United States Patent

[11] 3,575,677

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[54] ELECTRIC CIRCUIT INTERRUPTER

5 Claims, 5 Drawing Figs.

[52] U.S. Cl. 335/18, 336/84, 336/175, 200/144, 200/166
[51] Int. Cl. H01h 73/00
[50] Field of Search .... 336/84, 173, 175; 317/44; 335/174, 179, 18, 19; 324/127, (Inquired); 200/166 (C), 144

[56] References Cited
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3,323,057	5/1967	Haley	324/127X

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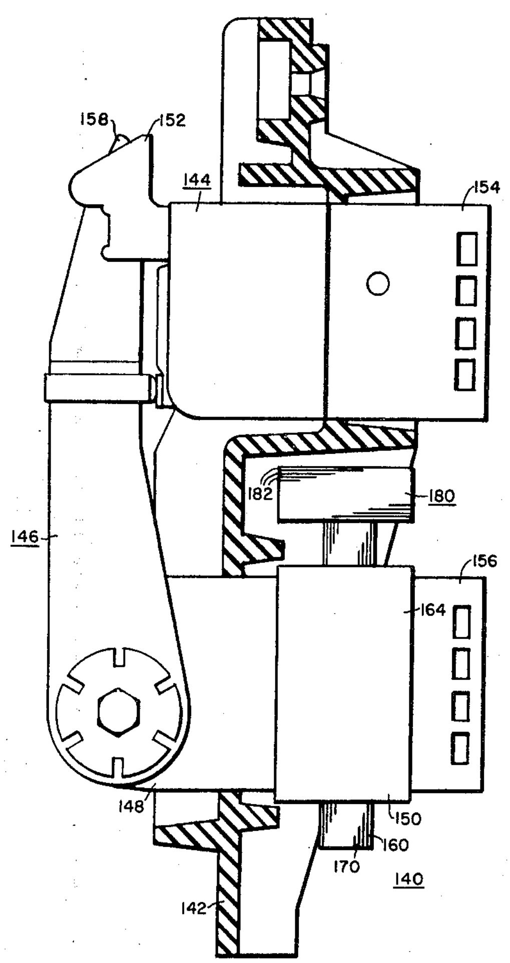
ABSTRACT: An electrical circuit interrupter having first and second contacts connected to first and second conductors, and a current transformer having a magnetic core and electrical winding assembly. The magnetic core of the current transformer is disposed to encircle one of the conductors, with a magnetic shield being disposed between the magnetic core and the other of the conductors, to prevent the flux from the other conductor from saturating a portion of the magnetic core.



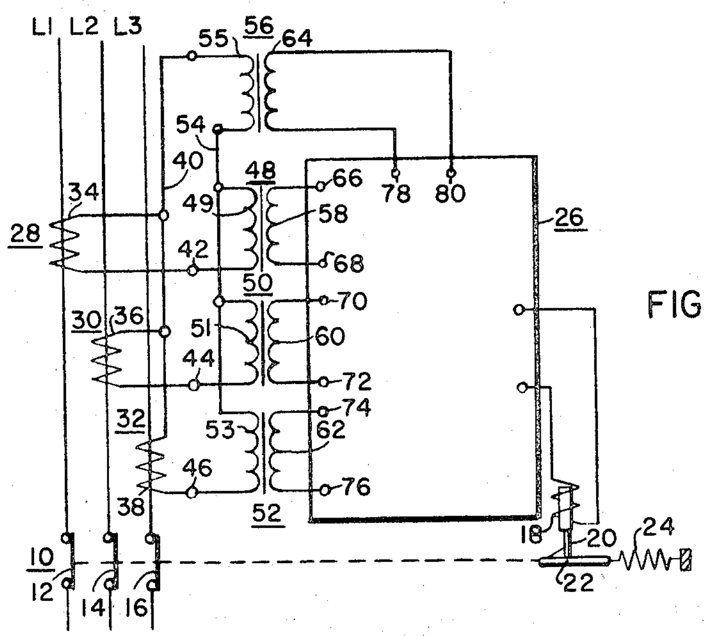


FIG. 1.

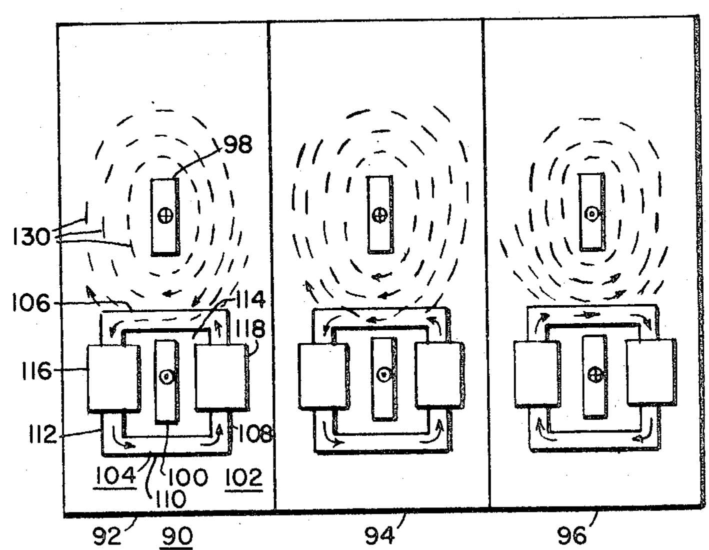


FIG. 2.

WITNESSES:
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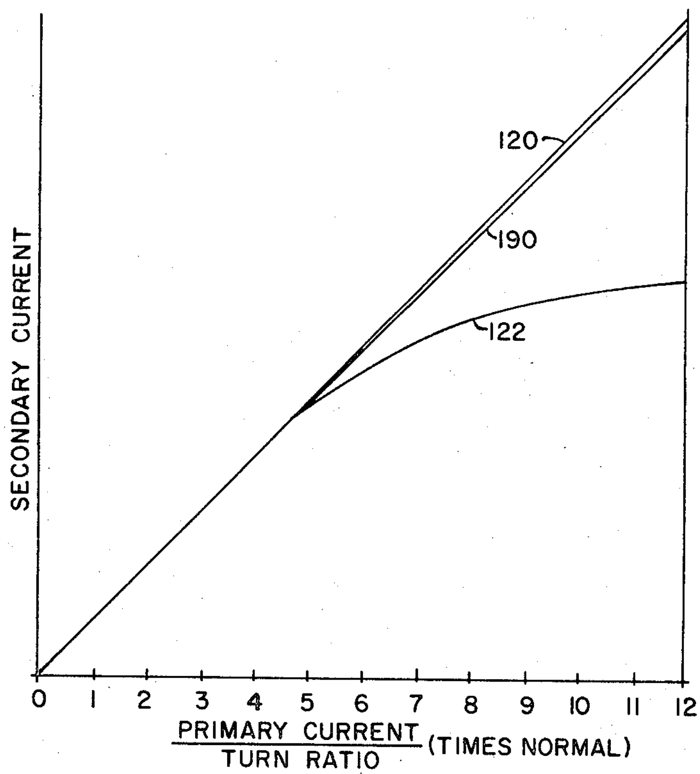
SECONDARY CURRENT
120
190
122
0 1 2 3 4 5 6 7 8 9 10 11 12
PRIMARY CURRENT / TURN RATIO (TIMES NORMAL)

FIG. 3.

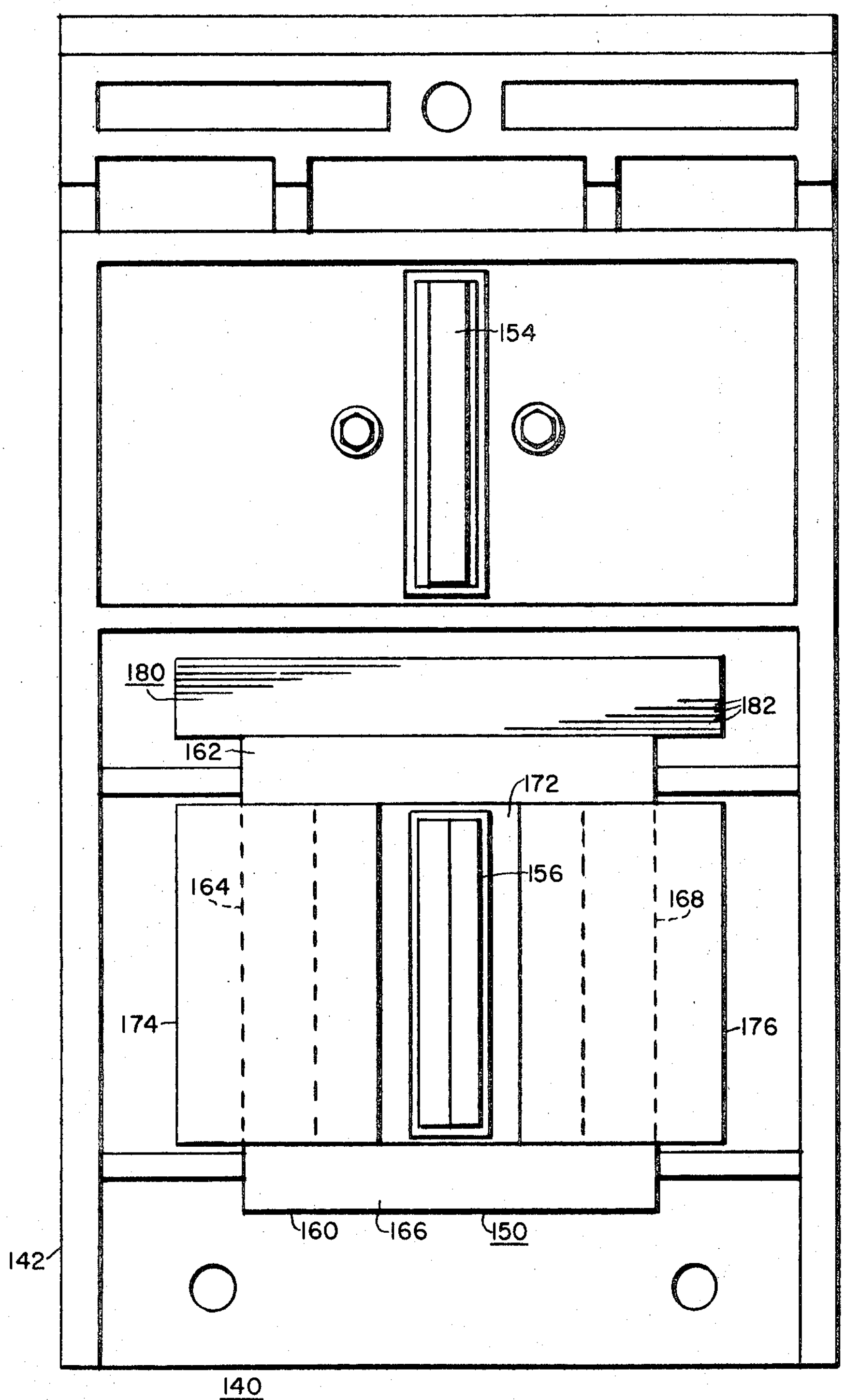

FIG. 4.

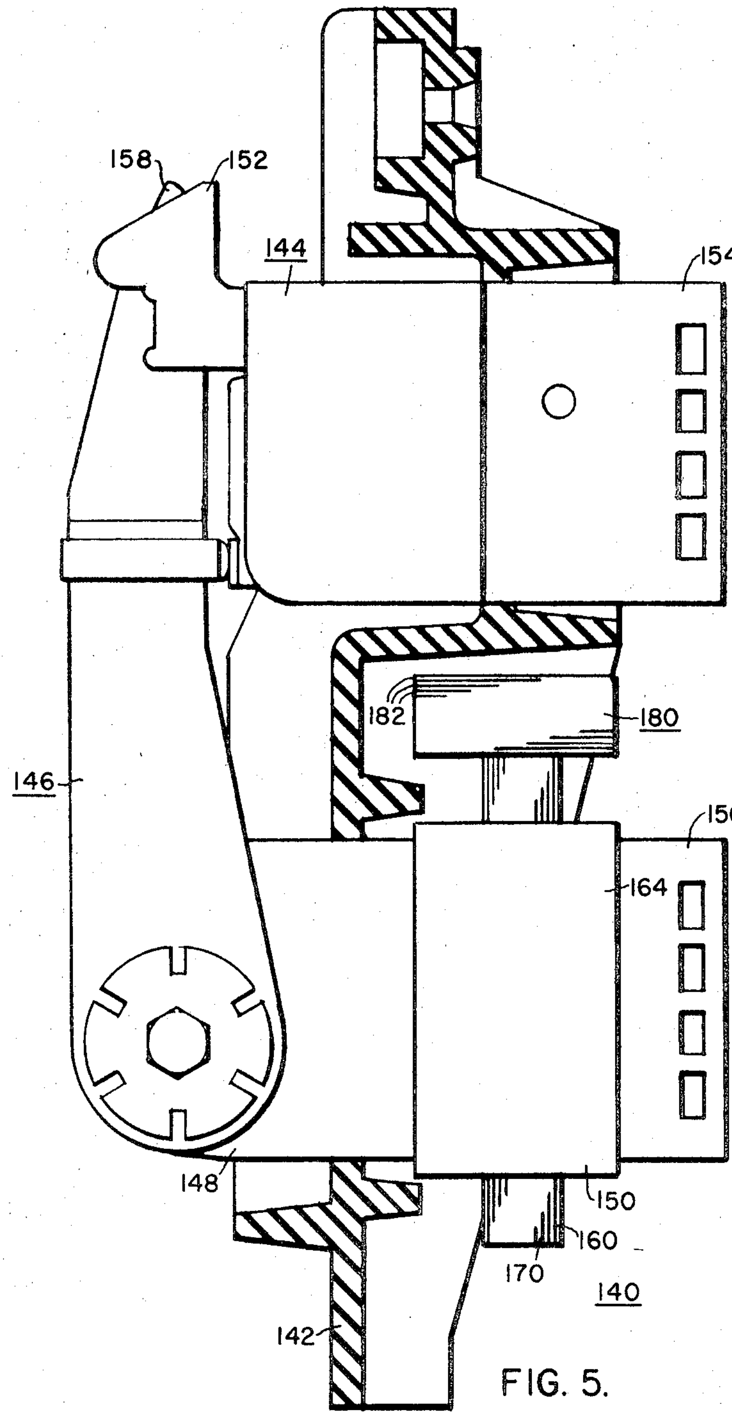

FIG. 5.

ELECTRIC CIRCUIT INTERRUPTER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates in general to electric circuit interrupters, such as circuit breakers, and more specifically to electrical circuit interrupters of the type which include a current transformer disposed to obtain a measure of the current flowing through the circuit interrupter.

2. Description of the Prior Art

Certain types of circuit interrupters, or circuit breakers, include movable and stationary contacts connected to spaced first and second electrical conductors or busses, respectively, with a current transformer disposed to provide a measure of the current flowing through the circuit breaker in order to provide signals for overcurrent protective relay apparatus. In the prior art, circuit interrupters of this type have had certain disadvantages with respect to the size of the circuit interrupter relative to the switchgear housing or cubicle in which the circuit interrupter is normally mounted. Recently, attempts have been made to overcome this size disadvantage by providing insulating base structures for circuit interrupters which enable a current transformer to be mounted thereon without substantially increasing the overall size of the circuit interrupter. For example, copending application Ser. No. 770,149, filed Oct. 24, 1968, by F. Bould, which is assigned to the same assignee as the present application, disclosed a circuit interrupter of this type.

The compact structures for containing the movable and stationary contacts, their associated electrical busses and terminals, and current transformer, however, do not have room for the conventional toroidal-type current transformer. Instead, a rectangular magnetic core structure is utilized, with available space dictating that windings be disposed on only two leg portions of the rectangular core. The magnetic core must be oriented such that one of the remaining leg portions which would normally also be a winding leg portion in conventional current transformer practice, is disposed between the spaced first and second conductors connected to the stationary and movable contacts. While this arrangement is satisfactory from the standpoint of overall space, the compact structure, and the type of current transformer structure it necessitates, leads to inaccuracies in the ratio of the current transformer due to stray magnetic fields, with the inaccuracies being beyond allowable limits. The current transformer provides signals for overcurrent protective relays, of the electromechanical, or of the solid-state type, and also ground detectors, which for proper operation, require that the current transformer ratio remain accurate up to 12 times rated current. Also, an accurate indication of ground current must be given up to six times normal or rated current. An example of a solid-state protective system, including overcurrent protection and ground current detector and protection, which requires an accurate ratio over a wide range of current, is disclosed in copending application Ser. No. 765,584, filed Oct. 7, 1968, by J. Watson, F. Thompson, and F. Johnson, which application is assigned to the same assignee as the present application.

Thus, it would be desirable to provide a new and improved circuit interrupter of the type which includes a current transformer mounted thereon, which may take advantage of the new structures for reducing the overall size of the circuit interrupter, without a degradation in the accuracy of the ratio of the current transformer as its primary current is increased up to 12 times the normal or rated current of the circuit to be protected.

SUMMARY OF THE INVENTION

Briefly, the present invention is a new and improved circuit interrupter which includes first and second contacts connected to first and second spaced conductors or busses, respectively, and a current transformer. The current transformer includes a rectangular type magnetic core of stacked construction, disposed about the first conductor, with the leg of the magnetic core disposed between the spaced conductors being free of windings, as is the parallel or opposite leg. The remaining legs of the magnetic core are winding legs, each including a secondary coil disposed thereon, which may be connected in series or in parallel. A magnetic shield, including a bundle of superposed laminations, is disposed adjacent the leg of the magnetic core which is located between the spaced conductors, with the major planes of the laminations of the magnetic shield being substantially perpendicular to the major planes of the laminations of the magnetic core, to provide a low reluctance path for flux from the second conductor, preventing this flux from entering the magnetic core and causing saturation thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages and uses of the invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIG. 1 is a schematic diagram of electrical circuit-interrupting apparatus which may be constructed according to the teachings of the invention;

FIG. 2 is a functional view of a three-phase circuit interrupter, which illustrates the flux pattern therein;

FIG. 3 is a graph which plots the secondary current of a transformer mounted on a circuit interrupter, against the primary current divided by the turn ratio of the current transformer, for an ideal current transformer, a current transformer constructed according to the teachings of the invention, and a current transformer constructed according to the teachings of the prior art;

FIG. 4 is an elevational view of a circuit interrupter constructed according to the teachings of the invention; and

FIG. 5 is an end elevational view, partially in section, of the circuit interrupter shown in FIG. 4.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawings, and FIG. 1 in particular, there is illustrated a circuit breaker **10** connected to line conductors L1, L2 and L3 of an electrical power system or circuit. While the teachings of the invention may be applied to single-phase electrical systems, it will be assumed for purposes of discussion that the electrical system is a three-phase system.

The circuit breaker **10** isolates a portion of the electrical system when it is subjected to abnormal or fault conditions, such as an overcurrent condition. Circuit breaker **10** includes a plurality of separable line contacts **12**, **14** and **16**, which are engaged when the circuit breaker is closed, and disengaged when the circuit beaker is open. Circuit breaker **10** includes a trip coil **18**, which, when energized when the circuit breaker **10** is closed, results in tripping the circuit breaker, opening its contacts **12**, **14** and **16**. As illustrated diagrammatically in FIG. 1, energization of the trip coil **18** may actuate an operating member **20** to release a latch member **22**, opening contacts **12**, **14** and **16** under the influence of suitable operating means, such as a spring **24**.

The trip coil **18** of circuit beaker **10** is connected to be responsive to protective means **26**, which in turn is responsive to the current flowing in the line conductors L1, L2 and L3. Protective means **26** is responsive to the current flowing in each of the line conductors, energizing the trip coil **18** when the highest of the line currents exceeds a predetermined value. Also, if desired, protective means **26** may respond to a predetermined ground current in the electrical system which includes conductors L1, L2 and L3, to energize the trip coil **18** when the ground current exceeds a predetermined value. Suitable protective means **26** is disclosed in the latter of the hereinbefore mentioned copending applications.

In order to obtain a plurality of output currents which are directly proportional to the currents in line conductors L1, L2 and L3, a plurality of current transformers **2**, **30** and **32** are provided as shown in FIG. 1, with their primary windings, which may be the line conductors themselves, being energized in accordance with the line currents in the line conductors L1, L2 and L3, respectively. The secondary windings 34, 36 and 38 of current transformers 28, 30 and 32, respectively, are wye connected between a neutral conductor 40 and the output terminals 42, 44 and 46 of windings 34, 36 and 38, respectively. In order to further step down the output currents of current transformers 28, 30 and 32, transformers 48, 50 and 52 may be connected between the secondary windings 34, 36 and 38 and the input terminals of protective means 26. More specifically, the primary windings 49, 51 and 53 of transformers 48, 50 and 52, respectively, are wye connected between the output terminals 42, 44 and 46 of current transformers 28, 30 and 32, respectively, and a neutral conductor 54, with the neutral conductor 54 being connected to the neutral conductor 40 of current transformers 34, 36 and 38. The neutral conductors 54 and 40 may be connected together, as shown, through the primary winding 55 of a ground current transformer 56, when ground current tripping protection is desired. When ground current tripping protection is not required, the neutral conductors 40 and 54 would be connected directly together. The secondary windings of the intermediate transformers 48, 50 and 52 are connected to the input terminals 66 and 68, 70 and 72, and 74 and 76, respectively, of protective means 26, to provide three output currents which are proportional to the line currents in the line conductors L1, L2 and L3 of the electrical system. The secondary winding 64 of the ground current detection transformer 56 is connected to input terminals 78 and 80 of protective means 26.

Protective means 26, especially protective means of the solid-state type disclosed in the latter hereinbefore mentioned copending application, requires an accurate measure of the line currents up to 12 times the rated or normal line current, in order to properly perform the required functions. The trend towards more compact circuit-interrupting devices has placed the conductors or busses connected to the movable and stationary contact assemblies of the circuit-interrupting device closer together, and has reduced the amount of space available for mounting the current transformer for providing the signals responsive to the line currents. Thus, the conventional toroidal-type current transformer with an evenly distributed winding cannot be used because of the size limitations.

FIG. 2 is a functional view of a three-phase circuit interrupter 90 having three similar sections 92, 94 and 96 for interrupting the three phases of the electrical system. Since each section of circuit interrupter 90 is similar in construction, only section 92 will be described in detail. Section 92 of circuit interrupter 90 illustrates the spaced conductors or busses 98 and 100 which connect its stationary and movable contacts with the line conductors, and the general construction of a current transformer 102 of the type required to enable the overall size of circuit interrupter 90 to be reduced.

Current transformer 102 includes a generally rectangular magnetic core structure 104 having winding leg portions 108 and 112, and yoke portions 106 and 110, which define a window or opening 114 through which conductor 100 passes. Electrical coils 116 and 118 are disposed on winding leg portions 112 and 108, respectively, which are interconnected to provide the secondary winding of the current transformer 102. While coils 116 and 118 may be designed for either series or parallel connection, more accurate results are obtained when they are parallel connected. The primary winding is the buss or conductor 100.

The structure of current transformer 102 lends itself to the new compact type of circuit interrupting device, since it has two legs, 106 and 108, which have no windings or coils thereon. Hence these legs may be called yoke portions instead of leg portions. However upon testing current transformers of this type while mounted on these new circuit-interrupting devices, they were found to provide inaccuracies at current levels between five and 12 times normal line current.

FIG. 3 is a graph which plots the secondary current of a current transformer against the primary current divided by the turn ratio. In an ideal current transformer the result should be a straight line which bisects the ordinate and abcissa, indicated by line 120. Upon testing 1,600 to 5 ratio current transformers constructed similar to current transformer 102 shown in FIG. 2, while mounted on a circuit interrupter such as disclosed in the first of the hereinbefore mentioned copending applications, the secondary current started to become nonlinear at about five times normal or rated current, as indicated by curve 122. Further, at 12 times normal or rated current, the secondary current was only about 60 percent of its actual value. Also, with the current transformers connected in a system as illustrated in FIG. 1, the current transformers indicated a ground current of 1½ to two times rated continuous current, when there was no ground current flowing.

It has been recognized that the accuracy of a current transformer disposed adjacent a high-current bus is deleteriously affected. The paper entitled "The Accuracy of Current Transformers Adjacent To High Current Busses" by R. A. Pfuntner, AIEE Transactions, Volume 7, page 1,656, 1951, provides a theoretical analysis of the effect that adjacent high-current busses have on the accuracies of current transformers.

The accuracy of the type of current transformer construction shown in FIG. 2 is even more adversely affected than conventional types of current transformers, such as those of the toroidal type or rectangular types in which all four legs contain secondary coils. The presence of a coil uniformly disposed about the magnetic core provides corner fluxes which oppose the leakage flux from the adjacent bus, and reduces the error due to these leakage fluxes. With the construction of the current transformer shown in FIG. 2, the flux 130 encircling bus 98 enters the leg or yoke portion 106 of magnetic core 104, and it always aids the flux produced in the core 104 regardless of the direction of the alternating current, as the direction of the instantaneous current in one of the busses will always be opposite to the direction of the instantaneous current in the other of the busses. Thus, yoke 106 quickly saturates, reducing the flux circulating in the core, which thus reduces the secondary output. Further, the resulting distortion of the secondary current causes a false indication of ground current.

In an attempt to prevent saturation, the cross section of the saturating yoke or leg portion 106 was increased, but this effort was unsuccessful. A copper shield disposed between the yoke portion 106 and bus 98, was also unsuccessful. Further, an attempt to eliminate the false indication of ground current by using a short circuited tertiary winding, was also found to be unsuccessful.

FIGS. 4 and 5 are elevational views of a circuit interrupter 140 constructed according to the teachings of the invention, which enables accurate current transformer readings to be obtained up to 12 times the rated current of the circuit being protected. Since the circuit breaker for each phase of a three-phase electrical system would be similar, the circuit breaker for a single phase only is shown in FIGS. 4 and 5. In general, the circuit interrupter or circuit breaker 140 may be of the drawout type, mounted on a suitable framework provided with rollers which enables the circuit breaker to be moved into and out of an associated switchgear cubicle, which connects and disconnects, respectively, the circuit breaker 140 with an electrical circuit to be protected. Circuit breaker 140 includes an insulating base or support member 142, a stationary contact assembly 144, a movable switch or contact arm 146 having main and arcing contact members mounted thereon, a pivot support member 148 for supporting the movable contact arm 146, and a current transformer 150.

The stationary contact assembly 144 is rigidly supported on the insulating base member 142, and it includes stationary contacts 152 and a conductor or bus 154 which extends through an opening in the insulating base member 142. The outwardly extending end of bus 154 includes means for accepting a disconnecting-type contact assembly adapted to engage a conductor within the associated switcher cubicle.

The pivot support member 148 is also rigidly supported on the insulating base member 142, and it includes a conductor or bus 156 which extends through an opening in the insulating base member 142. The outwardly extending end of bus 156 includes means for accepting a disconnecting-type contact assembly adapted to engage another conductor within the associated switchgear cubicle. The movable contact arm 146 is pivotally supported by the pivot support member 148, and it includes main contacts 158 for engaging the stationary contacts 152.

Thus, the stationary and movable contacts 152 and 158 are connected to conductors or busses 154 and 156, respectively, which extend outwardly from the insulating base member 142 in predetermined spaced relation. Busses 154 and 156 are disposed on a common vertical centerline disposed through each of the busses.

As clearly illustrated in FIG. 4, there is insufficient space about either of conductors 154 or 156 for mounting a toroidal-type current transformer, or even a rectangular-type current transformer which has coils or windings disposed on all four of its leg portions. In order to fit within the space provided, current transformer 150 is of the rectangular-type construction, but it has coils disposed on only two of its legs, and it is disposed about conductor 156.

More specifically, current transformer 150 includes a generally rectangular magnetic core structure 160 of the stacked type, having four leg portions 162, 164, 166 and 168. Each of the leg portions includes a stack or bundle of superposed metallic magnetic laminations 170, with the stacks being arranged to define a rectangular opening or window 172 for receiving coils or windings. The ends of the laminations in each of the leg portions may be offset or staggered, to enable the legs to be joined with an interleaved, low reluctance joint. The magnetic core 160 is disposed to encircle bus 154, and is oriented such that leg portion 162 is disposed between the spaced conductors 154 and 156, with its longitudinal dimension being substantially perpendicular to a line drawn between the geometrical centers of conductors 154 and 156.

Electrical coils 174 and 176 are disposed on opposite or parallel leg portions 164 and 168, respectively, while leg portions 162 and 166 are free of windings or coils. Thus, leg portions 164 and 168 are referred to as winding legs, and leg portions 162 and 166 are referred to as yoke portions.

As hereinbefore stated, this type of current transformer construction, when disposed adjacent a high-current bus, such as bus 154, has its accuracy substantially impaired due to flux encircling the high current bus 154, which may enter and saturate a portion of the magnetic core. This disadvantage of the current transformer 150 is almost completely eliminated, when following the teachings of the invention, by disposing magnetic shield member 180 between current transformer 150 and bus 154.

More specifically, magnetic shield member 180 is constructed of a plurality of metallic, magnetic laminations 182, which are stacked or superposed to provide a bundle of laminations, which bundle is disposed adjacent leg or yoke portion 162 of the magnetic core 160. As illustrated in FIGS. 4 and 5, magnetic shield member 180 may be mounted on yoke portion 162, if a thin sheet of electrical insulation, or an insulating coating, is disposed between the shield and yoke portion to prevent the edges of the laminations of the yoke portion from being electrically shorted.

It is important to note that the major planes or major surfaces of the laminations 182 which make up the magnetic shield 180 are disposed perpendicular to the major planes or surfaces of the laminations 170 of the magnetic core 160. The laminations 170 of the magnetic core 160 have their major surfaces disposed parallel with the basic plane of the insulating support member 148, while the major surfaces of laminations 182 of the magnetic shield member 180 are disposed perpendicular to the basic plane of the insulating support member 142.

It should further be noted that the dimensions of the laminations 182 of the magnetic shield member 180 are greater than the dimensions of the top of yoke portion 162, such that the magnetic shield member 180 overhangs or extends outwardly from the yoke portion 162 in all directions. In other words, the width of the laminations 182 is wider than the build dimension of the magnetic core 160, and the length of the laminations 182 is longer than the laminations of which the yoke portion 162 is formed. Then, by aligning the geometrical centers of the magnetic shield member 180 and the yoke portion 162, the magnetic shield 180 will overhang all of the edges of the yoke portion 162.

The orientation of the major surfaces of laminations 182 of magnetic shield member 180 perpendicular to the major surfaces of the laminations of magnetic core member 160, requires that the flux which encircles conductor or bus 154 pass through shield 180 at right angles to its laminations, in order to reach the magnetic core 160 of the current transformer 150. This arrangement produces large eddy currents in the laminations 182, which generate a counterflux. Also, flux which enters and leaves an individual lamination of the magnetic shield member 180 encounters an extremely low reluctance between the entry and exit points in the lamination, so that there is little magnetomotive force available for penetrating laminations lower in the stack of laminations. Further, the overhanging shield member 180 protects the magnetic core 160. The flux from conductor 154 strikes the shield rather than the magnetic core, as the magnetic core is within the "shadow" of the magnetic shield member.

A circuit interrupter was constructed according to the teachings of the invention, utilizing 1,600 to 5 ratio current transformers, with the current transformers having magnetic shields disposed as shown in FIGS. 4 and 5. As illustrated by curve 190 in FIG. 3, the secondary current was accurate within ±3 percent, up to the required 12 times rated current. Further, at six times the normal or read current, the ground current indication was within 2 percent of the actual current flowing. These inaccuracies are within the required ratings of this type of circuit interrupter, making it possible to use solid-state protective apparatus which requires very accurate indications of line current and ground current.

In summary, there has been disclosed a new and improved circuit interrupter and current transformer combination, which enables a rectangular core-type current transformer with windings disposed on only two legs thereof, to be used in order to conserve space, while still providing signals in response to line and ground current within the require accuracies up to 12 times the rated current of the circuit being protected. Further, the construction of the current transformer which provides these results is of simple, low-cost construction, solving a difficult problem while adding little cost or complexity to the circuit interrupter.

Since numerous changes may be made in the above-described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in foregoing description or shown in the accompanying drawings shall be interpreted as illustrative, and not in a limiting sense.

I claim:

1. An electrical circuit interrupter comprising:

first and second contact means adapted to make and break an electrical circuit,

first and second spaced conductors connected to said first and second contact means, respectively, and

a current transformer disposed to obtain a measure of the current flowing through the circuit interrupter, said current transformer including a magnetic core disposed to encircle said first conductor, electrical winding means disposed about said magnetic core, and magnetic shielding means disposed between said magnetic core and said second conductor, said magnetic shielding means providing a low reluctance path for the flux from said second conductor, said magnetic core of the current transformer being of the stacked type, including a plurality of superposed layers of metallic laminations, with the laminations of each layer being arranged to define a closed magnetic loop about the first conductor said magnetic shielding means including a plurality of superposed metallic, magnetic laminations disposed with the major planes of the laminations of the magnetic core.

2. An electrical circuit interrupter comprising:

first and second contact means adapted to make and break an electrical circuit,

first and second spaced conductors connected to said first and second contact means, respectively, and

a current transformer disposed to obtain a measure of the current flowing through the circuit interrupter, said current transformer including a magnetic core disposed to encircle said first conductor, electrical winding means disposed about said magnetic core, and magnetic shielding means disposed between said magnetic core and said second conductor, said magnetic shielding means providing a low reluctance path for the flux from said second conductor, said magnetic core of the current transformer being of the stacked type, including a plurality of layers of laminations stacked to provide a predetermined build dimension, with the laminations of each layer being arranged about the first conductor to provide first and second winding leg portions joined by first and second yoke portions, said first yoke portions being disposed between said first and second conductors, said electrical winding means including first and second coils disposed about said first and second winding leg portions, respectively, and the magnetic shielding means including a plurality of superposed metallic laminations disposed adjacent said first yoke portion, with the major planes of its laminations being substantially perpendicular to the major planes of the laminations of said first yoke portion.

3. The electrical circuit interrupter of claim 2 wherein the laminations of the magnetic shielding means are longer and wider than the length and build dimensions, respectively, of the first yoke portion, extending outwardly beyond the outer edges of the end of the first yoke portion to enable the magnetic shielding means to intercept the flux of the second conductor before it reaches the first yoke portion of the magnetic core.

4. The electrical circuit interrupter of claim 2 wherein the first and second coils are connected in parallel.

5. An electrical circuit interrupter comprising:

first and second contact means adapted to make and break an electrical circuit;

first and second spaced conductors connected to said first and second contact means, respectively, and

a current transformer disposed to obtain a measure of the current flowing through the circuit interrupter, said current transformer including a magnetic core disposed to encircle said first conductor, electrical winding means disposed about said magnetic core, and magnetic shielding means disposed between said magnetic core and said second conductor, said magnetic shielding means providing a low reluctance path for the flux from said second conductor, said magnetic core of the current transformer being substantially rectangular in shape, having first and second winding leg portions joined by first and second yoke portions, said winding leg and yoke portions each being formed of superposed metallic laminations, with the first yoke portion being located between the first and second spaced conductors, and said magnetic shielding means including a bundle of stacked metallic magnetic laminations disposed immediately adjacent the first yoke portion, between the first yoke portion and the second conductor, with the major planes of the laminations of the magnetic shielding means being perpendicular to the major planes of the laminations of the first yoke portion.