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(54) ELECTROMAGNETIC TRIP DEVICE

(71) We, MITSUBISHI DENKI KABUSHIKI KAISHA, of No. 12, Marunouchi 2-chome, Chiyoda-ku, Tokyo, Japan, a Body Corporate organized and existing under the laws of Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particualrly described in and by the following statement:—

This invention relates to an electromagnetic trip device responsive to overcurrents flowing through a circuit interrupter.

An object of the invention is to provide an electromagnetic trip device for use in a circuit interrupter, which will be reliably responsive to overcurrents flowing through the interrupter due to the occurrence of overloads but will not respond to any momentary heavy current or rush current flowing through the interrupter, for example, upon starting an electric motor.

According to the invention there is provided an electromagnetic trip device for use in a circuit interrupter, and comprising an electromagnetic winding for connection to a load circuit, a hollow cylindrical member encircled by said electromagnetic winding, a magnetic plunger armature disposed within said hollow cylindrical member, means damping movement of the plunger armature in said member, a magnetic cover member closing an open end of said hollow cylindrical member, a restoring spring disposed between said cover member and said plunger armature, a magnetic yoke supporting said hollow cylindrical member, a tripping armature pivotably mounted on said yoke for tripping the circuit interrupter, and a magnetic shunt member disposed in parallel magnetic relationship with said tripping armature, whereby one magnetic circuit is formed composed of said yoke, said plunger armature, said cover member and said tripping armature, and another magnetic circuit is formed composed of said yoke, and said plunger armature and said magnetic shunt member.

The magnetic shunt member is conveniently in the form of a flat sheet of small cross-sectional area.

The invention will be further described by way of example in conjunction with the accompanying drawings in which:—

Figure 1 is a side elevational view, partly in longitudinal section, of an electromagnetic trip device according to the invention;

Figure 2 is a plan view of a magnetic shunt member illustrated in Figure 1;

Figure 3 is a view similar to Figure 1 but illustrating the device in its operated position;

Figure 4 is a magnetic circuit for the electromagnetic trip device illustrated in Figures 1 and 3; and

Figure 5 is a graph illustrating the time delay-current characteristics of the device illustrated in Figures 1 and 3, as compared with a conventional device.

Figure 1 shows a substantially L-shaped yoke 1 of any suitable magnetic material, provided on a first leg of the "L" with a circular opening 2 in which is sealed a hollow cylindrical member 3 open at one end and closed at the other end. The hollow cylindrical member 3 may be of any suitable metallic material, e.g. brass, and has an amount of damping oil (not shown) disposed therein. A plunger armature 4 having a predetermined length is disposed within the hollow cylindrical member 3 for longitudinal movement and has a reduced diameter portion at that end remote from the closed bottom end of the cylindrical member 3. The armature 4 is engaged on that reduced diameter portion by an end of a restoring spring 5 disposed within the hollow cylindrical member 3. The spring 5 bears at the other end on a cover member 6 of any suitable magnetic material snugly fitted into the open end of the cylindrical member.

The cylindrical member 3 has an electromagnetic winding 7, disposed around that portion thereof extending upwardly from the said first leg of the L-shaped yoke 1 and adapted to be connected to the associated

load circuit (not shown). A magnetic shunt member 8 of any suitable magnetic material, e.g. iron of small cross-sectional area, is disposed in contact with the end face of the winding 7 remote from the first leg of the L-shaped yoke 1. The magnetic shunt member 8 has a circular opening 9 (see Figure 2) complementary in shape to the cylindrical member 3, which is fitted into the opening. The magnetic shunt member 8 is preferably in the form of a flat sheet. The magnetic shunt member 8 has one end edge A abutting against the second, or vertical leg of the "L" as shown in Figure 1. Thus the electromagnetic winding is sandwiched between the magnetic shunt member 8 and the first leg of the yoke 1. Preferably the magnetic shunt member 8 is in such a position that, when the armature 4 contacts the bottom of the cylindrical member 3 as shown in Figure 1, it is located substantially at the middle point between the lower end of the magnetic cover member 6 and the top of the armature 4. In order to position the magnetic shunt member 8 a cylindrical spacer 10 of any suitable electrically insulating material is fitted onto the cylindrical member 3 and between the cover member 6 and the magnetic shunt member to press the latter against the adjacent end face of the winding 7.

An L-shaped armature 11 is pivotably mounted on the free end portion of the second leg of the L-shaped yoke 1 and has one end 12 adapted to engage, for example, a latch (not shown) of the circuit interrupter. A spring 13 having an intermediate portion wound around the pivot axis of the armature 11 tends to rotate the latter in the direction of the arrow, the direction as viewed in Figure 1, thereby normally to maintain the other leg of the L-shaped armature 11 separated from the cover member 6 as shown in Figure 1.

The arrangement illustrated operates as follows: If the electromagnetic winding 7 has flowing therethrough a current having a magnitude less than the rated current of the circuit interrupter, then the spring 13 exerts on the armature 11 a force overcoming the attraction provided by the electromagnetic winding 7 whereby the armature 11 is prevented from moving toward the cover member 6.

On the other hand, if the current flowing through the electromagnetic winding 7 increases, for example, to 125% of the rated current, then the armature 4 is moved to its position illustrated in Figure 3 by the attraction due to the energized winding 7, against the action of the spring 5. This permits the magnetic flux generated by the electromagnetic winding 7 to flow in an increased amount through the armature 11 until the latter is attracted to the magnetic cover member 6 against the action of the spring 13. It is to be noted that during the movement of the armature 4 the damping oil within the hollow cylindrical member 3 moves through a narrow clearance between the armature 4 and the cylindrical member 3, so that the armature will move at a speed controlled by the viscous resistance of the oil. Therefore the movement of armature 11 will be delayed relative to the overcurrent causing the movement as shown by the solid line in Figure 5, wherein the response time of the armature 11 is plotted as a function of the current.

If, with the plunger armature 4 in its position shown in Figure 1, an overcurrent having a magnitude equal to from 5 to 10 times the rated current flows through the electromagnetic winding 7 due to starting of an associated electric motor or for other reasons, a great part of the magnetic flux generated by the winding 7 first flows into the magnetic shunt member 8 through the yoke 1 and the plunger armature 4, and only a very small part of the magnetic flux flows through the pivoted armature 11, so that the pivoted armature 11 remains initially at its normal position shown in Figure 1. However, if such an overcurrent continues to flow through the winding 7, the plunger armature 4 is attracted toward the cover member 6 due to magnetomotive force generated by the winding 7; the movement of the plunger armature 4 is damped owing to the viscous resistance of the damping oil. As the plunger 4 is moved the magnetic flux flowing through the magnetic shunt member 8 gradually increases until magnetic shunt member 8 is saturated. Then the magnetic flux flows principally through the pivoted tripping armature 11 thereby to pivot the pivoted armature 11 and trip the interrupter with a predetermined short time delayed after the occurrence of the overcurrent.

A transient overcurrent occrring in normal operation upon closing the circuit interrupter e.g. for starting a motor is called a "rush current". The rush current has a magnitude equal to from 5 to 10 times the rated current but is not to be interrupted by the interrupter. Therefore the abovementioned short time delay is set to be longer than the duration of the rush current.

Upon the occurrence of a heavy current such as a shortcircuiting current having a magnitude equal to or more than several ten times the rated current, the winding 7 proprovides a sufficiently high magnetomotive force to pivot the pivoted armature 11 instantaneously and trip the interrupter before the plunger armature 4 begins to move toward the cover member 6.

In order to ensure that the pivoted armature 11 will operate with a relatively low overcurrent such as an overcurrent having a

magnitude equal, for example, to 125% of the magnitude of the rated current, the magnetic flux ϕ^1 in pivoted armature 11 due to that current flowing in winding 7 when the plunger armature 4 is attracted to the magnetic cover member 6 as shown in Figure 3, must be sufficient to render the electromagnetic attraction acting upon the pivoted armature 11 somewhat greater than the force exerted by the spring 13. To prevent operation by a rush current, the flux ϕ in armature 11 due to the current in winding 7, with the plunger armature 4 contacting the bottom of the hollow cylindrical member 3 as shown in Figure 1, must be low as possible: In other words, it is required to render ϕ/ϕ^1 as small as possible.

The attainment of the relationship just described will subsequently be described in conjunction with Figure 4 wherein a magnetic circuit for the present device is illustrated.

With the plunger armature 4 and pivoted armature 11 in their positions shown in Figure 1, R_1 represents the reluctance of a magnetic path traced from the edge A of the magnetic shunt member 8 through the yoke 1 and the plunger armature 4 and back to the other end portion of the magnetic shunt member 8, R_2 represents the reluctance of a magnetic path extending between the magnetic shunt member 8 and the magnetic cover member 6, R_3 is the reluctance of a magnetic path extending between the cover member 6 and the edge A of the magnetic shunt member 8 through the pivoted armature 11 before the armature 11 adheres to the cover member 6, and R_4 is the reluctance of magnetic shunt member 8. With the plunger armature 4 contacting the magnetic cover member 6 as shown in Figure 3 but before armature 11 moves, the reluctances corresponding to R_1, R_2 and R_4 are designated R_1^1, R_2^1 and R_4^1. u_{s0} designates the magnetomotive force resulting from a flow of rush current through the electromagnetic winding 7 while $u_{1.25}$ designates the magnetomotive force resulting from an overcurrent whose magnitude is equal to 125% of the rated magnitude.

When the plunger 4 is in its position shown in Figure 1, it is apparent from Figure 4 that the magnetic flux ϕ in the pivoted armature 11 due to the winding 7 excited by a rush current is expressed by the equation.

$$\phi = \frac{u_{s0}}{R_1 + \dfrac{R_4(R_2+R_3)}{R_4+R_2+R_3}} \times \frac{R_4}{R_4+R_2+R_3} = \frac{u_{s0}}{(R_1+R_2+R_3) + \dfrac{R_1}{R_4}(R_2+R_3)} \quad (1)$$

If the movable iron core 4 is in its position illustrated in Figure 3, and the winding 7 is energized with a 125% over-current, then the magnetic flux ϕ^1 is expressed by the equation

$$\phi^1 = \frac{u_{1.25}}{R_1^1 + \dfrac{R_4^1(R_2^1+R_3)}{R_4^1+R_2^1+R_3}} \times \frac{R_4^1}{R_4^1+R_2^1+R_3} = \frac{u_{1.25}}{R_1^1+R_2^1+R_3+\dfrac{R_1^1}{R_4^1}(R_2^1+R_3)} \quad (2)$$

Dividing the equation (2) by the equation (1) yields the ratio:

$$\frac{\phi}{\phi^1} = \frac{(R_1^1+R_2^1+R_3) + \dfrac{R_1^1}{R_4^1}(R_3^1+R_3)}{(R_1+R_2+R_3) + \dfrac{R_1}{R_4}(R_2+R_3)} \times \frac{u_{s0}}{u_{1.25}} \quad (3)$$

As previously described, the magnetic shunt member 8 is relatively small in cross-sectional area. Therefore, if the movable iron core 4 is in its position illustrated in Figure 3, the magnetic flux flowing through the magnetic shunt member 8 is high and may saturate it. When the member is in the saturated state it can be assumed that $R_4^1 > R_4$ and $R_4^1 > 10R_1^1$. From this assumption $R_1^1+R_2^1+R_3$ can be considered to be very much larger than $\dfrac{R_1^1}{R_4^1}(R_2^1+R_3)$ in the numerator of the equation (3) and

therefore $\frac{R_1^1}{R_4^1}(R_2^1+R_3)$ becomes negligible. Thus the flux ratio will be expressed by the equation

$$\frac{\phi}{\phi^1} = \frac{R_1^1+R_2^1+R_3}{(R_1+R_2+R_3)'+\frac{R_1}{R_4}(R_2+R_3)} \times \frac{u_{s0}}{u_{1.25}} \qquad (4)$$

On the other hand, if the magnetic shunt member 8 is not used, as in the prior art devices, the reluctance R_4 or R_4^1 in the magnetic circuit of Figure 4 is extremely large which is equivalent to an open circuit state. Under these circumstances, the magnetic fluxes ϕ and ϕ^1 are expressed respectively by the equations

$$\phi = \frac{u_{s0}}{R_1+R_2+R_3} \qquad (5)$$

and

$$\phi^1 = \frac{u_{1.25}}{R_1^1+R_2^1+R_3} \qquad (6)$$

The corresponding flux ratio is expressed by the equation

$$\frac{\phi}{\phi^1} \quad \frac{R_1^1+R_2^1+R_3}{R_1+R_2+R_3} \times \frac{u_{s0}}{u_{1.25}} \qquad (7)$$

From comparison of equation (4) with equation (7) it is apparent that equation (4) is greater in denominator than equation (7) by a value of $\frac{R_1}{R_4}(R_2+R_3)$ and that the flux density ratio $\frac{\phi}{\phi^1}$ is accordingly smaller. This increases the momentary current required to trip the device, and has the result that the movable iron piece 11 can have a time delay-current characteristic whose higher current end is extended towards higher currents as shown in Figure 5 by the chain line, whereas the prior art devices have characteristics as indicated by the dashed line.

WHAT WE CLAIM IS:—

1. An electromagnetic trip device for use in a circuit interrupter and comprising an electromagnetic winding for connection to a load circuit, a hollow cylindrical member encircled by said electromagnetic winding, a magnetic plunger armature disposed within said hollow cylindrical member, means damping movement of the plunger armature in said member, a magnetic cover member closing an open end of said hollow cylindrical member, a restoring spring disposed between said cover member and said plunger armature, a magnetic yoke supporting said hollow cylindrical member, a tripping armature pivotably mounted on said yoke for tripping the circuit interrupter, and a magnetic shunt member disposed in parallel magnetic relationship with said tripping armature, whereby one magnetic circuit is formed composed of said yoke, said plunger armature, said cover member and said tripping armature, and another magnetic circuit is formed composed of said yoke, said plunger armature and said magnetic shunt member.

2. An electromagnetic trip device according to claim 1, in which said magnetic shunt member is in the form of a flat sheet of small cross-sectional area.

3. An electromagnetic trip device substantially as herein described and illustrated in the accompanying drawings.

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