

(b) The control circuit (50) for each of the surge absorbing units (10, 30) is configured to keep the relay contact (24) turned off before detecting the first surge voltage absorbing circuit exhausted (the state signal S13 comes into an Off state), and turn on the relay contact (24) when detecting the first surge voltage circuit (13) exhausted.

[0044]

The surge protective apparatus 1 further includes: three-phase voltage lines (2R, 2S, 2T); and a neutral line (2N). The surge absorbing unit group (10RN, 10SN, 10TN, 10RG, 10SG, 10TG and 30) includes three voltage line-to-neutral line surge absorbing units (10RN, 10SN, 10TN) inserted respectively between the three-phase voltage lines (2R, 2S, 2T) and the neutral line (2N).

[0045]

The surge absorbing unit group (10RN, 10SN, 10TN, 10RG, 10SG, 10 TG and 30) includes a neutral line-to-ground potential surge absorbing unit (30) inserted between the neutral line (2N) and a conductor (2G) of a ground potential. The group of surge absorbing units (10RN, 10SN, 10TN, 10RG, 10SG, 10TG and 30) includes three voltage-line-to-ground potential surge absorbing units (10RG, 10SG and 10TG) inserted between the

three-phase voltage lines (2R, 2S, 2T) and a conductor (2G) of a ground potential, respectively.

[0046]

Each voltage line-to-neutral line surge absorbing unit (10RN, 10SN, 10TN) includes: a surge voltage absorbing circuit (11) for overvoltage connected in series to a parallel circuit including the first surge voltage absorbing circuit (13) and the second surge voltage absorbing circuit (14, 24); a switch unit (21) connected in parallel to the surge voltage absorbing circuit (11) for overvoltage and configured to short-circuit or open a couple of terminals of the surge voltage absorbing circuit (11) for overvoltage. The control circuit (50) includes a voltage detecting circuit (55) to detect voltages between the three-phase voltage lines and the neutral line. The control circuit (50) is configured to short-circuit the switch unit (21) in a corresponding voltage line-to-neutral line surge absorbing unit (10RN, 10SN, 10TN) when the detected voltages are less than a predetermined threshold voltage (V_{TH}). The control circuit (50) is configured to open the switch unit (21) in the corresponding voltage line-to-neutral line surge absorbing unit (10RN, 10SN, 10TN) when the detected voltage is the threshold voltage (V_{TH}) or more.

[0047]

The voltage line-to-ground potential surge absorbing unit (10RG, 10SG, 10TG) further includes: a surge voltage absorbing circuit (11) for overvoltage connected in series to a parallel circuit including the first surge voltage absorbing circuit (13) and the second voltage absorbing circuit (14, 24); a switch unit (21) connected in parallel to the surge voltage absorbing circuit (11) for overvoltage for opening or short-circuiting a couple of terminals of the surge voltage absorbing circuit (11). The control circuit (50) includes a voltage detecting circuit (55) configured to detect voltages between the respective three-phase voltage lines and a conductor (2G) of the ground potential. The control circuit is configured to short-circuit the switch unit (21) in a corresponding voltage-line-to-ground-potential surge absorbing unit (10RG, 10SG, 10TG) when the detected voltage is less than a predetermined threshold voltage (V_{TH}). The control circuit is configured to open the switch unit (21) in a corresponding voltage-line-to-ground-potential surge absorbing unit (10RG, 10SG, 10TG) when the detected voltage is the threshold voltage (V_{TH}) or more.

[0048]

The first and second surge voltage absorbing circuits (13, 14) output state signals (S13, S14) indicating exhaustion states thereof, respectively. The control circuit (50) outputs a status signal (ST 11 to ST14, ST41 to ST44) as a monitor signal which is a combination of the state signals (S13, S14) which are outputted from respective surge absorbing units constituting the surge absorbing unit group (10RN, 10SN, 10TN, 10RG, 10SG, 10TG, 30).

[0049]

According to the embodiment with this configuration, even if the first surge voltage absorbing unit 13 is exhausted in any of the surge absorbing units (10, 30), the second surge voltage absorbing circuit (14, 24) continues to absorb a surge voltage, thereby achieving a high maintainability. In addition, the status signals (ST11 to ST14, ST41 to ST44) are outputted as monitor signals, the status signals being combination of state signals (S13, S14) outputted from the respective surge absorbing units. Thereby, an exhaustion degree of the whole surge protective apparatus 1 is understood at a remote place, which enables planned maintenance with a time allowance, thereby achieving a higher maintainability.

[0050]

<Modification>

This invention is not limited to the above described embodiment and various modifications are possible. The above described embodiment shows an example for easily understanding the invention, and is not necessarily limited to one provided with all the described configurations. A part of a configuration of one embodiment may be replaced with a configuration of other embodiment. A configuration of other embodiment may be added to a configuration of one embodiment. A part of a configuration of each embodiment may be deleted. Other configuration may be added to or replaced with the part of each embodiment. For example, the description below will be given of a possible modification of the above described embodiment.

[0051]

(Modification of SPD)

(1) Though the above described embodiment uses the SPDs 11 to 16 and 33 to 36 shown in FIGS. 2A and 2B, the SPD 70 shown in FIG. 6 may be

used in place of them. The SPD 70 is identical to the SPD 11 and the like in including an MOV 102 and a temperature fuse 101 connected in series. On the other hand, the SPD 70 includes a photocoupler 104 in which an LED 104a and a phototransistor 104b are sealed.

[0052]

The LED 104a is connected in series to a resistor unit 103. The series circuit of the LED 104a and the resistor unit 103 is connected in parallel to the MOV 102. Herein, when some voltage is applied to the normal SPD 70, a current flows through the LED 104a via the temperature fuse 101 and the resistor unit 103 thereby to turn on the LED 104a. This turns on phototransistor 104b.

[0053]

On the other hand, when the MOV 102 is exhausted and the temperature fuse 101 is blown out, the LED 104a is turned off and the phototransistor 104b comes to an Off state. Though some voltage is applied to the SPD 70, the phototransistor 104b in an Off state shows that the MOV 102 is exhausted and the temperature fuse 101 is blown out. The On/Off state of the phototransistor 104b is outputted to outside as a state signal S70. In this modification, acquiring an effective signal value as the state signal S70 requires applying some voltage to the SPD 70. Other points are used as well as those of the SPD 11 and the like in the above described embodiment.

[0054]

(2) The SPD 70 of the modification in FIG.6 houses the photocoupler 104 therein. On the other hand, the SPD, which does not house the photocoupler 104 and outputs a connection point of the MOV 102 and the temperature fuse 101 as an intermediate terminal for a monitor, is also known. This kind of SPD may be used in place of the SPDs 11 to 16 and 33 to 36 in the above described embodiment and a photocoupler may be connected to an intermediate terminal for a monitor separately.

[0055]

(3) In the above described embodiment, though the SPD 70 housing the MOV 102 is applied as the SPDs 11 and 12 for overvoltage, the MOV 102 may be replaced with a gas arrestor. The gas arrestor has a characteristic that when the gas arrestor start to discharge once, the continuous current

occurs even after the surge voltage disappears. Therefore, it is necessary to carefully use the gas arrestor in place of the SPD for normal voltage.

[0056]

(Modification of Quantity of Surge Absorbing Units 10 and 30)

(1) The above described embodiment includes surge absorbing units 10RG, 10SG, 10TG and 30 mainly corresponding to a common mode; and surge absorbing units 10RN, 10SN and 10TN. Though the total number of surge absorbing units 10 and 30 is seven, a part of these surge absorbing units may be omitted for cost reduction.

[0057]

For example, if the neutral line 3N of the external power supply system 3 may be grounded in the vicinity of the surge protective apparatus 1, a decrease surge voltages generated at the neutral lines 3N and 2N is expected. In this case, the surge absorbing unit 30 may be omitted. If it is directed to correspondence especially to a "normal mode" in the surge voltage, the surge absorbing units 10R, 10SG and 10TG may be omitted. On the contrary, if it is directed to correspondence especially to a "common mode", the surge absorbing units 10RN, 10SN and 10TN may be omitted.

[0058]

(Modification of Distribution System)

Though the above described embodiment describes the example of applying a distribution system of a three-phase four-wire system, other distribution system may be adopted. For example, a three-phase three-wire system with a grounded S phase is often used in Japan. In this case, a surge absorbing unit between an R phase and an S phase (ground) and a surge absorbing unit between a T phase and an S phase (ground) may be provided. The distribution system is not limited to "alternating current" and may be also "direct current". In this case, a surge absorbing unit may be inserted between the plus side and the minus side.

[0059]

(Modification of Status Signal)

In the above described embodiment, the state signals S11 to S16 and S33 to S36 outputted from respective SPDs 11 to 16 and 33 to 36 are combined to be status signals ST11 to ST14 and ST41 to ST44 to be outputted to the external monitor and the like. However, a method for combining state

signals is not limited to the above described embodiment, and various methods may be adopted.

[0060]

For example, state signals outputted from the respective surge absorbing units 10 may be outputted as status signals as they are. In the above described embodiment, four systems of status signals (ST11 to ST14 or ST41 to ST44) are outputted from one surge absorbing unit 10 and 30. Therefore, if these status signals are outputted to the external monitor and the like as they are via an external interface 58, status signals of 28 systems in total are outputted.

[0061]

However, outputting an OR operation result of the same kind of status signals via the external interface 58 may reduce the number of signals to be outputted. For example, the signals of four systems may be outputted, the four systems including "OR operation result of all signals ST11 and ST41", "OR operation result of all signals ST12 and ST 42", "OR operation result of all signals ST13 and ST 43", and "OR operation result of all signals ST14 and ST 44".

[0062]

(Modification of Disposal of Surge Protective Apparatus 1)

In the above described embodiment, the surge protective apparatus 1 is inserted between the external power supply system 3 and the apparatus 4 to be protected. If a consumption power of the apparatus 4 to be protected is larger, this occasionally induces an increase of the surge protective apparatus 1 in size and cost. In this case, the apparatus 4 to be protected and the surge protective apparatus 1 may be connected in parallel to the external power supply system 3. Especially, if the surge protective apparatus 1 is added to the apparatus 4 to be protected which has already existed, a parallel connection may be used.

WHAT IS CLAIMED IS:

1. A surge voltage absorbing apparatus comprising:

(a) a surge absorbing unit group including one or more surge absorbing units,

wherein one of the surge absorbing units comprising:

a first surge voltage absorbing circuit inserted between two lines on which a surge voltage may occur, and including a first surge voltage absorbing element having a couple of terminals and coming to a conductive state when a predetermined voltage or more is applied to the couple of terminals;

a relay contact; and

a second surge voltage absorbing circuit connected in parallel to the first surge voltage absorbing circuit, and including a second surge voltage absorbing element connected in series to the relay contact and coming to a conductive state when said predetermined voltage or more is applied to the second surge voltage absorbing element; and

(b) a control circuit for each of the surge absorbing units configured to keep the relay contact turned off before detecting the first surge voltage absorbing circuit exhausted and configured to turn on the relay contact when detecting the first surge voltage absorbing circuit exhausted.

2. The surge voltage absorbing apparatus according to Claim 1, further comprising three-phase voltage lines and a neutral line,

wherein the surge absorbing unit group comprises three voltage line-to-neutral line surge absorbing units inserted respectively between the three-phase voltage lines and a neutral line.

3. The surge voltage absorbing apparatus according to Claim 2,

wherein the surge absorbing unit group comprises a neutral line-to-ground potential surge absorbing unit inserted between the neutral line and a ground.

4. The surge voltage absorbing apparatus according to Claim 2 or Claim 3,

wherein the surge absorbing unit group comprises three voltage line-to-ground potential surge absorbing units inserted respectively between the three-phase voltage lines and a ground.

5. The surge voltage absorbing apparatus according to Claim 2,
wherein each of the voltage line-to-neutral line surge absorbing units further comprises:

a surge voltage absorbing circuit for overvoltage connected in series to a parallel circuit including the first surge voltage absorbing circuit and the second surge voltage absorbing circuit; and

a switch unit connected in parallel to the surge voltage absorbing circuit for overvoltage and configured to short-circuit or open a couple of terminals of the surge voltage absorbing circuit for overvoltage,

wherein the control circuit comprises a voltage detecting circuit configured to detect a voltage between a three-phase voltage line and the neutral line,

wherein the control circuit is configured to short-circuit the switch unit in a corresponding voltage line-to-neutral line surge absorbing unit when a detected voltage is less than a predetermined threshold voltage, and

wherein the control circuit is configured to open the switch unit in the corresponding voltage line-to-neutral line surge absorbing unit when the detected voltage is said predetermined threshold voltage or more.

6. The surge voltage absorbing apparatus according to Claim 4,

wherein the voltage line-to-ground potential surge absorbing unit further comprises:

a surge voltage absorbing circuit for overvoltage connected in series to a parallel circuit including the first surge voltage absorbing circuit and the second surge voltage absorbing circuit;

a switch unit connected in parallel to the surge voltage absorbing circuit for overvoltage and configured to short-circuit or open a couple of terminals of the surge voltage absorbing circuit for overvoltage,

wherein the control circuit comprises a voltage detecting circuit configured to detect a voltage between the three-phase voltage line and the ground,

wherein the control circuit is configured to short-circuit the switch unit in the corresponding voltage line-to-ground potential surge absorbing unit when the detected voltage is less than a predetermined threshold voltage, and

wherein the control circuit is configured to open the switch unit in the corresponding voltage line-to-ground potential surge absorbing unit when the detected voltage is said predetermined threshold voltage or more.

7. The surge voltage absorbing apparatus according to Claim 5 or Claim 6,
wherein each of the first surge voltage absorbing circuit and the second surge voltage absorbing circuit includes a metal oxide varistor, and

wherein the surge voltage absorbing circuit for overvoltage includes a gas arrester.

8. The surge voltage absorbing apparatus according to any one of Claims 1 to 7,

wherein the first surge absorbing circuit and the second surge absorbing circuit output state signals indicating exhaustion states, respectively, and

wherein the control circuit outputs as a monitor signal a status signal that is a combination of the state signals outputted from the respective surge absorbing units constituting the surge absorbing unit group.