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A. G. DARLING

2,358,215

PROTECTIVE SYSTEM

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Fig. 1.

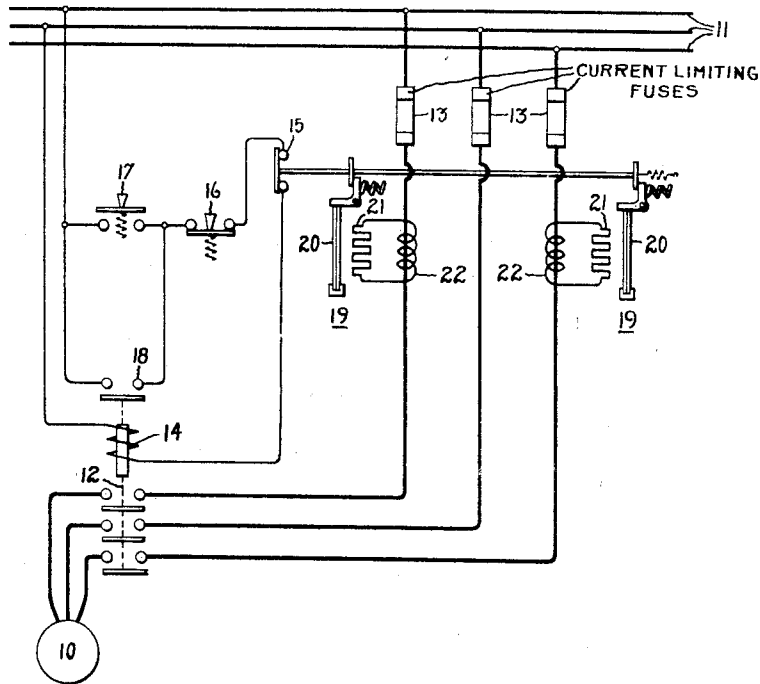
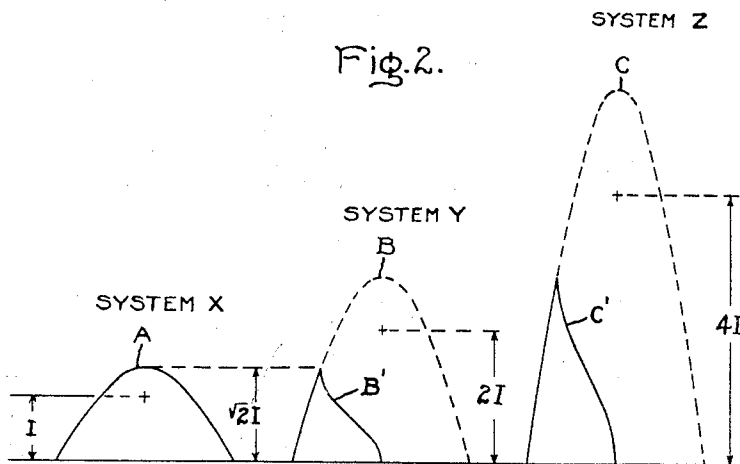


Fig. 2.



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UNITED STATES PATENT OFFICE

2,358,215

PROTECTIVE SYSTEM

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Application January 29, 1942, Serial No. 428,739

4 Claims. (Cl. 175—294)

My invention relates to protective systems and more particularly to such systems employing a current-limiting fuse in series with another switching or circuit-interrupting device or other electrical apparatus or device.

When rating electric switching devices or apparatus, one of the essential factors involved is the short-time current rating which is defined as the maximum r. m. s. total current which the device or apparatus shall be required to carry for any interval of time however small up to one second. If a given switching device or apparatus, such as an electric switch, circuit breaker, or contactor, has a short time current rating of I r. m. s. amperes, then such a device, assuming sinusoidal quantities, can be used safely on a system capable of producing a maximum crest value of short-circuit current equal to $\sqrt{2}I$ amperes. The short-time current rating of the switching device is, therefore, a measure of the ability of the switching device to withstand the electromagnetic forces exerted on the component parts thereof and also a measure of its heat storage ability.

It has been known for some time that, if a current-limiting fuse is connected in series with such a switching device which current-limiting fuse limits the current to a value equal to or below the crest of the momentary or short-time rating of the switching device, such a switching device may be used on systems capable of otherwise producing a considerably higher maximum short-circuit current than the rating of the switching device.

I have discovered the paradoxical phenomenon that a switching device connected in series with a current-limiting fuse may safely be used on a system otherwise capable of producing a maximum short-circuit current materially higher than the momentary rating of the switching device even though the current-limiting fuse limits the maximum current to a value considerably above the short-time rating of the switching device and, without the current-limiting fuse in series therewith, such switching device would be entirely inadequate for currents of such magnitudes.

Accordingly, it is an object of my invention to provide a new and improved arrangement of circuit-switching device and current-limiting fuse whereby the switching device will actually pass with safety a considerably higher current than would otherwise be possible and may accordingly be used safely on systems capable of producing a maximum short-circuit current not only many

times above the momentary rating of the switching device but even considerably higher than the permissible value of the maximum current which may flow as limited by the current-limiting fuse.

Further objects and advantages of my invention will become apparent as the following description proceeds and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention, reference may be had to the accompanying drawing in which Fig. 1 is a schematic diagram illustrating an application of my invention, and Fig. 2 represents typical wave forms to aid in understanding my invention.

Although my invention is applicable to any circuit-switching device, I have chosen solely for explanatory purposes to illustrate my invention in connection with a starting circuit for an electric motor. It will be obvious, however, that it may be applied to any system including a load circuit and supply circuit with a switching device interconnecting said circuits. Referring now to Fig. 1, I have illustrated schematically a load circuit as comprising a motor 10 connected to a supply circuit 11 through a switching device, such as a contactor generally indicated at 12, and current-limiting fuses 13 serially arranged with circuit-interrupting or switching device 12. In order to illustrate my invention, supply circuit 11 is illustrated as a polyphase alternating-current circuit having three phase conductors and, consequently, since the load circuit is also a three-phase circuit, three current-limiting fuses are required and circuit-interrupting device 12 must be capable of controlling three conductors. As will be described in greater detail hereinafter, current-limiting fuses 13 are designed so as considerably to limit the maximum short-circuit current which may flow between supply circuit 11 and the load circuit comprising motor 10. However, the current-limiting action of fuses 13 is such that the maximum current permitted to flow is still considerably above the momentary rating of circuit-interrupting device 12 and yet, as will be explained hereinafter, the circuit illustrated in Fig. 1 is adequately protected without danger to any of the associated apparatus. The current-limiting fuses are preferably of the form and construction shown in United States Letters Patent 2,188,816, Rankin, assigned to the same assignee as the present application.

Any well-known control circuit may be provided to control the operation of the protective

system illustrated in Fig. 1. Accordingly, I have illustrated switching device 12 as a solenoid-operated contactor including an operating winding 14 which is energized from supply circuit 11 through normally closed stop switch 16, normally open start switch 17, and control contacts 15 normally biased to the closed position, to be described hereinafter.

In order to enable the operator to release start switch 17 after the starting operation has been initiated, I provide seal-in contacts 18 connected in parallel with start switch 17 and controlled in response to the operation of the solenoid having winding 14 for operating contactor 12. Accordingly, assuming that contacts 15 are closed, contactor 12 may be closed merely by depressing start switch 17, whereupon winding 14 is energized. Opening of contactor 12 is obtained by breaking the energizing circuit of winding 14 through operation of stop switch 16.

The current-limiting fuses 13 are selected to operate only under actual short-circuit conditions. However, in order to protect the motor 10 against sustained overloads, locked rotor conditions, single phasing, or overheating caused by too frequent starting, I provide a plurality of thermal relays generally indicated at 19, each associated with a different phase conductor and arranged so that, when either one operates, it will cause contacts 15 to open resulting in de-energization of the winding 14 of solenoid-operated contactor 12 and consequent interruption of the circuit between motor 10 and supply circuit 11. The thermal relays 19 comprising a bimetallic element 20 and a heating coil 21 are not my invention but are disclosed and claimed in United States Letters Patent 1,854,007, Weber, assigned to the same assignee as the present application. It should be understood that the heating coils 21 may be connected directly in series with the main power circuit as shown in the above-mentioned Weber patent or, in the event that the magnitude of the current supplied to the motor 10 is above the rating of heating coils 21, suitable current transformers 22, as shown in Fig. 1, may be provided.

In order to understand the phenomenon involved in my invention, reference may be had to Fig. 2 where curves A, B, and C, respectively, represent the first loop of the maximum short-circuit current in r. m. s. amperes equal to I , $2I$, and $4I$ capable of being produced by the systems X, Y, and Z, respectively. For the purpose of illustration, it is assumed that the direct-current components of the short-circuit currents in these three systems are zero and that the first loops of current, as indicated by the curves A, B, and C, are sinusoidal. It will be understood then that, in each of the three systems, the peak value or crest value of this current is equal to the square root of two multiplied by the r. m. s. value. In actual practice, the first current loop produced by the system is symmetrically sinusoidal only if the short-circuit occurs at the voltage crest. However, since the explanation of the phenomenon involved is greatly simplified by making the above assumptions, it is deemed advisable to do so since it can also be shown that the same principles apply under all other short-circuit conditions.

If a given circuit-interrupting device, such as contactor 12 of Fig. 1, has a momentary or short-time rating of I r. m. s. amperes, then it can safely be connected in a system, such as system X, which is capable of producing a short-

circuit current of I r. m. s. amperes having a symmetrical crest value of $\sqrt{2}I$ amperes. The limitation imposed on the circuit-interrupting device is based, as was mentioned above, on the ability of the device in question to withstand the electromagnetic forces exerted upon the component parts thereof and its ability to store heat. As pointed out in an article entitled "The current-limiting power fuse" by D. C. Prince and E. A. Williams, Jr., appearing at page 11 of the Transactions of Electrical Engineering, Volume 58, if the same switching device is connected in series with a current-limiting fuse which limits the crest value of the short-circuit current to $\sqrt{2}I$ amperes as indicated by the current curve B' of system Y, then the device will safely pass the momentary current of system Y and, consequently, will have an effective short-time rating of $2I$ r. m. s. amperes when applied on system Y in the manner indicated.

I have found and provided by test that a switching device having a momentary rating of I r. m. s. amperes with reference to system X of Fig. 2 when used with a current-limiting fuse connected in series therewith will not only function safely on system Y but will also function safely on larger systems, as, for example, on system Z, which is capable of producing an initial short-circuit current of $4I$ r. m. s. amperes and, furthermore, as indicated by curve C' of system Z, the crest current that will be safely passed by such switching device is considerably higher than the $\sqrt{2}I$ amperes and, in fact, may be several times that value. In other words, a switching device, such as 12, having a momentary or short-circuit current rating of I r. m. s. amperes when used without the current-limiting fuses may, when used with current-limiting fuses 13 on system Z, be effectively rated as $4I$ r. m. s. amperes instead of I r. m. s. amperes with reference to system X or $2I$ r. m. s. amperes as was thought the case prior to my invention.

It is my belief that this new and unexpected result is accomplished by virtue of the fact that the rate of rise of the current of system Z is four times as high as that of system X and twice as high as that of system Y and that the shape of the initial loop of current is modified by the fuse in such a way that the duration of this current flow is only fifty per cent of that of system X. Obviously, any apparatus or device has a specific amount of inertia which must be overcome to obtain movement. A finite length of time is required in which this inertia is overcome and, therefore, a finite length of time is required in which the electromagnetic forces involved may cause damage to the switching device. It is believed and it has been discovered by tests that the circuit-interrupting action of a current-limiting fuse is so rapid that the mechanical parts of the device or apparatus can be designed with sufficient inertia to preclude appreciable movement and consequent damage when subjected to much higher electromagnetic forces than was heretofore thought possible.

It has been shown that a switching device connected in series with a current-limiting fuse can safely pass much higher crest currents than was heretofore thought possible and, consequently, in accordance with my invention, relatively inexpensive circuit-controlling equipment may now be used adequately to protect systems when used in combination with series connected current-limiting fuses for which they were thought to be entirely inadequate heretofore.

It should be understood that my invention is not limited to the specific details and arrangement thereof herein illustrated and I intend in the appended claims to cover all changes and modifications that fall within the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a supply circuit, a load circuit, an electric switching device having relatively movable contacts interconnecting said supply and load circuits, and a current-limiting fuse in series with said switching device for limiting the maximum short-circuit current which may flow between said supply and load circuits to a value considerably above the maximum current capable of being carried safely by said switching device when not connected in series with said current-limiting fuse, said series connected current-limiting fuse rendering said switching device adequate for short-circuit currents materially in excess of the values which the device can safely withstand without the use of the current-limiting fuse.

2. In combination, a supply circuit, a load circuit, an electric switching device having relatively movable contacts interconnecting said supply and load circuits, and a current-limiting fuse in series with said switching device for limiting the maximum short-circuit current which may flow between said supply and load circuits to a value considerably above the maximum current capable of being carried safely by said switching device when not connected in series with said cur-

rent-limiting fuse, said series connected current-limiting fuse rendering said switching device adequate for all over current conditions.

3. In combination, a supply circuit, a load circuit, an electric switching device having relatively movable contacts interconnecting said supply and load circuits, and a current-limiting fuse in series with said switching device for limiting the maximum short-circuit current which may flow between said supply and load circuits to a value considerably above the maximum current capable of being carried safely by said switching device when not connected in series with said current-limiting fuse, said series connected current-limiting fuse modifying the magnitude and duration of short-circuit current to permit the interrupting device to pass safely a considerably higher current than would be otherwise possible.

4. In combination, a supply circuit, a load circuit, an electric switching device having relatively movable contacts interconnecting said supply and load circuits, and a current-limiting fuse in series with said switching device for limiting the maximum short-circuit current which may flow between said supply and load circuits to a value considerably above the maximum current capable of being carried safely by said switching device when not connected in series with said current-limiting fuse, said series connected current-limiting fuse rendering said circuit-interrupting device adequate for applications in electrical supply systems of higher capacities than was heretofore thought possible.

ALAN G. DARLING.

Certificate of Correction

Patent No. 2,358,215.

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ALAN G. DARLING

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 2, second column, line 2, for

$\sqrt{1I}$ read $\sqrt{2I}$

line 21, for the word "provided" read *proved*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 14th day of November, A. D. 1944.

[SEAL]

LESLIE FRAZER,
Acting Commissioner of Patents.

Certificate of Correction

Patent No. 2,358,215.

September 12, 1944.

ALAN G. DARLING

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 2, second column, line 2, for

$\sqrt{11}$ read $\sqrt{21}$

line 21, for the word "provided" read *proved*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 14th day of November, A. D. 1944.

[SEAL]

LESLIE FRAZER,
Acting Commissioner of Patents.